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The Market Ramp-Up of Electric Road Systems in Germany and the EU –

A critical Analysis of the Economic and Regulatory Timeframe and its defining Variables

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List of abbreviations

AFID	*Alternative Fuels Infrastructure Directive*
BEV	*Battery Electric Vehicle*
BGL	*Bundesverband Güterkraftverkehr Logistik und Entsorgung*
BMVI	*Bundesministerium für Verkehr und digitale Infrastruktur*
C-BEV	*Catenary battery electric vehicles*
C-HEV	*Catenary (diesel) hybrid electric vehicles*
EC	*European Commission*
ECJ	*European Court of Justice*
ERS	*Electric Road Systems*
EU-ETS	*EU emission trading system*
GHG-Savings	*Greenhouse Gas Savings*
Heavy trucks	*Trucks weighing 40t or more*
km/a	*Kilometers per year*
Mt CO_2-e	*Million tons CO2-eq.*
NECPs	*National Energy and Climate Plans*
nEHS	*German national emission trading system*
PPP	*Private-Public-Partnership*
PtL	*Power-to-liquid*
Reference sources	*Short summary term for the sources examined in the meta-analysis: Jöhrens, et al. (2020), Hacker, et al. (2020), Wietschel, et al. (2017) and NPM (2020).*
TCO	*Total-Cost-of-Ownership*
TEN-T	*Trans-European Transport Network*
tkm	*Ton kilometers*
TRL	*Technology Readiness Level*
WtW-savings	*Well-to-Wheel-savings*

1. Introduction

Scientists have been warning about the devastating effects of climate change for many decades. An increase in the average global temperature leads to more frequent extreme weather events, a significant rise in sea level and a general disruption of global ecosystems that threatens the lives of most living creatures on the planet (EC, 2021a). In recent years, this development has increasingly been taken into account by policy makers. Both the EU and the German government have recently presented climate protection plans that call for the decarbonization of all sectors of the economy. Under the Green New Deal, the EU has tightened its interim savings targets and plans to become climate neutral by 2050 (EC, 2021b). While most economic sectors have already achieved notable greenhouse gas savings (GHG-Savings), emissions from the transportation sector have stagnated for several decades and continue to be dominated by diesel, as will be discussed later in this paper. As the pressure to act in the sector grows accordingly, it is important to deploy alternative, zero-emission propulsion systems to enable a timely decarbonization. Electric Road Systems (ERS) represent such a system and will be analyzed in this paper for their current and future market position as well as their applicability compared to other alternative propulsion systems.

Beforehand, however, the technical background to ERS technology will be briefly explained here to give the reader a better basic understanding of the subject. ERS are dynamic power transfer systems that enable power transfer from the grid to the vehicle while driving. They are especially relevant for trucks with particularly heavy weights, since they cannot realistically be operated battery-electrically, as the battery would have to be of enormous weight for this purpose. This will be explained in more detail in subsequent chapters. Figure 1 shows the basic steps that enable the operation of ERS.

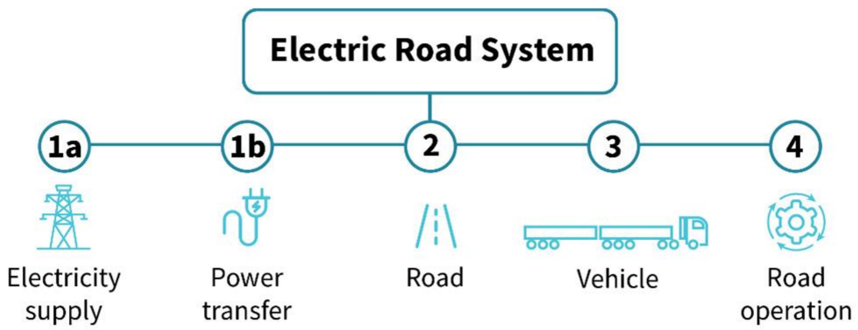

Figure 1 - Basic depiction of ERS. Source: Hartwig, et al. (2020, p. 4).

There are three systems that enable power transfer. In catenary systems, the power is taken from the catenary via a pantograph on the vehicle. In conductor rail systems, the vehicle draws current from a conductor rail embedded in the road. In inductive systems, the energy is transmitted to the vehicle via induction coils within the road. A graphical representation of the respective systems can be found in Figure 2.

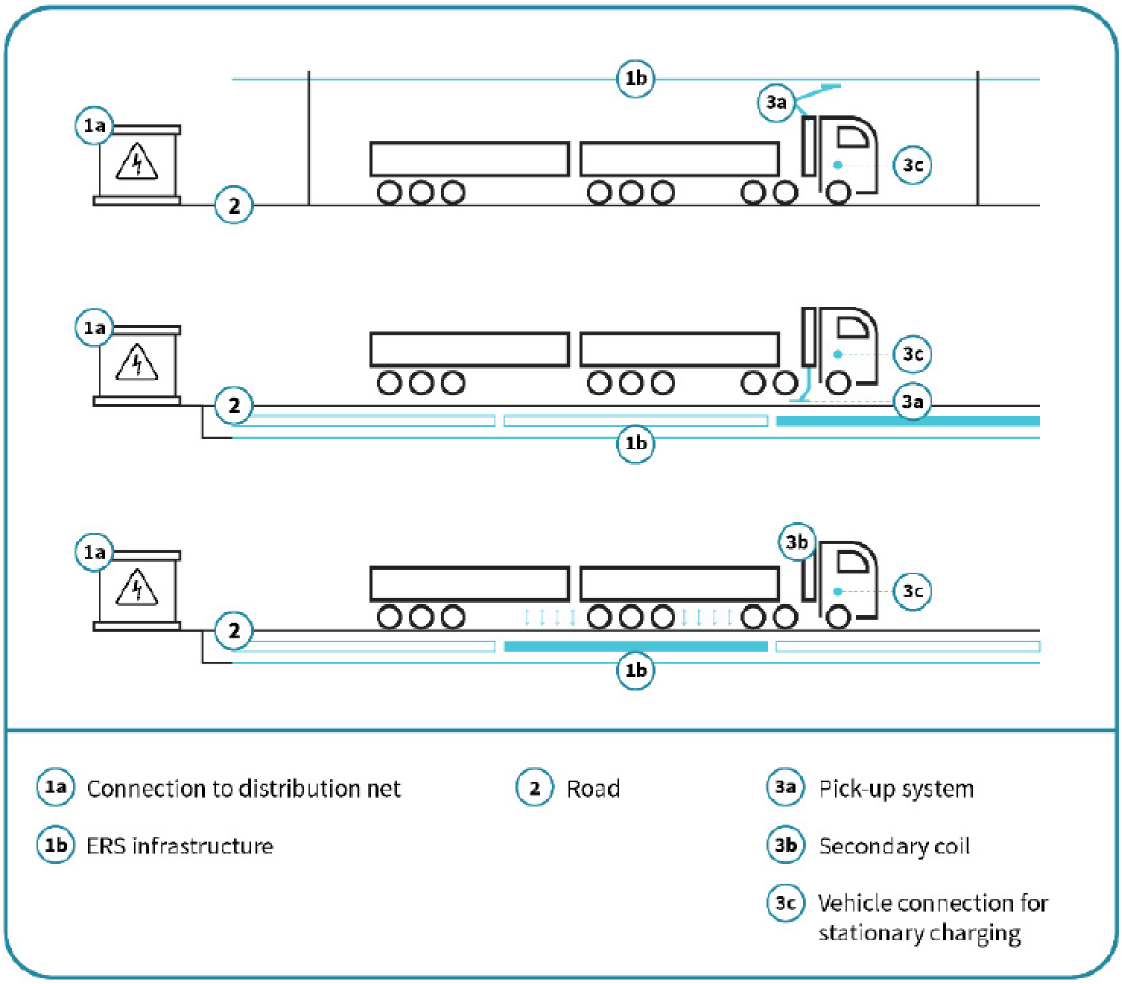

Figure 2 - Three technological approaches to ERS infrastructure. Source: Hartwig, et al. (2020, p. 5).

Logically, electrification should take place along the most heavily traveled truck routes. In addition to dynamic power supply while driving, there are concepts for propulsion systems when not connected to ERS, such as an integrated diesel engine or a (small) battery to provide some flexibility away from the electrified routes (Hacker, et al., 2020a). These can also be used for sections that, for example, could not be electrified if catenary lines were installed, such as tunnels. An important advantage of the overhead contact line system and the conductor rail system in particular is the high energy efficiency, which is on par with pure battery electric propulsion systems. It amounts to over 80% (Jöhrens &

Helms, 2020). The three systems are on different Technology-Readiness-Levels[1] (TRL). This will be discussed in the following chapters. The research question that will be further explored in this paper is:

How can a timeframe for the market ramp-up of Electric Road Systems in Germany and, in perspective, also in the EU for heavy-duty road transport be designed that meets the GHG reduction targets of the EU until 2030 and until 2050, respectively?

The aim of this paper is therefore to identify political, economic and legal-regulatory variables for an efficient market ramp-up of ERS and, incorporating these factors, to develop several scenarios into a timeframe for ERS deployment. To this end, the current state of research will first be elaborated. Furthermore, the overarching methodology of scenario analysis and policy analytic veto player theory will be explained. This is followed by a comprehensive policy analysis around German and European GHG reduction targets and methods as well as ERS. Moreover, a meta-analysis on existing market ramp-up calculations for ERS in Germany is conducted, in which the results of these sources are combined and evaluated. The results found in this respect are compared with the input given in six conducted guideline-based interviews with relevant stakeholders related to ERS in the following chapter. Finally, three scenarios are created from the data found, which describe possible market ramp-up scenarios for ERS in Germany and the EU. Finally, a conclusion is drawn.

2. State of Research

In this chapter, I will summarize and analyze the current state of research regarding ERS. In order to do so, I will firstly contextualize current GHG-emissions, potential savings and the electricity mix. Secondly, I will compare ERS to other propulsion systems in heavy-duty road transport and highlight their relevance in this context. Thirdly, I will closely inspect the economic and infrastructural framework for the development of ERS, especially regarding the TCO calculation of transport operators, economic policy management options, as well as data on ERS-infrastructure construction. Moreover, I will examine current government initiatives as well as the regulatory framework to build the system.

[1] The concept of the Technology-Readiness-Level was originally conceived at NASA in 1974 for space technology development. Later, in 1989, they were formally defined. For more information, see Boltze 2020, p. 42.

2.1 Assessment of the development of GHG emissions and the electricity mix

GHG emissions in the EU and Germany could be lowered from ca. 5750 million tons CO_2-eq. (Mt CO_2-e) to 4250 Mt CO_2-e (European Parliament, 2020a) and 1251 to 839 Mt CO_2-e from 1990 to 2020 (Kemmler, et al., 2020, p. 24), respectively. This reduction is equivalent to ca. 25% for the EU and 33% for Germany. Regarding a reduction target of at least 55%, this leaves a current gap of 1662.5 (30%) and 276 (22%) Mt CO_2-e until 2030, respectively. Kemmler, et al. (2020, p. 12, 24) estimate the German GHG reduction gap in 2030 at 13.4% without further measures and 7.2% with current measures[2], while the European gap is estimated at 19% without further measures (EEA, 2020a). However, while most sectors both in the German and European perspective are able to present discernible GHG reductions, the transport sector stagnated, with 163 Mt CO_2-e in 1990 and 162 Mt CO_2-e in 2020 in Germany, or even notably increased in the observed timeframe, with 787 Mt CO_2-e in 1990 and 931 Mt CO_2-e later on, in the EU (EEA, 2020b). This development highlights the relevance and time pressure inherent in the GHG development of the transport sector facing the ambitious goal of GHG neutrality by 2050. For light and medium vehicles, significant reductions can be achieved by switching to Battery Electric Vehicles (BEV). However, the situation is different for heavy trucks, as I will show in the following chapter. Truck emissions in Germany account for roughly 25% (41.3 Mt CO_2-e) of the total transport sector emissions, with heavy trucks accounting for roughly 48% (19.7 Mt CO_2-e) of all truck emissions, although making up only 6.82% of the total number of trucks in Germany (Wietschel, et al., 2017, p. 1). In order to contribute to the targeted climate reductions and the medium-term climate neutrality, a quick solution for this sector must be found. ERS represent a viable option for this purpose. The electricity mix also plays a major role for ERS. In Germany, the factor has decreased almost continuously since 1990.While in 1990 it was still emitting 764 g/kWh, in 2000 it was 644 g/kWh, in 2010 555 g/kWh, in 2015 527 g/kWh and in 2019 401 g/kWh (Icha & Kuhs, 2020, p. 10). This corresponds to reductions in emission factor of 100 g/kWh and 89 g/kWh, respectively, in the first two decades and 144 g/kWh in the period from 2010 to 2019, with most of these reductions being achieved from 2015. The potential climate protection contribution of ERS also depends to a large extent on the further development of the emission factor of the electricity mix.

[2] This data relates to the 55% reduction target, which is no longer in effect for Germany. Following the decision of the Federal Constitutional Court in 2021, the target is now 65%, which is why the reduction gap is correspondingly larger. The current measures relate to the German “Klimaschutzprogramm”. Further explanations can be found in Kemmler, et al. (2020, p. 18).

2.2 Transportation performance trends and ERS in comparison to other alternative propulsion systems in heavy-duty road transport

In addition to ERS, there are numerous other propulsion systems that can contribute to the decarbonization of heavy-duty road transport. These mainly include railways, BEVs, Power-to-liquid (PtL) trucks, and finally the different forms of ERS, including induction-based systems, conductor rail and catenary systems.[3] Generally, the literature agrees on a continuously growing freight transport trend in Germany and the EU in the period until 2050, with annual growth rates between 1-2% (Hacker et al., 2020, p. 15; Diemer and Dittrich, 2019, pp. 8-10; Calliess et al., 2012, pp. 137-143). The modal split of freight transport in the EU is mainly determined by trucks, which currently account for more than 72% of total freight transport, while railways account for more than 15% and inland navigation for 10% (EEA, 2013). The numbers on German freight transport only differ slightly with around 70% freight transported by trucks and 17% by rail, while inland navigation remains at 10% (Calliess et al. 2020, p. 138). “Current forecasts estimate further growing freight transport demand and a share of rail transport which will not significantly exceed the current share of 18 % (based on tkm). Therefore, also in future, road freight transport will have to bear more than 70 % of the freight transport performance” (Boltze, 2020, p. 36). Other experts see more potential for shifting freight transport from road to rail, but even assuming ambitious measures, this potential will be limited to ca. 27% of total freight traffic in the coming decade, leaving the major part of freight transport to the road (Lobig, et al., 2017). This highlights the relevance of alternative, low-emission propulsion systems for trucks.

The electric engine of BEVs allows an energy efficiency of roughly 90%, which is among the highest of all propulsion systems. In comparison, diesel trucks only reach efficiencies of around 30-40% (Wietschel, et al., 2017, p. 96).[4] However, in order to allow for high driving distances, BEV trucks in high weight categories (>32t) would require batteries with very high weights and unreasonably long charging pauses.

> “Driving a 40t-truck for 800 km from Hamburg to Munich would need about 1.700 kWh [...]. Even for a lithium ion battery with an energy density of 200 Wh/kg that would lead to a battery weight of 8.5 t. For trucks with such heavy batteries the reduced payload and battery costs are as critical as the availability of raw materials for the batteries. To improve that situation significantly, it needs radical innovations in energy storage which are not predictable” (Boltze, 2020, p. 37).

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[3] Since LNG trucks, similarly to diesel trucks, burn fossil resources and emit greenhouse gases, they are not considered in this list.

[4] This efficiency relates to the efficiency of the engine; the upstream chain (efficiency of the power production) is not taken into account.

In sum, BEVs appear to be a potent solution for freight transport in lower weight categories but cannot provide a solution for freight transport in high weight categories. PtL-trucks are based on synthetic fuels, such as hydrogen, which are produced using electric energy. Due to energy losses in the production process, this method turns out be less energy efficient compared to the direct use of electric energy. The literature agrees, that PtL-trucks might be a viable option in certain fields of freight transport, but forecast it to be overall notably more expensive than direct use of electricity, including ERS (Wietschel, et al. 2017, pp. 98-103; Hacker, et al., 2020b, p.15; Kemmler, et al., 2020, p.14).

> "In the context of the wider energy transition and the imperative to fully decarbonise all economic sectors including the power, industry and heating sectors, substantial additional renewable electricity capacity will be needed in Europe. Renewable electricity should therefore be used as efficiently as possible. Because the decarbonisation of the aviation and shipping sectors as well as other hard-to-abate sectors such as industry will rely on electricity-based fuels and renewable hydrogen in particular, direct electrification should take precedence in road transport wherever feasible, including long-haul trucking" (Suzan & Mathieu, 2021, p. 47).

The deployment of PtL trucks, and hydrogen-based trucks in particular, therefore appears to face some challenges. Regarding different types of ERS, induction-based ERS systems present the highest infrastructure costs among all electric road systems, have the lowest TRL and have been affected by technical problems in pilot projects (Hartwig, et al., 2020a). Conductor-Rail systems have a higher TRL and are less expensive, but the anticipated costs of the system are still notably higher than the cost for catenary systems, which have the highest TRL as well. Due to the direct use of electric energy, catenary and conductor rail systems turn out to be similarly efficient as BEVs. Wietschel et al. (2017, p. 69) estimate the infrastructure costs of a 3900 km conductor rail ERS-network in Germany to be ca. 30% and those of an induction-based system to be almost 200% more expensive than the costs associated with the construction of a catenary system. Consequently, the catenary system is considered the most cost-efficient ERS option. Finally, the reviewed literature agrees, that a mix of different alternative propulsion options represents the best approach for rapid decarbonization of the transport sector. Given the increasing volume of freight transport and the lack of cost-efficient alternative propulsion systems, ERS, and the catenary system in particular, appear to be a potent decarbonization option for this purpose.

2.3 Economic and infrastructural framework for the development of ERS

This subchapter is dedicated to the task of summarizing and depicting previous research on the economic situation of all relevant ERS market participants, as well as examining the infrastructural framework to build the system. To this end, the TCO calculation is first presented from the perspective of transport companies. In the next step, I will take a closer look at economic policy management options and framework data on the expansion and costs of infrastructure. The TCO calculation, economic and regulatory framework as well as the development of GHG emissions will be analyzed and evaluated in detail as part of the meta-analysis in chapter 6.

2.3.1 TCO calculation of transport companies

International competition in the heavy-duty road transport market is high and margins are correspondingly low, mostly in the low single-digit percentage range (Forseke, 2011). The introduction of ERS thus can only succeed if the system is economically viable in the long term, ideally with economic advantages over diesel trucks. Market ramp-up calculations for Germany were conducted by Jöhrens, et al. (2020), Hacker, et al. (2020b), Wietschel, et al. (2017) and NPM (2020). From now on, I will refer to these as the `reference sources´. Currently, similarly comprehensive scientific projections for the introduction of ERS in other countries do not seem to exist. The calculations of the reference sources are mostly scenario-based and compare overhead costs, fixed operating costs, and variable operating costs for various alternative propulsion systems, mainly focused on catenary and diesel trucks. The scenarios are based on different assumptions regarding price- infrastructure- and regulatory developments. However, all of them show, that ERS-trucks currently comprise significantly higher overhead costs and notably lower variable costs compared to diesel. The reason for the price differences in the variable costs is that electricity is a cheaper power source than diesel when production costs and energy efficiency are taken into account, while the price difference in overhead costs can be explained by the high prices of ERS trucks at the beginning of the market ramp-up without highly scaled mass production. However, with upscaled mass production and a fully built ERS infrastructure, the difference in overhead costs diminishes, while the variable cost advantage of ERS advances further. Consequently, economic superiority of ERS trucks over diesel trucks is determined by the annual mileage, as cheap power consumption outweighs high initial costs. Moreover, as the construction of the ERS infrastructure progresses and mass production is upscaled, economic superiority increasingly shifts towards ERS trucks.

2.3.2 Economic policy management options

General policy options to influence the market ramp-up of ERS comprise economic incentives or subsidies for ERS trucks as well as levies for GHG-emitting vehicles. Jöhrens, et al. (2020, p. 55) list purchase bonuses, electricity price reductions, toll reductions and CO_2-pricing as viable options. In doing so, the authors emphasize that the focus of subsidies for maximum GHG savings should be on ensuring that as many miles traveled as possible are electric. In the calculation example provided by the authors, they show that toll and electricity price reductions are suitable for this purpose, while a purchase premium ensures more cars are purchased, but is associated with fewer kilometers driven electrically compared to the other subsidy options. Given the low margins in the road transport industry and because of the natural risk associated with the introduction of new, market-changing technologies, the authors who have performed market ramp-up calculations consider initial economic support for the technology to be reasonable (Jöhrens, et al., 2020, p. 55; Hacker, et al., 2020b, p. 23). However, they also agree, that these measures should be temporary, that a degressive support regime might be preferable and that the most accurate long-term instrument is CO_2-pricing. As the transport sector is currently not covered by the EU emission trading system (EU-ETS)[5], countries need to establish their own system in order to do so. (EC, 2020a). Germany, for example, established a national emission trading system (nEHS) in 2021, which aims to fulfil this task (Deutsche Emissionshandelsstelle, 2021). Nevertheless, a certain degree of caution is recommended when implementing CO_2-pricing. Currently, the transport business is based almost entirely on diesel trucks with no option to avoid GHG-emissions (Wietschel, et al., 2017, pp. 144-150). Since smaller, less capitalized transport companies are more vulnerable to price shocks, CO_2-pricing without the option to emit less CO_2 effectively forces these companies out of the market, while their market share is divided among the remaining companies. The considerations made highlight the importance of careful consideration in the choice of economic policy measures. While several aspects are already covered by the existing literature, more research is necessary in order to optimize economic policies in regard to the introduction of ERS.

[5] Flights within the EU are included in the EU ETS, but no other segment of the transport sector is.

2.3.3 Economic and organizational framework for the construction of ERS

Most of the reference sources agree, that a final expansion of nearly 4000 km should be targeted. However, the projections about the expansion speed differ among the authors. Hacker, et al. (2020b, pp. 193-196) offer three scenarios with the construction beginning in 2020 and ending between 2035 and 2045, while Wietschel, et al. (2017, p. 141) and Jöhrens, et al. (2020, p. 25) created scenarios in which the infrastructure expansion could be completed between 2020 and 2030. NPM (2020) was able to take into account the most recent expansion plans of the German government and estimates, that around 350 km of ERS infrastructure, which is less than 10% of the targeted 4000 km, are built until 2025 and 2000 km until 2030. The projected average annual expansion rate differs between 150 km and 400 km, as will be shown in chapter 6.1. This is also due to uncertainties in the construction process. According to Hartwig, et al. (2020b, p. 137), it plays a crucial role which construction model is used to build the ERS infrastructure. The author considers the possibility of a public-private partnership (PPP) and emphasizes the transfer of risk to the private partner. This could be ensured, for example, by an availability model in which the private partner is remunerated according to the operational availability of the infrastructure. In this case, the private partner would have a high natural interest in the functionality and availability of the infrastructure, which can help minimize operational deficiencies. The estimated costs for the construction of the infrastructure vary similarly wide between €6.5 billion and €16 billion. At first glance, this may seem like a lot of money, but it is put into perspective both over the 10-25-year construction period under consideration and in light of the cost of alternative technology options.

2.4 Regulatory framework and government initiative

The regulatory framework includes a legal and organizational assessment as well as the standardization process of the technology. Due to the scope of these topics and the limitations of this paper, only central aspects will be addressed here with further reference to existing research. A full list of recommended actions in the legal sphere can be found in Hartwig, et al. (2020a, pp. 21-41). However, the aspects likely to be most relevant to the timeline for the market ramp-up are an inclusion of ERS in the Alternative Fuels Infrastructure Directive (AFID) and further coverage in Directive 1999/62/EC on the charging of heavy-duty vehicles for the use of certain infrastructures (ibid.). A revision of the AFID will take place in 2021 (European Parliament, 2020b). If ERS are not or not sufficiently considered in this context, a later legal implementation might induce further delays in the process. Beside the organizational issues already addressed in 2.3.3, planning approval procedures might be necessary for the large-scale expansion of ERS (Gurske, 2021). Most of these procedures can be completed in a period of less than 12 months, with upward deviations becoming rare (Unabhängiges Institut für Umweltfragen, 2012). For the standardization process, the development of a meter that conforms to measurement and calibration law for billing by kWh[6], the development of a suitable pantograph, and ideally the European harmonization of these technologies are central. As the development of these devices confronts companies with notable costs, a reduction of market risk is crucial for a smooth market ramp-up. Such planning security can best be ensured by a guiding governmental framework plan (Hartwig, et al., 2020b, pp. 65, 134). An initial approximate basis for one is given in the German Roadmap for propulsion technologies, which indicates the market ramp-up of BEVs in regional and long-distance transport, hydrogen-based trucks, and catenary trucks. According to this plan, 300 km of commuter highway will be electrified between 2021 and 2025. A path decision on the large-scale roll-out for ERS is to be made in 2025. If the decision is positive, it is assumed that the infrastructure will be extended to a total of 2000 km by 2030. However, this plan does not yet include any concrete statements on economic policy funding and emphasizes that a path decision for Germany will not be made until 2025 (NPM, 2020, p. 19; BMVI, 2020, p. 15). In this respect, it can be interpreted more as the first step toward a comprehensive plan, which does not yet offer noteworthy planning security.

3. Methodology

As the goal of this paper is to develop a framework for the future potential market ramp-up of ERS as a new technology, the choice for a fitting methodology must be based on a future forecast approach. Moreover, the thesis´ scope is limited by its length and the available resources. Possible methods of research into the future primarily include modeling, Delphi surveys, roadmapping procedures and scenario analysis. In most cases, these are used in accordance with the forecasting approach to analyze the future. However, a backcasting approach is also possible, which in principle can be understood as a scenario process backwards. Combinations of these methods can be deployed as well. Since elaborate

[6] Other billing methods are also conceivable, but less adequate, according to Hartwig, et al. (2020b, pp. 63-70).

mathematical modeling and multi-layered expert surveys as part of the Delphi method are beyond the scope of this paper, scenario analysis will be used as the primary method in this paper (Kosow, et al., 2008, pp. 61-67).

3.1 Scenario Analysis

The aim of the method is to depict a possible future situation including the development paths leading to this situation. In this context, a scenario firstly deliberately does not represent a comprehensive picture of the future, since its function is to direct the perception specifically to one or more particular sections of reality. Secondly, it is important to note that the selection and combination of (key) factors is constructive work. The classification of factors into relevance classes as well as their interactions is suggested by the available data, depending on the case, but also requires profound knowledge in the subject area. Nevertheless, such classifications are always based on subjective and normative assessments and must therefore be justified in detail. Thirdly, all scenarios are thus based on assumptions about how the future will unfold. In the process, future scenarios are presented as funnels. Events can be estimated more inaccurately in the distant future than in the near future due to the multiple interactions of variables. Thus, the further the scenario is projected into the future, the wider the so-called scenario funnel expands, as can be seen in Figure 3 (ibid., p 9-13).

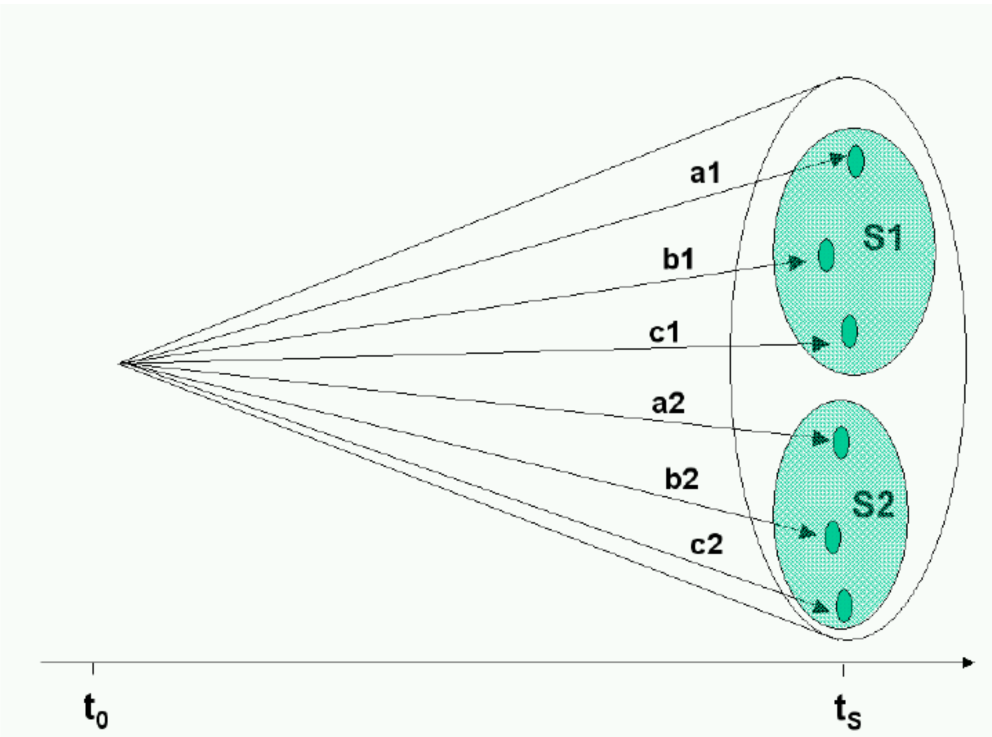

Figure 3 - The scenario funnel. Display according to Kosow, et al. (2008, p. 13).

The function of the developed scenarios amount to the knowledge, communication, goal formation and strategy formation function. They reveal the limits of knowledge, define future scopes and priorities, support scientific and societal discourse, can develop normative future visions and provide planners with points of orientation (Greeuw, et al., 2000, pp. 7-9). Three types of scenario analysis can be distinguished: Trend extrapolation, creative-narrative scenario technique, and systematic-formalized scenario technique. Trend extrapolation is used to project existing quantitative data on a scenario basis, while creative narrative scenario techniques are mainly used for scenarios with only two to three key factors. Systematic-formalized scenario techniques, on the other hand, are used to process a large number of quantitative and qualitative (key) factors and to examine their interactions. Due to the novelty of the ERS technology, no existing trend can be extrapolated. And because of the multitude of (key) factors, the systematic-formalized scenario technique is particularly suitable compared to the creative-narrative one (Kosow, et al., 2008, pp. 32-55). The scenario analysis itself can be divided into five phases: Scenario field identification, key factor identification, key factor analysis, scenario generation, and scenario transfer, as can be seen in Figure 4.

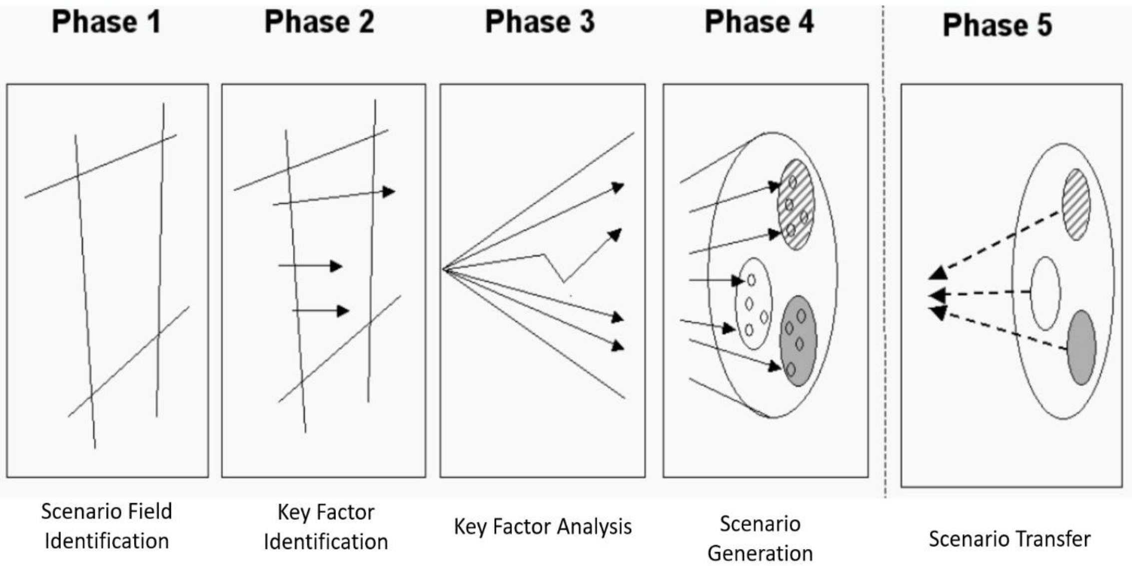

Figure 4 - The five phases of scenario analysis. Display according to Kosow, et al. (2008, p.20).

A basic identification of the scenario field was given in chapter 2 and based on the available literature. How key factors are identified in scenario processes varies widely. Depending on the case under investigation, they can be identified through analysis-intensive empirical and theoretical preparatory work, but they can also be integrated through workshops and survey rounds or interviews (Kosow, et al., 2008, p. 21). A workshop, six interviews with relevant stakeholders in the field of ERS and a thorough meta-analysis were conducted accompanying this thesis and will serve as a basis for identifying and analyzing the key factors.

The meta-analysis will aggregate and evaluate previous research results on market ramp-up calculations of ERS. For this purpose, four market ramp-up calculations for Germany were evaluated. The core data regarding speed of deployment and costs of infrastructure, TCO calculation and GHG emissions are presented in tabular and graphical form with mean values of the overall findings. Where data from the reference sources was not measured consistently, they were converted accordingly. For example, variable costs were calculated per kilometer and consumption measured in either kWh or MJ was standardized in order to present consumption prices in a uniform manner. Since the conditions for the introduction of the technology also depend to a large extent on the political conditions and regulations at national and EU level, but only very limited literature is available in this context, a political analysis will also be conducted as a key factor for the introduction. In order to do so, relevant political stakeholders in Germany and the EU and their influence on the decision-making process will be identified in a first step. In a second step, the veto player theory will be deployed to identify potential political resistance and intersections in the decision-making process of the involved stakeholders. Finally, three forecasting scenarios are created, providing for the scenario generation. Furthermore, a backcasting approach based on the existing data will be illustrated.

3.2 Variable Overview

In order to provide the reader with a better overview of the topic, a comprehensive overview of the variables relevant for the market ramp-up of ERS will be given at this point. It will be investigated which factors X enable a certain event "market ramp-up of ERS" Y and in which way they contribute to it. Accordingly, this is a Y-centric analysis. The background to this is that sustainable electricity replaces diesel or gas as an energy source in heavy-duty road transport. Regarding ERS, this is only possible if sufficient infrastructure is provided, if vehicle operation is attractive enough for logistics companies to switch to ERS trucks, and if the electricity used is most sustainable. The variables defined for this purpose were therefore divided into "Infrastructure expansion", "Vehicles on ERS"[7] and "Share of renewables in electricity mix". These three superordinate variables continue

[7] Ultimately relevant for the calculation are the ton kilometers driven, since different vehicles transport different weights of goods and emit different amounts of GHG.

to depend on subordinate variables. Infrastructure expansion depends primarily on the political decision-making process, the planning process, and the construction process. The number of vehicles on the ERS and the ton kilometers (tkm) driven on it depend on the costs of vehicle production and availability, as well as a suitable business model and an advantageous Total-Cost-of-Ownership (TCO) calculation for logistics companies. The share of renewables in the electricity mix also depends on bureaucratic simplifications and legal backing for renewables, especially in Germany. Economic incentives and levies on fossil fuel can also contribute to the increased use of renewables. For capacity reasons, however, a more in-depth analysis of the development of the electricity mix cannot be conducted in this paper. Nevertheless, its relevance is emphasized here. An illustrative representation of the information described above can also be found in Figure 5. It graphically displays the scenario field and key factor identification and is based on the literature review.

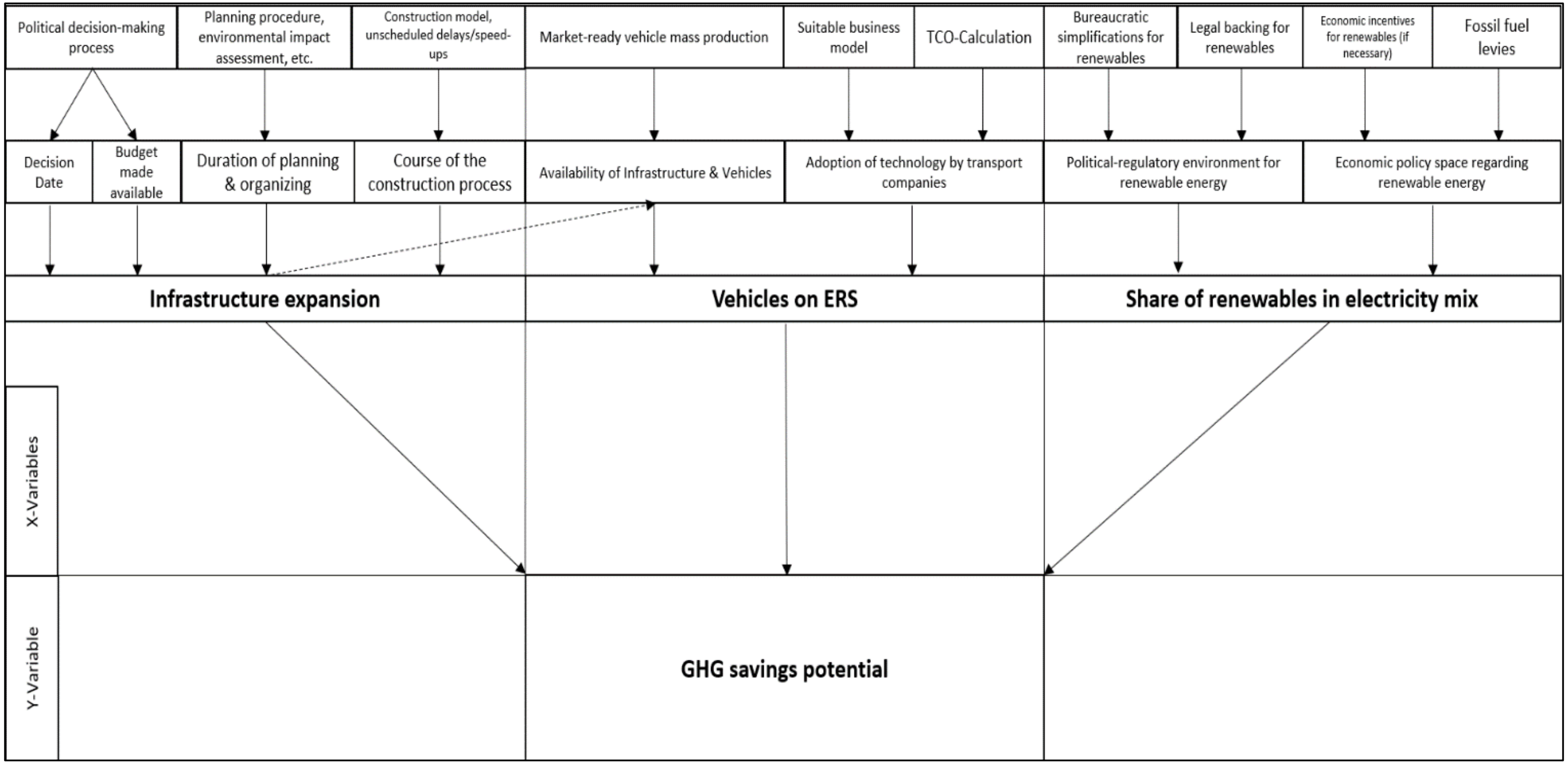

Figure 5 - Overview of variables for the market ramp-up of ERS. Source: Own representation.

3.3 The scenario space as a spider chart

For further illustration and explanation, a simplified formula for the calculation of GHG emissions and its representation in a spider chart is given here. The GHG emissions are calculated by the tkm driven electrically, the emission factor of the electricity mix and the efficiency of the propulsion system. The tkm traveled are dependent on the expansion status of the infrastructure and the vehicles driving along the infrastructure, as shown in Figure 6. In the German case, 100% infrastructure expansion is equivalent to an expansion length of about 4000 km. The percentage of vehicles on ERS is measured by the percentage of all vehicles that can potentially use ERS. In our example, these are all heavy trucks in Germany.[8] If one of these variables is zero, the total savings are also zero. Otherwise, the savings result from a combination of these values. Two exemplary development states of ERS expansion can also be found in Figure 6. The primary purpose is to show that all these variables must be facilitated in combination for a successful system. A fully developed infrastructure has little effect if few vehicles use it or if the electricity mix is dominated by fossil fuels. Conversely, the effect is also small if only a few percent of the infrastructure are developed, but a relatively large number of vehicles use this short developed route.

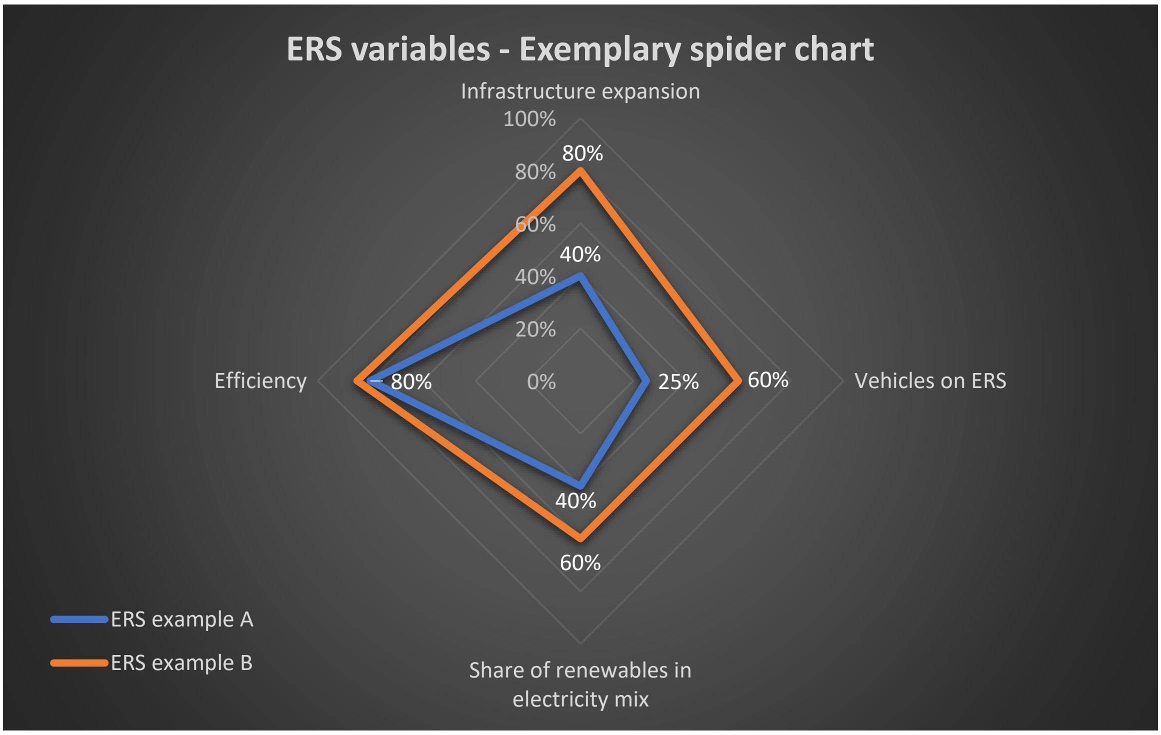

Figure 6 - Simplified representation of the variables relevant for the GHG emissions of ERS. Source: Own representation.

[8] It is also conceivable that other vehicles such as buses or smaller trucks use ERS. The example can also be extended beyond the borders of Germany, e.g., to the EU.

4. Veto Player Theory

The introduction of ERS as a new technology and the speed and quality of the process depend to a large extent on the political decision-making. The acceptance of a new technology in the political framework can best be described in terms of the approval and opposition of the political decision-makers. In this context, veto player theory is an ideal tool for analyzing these indicators. Moreover, as I will argue in the course of this paper, much depends on the European or international acceptance of the technology. Economies of scale in production as well as the creation of secondary markets strongly contribute to the economic viability of the technology. In this context, a game-theoretic approach with states as stakeholders in an interdependent decision-making situation would also be conceivable. The maximum benefit under economic and climate protection restrictions could be achieved in such a game-theoretical situation if as many countries as possible adapt the technology (based on the current scientific status quo), while individual countries have an economic incentive to continue using fossil fuels as long as they are cheaper. According to the theory, cooperative bargaining could then lead to a Pareto-optimal[9] result, which would mean the acceptance of the technology under the assumptions made. If, on the other hand, states do not engage in such a bargaining process or consider only an economic and not a climate protection restriction, the framework changes, and the economies of scale decrease (Breyer, 2015). For capacity reasons, however, such a game-theoretic examination will not be conducted here and is noted here only as an excursus. For future research, however, this could represent an interesting field of study.

So, in this context, veto player theory presents itself as a suitable tool for analyzing the political process. According to Tsebelis (1995, p.302), a veto player is "an individual or collective actor whose agreement is required for a change in policy." He distinguishes between veto players defined by the constitution (institutional veto players) and those who are part of a governing coalition (partisan veto players). Additionally, he defines veto players that present “take it or leave it” proposals to other veto players as agenda setters. As they have to make proposals acceptable by the other veto players, they will select among the feasible outcomes they prefer the most and have a certain degree of control over the specific changes to the status quo (Tsebelis, 2002, p. 13).

To illustrate the decision-making process, the author plots the substantive positions of the

[9] Pareto optimality is the condition, in which it is not possible to benefit one stakeholder without worsening the position of another.

veto players in two-dimensional space and maps their preferences by indifference curves. The intersection of all relevant stakeholders forms the political solution space and is referred to by Tsebelis as the "winset", as shown in Figure 7. If the indifference curves do not intersect or touch, there is no winset and an issue is characterized by political stability, so that the status quo is maintained. (Tsebelis, 1995, p. 295).

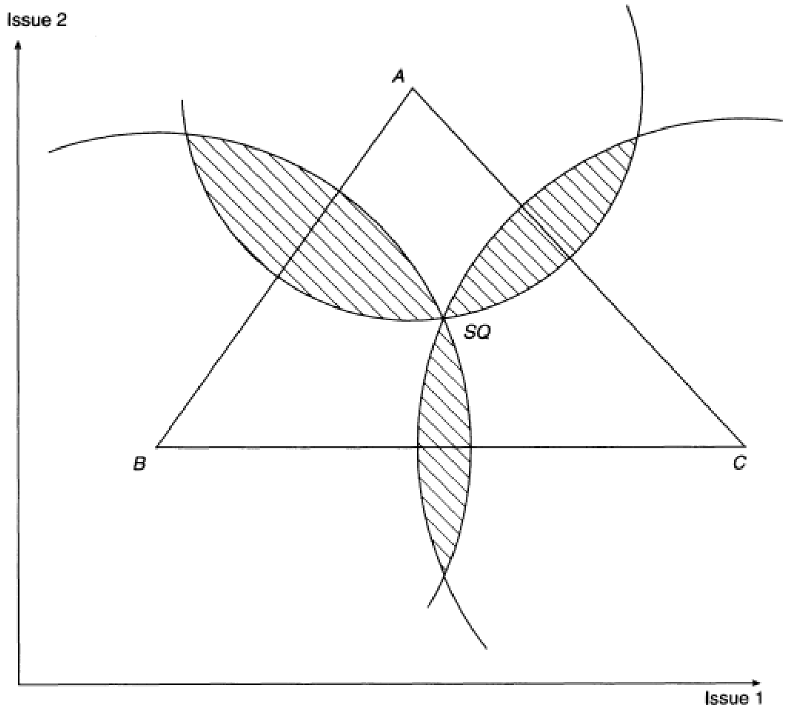

Figure 7 - Winset of status quo with three players in two dimensions. Display according to Tsebelis (1995, p. 296).

The author introduces some propositions that determine the stability of the status quo. Firstly, as the status quo of n+1 players is a subset of the winset of the status quo of n players, the winset of the status quo does not increase if new veto players enter the system, but it can decrease. Consequently, additional veto players contribute to stabilizing the status quo. Secondly, as the distance of veto players from the status quo increases, the winset does not increase, but it can decrease. This can be understood as the ideological distance or proximity to the status quo. Thirdly, substantive disagreement within the group of a collective stakeholder, which can also be referred to as low cohesion, increases the likelihood of changing the status quo. Additionally, in the event of a change of government, the ideological gap between the governments also adds to the likelihood of a shift from the status quo (Tsebelis, 1995, pp. 297-301). The influence of these factors on the decision-making process regarding ERS will be analyzed n in chapter 5.3.

5. Political Analysis

This chapter will focus on the political analysis regarding the decision-making process for the market ramp-up of ERS. The political decision is the responsibility of the political decision-makers. In democracies, these are primarily government coalitions and parliamentary representatives. As shown in Figure 8, societal and economic stakeholders contribute to agenda setting and the decision-making process by influencing policymakers. Ultimately, judicial review can also have the effect of revising decisions reached, which will also be taken into account in this examination. In order to analyze the political preferences of societal and economic stakeholders, lobbying work of companies, civil surveys on the assessment of climate change as a field of concern as well as the media relevance of climate change will be evaluated. The underlying idea is that strong political pressure to mitigate climate change could also provide momentum for ERS as a particularly cost-effective, efficient option to decarbonize heavy-duty road transport. Further, where possible, the attitudes of societal and economic stakeholders toward ERS will be evaluated. However, since pilot projects with extensive accompanying research on ERS exist mainly in Germany, the political attitude towards ERS of the mentioned stakeholders is evaluated only for Germany. For this purpose, the political landscape in Germany is analyzed first. In a second step, the European perspective on ERS is examined in more detail. Finally, the results found are contextualized and evaluated in the veto player theory.

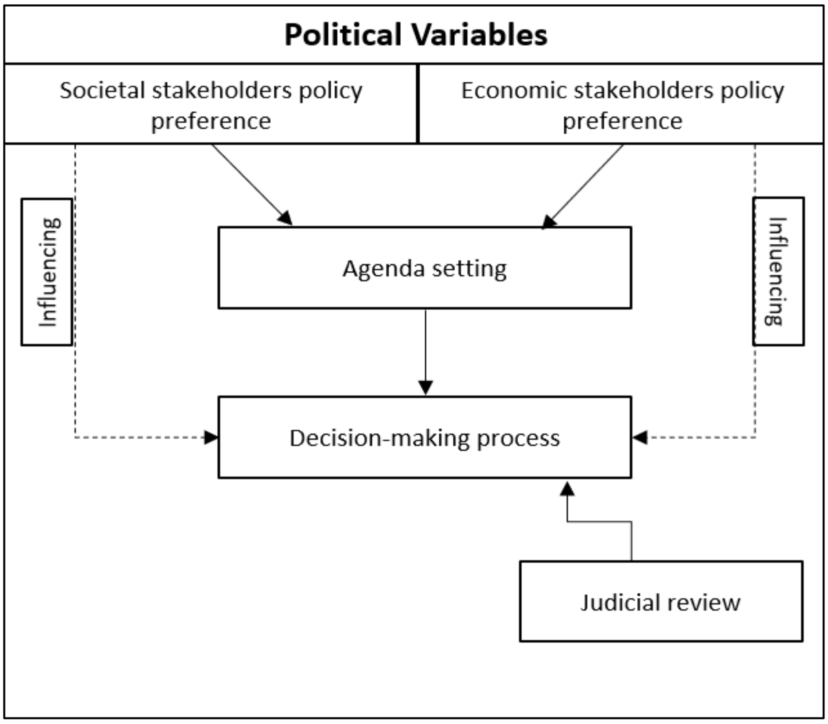

Figure 8 - Simplified illustration of the political decision-making process. Source: Own representation.

5.1 The political landscape in Germany

According to the Special Eurobarometer 490 – Report on Climate Change (2019), 30% of the German respondents in 2019 considered climate change the single most serious problem the world is facing, only second to poverty, hunger and lack of water. In 2017, only 14% and thus less than half of the respondents shared this assessment. When asked about the biggest current problem areas (up to four could be named), 71% of Germans surveyed named climate change, an increase of 18 percentage points compared to 2017. Furthermore, they consider business and industry (62%), the EU (52%) and their national government (51%) to be the institutions most responsible for tackling climate change. These numbers also increased by 17-24 percentage points from 2017 to 2019. 81% of the respondents agreed, that more financial support should be given to the transition to clean energies while cutting subsidies for fossil fuels. This development was accompanied by an increased presence of socially organized groups with a climate protection focus, such as Fridays for Future or Extinction Rebellion, which each started in 2018 (DW, 2021; Schneider & Toyka-Seid, 2021). Also, the media presence around climate change increased fourfold from 2018 to 2019 (PMG, 2021). Therefore, there is no doubt, that the socio-political preference for and the focus on climate protection has increased over time.

A comprehensive study of the attitudes of economic stakeholders toward climate protection would go beyond the scope of this paper. However, it can be assumed that profit-oriented companies hold aversions to climate protection measures if it is associated with significant additional costs. Furthermore, it can be assumed that this attitude is usually not openly formulated in view of the strong predominance of support for climate protection within the population, in order not to damage the image of the respective company. Thus, climate change is now less frequently denied by the relevant representatives and lobbyists. Instead, there are more frequent attempts to postpone effective climate protection measures or to neutralize emissions e.g. by carbon capture, instead of reducing them (Deckwirth, et al., 2020). Regarding opposition to climate protection, a study by Influence Map (2015) concluded that 45 of the 100 largest industrial corporations worldwide actively fight climate protection laws and are members of corporate associations that position themselves against climate protection. This applies in particular to fossil fuel producers, the chemical industry, the metal processing industry, the automotive industry, and many others. In Germany, for example, corporations such as BASF, VW, Daimler and BMW can be named. All in all, there is considerable resistance to climate protection measures of several companies at both German and international level (Deckwirth, et al., 2020; Euractiv, 2019, Mestermann, 2021).

As far as the German market for heavy trucks is concerned, the main players are Daimler, Volkswagen, DAF, Volvo and Iveco. The market for heavy trucks in 2015 was dominated by Daimler and MAN (part of Volkswagen), as can be seen in Figure 9.

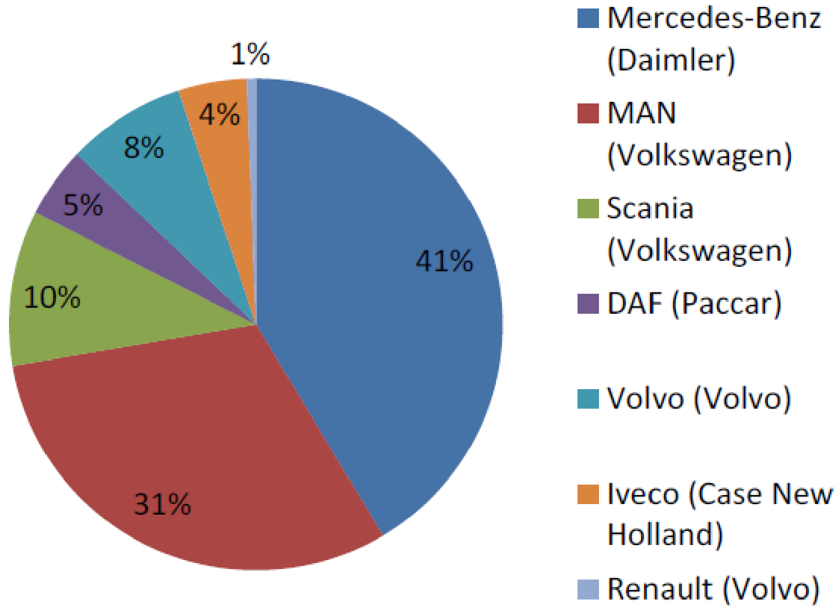

Figure 9 - Market shares of heavy trucks in Germany 2015. Source: Partial extract from Wietschel, et al. (2017, p. 225).

According to Wietschel, et al. (2017), however, Daimler considers the catenary technology rather skeptical. As far as electrified trucks are concerned, MAN focused on battery-electric trucks with a rather short range (200 km) and diesel-hybrid concepts. DAF and Iveco also define themselves mainly through hybrid concepts. Volvo was a Siemens partner in the Californian ehighway project, but primarily focuses on efficiency improvements of the diesel engine as well as other liquid fuels. Scania has been a partner in several catenary projects and is interested in further production of catenary trucks. At this point, however, it should be mentioned that the data of Wietschel, et al. is still from 2017 and although this is a fairly short period of time, it may not fully reflect the rapid changes in the industry. However, the assessment towards ERS at this point in time reflects a rather skeptical picture by truck manufacturers.

Regarding judicial review, the German Federal Constitutional Court has declared the previous decision-making process on climate protection to be partly incompatible with the constitution and ordered a revision of the Climate Protection Act. According to the decision, the measures stipulated in the law up to 2030 were not sufficient and shifted the burden of reducing emissions to a significant extent to the period after 2030. Since this is done at the expense of the younger generation and thus restricts their freedom rights, a rectification of the law was necessary (Deppe, 2021). The law was subsequently amended within a relatively short period of time. According to this, Germany is now to become climate neutral by 2045 instead of 2050 and to reduce GHG emissions to 65% instead of 55% by 2030 (Euronews, 2021). On the one hand, this ruling demonstrates the influence of judicial review on the decision-making process; on the other hand, it also results in a significantly increased pace for the decarbonization of all sectors. This highlights the pressure for action to rapidly decarbonize all sectors of the economy. The rigid heavy-duty road transport sector in particular, which has seen stagnant emissions over the past 30 years, is therefore in need of a timely major overhaul.

In addition to surveys, media coverage, societal movements and judicial decisions on climate change, the perception of the ERS-technology by societal and market stakeholders also plays a role. For example, public opposition or a hesitant uptake of the technology by market participants can have a slowing effect on a potential market ramp-up. In their analysis of the socio-political acceptance towards ERS, Burghard & Scherrer (2020, pp. 21-30) evaluated newspaper articles and citizen inquiries on ERS and found, that the media response toward the technology remained largely neutral with little deviation, while the perception of locals was mostly negative. Most discussed and criticized in both contexts were the costs and the economic viability of the project. It was also noticeable that the climate contribution was questioned and that ERS were often seen as a competitor to rail and as a possible traffic restriction. In terms of market acceptance, the authors found that the transport companies already involved have a positive attitude, while those that are not yet involved tend to adopt a more cautious or even negative stance. Here, too, costs, cost-effectiveness and planning security play a key role for the companies. The authors recommend highlighting the benefits of ERS trucks in synergy with rail as part of a clear narrative, since rail capacity is far from sufficient to handle the growing heavy-duty road transport, as shown earlier. Furthermore, positive local environmental impacts and reduced noise emissions should also be highlighted to communicate this benefit to critical citizens. Ideally, the public could be informed about and involved in important steps in the project at an early stage and on an ongoing basis (ibid., p. 37-39).

Overall, climate protection is therefore one of the main global problem areas in the perception of Germans. This development has become even more pronounced in recent years. While the highest German court recently ordered an increase in the speed of climate protection and while there is great support for measures to combat climate change from societal stakeholders, a significant part of economic stakeholders aims to weaken and postpone climate protection measures. ERS as a decarbonizing technology remain rather unknown to the broader public in this context. The attitude of both societal and market stakeholders toward ERS is neutral to skeptical, which overall tends to represent a negative perception. However, as explained, a large part of the skeptical perception of market-side actors toward ERS is based on a lack of planning security, while societal concerns and criticisms often contradict the state of scientific knowledge. It can be suggested that the objective scientific advantages of the technology are communicated in detail. In particular, the high efficiency and the high climate contribution as well as the associated low long-term energy costs compared to alternative decarbonizing technologies should be emphasized, which have already been discussed in previous chapters. Furthermore, a political framework plan could largely cover the existing gaps in the planning security of companies and thus improve attitudes towards the technology.

5.2 The European Scope

In the following subchapters, the European scope for the expansion of ERS will be analyzed. First, the development of the policy preferences of social and economic stakeholders in relation to climate protection in general will be examined in more detail. Furthermore, the organization of climate protection in the EU will be examined. These more general chapters will provide an overview of the position of ERS in the pool of a variety of different climate protection measures. In addition, the concrete ERS initiatives in EU member states and on the international level will be presented next. Finally, the information found is applied to a possible EU-wide implementation of the system.

5.2.1 Development of European Policy Preferences over Time

The development of EU-wide survey results on attitudes toward climate protection is similar to German survey results, but at a slightly lower level. 12% of EU residents considered climate change to be the single most serious problem facing the world as a whole in 2017, while 23% named it in 2019. 43% considered climate change to be one of the biggest problem areas (up to four could be named) in 2017, while 60% named it in 2019 (EC, 2019). Interestingly, the temporal progression of the surveys reveals that the perceived urgency of climate change as a problem area decreased over time from 2011 to 2017, then increased significantly in 2019, as shown in Figure 10. This highlights the leap in perceived importance that climate change took after 2017, not only in Germany but also in the EU.

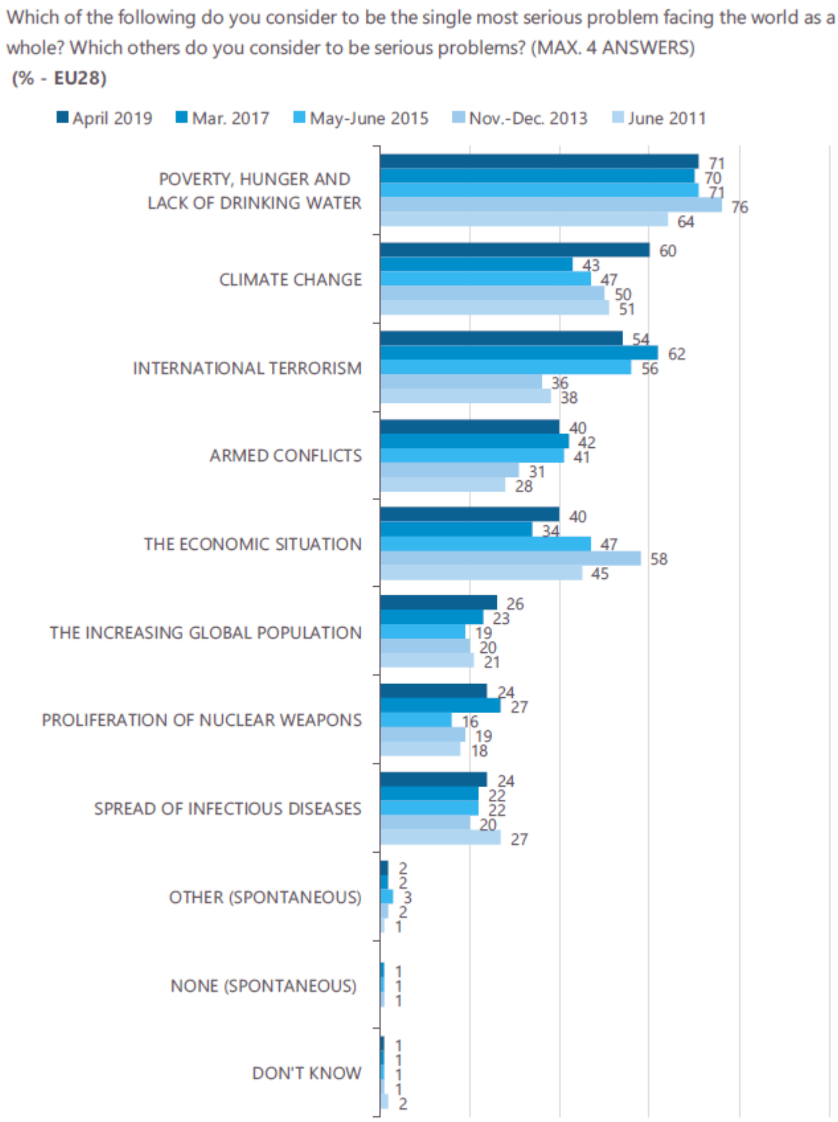

Figure 10 - Survey on the biggest global problem areas as perceived by EU-28 citizens. Source: EC (2019a, p 13.).

This is particularly the case for the Northern European and Midwestern parts of the EU, as well as the German-speaking countries. A detailed illustration of the assessment by country can be found in Figure 11. In the remaining countries, poverty, hunger and lack of water, the economic situation and terrorism are seen as the greatest problem areas.

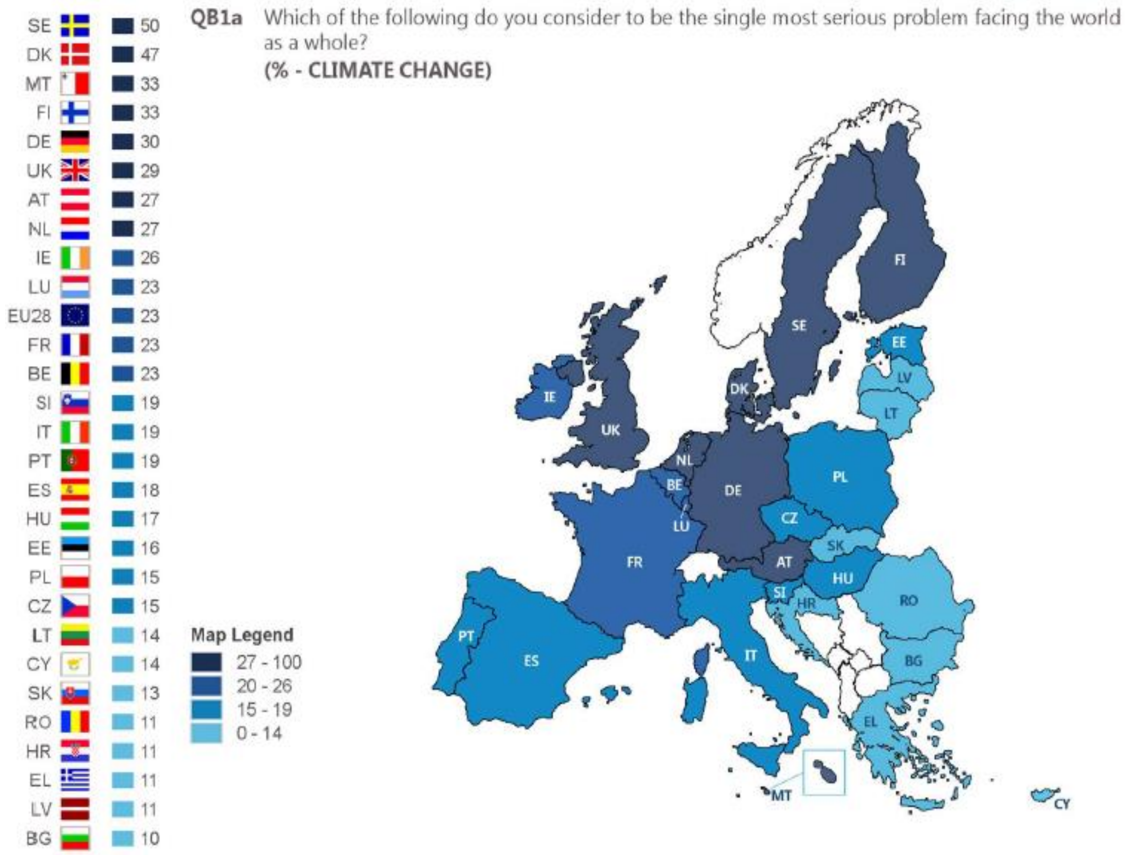

Figure 11 - Survey on the biggest global problem currently facing the world, categorized by EU member states. Source: EC (2019a, p. 7).

Similarly, to the German respondents, EU-28 respondents also agree that national governments (55%), business and industry (51%) and the EU (49%) are the institutions most responsible for tackling climate change. Again, a notable jump in mentions between 10-13% from 2017 to 2019 could be observed. In the EU, even 84% of the respondents agreed, that more financial support should be given to the transition to clean energies while cutting subsidies for fossil fuels. What might also be interesting in this context is that 72% of respondents agree that reducing fossil fuel imports from outside the EU can increase energy security and benefit the EU economically.

Concluding, it can be said, that

> "The overall results show the increasing seriousness of climate change for respondents. This is reflected not only in the increase in personal actions to fight climate change, but also in widespread support for national and EU-level measures to tackle it. Climate change is increasingly seen by EU citizens as one of the most serious challenges facing the world as a whole. Since 2017 it has overtaken the rise of international terrorism, and now ranks as the second most serious problem after poverty, hunger and lack of drinking water. An increasingly large majority of respondents see climate change as a serious problem. Furthermore, the proportion who consider it a very serious problem has increased for the second consecutive survey: up five points since 2017 and ten points since 2015, to almost eight in ten (79%) in the current survey. Almost all respondents (93%) think climate change is a serious problem" (EC, 2019, p. 94).

5.2.2 Organization of climate protection within the EU

European climate protection is divided into the EU-ETS and the so-called effort sharing. Around 40% of all GHG emissions generated in the EU are traded in form of emission certificates via the EU-ETS, which covers in particular the electricity and heat generation sectors, energy-intensive industry sectors including oil refineries, steel works and chemicals, and air traffic in the European Economic Area. Effort-sharing captures the remaining 60% of GHG emissions by setting targets for all member states based on economic performance for non-ETS sectors such as transport, buildings and agriculture (Salb, et al., 2018, p. 21). At this point, it should be mentioned that the interim GHG reduction targets for 2020 and 2030 are significantly lower for effort sharing than for the EU-ETS. Sectors in the EU-ETS should reduce their GHG emissions by 21% by 2020 and 43% by 2030, while sectors in effort sharing should reduce their emissions by only 10% by 2020 and 30% by 2030.[10] This also involves ERS, as they are part of the transport sector and thus also part of effort sharing. Notably, twelve economically weaker member states were allowed to increase their GHG emissions between 2% and 20% until 2020. The target for 2020 was reached by overcompensation of the remaining 16 member states (EEA, 2020c). In order to reach their targets, nations must submit so-called National Energy and Climate Plans (NECPs) in which they set nationally binding targets for their respective nations. According to this, the EU sets the overall GHG reduction target, but leaves it up to the member states to decide how to achieve it. A possible top-down process in which the EU determines a suitable decarbonization technology and organizes and structures its EU-wide expansion thus seems unlikely. In this context, it seems more likely that individual member states will put forward different strategies and the most suitable one will be adapted and copied (in parts) by others in a bottom-up process.

In particular, member states with low GHG reduction targets and those that are comparatively averse to climate action may initially avoid investing in climate protection measures. However, since the climate protection act is a regulation and thus has direct legal effect (EC, 2020b), infringement proceedings are in principle possible in the event of non-compliance with the stipulations made (EC, 2021c). National climate protection measures will only be evaluated once until 2023 and from then on only every five years.

[10] The reference year for this data is 2005 and not 1990 as is usually the case. EU-ETS and effort sharing together then result in a reduction target of -20% for 2020 and -40% for 2030 compared to 1990.

On deviations from targets, the regulation states the following:

> "Where the Commission finds, under due consideration of the collective progress assessed in accordance with Article 5(1), that a Member State's measures are inconsistent with that objective as expressed by the trajectory referred to in Article 3(1) or inadequate to ensure progress on adaptation as referred to in Article 4, it may issue recommendations to that Member State. The Commission shall make such recommendations publicly available" (2020/0036/COD, Art. 6 (2)).

Following the issuance of such a recommendation

> "the Member State concerned shall set out, in its first progress report submitted in accordance with Article 17 of Regulation (EU) 2018/1999, in the year following the year in which the recommendation was issued, how it has taken due account of the recommendation. If the Member State concerned decides not to address a recommendation or a substantial part thereof, that Member State shall provide the Commission its reasoning" (2020/0036/COD, Art. 6 (3b)).

If this process is still considered insufficient to meet the objectives of the regulation in question, the Commission may refer the case to the Court of Justice. If the Court finds that a country has violated EU law, the country must take action to comply with the Court's ruling. If this is not the case, the Commission can refer the case again to the Court of Justice, which is then empowered to impose sanctions in the form of a lump sum or a daily amount payable until the member state conformed to the violated regulation (EC, 2021d). The amount of the sanctions will depend on the case, but there are minimum amounts for such financial sanctions. These range from several hundred thousand euros for smaller states to millions for larger ones, and also take into account the economic power of the member states (EC 2020/C301/01).

The occurrence of such sanctions and their potential amount have a significant influence on the implementation of the climate targets by the member states and shall thus be examined in the following. It should be noted that after 2023, sanctions could be imposed in 2029 at the earliest, but more likely in 2030 or later, due to the lengthy process outlined above. Regarding the achievement of the 1.5°C Paris degree target and a pending climate tipping point, such late sanctions could possibly miss their purpose.

According to Ziegler (2015, p. 4), 5% of infringement cases end up at the European Court of Justice (ECJ). And only for a fraction of these are financial sanctions actually imposed. The level of the fine is measured in consideration of the importance of the rules breached and the impact of the infringement on general and particular interests, the period the EU law has not been applied and the country's ability to pay, ensuring that the fines have a deterrent effect (EC, 2021d). More detailed information can be found in the database "European Commission at work", which lists about 22.000 infringement cases (EC, 2021e). However, exact statistics on the level of penalties in categorized cases cannot be derived from this and could not be found in the context of this study. As a reference, specific recent cases were considered. In these cases, the ability to pay and the negative economic impact on the member state are also taken into account, which can mitigate the amount of the penalty. This was the case in a judgment against Greece, which implemented water protection measures against nitrates too late and was ordered to pay 3.5€ million (ECJ C-298/19 , 2020). With a Greek GDP in the year of the penalty 2020 of 189.26€ billion (Statista, 2021), this results in a GDP-penalty ratio of 0.00185% and thus just under two hundred thousandths penalty share of GDP. Similar values could also be found in judgments against Belgium, Romania, Spain, Ireland and Italy, with lump sums always in the single-digit millions sometimes paired with daily payments ranging from 5000€-89000€ (ECJ Judgement in Cases C-543/17, C-549/18, C-550/18, C-658/19, C-298/19, C-576/18). The payable amount of these penalties must have both an efficient steering effect while not constituting a serious economic restriction. In view of the scope of the penalties imposed, the balance seems to point more towards the latter. Of course, this also depends on the above-mentioned penalty assessment criteria and the interpretation of the ECJ, which is why an assessment of the penalty level for future violations of the Climate Protection Law cannot be given here. However, if penalties turn out to be low compared to abatement costs (specifically for ERS), late or non-compliance is quite possible, especially in countries that have an adverse attitude towards climate protection. This may have a correspondingly negative impact on the EU-wide expansion of ERS. An adequate solution could be daily fines until the regulation is implemented. However, these would have to be set at a correspondingly high level, as to actually affect the violating member state.

For the EU 2030 climate targets, no increases in GHG emissions are foreseen for individual member states in the future. As it stands, Bulgaria is the only country that is expected to uphold their emission level, while all others are aiming for a reduction between 2% and 40%. However, it is worth noting that ten eastern European member states are only aiming for a reduction of 2% to 15% and five southern European member states are aiming for a reduction between 26% and 16% (Sach, et al., 2020).[11] This may play a role in the EU-wide expansion of ERS, as will be discussed further. However, this data is likely to be out of date as it relates to an overall reduction of 40% compared to 1990 and the EU has adopted a 55% reduction target as part of the New Green Deal, as described earlier.

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[11] The Eastern European countries are Bulgaria, Romania, Latvia, Hungary, Croatia, Poland, Lithuania, Slovakia, Estonia, the Czech Republic and Slovenia. The Southern European countries are Greece, Portugal, Malta, Cyprus and Spain.

The NECPs are therefore to be revised until 2023 (Götze, 2019). A corresponding (presumably linear) increase in national savings targets is consequently to be expected.

5.2.3 ERS initiatives of EU member states and international partners

In addition to the three German test tracks, ERS field tests and test tracks have already been built in Sweden within the EU. As part of the eRoadArlanda, Electreon and eHighway projects, overhead catenary, conductor rail and inductive systems have been tested on test tracks of several kilometers in length (Reh, 2016; Janzon, 2019; eRoadArlanda, 2020). In Italy, the construction of approximately 6 km test track near Milan is planned (Rigoni & Melis, 2019; Randall, 2018). In France, Alstom has also expressed interest in electric road systems (Duprat, 2021). However, concrete projects are not yet known. Considerations for the use of the technology can also be found in the UK, the Netherlands and Austria (Patel, 2020; Otten, et al., 2020; Link, 2021). On the international level, a short test track has also been set up in California in the USA (Blanco, 2017). In Canada, simulations have been conducted for the introduction of ERS on the Canadian east coast (Kayser-Bril, et al., 2021). And in India, plans are underway to connect Delhi and Mumbai with ERS on a 1300-kilometer route (Mohanti, 2021). However, the plan is not yet approved and discussions are still ongoing. Even though most initiatives outside Germany and Sweden are still rather vague, there does seem to be interest in the technology. Within the EU, however, on closer inspection, this interest is (currently) limited to the mid-western and Scandinavian EU member states and Italy, which in the comparative group of all EU member states are both (rather) economically strong and have higher GHG reduction targets. Moreover, should the technology take hold at the international level, a secondary or tertiary market for used ERS vehicles could develop. This may be relevant for the TCO calculation and will be taken up again in chapter 6.

5.2.4 ERS on the European level

As stated earlier, Union-wide emission reduction targets are set by the EU. However, both the magnitude of national contributions and the way in which targets are met vary. Member states can thus develop individual measures to meet their respective targets. From an economic perspective, it may therefore make sense for individual member states to first pursue measures that are associated with low abatement costs (i.e., costs per ton of GHG avoided). This may be particularly relevant for member states with both a lower economic performance and a lower reduction target. Since these two factors are linked in effort sharing, the effect is twofold: the incentive for greater short- or medium-term emission reductions is lower due to lower reduction targets, while the available budget is also lower. In this context, if ERS have higher abatement costs than other measures within the sector group in effort sharing, there is a possibility that they will be avoided (initially) and (after a reassessment at a given time) may be built later. As lower reduction targets paired with lower economic power have been found in the European comparison, especially for ten Eastern European and, to a lesser extent, for five Southern European member states, this must be taken into account for European ERS expansion plans. If the logic described holds, a phased expansion of ERS infrastructure is likely. Starting with the wealthier member states, which at the same time have set higher GHG reduction targets, ERS expansion would proceed first in central-western Europe and Scandinavia. A first indication in favor of this logic is that the countries with high GHG reduction targets (and corresponding economic power) are nearly congruent with the countries that are already operating, planning, or evaluating ERS initiatives. In these regions plus Italy, which also has rather high GHG reduction targets in the comparison group of EU member states, most activities regarding ERS can be currently observed. If the system establishes itself and proves to be the most cost-effective and suitable decarbonization option for remaining member states in the future, expansion may also take place in these states. This process could be accelerated by providing financial relief to poorer member states.

This brings us to the Trans-European Transport Network (TEN-T), which maps the main freight routes in the EU. Trips coming to or from one of these regions make up 80% of the total EU road freight activity (in tkm) and 88% of total heavy-duty road transport. Only 12% of heavy-duty road transport is accordingly carried out outside this network. A total of 88 urban nodes are connected via 24.500 km core network, as shown in Figure 12 (Suzan & Mathieu, 2021, pp. 15-20). Expanding the ERS infrastructure along this network would thus cover nearly all heavy-duty road transport.

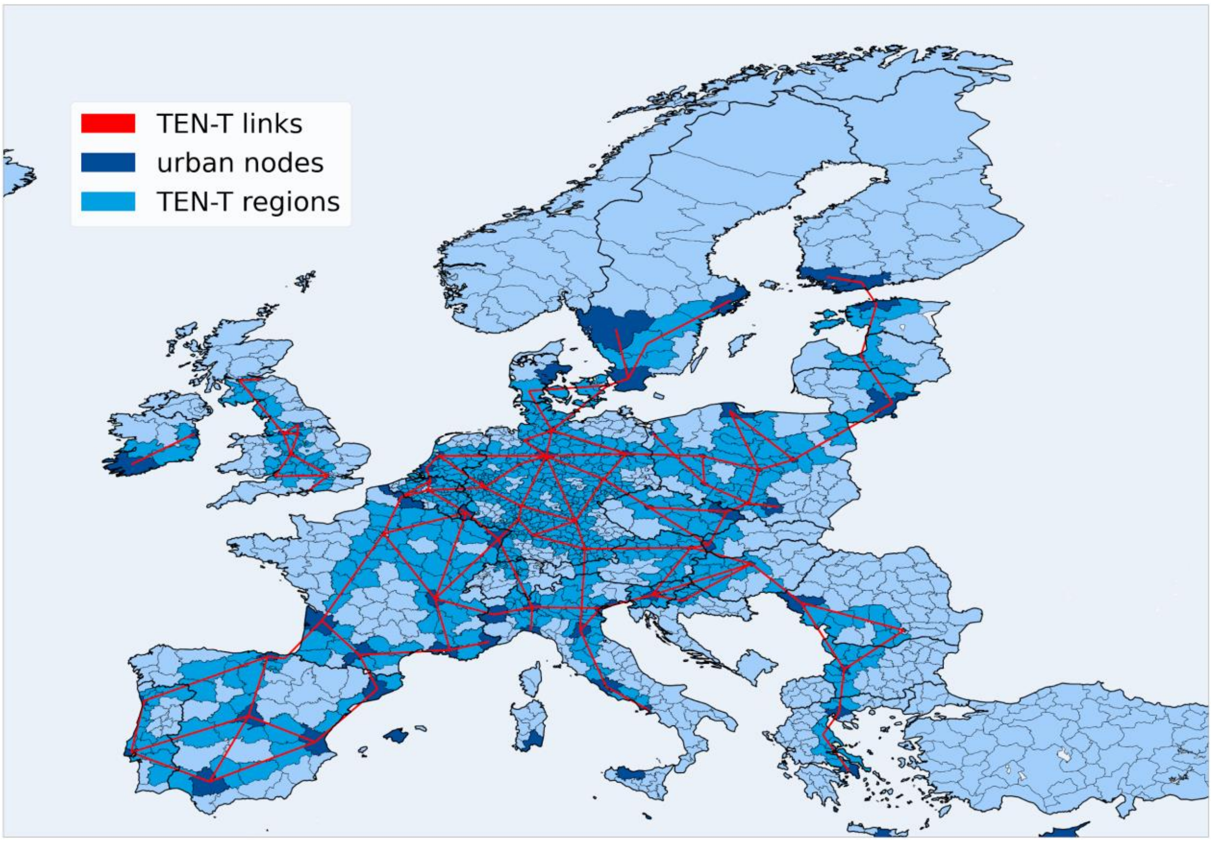

Figure 12 - TEN-T links and urban nodes in the EU. Source: Suzan & Mathieu (2021, p. 4).

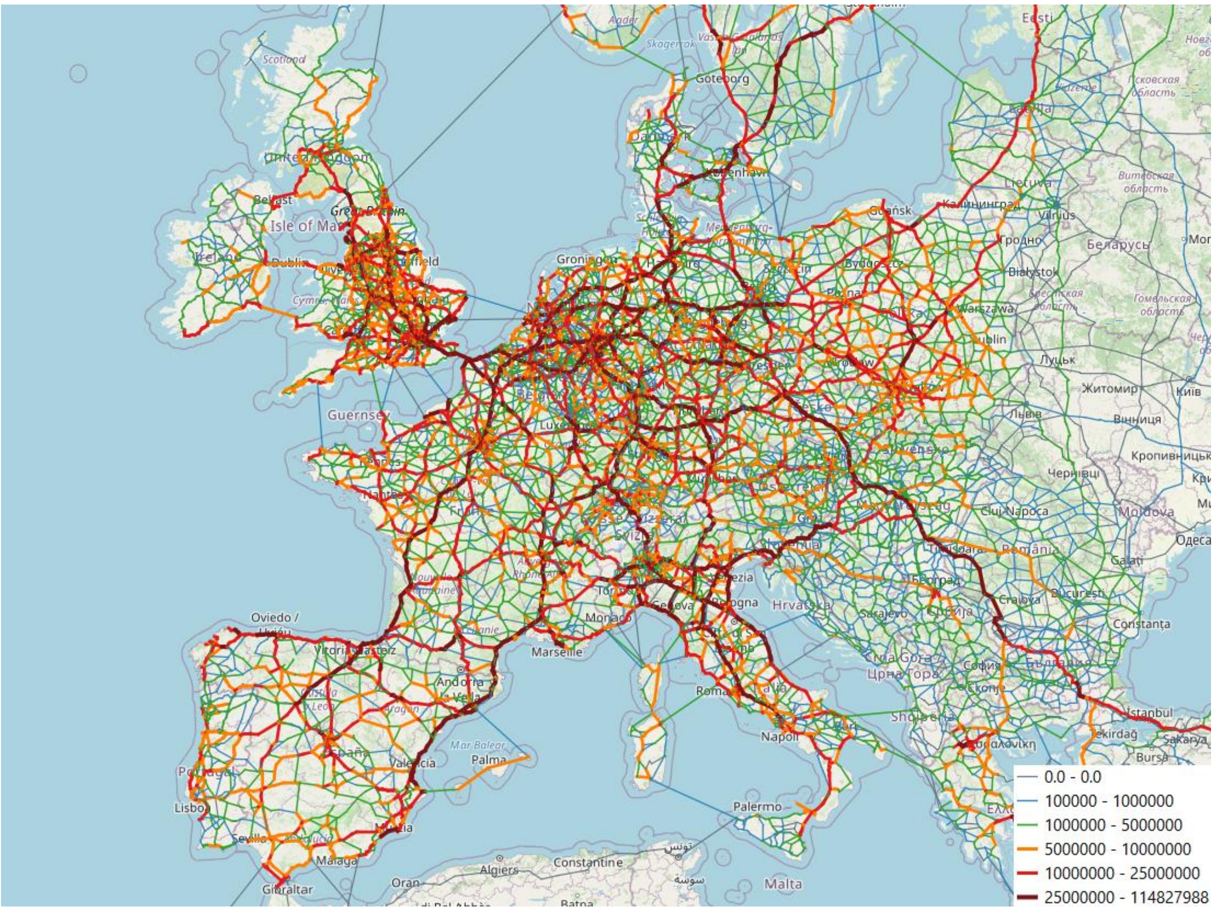

Figure 13 - Map of truck density flow in the EU. Source: Suzan & Mathieu (2021, p. 15).

In terms of tkm, the most active routes are all located in the western half of the EU, with three of these links located in Germany, as shown in Figure 14. Accordingly, expansion along these routes in particular would offer high GHG savings potential. For a long-term decarbonization strategy, however, the regions without such initiatives also play a vital role. Poland and Spain in particular have quite high truck traffic flows and should be considered accordingly. It should also be examined to what extent Brexit could affect a possible cooperation of decarbonization of heavy-duty road transport.

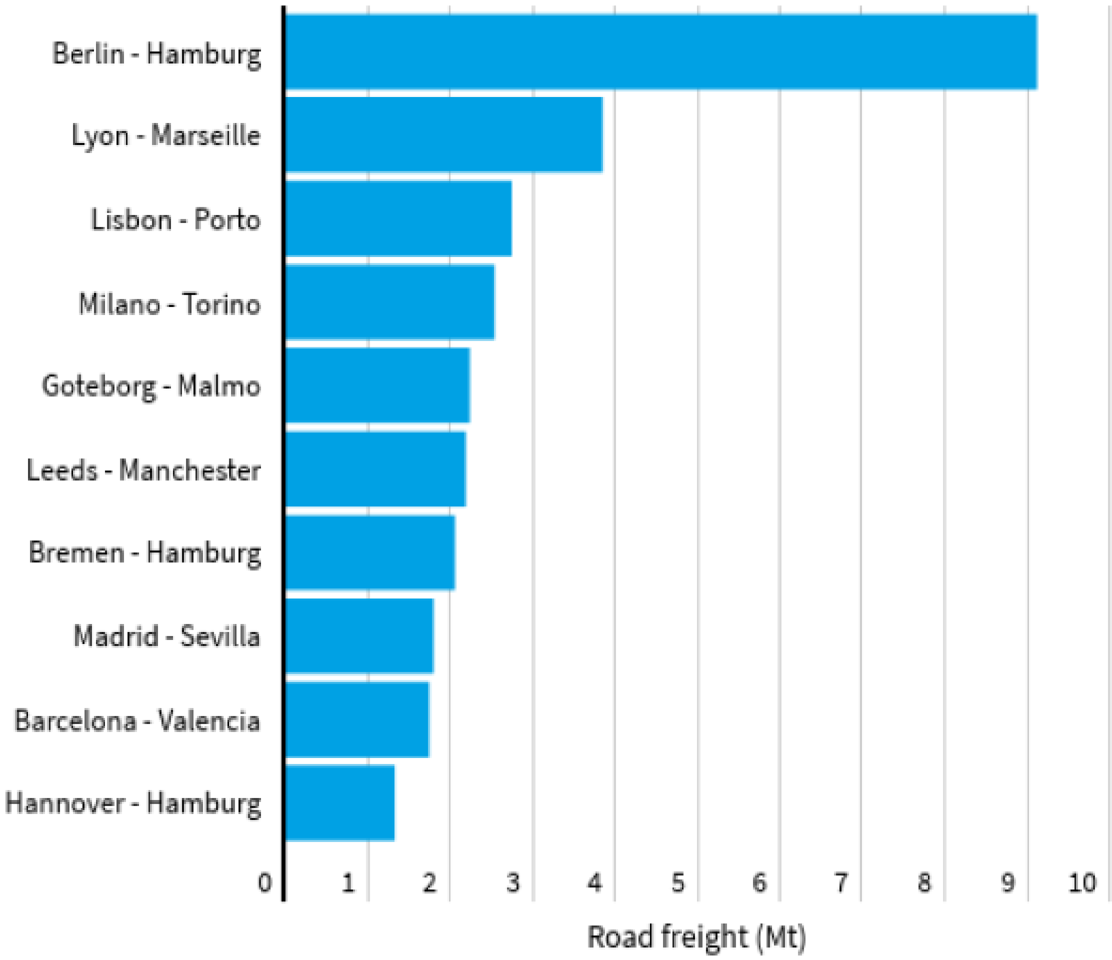

Figure 14 - Most frequented sections of the TEN-T core network. Source: Suzan & Mathieu (2021, p. 18).

In conclusion, it can be said that in recent years in particular, a strong majority of EU citizens have expressed their support for increased climate protection, also with the participation and organization of the EU. However, while the EU can define the target framework for climate protection goals, it remains primarily in the hands of the member states how they achieve their climate goals in effort sharing within the framework of the NECPs. Especially wealthier member states with higher climate targets have already conducted or announced field trials with regard to ERS, or have at least expressed interest in doing so. Since these countries also have the highest truck traffic volumes (in tkm), the (initially) highest savings potential with ERS could be realized in these countries. However, due to the construction time of the infrastructure, it is also vital for the long-term decarbonization goals of the EU that the transition to alternative propulsion systems in heavy-duty road transport in the other member states begins at an early stage.

This continues to depend on the following factors in particular: The development of alternative technologies, the cost of other decarbonizing measures within effort sharing, the level of penalty payments compared to investment costs, and the speed of expansion and success of the technology in the member states that built it first. Leaps in technology development and cost degression of alternative technologies are possible but relying on them strategically can be considered critical. If the penalty payments and the costs of other decarbonizing measures in effort sharing are low, this tends to inhibit the introduction of ERS. As already shown, monitoring of climate protection measures rarely takes place, which is why financial sanctions can only be imposed at a late stage, are generally imposed rarely and usually remain limited in scope. Consequently, this could turn out to be a possible inhibitor of ERS expansion, at least if and until the technology has proven to be clearly superior in economic terms. The expansion speed and success in countries that built ERS first is particularly relevant for further EU-wide projects. If the technology proves suitable and cost-effective early on, it can also be adapted earlier and with less risk by other member states.

5.3 Application of Veto Player Theory

The previous chapters have shown that national governments determine how to implement their climate targets depending on EU targets. In this context, it is primarily the members of the national parliaments of the EU member states who can be defined as veto players, who are influenced in their decision-making process by the political preferences of societal and economic stakeholders. Apart from special effects such as German compensatory mandates, the number of these can be assumed to be constant for the purpose of this study. In liberal democracies, parliamentarians are normally legally free in their voting decisions, but in practice they are mostly subject to party discipline, which, at least in Germany, is also frequently stipulated in coalition agreements (Tagesschau, 2015). In an interview, Marco Bülow, a former SPD member of parliament, describes how profit lobbying, concentration of power and factional discipline have increased dramatically over the last 20 years (Bellikli, 2021). Accordingly, legislative initiatives come almost exclusively from the government coalition and are usually approved unanimously. The cohesion of the decision-makers can thus assumed to be high. The variable aspect here lies more in the ideological proximity or distance to the status quo. It has been shown that societal stakeholders have developed significantly stronger political preferences for effective climate protection in recent years, while many, especially large economic stakeholders, are still skeptical or averse to climate protection measures and in some cases actively try to prevent or dilute measures. If these preferences are transferred from the societal actors to the parliamentarians, this is reflected in a greater distance to the status quo and thus in indifference curves that are further apart. As described in Chapter 4, a significant change in these relationships can come about through elections, in which representatives are "exchanged" and the balance of power shifts. If the ideological gap between the predecessor and successor governments is large, the leap from the old to the new status quo is often correspondingly large. In Germany, the social preference for more climate protection is also reflected in polls for the Bundestag elections (Infratest Dimap, 2021). The German green Party “Die Grünen” has recently made significant gains here. A possible change in the party landscape could therefore have a significant influence on climate protection measures and thus also on the further development of ERS in Germany, but also in all other EU member states. In addition, as already described, ERS have yet to prove themselves as the dominant technology for decarbonizing heavy-duty road transport. At the present time, a certain skepticism continues to prevail in large parts of the economic players in relation to ERS, not least due to a lack of planning security. Coalitions that are more positive about climate protection measures will also take this into account to a certain extent. The following chapter is intended to provide a more detailed look at the likely position of ERS in the environment of decarbonization technologies.

6. Meta-Analysis

The following meta-analysis includes summarized data from the comprehensive market ramp-up calculations and analyses of ERS adoption in Germany. The basis for this is primarily provided by the previously mentioned reference sources. First, the speed at which the infrastructure is constructed, and the associated costs will be examined in more detail and put into perspective. Furthermore, results on the current and future economic competitiveness of catenary trucks compared to diesel trucks will be presented. Finally, results on the GHG savings potential will be given. While pooling the market ramp-up calculations from a limited number of sources does not provide for a statistical basis, it does offer an overarching indication of the quantitative results to date related to ERS and therefore offers additional value. This will be presented in the following.

6.1 ERS construction speed and costs

The construction speed and the costs of the ERS infrastructure depend on many factors. In addition to political backing and the financial scale of the project, the construction model selected is particularly decisive. If a private construction partner is consulted within the framework of a PPP, particular attention should be paid to partial outsourcing of the risk to this partner. Remuneration according to the availability of the infrastructure could be appropriate in this context (Hacker, et al., 2020b, p. 131). In a study, Flyvbjerg, et al. (2002, pp. 282-285) were able to show that 9 out of 10 infrastructure projects in Europe end up with escalating costs, whereby increased average costs in road infrastructure projects with "only" 22% are still the lowest compared to connecting infrastructure (tunnels, bridges: 43%) and rail projects (34%). According to the authors, the systematic underestimation of costs can be seen consistently over the last 70 years. The article's explanatory approach cites a strategic miscalculation of costs in the context of an attractive financial proposition. The longer the targeted project construction period, the higher the likelihood of construction delays and escalating costs. A cross calculation and objective examination of the costs can therefore be recommended for the construction of ERS. The above-mentioned risk-sharing mechanism for private stakeholders also contributes to the reduction of escalating costs as well as a reduced risk of delays. This is particularly relevant since a fast, smooth infrastructure rollout is essential for the market ramp-up of ERS.

The reference sources have provided estimates of the construction speed of ERS infrastructure as part of their market ramp-up calculations. The assessments of the expansion rate vary between constant, exponential, and incremental expansion rates. The construction speed differs between 90 km/a and 720 km/a in specific years and averages at 331 km/a. As a result, and as an average of the sources examined, the infrastructure expansion reaches 1223 km after five years of construction and can be completed after 12 years with 3943 km of total expansion length, as can be seen in Figure 15.

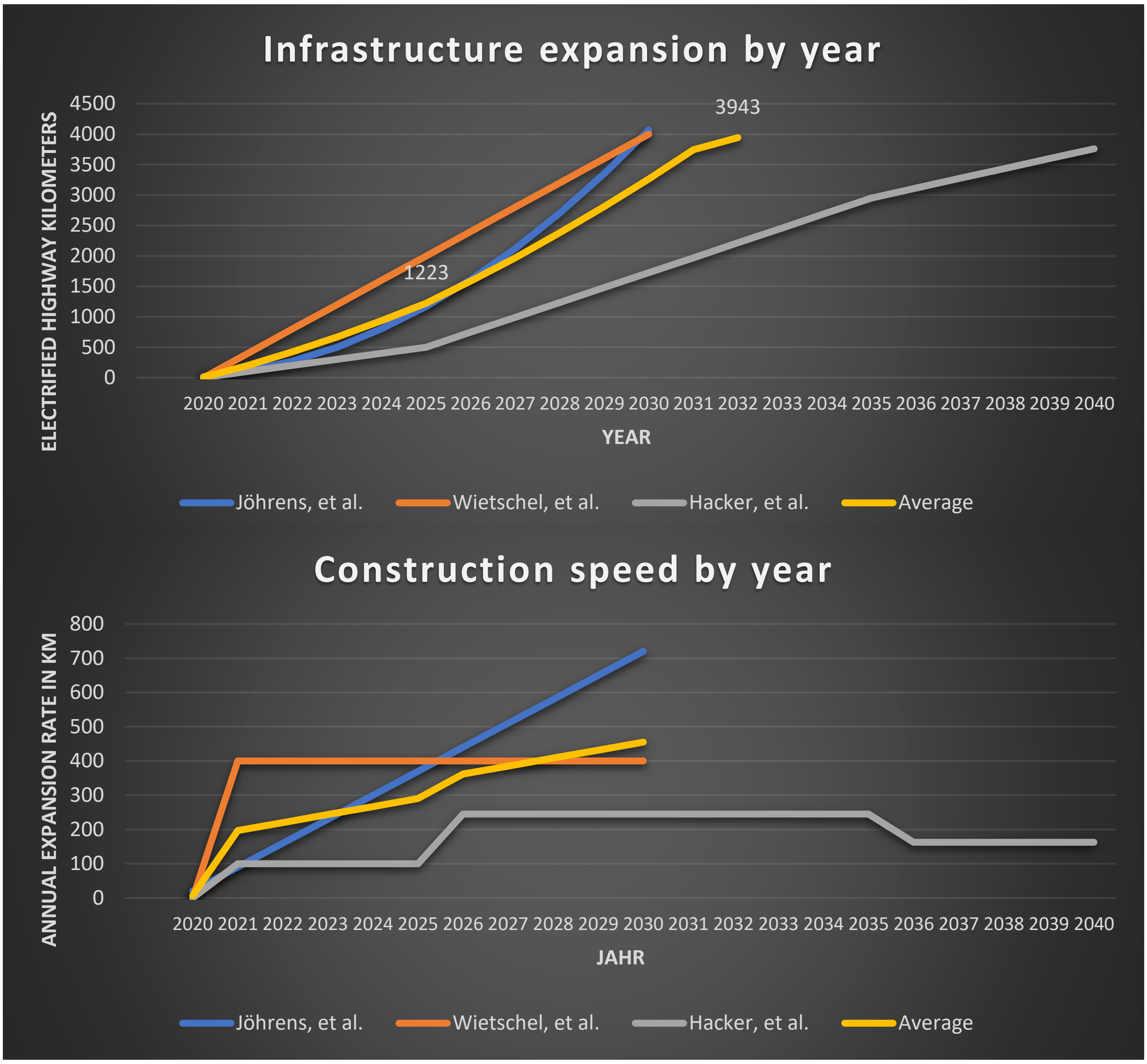

Figure 15- Construction Speed & Expansion length of ERS infrastructure by year. Own representation. Data according to Jöhrens, et al. (p.25), Hacker, et al. (2020b, p. 194), Wietschel, et al. (p. 147).

As for the cost of infrastructure expansion, the reference sources have provided different information, too. The expansion of the infrastructure to around 4000 km is expected to range between 6.55€ bn and 16€ bn. The average cost of the sources amounts to 11583€ bn. If an expansion period of 12 years is taken as a basis, this results in costs of less than one billion euros per year. Overall, the total costs of expanding the infrastructure therefore represent a block of costs of around 3% of the BMVI's annual budget. The annual infrastructure maintenance costs are then expected to range between 1.76% to 2% (115€ mn - 288€ mn) of the original expansion costs, as shown in Figure 16.

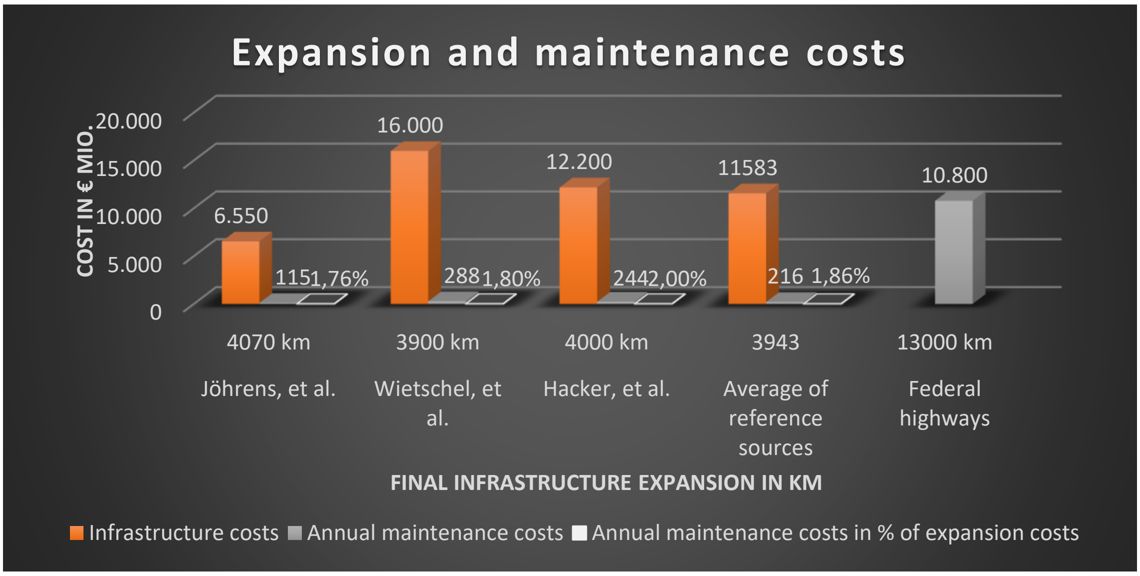

Figure 16 - Expansion and maintenance costs of road infrastructure. Own representation. Data according to Jöhrens, et al. (p. 58), Hacker, et al. (2020b, p. 128), Wietschel, et al. (p. 69).

The total construction costs over a 12-year construction period are roughly equivalent to the annual expenditures of the BMVI for the maintenance of the existing highways, which is estimated at 10.8€ bn. for 2020 (DVNW, 2020). In other words, this means that road maintenance alone takes up 36.21% of the BMVIs budget, which is roughly equivalent to the total expansion costs of the ERS infrastructure, as shown in Figure 17. This comparison is certainly not flawless, but it shows that the annual expansion costs of 3.24% of the budget are well within bounds. ERS infrastructure maintenance costs would then ultimately represent 0.72% of the annual BMVI budget (budget basis: 2020) and 2% of highway maintenance costs.

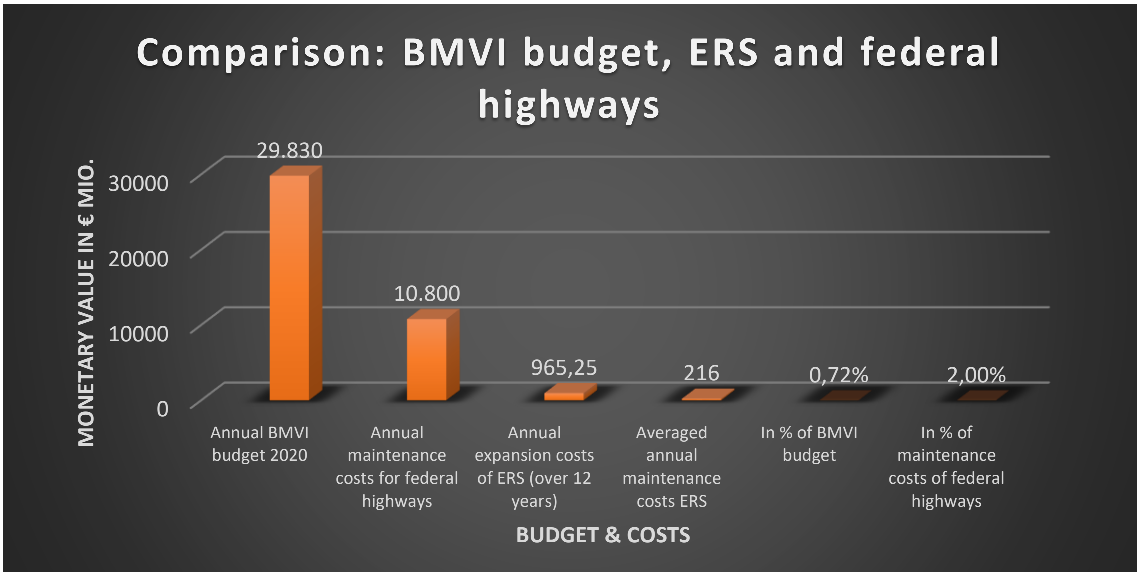

Figure 17 - Comparison of Budget, Highway and ERS costs. Own representation. Data according to Jöhrens, et al. (p. 58), Hacker, et al. (2020b, p. 128), Wietschel, et al. (p. 69), DVNW (2020).

In addition to comparing the available budget to the cost of infrastructure, ERS, and especially catenary systems, as discussed in Section 2.2, also perform notably well compared to other decarbonizing technologies in terms of cost. For example, a study by the national platform Future of Mobility (NPM, 2020, p. 20) found that the abatement costs for a ton of CO_2-eq. for BEVs and catenary trucks are nearly identical, but for a fuel cell truck they are almost triple. These results are supported by Wietschel, et al. (2017, pp. 9-10), who point to the significantly higher infrastructure expansion costs of PtL-technologies such as hydrogen, and identify an economic and business benefit only in the case of extreme electricity price drops due to the low energy efficiency of the technology.
Overall, ERS can be classified as the most cost-effective option for decarbonizing heavy-duty road transport. Considering the mostly international logistics routes of transport companies and the strong dependency on an existing infrastructure over (almost) the entire course of the journey, a European or international solution to the problem is highly preferable, as described in chapter 5. Even if calculations of reference sources have shown an economic viability of the system on a national level, a German go-it-alone approach does not seem to be an option here. Particularly in view of the cost degression of vehicle prices in the case of European or international scalability of the technology and the development of secondary and tertiary markets, clear economic advantages arise in the case of collective implementation. The ERS initiatives already described offer a good preliminary outlook for further expansion in some parts of Europe. However, cross-member state coordination along the TEN-T routes is vital for the success of the technology.

6.2 TCO Calculation diesel vs. catenary trucks

Beside the infrastructure costs, the TCO costs of transportation companies also play a vital role in the market ramp-up of ERS and the associated GHG savings potential. They define how affordable ERS trucks are and how quickly they will be adopted by the market given an appropriate expansion of the ERS infrastructure. The reference sources compared catenary trucks, as the most cost-effective ERS technology, to diesel trucks. Their calculations show that catenary trucks are characterized by high initial costs (overhead) in the first years, but the variable costs are lower due to the high efficiency of electricity as a fuel in combination with the electricity price. This is shown graphically by the fact that catenary trucks start at a higher point on the cost axis in the cost analysis, but the slope of their line is lower. However, primarily due to an onset of mass production for catenary trucks, battery and electricity price degression, a cost advantage for catenary trucks emerges between 2020 and 2030 at high mileages (Hacker, et al., 2020b, p. 89, Wietschel, et al., p. 83). Thus, according to Figure 18, in 2030 it is economically advantageous for a transport company to use a catenary truck instead of a diesel truck if the mileage over the life cycle exceeds 201.305 km[12], as can be seen at the intersection of the two curves. Since the average mileage of heavy trucks over their life cycle is over 600.000 km, an economic advantage should therefore occur for most transport companies.

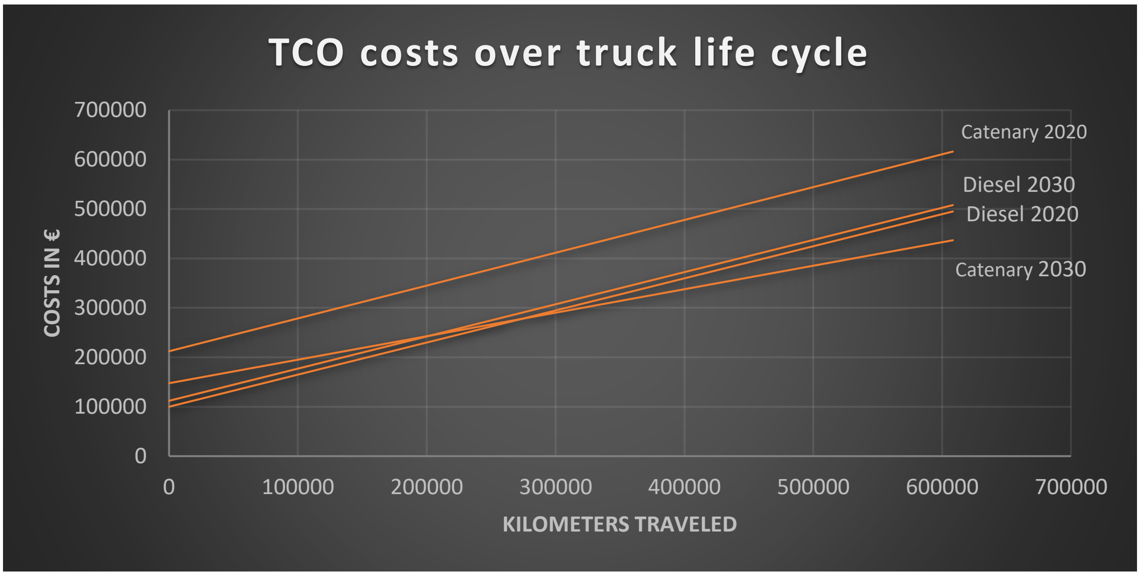

Figure 18 - Total Cost of Ownership over the lifecycle of a truck. Own representation. Averaged data according to Jöhrens, et al. (pp. 31, 83-85), Hacker, et al. (2020b, pp. 150-157, 170), Wietschel, et al. (pp. 91-92, 141-142, 160-164).

This process can be further accelerated and supported by catenary truck subsidies and levies on diesel trucks. This is illustrated in Figure 19, where the distance between a diesel truck at a CO_2-price of 200€/t has been defined as the maximum levy[13] and a total exemption from taxes and levies for catenary trucks as the maximum subsidy for catenary trucks. This distance forms the economic policy space.

[12] No CO_2 price was included in this calculation. If it were included, ERS trucks would be profitable at an even earlier stage. For more information, see Table 2.

[13] The upper limit of the levies for diesel trucks was set here at 200€/t CO_2 for scenario space delimitation purposes. However, higher CO_2 prices are also conceivable and would increase the economic policy space accordingly.

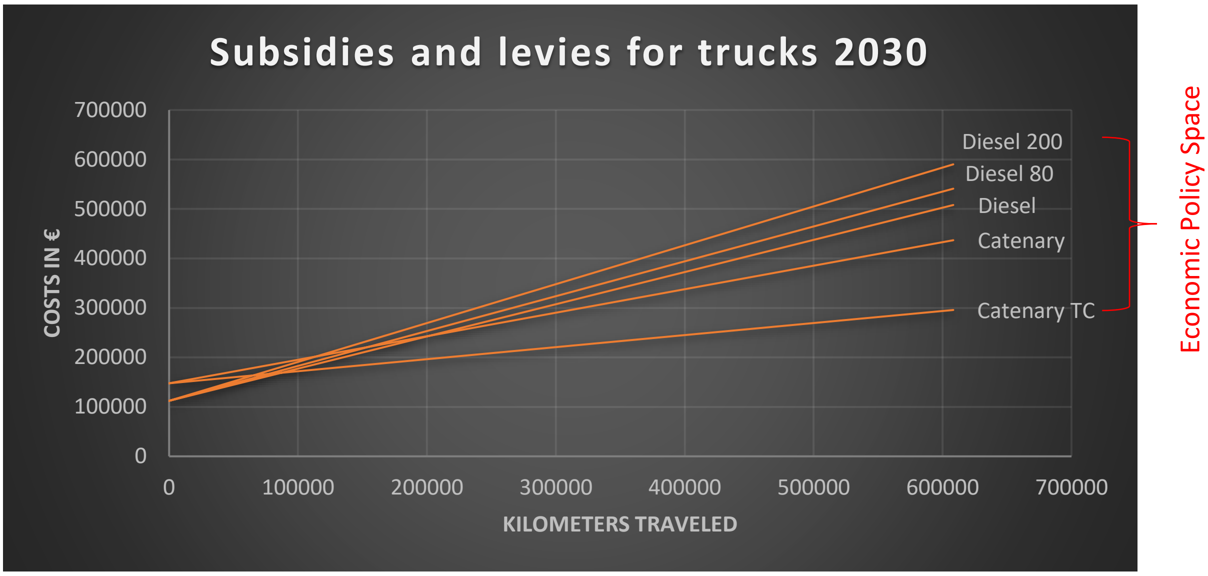

Figure 19- Economic policy space for catenary and diesel trucks in 2030. Own representation. Averaged data according to Jöhrens, et al. (pp. 31, 83-85), Hacker, et al. (2020b, pp. 150-157, 170-171), NPM (pp. 23, 41-42) Wietschel, et al. (pp. 91-92, 141-142, 160-164).

No quantified recommendation for a concrete formulation of subsidies and levies can be given in this paper. This depends primarily on the budget made available and the further development of the market ramp-up. However, some of the implications associated with the economic policy space will be discussed below.

The truck market is currently still completely dominated by diesel and gas trucks, as described in 2.2. Competition in the industry is very high, and the margins of logistics companies are usually in the low single digits (Ptock, 2015). If the CO_2-price is raised notably under the German nEHS before an economical alternative is made available, the additional costs can either be passed on to the consumer or they will be reflected in the companies' margins. If the former occurs, GHG emissions can likely be reduced to some extent, but at the expense of consumers (consumption cut due to higher price). If the latter occurs, logistics companies with low margins or low capitalization will be increasingly forced out of the market, while (usually larger) companies with higher margins and high capitalization will survive. This entails the risk of an oligopolization of the market. Due to the high level of competition in the transport industry, the latter option is considered more likely here. To avoid this risk and to ensure the full development of the efficient steering effect of the emissions trading system, it can be recommended to create alternatives to high-emission propulsion systems in heavy-duty road transport at an early stage. ERS represent such an alternative.

Regarding subsidies for catenary trucks, the primary options are purchase premiums, toll reductions and electricity price reductions. According to Jöhrens, et al. (p. 55), subsidies that are aimed at a particularly high number of kilometers driven electrically are particularly suitable, as the highest GHG savings effect can be achieved in this way compared to the costs. Accordingly, electricity price reductions or toll reductions are particularly appropriate, while purchase premiums can potentially develop disincentives. This should be taken into account when choosing economic policy instruments.

At this point, it should also be pointed out that the future is uncertain, and that a certain technology risk exists in any case. (Strong) technological advances in the development of other decarbonizing technologies may entail a corresponding price drop that fundamentally changes the TCO calculation. Therefore, this data can only be classified as a snapshot, which is subject to fundamental uncertainty in the context of future technology developments. Overall, though, all of the sources examined anticipate an economic advantage of catenary trucks over diesel trucks in 2030 from the mileage mentioned above. However, exactly when this advantage will materialize for how many companies and how many GHG emissions will be saved accordingly depends on the market development and the subsidies and levies adopted. These could be based on the additional costs of catenary trucks compared to diesel (coverage of a part of additional costs). Of course, other concepts are conceivable, too. To ensure planning security, the measures adopted should also be made transparent. In addition, a recurring evaluation and, if necessary, an adjustment of the instruments is recommended.

6.3 GHG-saving potential

As already explained in 2.1, total GHG emissions from heavy trucks in 2020 amounted to 19.7 Mt CO_2-e. In the following, this number will therefore be considered the maximum savings-potential of ERS. However, it is also quite possible that ERS are also used by buses and trucks in regional transport or other vehicles (Boltze, 2020, p. 37). If this is the case, the savings potential increases by a corresponding amount. The reference sources' GHG savings potential figures are based on their respective assumptions about the infrastructure expansion, the number of ERS trucks that use it and the development of the electricity mix (emission factor). They also distinguish between catenary (diesel) hybrid electric vehicles (C-HEV) and catenary battery electric vehicles (C-BEV), as C-HEVs are considered an option for the transition phase to C-BEVs. The ratio of C-HEVs and C-BEVs depends mainly on battery price degression and diesel prices. The later the ERS infrastructure is built, the more economic advantages are assumed for battery electric propulsion systems and thus the dominance of C-BEVs (Jöhrens, et al., 2020, pp. 33-34). Therefore, Wietschel, et al. created a parameter variation for the ratio of C-BEVs and C-HEVs (Wietschel, et al., 2017, p. 200), while the other two sources incorporated assumptions about the market ratio of C-BEVs and C-HEVs in their calculations. The anticipated savings potential for 2030 ranges quite uniformly between 2 and 3 Mt CO_2-e. On average, a value of 2.37 Mt CO_2-e is anticipated, as can be seen in Figure 20. This corresponds to only 12.03% of the GHG emissions of heavy trucks in 2020 and thus falls far short of the 65% savings target set by the German government. However, Wietschel, et al. also made a calculation for 2040, anticipating Well-to-Wheel-savings[14] (WtW-savings) of up to 9.1 Mt CO_2-e (7.7 in their M80 scenario)[15], depending on the scenario, which then corresponds to between 32%-47% (39.09% M80-scenario) savings.

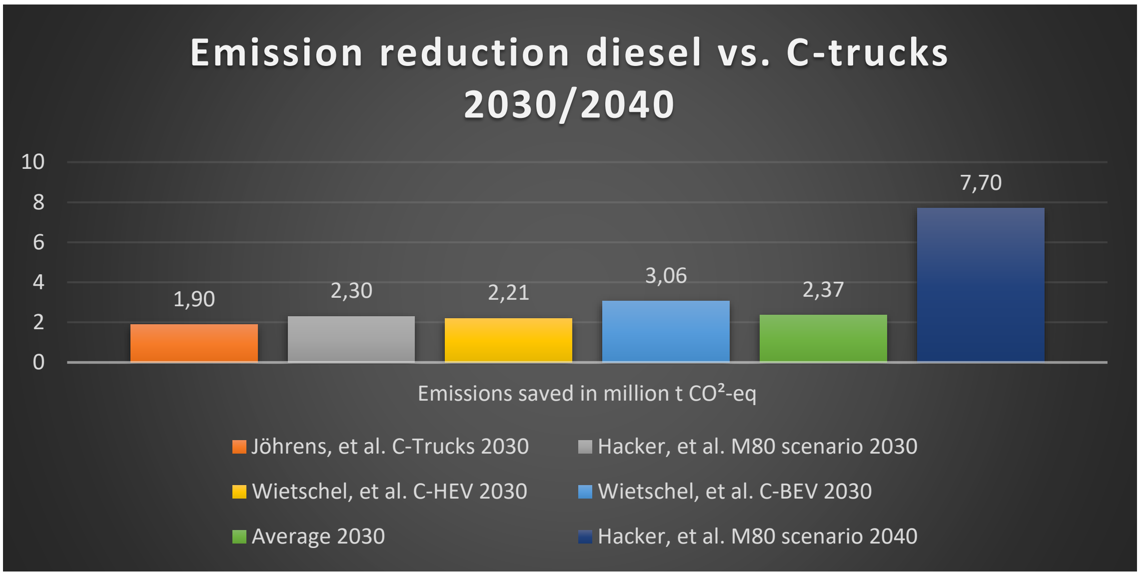

Figure 20 - Anticipated emission reductions of catenary and diesel trucks in different configurations. Own representation. Data according to Jöhrens, et al. (pp. 33, 38-40), Hacker, et al. (2020b, pp. 157-164, 211-212).

It is difficult to predict exactly how GHG savings will develop over the course of infrastructure expansion. However, different sources agree, that the savings potential of the infrastructure decreases with additional kilometers (diminishing marginal returns). The reason for this is that the infrastructure is expanded from most trafficked to less trafficked sections. Graphically, this results in a flattening exponential curve, as shown in Figure 21.

[14] Well-to-wheel emissions consider the entire impact chain for locomotion from the extraction and provision of propulsion energy to its conversion into kinetic energy.

[15] M80 describes a full infrastructure expansion in combination with a CO_2-price of 80€/t. It was chosen here because it is in the middle range of the scenarios considered by the authors. For other scenarios, see Hacker, et al (2020b, p. 211-212).

The cumulative savings correspond to the area under the curve. Figure 21 shows the expansion scenarios, their average and an associated savings curve. The averaged savings value of 2.37 Mt CO_2-e and the ratio of the share of electric trucks to electrified highway kilometers from Wietschel, et al. (p. 132) were used as a basis here. Wietschel, et al. point out that this curve most likely overstates the increase in savings potential over time. Accordingly, a somewhat lower slope of GHG savings can be assumed under real conditions. At this point, it must also be noted that this Figure represents only one variant of very many in the scenario space and can therefore be understood here at most as a tendency, but in no case as a forecast or prediction. However, the fact that most of the savings can be achieved in the early expansion phase once again emphasizes the benefits of a timely start of construction.

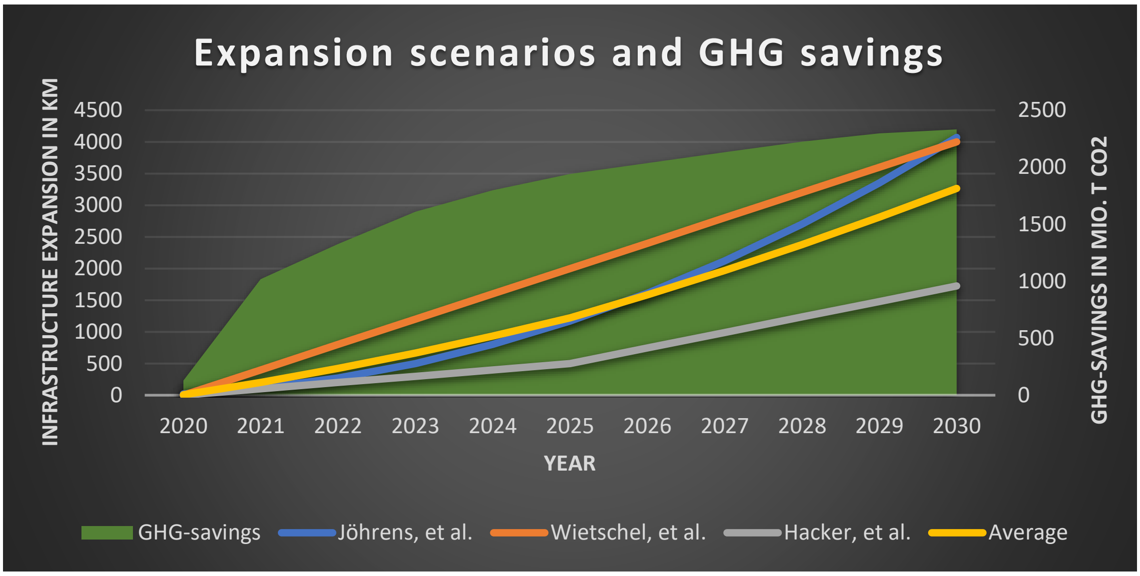

Figure 21 - GHG savings associated with the average construction scenario. Own representation. Data according to Jöhrens, et al. (p.25), Hacker, et al. (2020b, p. 194), Wietschel, et al. (p. 132, 147).

In conclusion, ERS alone are unlikely to achieve the federal government's GHG reduction target of 65% in the heavy-duty road transport sector by 2030. Even if only the lower reduction targets of effort sharing are considered, the targets are most likely not reached. An early start of expansion is recommendable nevertheless, as competing technologies are more expensive and the highest savings can be achieved in the early expansion phase. A combination with other decarbonizing technologies for the sector can help to approach the target, but at (partly significantly) higher abatement costs. Thus, an overcompensation of the other emitting sectors would be necessary to achieve the target. To limit this, a policy framework for a quick implementation of the mobility transition in heavy-duty road transport should be developed, published and executed in the near future.

7. Results of the guideline-based interviews

As part of this paper, six interviews were conducted with stakeholders related to ERS. The Autobahn GmbH des Bundes, the German Bundesverband Güterkraftverkehr Logistik und Entsorgung (BGL), Kisters AG, Alstom S.A. and the logistics companies Schanz and Contargo were interviewed. Autobahn GmbH has been responsible for the planning, construction, operation, maintenance, financing and management of the autobahns in Germany since the beginning of 2021 and is accordingly primarily responsible for a potential construction of ERS in Germany. The BGL is an association that primarily reflects the interests of the logistics industry and is therefore also relevant for the future expansion of ERS. Kisters AG is an IT service provider in the energy sector and develops, among other things, software solutions for power grids. Alstom S.A. from France is the second largest manufacturer of rail technology and logistics in the world, is aiming to build ERS in France and is also involved in international ERS projects. Finally, logistics companies Schanz and Contargo are involved in the German ERS pilot project ELISA and have already gained experience with the catenary system. The semi-structured interview format was chosen as method for conducting the interviews. As a profound method of qualitative social research, it provides a structured set of questions for the interviewees, but at the same time also offers the opportunity for targeted follow-up questions and setting of priorities. In addition to a general set of questions regarding the market ramp-up, some questions were asked that were specifically related to each interviewee. A more detailed representation of the interviews can be found in the appendix. The questions revolved around the interviewees´ assessment of the market ramp-up of ERS as well as a possible stakeholder model for the operation of ERS.

When asked which political, economic and regulatory aspects are central to the early introduction of ERS, the respondents unanimously answered political will and planning security are vital. In this context, some respondents mentioned the relevance of a business case, which should be temporarily regulated by subsidies and levies if necessary. Standardization, security aspects and European scalability were also mentioned. Potential problem areas mentioned were financing, (international) market distortion and resistance from the population. When asked about a possible start of construction in 2025 in Germany, the respondents had different opinions. In general, the opinion prevailed that the start of construction should not be later, and that 2025 as a starting date is quite possible, provided that political support with corresponding financial and organizational resources is provided. Planning approval procedures and environmental impact assessments were also mentioned in part as possible reasons for delay. In addition, comparisons were also drawn to the problems with stationary charging infrastructure, which could also occur in a similar form with ERS and possibly delay the ERS rollout. The BMVIs plans to achieve as much as 2000 km by 2030 and project completion (~4000 km) by 2035 were also viewed critically. Most respondents indicated that they believe this is possible, but only under quite positive conditions with strong political support.

In terms of stakeholder-specific questions, the rather skeptical perception of ERS in the logistics industry was confirmed by Schanz, partly due to concerns about the practicality and international deployability of the technology. Alstom particularly emphasized a European decision for some form of ERS, as well as uniform standardization in the EU, since interoperability of different systems imposes additional costs. To this end, they advocate support from the EU Commission. Kisters consider further grid expansion and stabilization vital, as ERS require further grid capacities. In addition, they expect a continuing downward trend in the emission factor of the German electricity mix in the next decades.

8. Scenario Generation

This chapter aims at creating reasoned scenario trajectories for the potential market ramp-up of ERS based on the previously gathered information. Three scenarios are created, the characteristics of which are based on more or less positive assumptions about the market ramp-up. Among other variables, the start date for construction, the speed of construction and the market environment vary depending on the scenario. First, a baseline scenario will be presented, the characteristics of which are based on current forecasts. This is followed by a negative and a positive scenario.

In the baseline scenario, the Germany-wide ERS expansion will start in 2025 in accordance with BMVI plans. By this time, around 350 km of highway are already electrified, also according to the BMVI plans. Of this, 50 km is accounted for by the pilot projects and 300 km by the electrification of commuter routes, which is to be completed between 2021 and 2025. Clear political concessions for Germany-wide expansion, including a time and framework plan, would have to be made here as early as 2022, so that there is enough time for regulatory and organizational variables in the following. The planning security created in the process would allow the existing legal structure to be precisely adapted to the new technology and would also simplify the standardization process. Any necessary planning approval process could then also be initiated early and likely completed before 2025, which also leaves leeway for the precise planning of the construction. The costs are estimated at around 12 billion euros in line with the current state of research. In this scenario, the construction pace is within the forecast range of the reference sources. As shown in Figure 22, an expansion to 1573 km takes place by 2030. By 2035, 3615 km of infrastructure is already in place, which can then be completed in the following year, 2036. The market ramp-up is accompanied by temporary subsidies for ERS and levies for fossil energy sources. Regarding the European transition process related to ERS, cross-border logistic processes are increasingly handled by ERS trucks, which provides a scaling advantage and reinforces the cost degression of the technology. Adaptation by several countries also creates a secondary market that enables the resale of the vehicles after their regular lifetime, which benefits the TCO calculation of logistics companies.

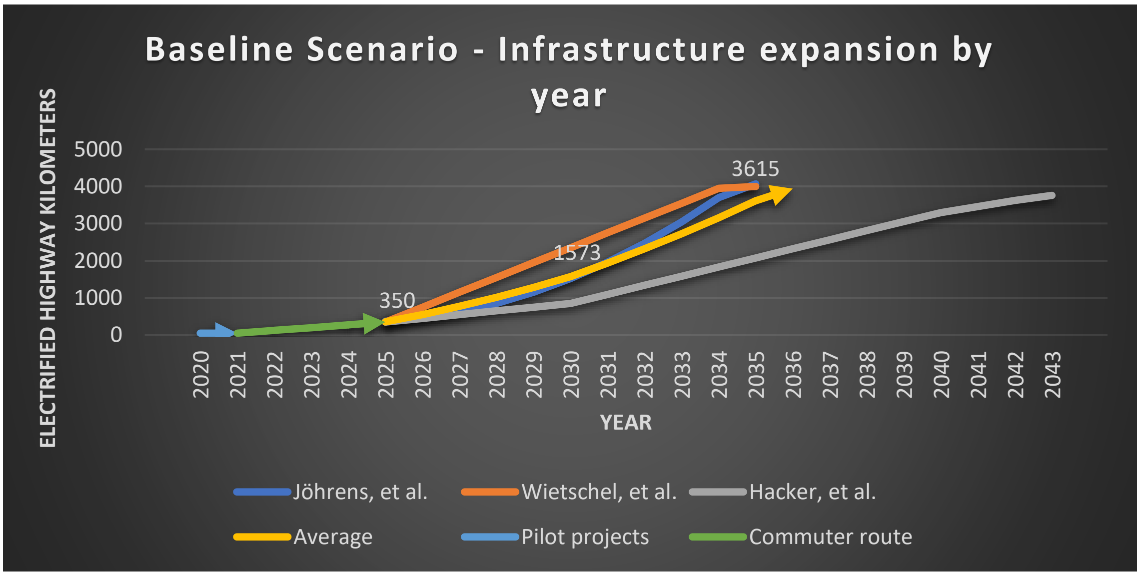

Figure 22 - Expansion of ERS infrastructure in the baseline scenario. Source: Own representation.

The German electricity mix is increasingly dominated by alternative energy sources over time, which increases the GHG savings of the system accordingly. Following the estimates of the reference sources from chapter 6.3, average savings for 2030 with a fully built infrastructure are expected to be 2.37 Mt CO_2-e, while Hacker, et al. (2020b) expect for 2040 already 7.7 Mt CO_2-e. Thus, in this scenario, savings can be expected to reach approximately between 3 and 6 Mt CO_2-e after completion of the infrastructure in 2036. By using the already described 19.7 Mt CO_2-e as a basis, achieving the old climate targets in effort-sharing (30%) would require a saving of just under 6 Mt CO_2-e by 2030.

However, with an expansion of about 1573 km in 2030, it can be assumed that the savings potential at that time is still significantly below 2.37 Mt CO_2-e, which, according to the reference sources, can be achieved with a complete expansion by 2030. In addition, the climate targets have been raised, as described in chapter 5.2.2, so the targeted savings in effort-sharing are likely to range around 40% instead of 30%. The medium-term climate targets up to 2030 can therefore not be achieved in this scenario.

In the negative scenario, the political attitude continues to be cautious, with approval for nationwide expansion not being given until 2026. Concrete legal adjustments, the standardization process, the planning approval procedure and further preparations for construction will then drag on until 2028. In addition, the construction process in this scenario is accompanied by problems, stalls in sections and takes a total of 17 years, as can be seen in Figure 23.

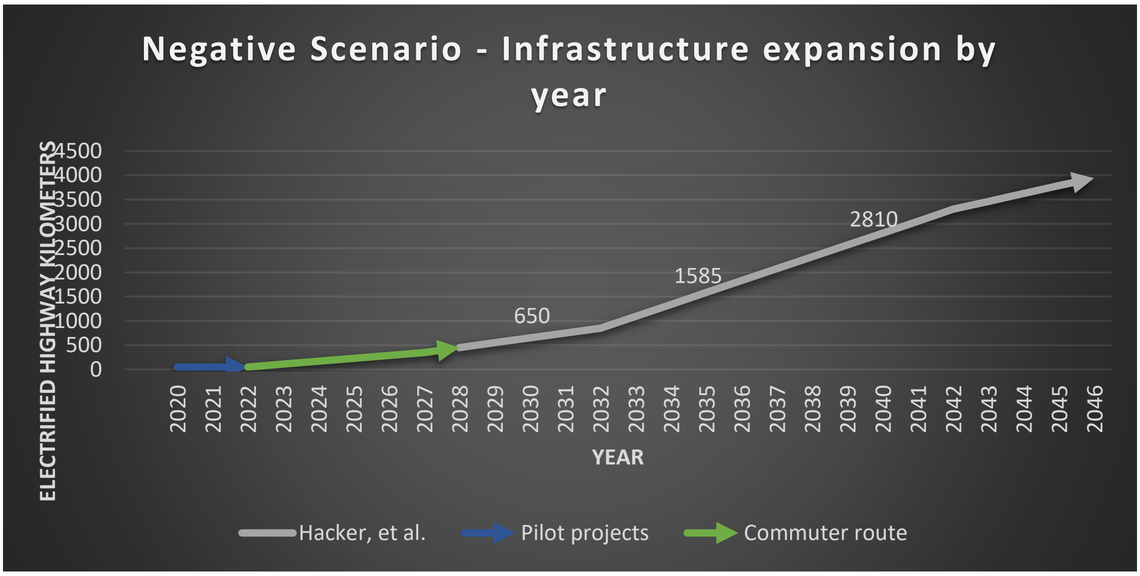

Figure 23 - Expansion of ERS infrastructure in the negative scenario. Source: Own representation.

The progress curve here is based on the negative scenario of Hacker, et al. (2020b) The market ramp-up is also accompanied by low subsidies and misaligned incentives, which convinces only few logistics companies and brings few vehicles to the ERS infrastructure. With only 650 km of completed infrastructure, only significantly less than 1 Mt CO_2-e can be saved in 2030, which is even further from the German and European savings targets than in the previous scenario, making up only a few percentage points of the original target. At the time of completion in 2046, the technology is then widely adopted in the German and partly in the European market, but the excess emissions in the heavy-duty road transport sector had to be offset by other sectors for a long time, which further burdened the GHG budget. In addition, construction costs were significantly higher than originally estimated. Cross-border logistics processes are only partially handled by ERS trucks here, the scaling advantage and thus the cost degression remain low, and no significant secondary market emerges as the technology was only deployed in few countries. Meanwhile, other technologies have developed more advantageously.

In the positive scenario, strong political pressure is exerted for increased climate protection. In order to safely meet the national and EU GHG reduction targets by 2030, a political-organizational framework plan for the market ramp-up of ERS is presented before the end of 2021. This will be followed in the same year by a start on adapting the legal structure to the new technology and advancing the (European) standardization process. Due to the new priority given to the topic, the 300 km commuter route can be completed as early as 2023 instead of 2025 by increased investments and efforts. The planning approval process and further construction preparations can also be started in 2021, so that the nationwide expansion can begin as early as 2023. Due to the high financial resources provided and a solid organization of the project, a high constant construction speed of 400 km per year can be maintained, as can be seen in Figure 24. The progress shown here relies on data of Wietschel, et al.

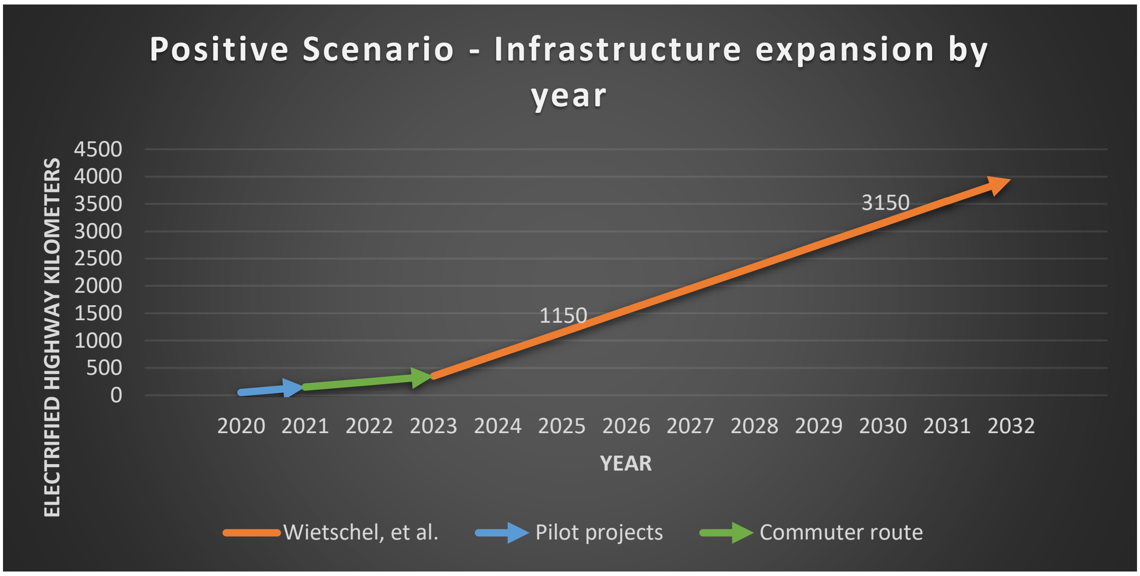

Figure 24 - Expansion of ERS infrastructure in the positive scenario. Source: Own representation.

High targeted initial subsidies coupled with high early infrastructure availability attract both further logistics companies and further vehicle manufacturers, which favors early mass production of ERS trucks and thus strong cost degression. The attractiveness of the system convinces other EU member states as well as countries on the international level. Cross-border logistics processes are therefore handled by ERS trucks at an early stage, the scaling advantage picks up speed as early as the mid-2020s, and secondary and tertiary market for the sale of the trucks emerge on the European and international level, respectively. By 2030, more than 3 Mt CO_2-e can be saved, and by the time the project is completed in 2032, the figure will be nearly 5 Mt CO_2-e. Due to the ambitious expansion of renewable energies, the emission factor of the electricity mix also continues to decrease, which, together with a further increase in vehicles on the system, will enable rapid additional GHG savings. The 2030 GHG savings target is still missed, however future savings targets can be achieved through the successful system.

A backcasting approach in which the 2030 climate targets would be met depends not only on a fully developed infrastructure, but also on the quantity and type of vehicles running on it and the emission factor of the electricity mix. Since the development of these factors remains variable, the following remarks can only estimate when the construction should necessarily have begun based on the information found.

For this purpose, as shown in 2.1, it must be taken into account that although the emission factor of the German electricity mix has decreased continuously since 1990, the downward trend only accelerated significantly from 2015 onward. In addition, both the high synergy effects that the adaptation of the technology by European partners and the likely high time requirement of this process should be taken into account. With an average expected construction time of around 12 years to build the full infrastructure over 4000 km, plus a buffer for difficulties in the process of up to five additional years, it can be assumed here that the start of construction to achieve the GHG savings envisaged in the effort-sharing for Germany should not have taken place after 2010. The emissions saved in the first years would likely be comparatively low in this case. However, the full synergy effects as a mixture of a potentially early European adaptation of the technology, the associated logistical advantages of cross-border transport, the onset of mass production of the vehicles and the associated cost degression, increased demand from logistics companies, and a sharply declining emission factor in the electricity mix would lead to greatly accelerated GHG savings over time. Of course, this backcasting approach remains a hypothetical scenario that outlines an alternative past. However, it highlights the time-intensity of such processes and the value of early and determined planning.

9. Conclusion

In light of increasing global extreme weather events such as this year's enormous heat wave in North America, as well as the flood disasters in Midwest Europe and China, the devastating extent of climate change is revealed once again (World Meteorological Organization , 2021). If the output of GHG emissions is not drastically reduced in the near future, such events will only increase in intensity and frequency, severely disrupting global ecosystems. Consequently, time is of the essence. This development is increasingly being followed, at least in the EU, with the adoption of the New Green Deal. In this context, ERS are only a small cog in the wheel of possible global climate protection measures. In view of stagnating or increasing GHG emissions from heavy-duty road transport over the past thirty years, and without significant decarbonizing technological advances in that time, however, this cog could prove essential. Unlike in the passenger car sector, a switch to battery electric propulsion systems for heavy duty road transport is impractical and unrealistic from today's perspective due to enormous battery weights and long charging times. Alternative propulsion systems, such as hydrogen-based ones, are possible in principle, but are estimated to be significantly more expensive than ERS. Significant advances in competing technologies such as BEVs or hydrogen propulsion systems could fundamentally change this situation. However, such advances take time and might not occur at all. And time is likely the most valuable resource in the fight against climate change that must not be wasted. In this respect, ERS and especially the cost-effective catenary system, present an attractive option as decarbonization measure in heavy-duty road transport. As an infrastructure-dependent measure, however, the initiative to build such a system depends mainly on national governments. In Germany and some other EU member states ERS test and pilot projects have already been carried out. Germany has also decided to expand 300 km of ERS commuter line and plans to decide on a Germany-wide ERS expansion in 2025.

As a result of this work, the decisive factors for the success of a market ramp-up were identified and analyzed, and three possible market ramp-up scenarios were presented. In the context of the time limit described above, the date of the start of infrastructure expansion, as well as the planning process to be carried out beforehand and the choice of a suitable construction model are particularly decisive. These factors depend primarily on the political process in the EU and the member states concerned. In this context, it was found that the GHG reduction targets of the respective member states are set within the framework of EU effort-sharing, but that the climate protection instruments are chosen by the member state. According to the Veto Player Theory, a political change from the status quo to ERS depends on the number, cohesion, and ideological distance between the veto players. Since the identified veto players are primarily the members of the respective national parliaments, and their number and cohesion are approximately constant, the ideological distance between them remains as major indicator of the stability of the status quo. Moreover, changes in government usually destabilize the status quo significantly, especially if the ideological distance to the previous government was large. Since members of parliament in democracies are interested in being (re)elected, they usually base their political decisions primarily on the policy preferences of social and economic stakeholders. In the analysis, it was found that the presence of and societal support for significantly stronger climate protection measures in Germany and the EU has increased sharply, especially in recent years, while many economic stakeholders have sought to postpone or dilute effective climate protection measures. This discrepancy has led to a strengthening of the Green Party, at least in Germany. This political momentum for climate protection measures can potentially pave the way for ERS. However, to achieve this, ERS must first establish as cost-effective technology on the market. With high initial government investments, a strong economic moat also surrounds the technology. Moreover, since the specific climate protection measures are not organized top-down by the EU, it can be assumed that member states with high GHG reduction targets and high economic power will expand the system first. If it then proves to be a success, further expansion in economically weaker member states with lower GHG reduction targets can be expected. However, as a stepwise process, this takes time. Additionally, EU control mechanisms to meet national climate targets can be viewed critically. In view of very long periods between controls, a lengthy control procedure and rarely imposed sanctions, non-compliance is conceivable, especially for climate protection-averse member states.

Currently, construction projects and construction plans can be found mainly in the northern and western parts of the EU. Economic strength and savings targets are comparatively higher here than in southern and eastern member states. However, for a successful market ramp-up of the system, the European and international scalability of the system is of particular importance. Logistical processes are usually handled across borders in the EU, which is why it is highly impractical to end the infrastructure at national borders. At the same time, an absolute majority of 88% of Europe's heavy-duty road transport is handled by the TEN-T network, which covers 24.500 km and connects the most important urban nodes. Electrification of this route alone would enable correspondingly large potential savings. In addition, a larger market for the success of the system brings vital scaling and cost degression effects. Mass production and increasing competition among vehicle manufacturers make the ERS truck affordable for logistics companies, and a large market enables potential resale to secondary or tertiary markets, further reducing costs. This makes it clear that the European scale of this project is vital for a successful market ramp-up.

In a meta-analysis, the results of various sources that have already conducted market ramp-up scenarios for Germany were combined and evaluated. Such extensive studies currently exist only for Germany, which is why a comparable analysis could not be carried out for the EU. According to the average of the sources, a construction process of approx. 12 years can be estimated in Germany up to an expansion length of approx. 4000 km at an averagely expected cost of 11.5€ bn. For the 12 years of expansion, this corresponds to 3.24% of the BMVI budget (budget basis: 2020) and thus seems to be quite affordable. As a comparison, the annual maintenance costs of the autobahn alone cost 10.8€ bn and thus over 36% of the BMVIs annual budget. From the logistics companies' point of view, their TCO calculation plays a role as well. With increasing cost degression over the life cycle of ERS trucks, it can be assumed according to the scenario results of the reference sources that ERS trucks will become more cost effective than diesel trucks between 2020 and 2030. Exactly when this economic advantage will occur depends on the profile of the trucking company, the kilometers driven and the corresponding subsidies for ERS trucks and the levies on fossil fuels. The savings potential by 2030 in the scenarios of the reference sources ranges between 1.9 and 3.06 Mt CO_2-e, which is far below the targeted savings. However, one source assumes a savings potential of up to 9.1 Mt CO_2-e by 2040, which is significantly closer to the savings targets. Accordingly, the reference sources also recommend initially using a mix of different alternative propulsion systems, in order to come closer to achieving the savings target, even if this entails potential additional costs.

The results found were further compared with the statements of relevant stakeholders related to ERS in the course of guideline-based interviews. Most of them considered a nationwide start of expansion in 2025 as possible and necessary but were skeptical about an expansion length of 2000 km by 2030 and, if this speed were to be maintained, completion by 2035. According to them, this would be possible in principle, but only with strong political pressure, will and the corresponding financial resources. Among the vital factors for the success of the project, the interviewees named an existing business case and thus corresponding initial funding, rapid standardization, planning security and European scalability.

Based on this information, three scenarios for the market ramp-up of ERS were generated. In the baseline scenario, a Germany-wide expansion in line with the BMVI's plans begins in 2025 and can be completed by 2036 according to the average estimate of the reference sources. In the negative scenario, construction does not start until 2028 due to weak political support and planning difficulties. Further problems accompany the construction process, which is why completion is not possible until 2046. In the positive scenario, strong political pressure is exerted, which is why construction can begin as early as 2023 and, due to strong political and financial support, as well as solid planning and an efficient construction model, can be completed as early as 2032. However, in none of these scenarios can the 2030 savings target be achieved.

The research question, how a timeframe for the market ramp-up of ERS in Germany and the EU can be designed, that meets the EU GHG reduction targets until 2030 and 2050, can thus be answered as follows: According to the current state of research, the timeframe for achieving the set climate targets by 2030 in heavy-duty road transport by ERS has passed. For this purpose, a significantly earlier project start would have been necessary. Even with the simultaneous introduction of other alternative propulsion technologies, this target is unlikely to be achievable. However, according to the current state of research, ERS represent one of the best options for decarbonizing heavy-duty road transport. Through scaling effects, very high amounts of GHG emissions can be saved at comparatively low costs, especially in the case of an EU-wide expansion, as shown in the scenario generation.

In conclusion, the complexity and the multitude of variables that are crucial for a successful market ramp-up of ERS can be emphasized. This work has been able to provide an insight into the interdisciplinary parameters for influencing the market ramp-up of ERS. However, in this context it represents only a first step. Further research is needed, in particular regarding the Europeanization of the technology and the political situation surrounding ERS. Considering the stagnation of GHG savings in heavy-duty road transport over the past 30 years, the need for action with looming, increasing climate disasters, is great. Particularly in the light of potentially delayed infrastructure development across European regions, infrequent reviews of EU member state climate targets and infrequent financial penalties for non-compliance-cases, it is important to note that EU-wide infrastructure development is essential to the success of the system. According to the assessment made in this paper, high GHG savings depend primarily on an early policy path decision with a strong political commitment to the chosen technology or technologies as well as early organizational and regulatory preparations for the deployment of the technology, as well as effective, rapid, and qualitative construction of the infrastructure, and appropriate, targeted subsidies and levies for the technologies involved. Since ERS are currently estimated to be the most cost-optimal option for saving GHG emissions in heavy-duty road transport, they should be sufficiently considered in future policy framework plans. Additionally, a mechanism to involve European partners should be considered. If the expansion is delayed in Germany and other economically strong member states, there is a risk that the project will be dragged out in time by other EU member states as well. In light of the enormous time and action pressure created by climate change, we cannot longer afford such delays. Or to put it in the words of Boltze (2020, p. 42):

> "There is certainly an urgent need for making road freight transport more sustainable. As we do not have so many alternatives, the eHighway system seems to be an option very worthwhile to follow. Without any doubt, this will create some costs. However, what we cannot afford at all is doing nothing."

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Appendix

List of Tables

ERS Construction Scenarios and costs	Wietschel, et al.			Average	Jöhrens, et al.			Average	Hacker, et al.						Average	Mean Average
	2020	2025	2030		2020	2025	2030		2020	2025	2030	2035	2040	2045		
State of construction neg. scenario									0	500	1315	2130	2945	3760		
Construction speed/a in km neg. scenario									0	100	163	163	163	163	150,4	
State of construction neutr. scenario	0		4000		20	1170	4070		0	500	1725	2950	3760			
Construction speed/a in km neutr. scenario			400	400		230	580	405	0	100	245	245	163		188,25	331,08
State of construction/a in km pos. scenario									0	1250	3000	3760				
Construction speed pos. scenario									0	250	350	152			250,67	
Expansion length in km		1200	4000				4070			500	1725		3760			3943,33
Construction costs in € million		2.000	16.000				6.550			850	5.100		12.200			11583,33
Annual maintenance costs in € million		36	288				115			17	102		244			215,67
Maintenance costs as % of expansion costs		1,80%	1,80%				1,76%			2,00%	2,00%		2,00%			1,86%

Table 1 - ERS Construction scenarios and costs. Refers to Figures 15-17. Source: Wietschel, et al. (2017, p. 75, 141); Jöhrens, et al. (2020, p. 25, 47, 52, 57, 58); Hacker, et al. (2020, p. 22, 128, 194, 219).

TCO-Costs: Diesel vs. Catenary Truck		NPM (Technology Comparison TC)			Wietschel, et al.			Hacker, et al.			Jöhrens, et al.			Average (without NPM)		
		2020	2025	2030	2015*	2025	2030	2020	2025	2030	2020	2025	2030	2020	2025	2030
Diesel Truck																
Overhead: Purchase (€)		100.000	101.400	102.800	102.000		128.673		101.322	110.020	98.000		98.000	100000	101322	112231
Variable operating costs (€/km)	Consumption	0,204		0,204	0,311		0,369		0,274	0,244	0,322		0,323	0,316		0,312
	Service & Maintenance	0,146		0,154	0,143		0,143		0,141	0,141	0,106		0,122	0,124		0,135
	Toll				0,187		0,187		0,167	0,167	0,187		0,187	0,187		0,180
	Lubricant										0,016		0,015	0,016		0,015
	AdBlue				0,006		0,009							0,006		0,009
nEHS 80€/t CO²										0,054						
nEHS 200€/t CO²										0,135						
Diesel (∑Fix)+(∑Var)		0,349		0,357	0,647		0,708		0,582	0,552	0,630		0,646	0,650		0,651
Diesel (∑Fix)+(∑Var) (nEHS 80)																0,705
Diesel (∑Fix)+(∑Var) (nEHS 200)																0,786
TCO-Lifecycle costs in €														495132		508083
TCO-Lifecycle costs in € (nEHS 80)																540932
TCO-Lifecycle costs in € (nEHS 200)																590206
Catenary Truck																
Overhead: Purchase (€)		450000		177500	286800		189200		150039	137876	138000	119500	115000	212400		147359
Variable operating costs (€/km)	Consumption	0,072		0,086	0,252		0,208		0,208	0,184	0,238		0,167	0,245		0,186
	Service & Maintenance	0,153		0,158	0,380		0,107		0,122	0,122	0,106		0,122	0,243		0,117
	Toll				0,176		0,176		0,167	0,167	0,176		0,176	0,176		0,173
Catenary Truck (∑Fix)+(∑Var)		0,225		0,244	0,808		0,491		0,497	0,473	0,520		0,464	0,664		0,476
TCO-Lifecycle costs in €														616261		437059
TCO-Lifecycle costs TC in €														349028		295970
Average annual mileage (in km)		114.000			114.000			100.000			101.400			107350		
Duration of Truck use in years		6			6			5						5,67		

Table 2 - TCO Comparison between Diesel and Catenary Trucks from 2020 to 2030. Sources: NPM (2020, pp. 21, 23, 41-45); Jöhrens, et al. (2020, pp. 31, 83-85); Hacker, et al. (2020b, pp. 150-157, 170); Wietschel, et al. (2017, pp. 91-92, 141-142, 160-164).
Refers to Figures 18-19. The source NPM refers only to a pure technology comparison and is thus not comparable with the other sources. Therefore, it is not included in the averaging. However, it does play a role for Figure 19. Purchase prices vary widely depending on the assumptions made by the authors about production scaling, secondary markets, and vehicle depreciation. Insurance costs and driver costs were assumed to be equal for the purpose of this study and were thus not included. Toll costs vary depending on assumptions made by the authors.
** Since this source was written a few years before the others, it refers to 2015 instead of 2020. Although price changes occurred during that period, it is treated equally to the other sources for the purposes of this examination.*

Emissions 2030 in Mio. t CO^2-e			Wietschel, et al.				Jöhrens, et al.			Hacker, et al. (HEV/BEV Mix)		Jöhrens, et al. 2020-2030 accumulated emissions (C-HEV)		
			Diesel	C-HEV	C-BEV	Saved Emissions	Diesel	C-Trucks (HEV/BEV Mix)	Saved Emissions	Saved Emissions 2030	Saved Emissions 2040	Diesel	C-BEV	Saved Emissions
Neg. Scenario										1,1	6,3	70,94	63,48	7,46
Baseline Scenario				3,56		2,206								
			5,769		2,707	3,062	5,97	4,1	1,9	2,3	7,7	70,94	62,36	8,58
Positive Scenario										3,9	9,1	70,94	61,73	9,21
Total Emissions GER 2015	907	In relation to baseline				0,34%			0,21%	0,25%	0,85%			
Emissions in Traffic GER 2015	161	In relation to baseline				1,90%			1,16%	1,43%	4,78%			
Total Truck Emissions GER 2015	41,3	In relation to baseline				7,41%			4,53%	5,57%	18,64%			
Heavy Truck Emissions GER 2015	19,7	In relation to baseline				15,54%			9,49%	11,68%	39,09%			
Total Emissions GER 2030	731	In relation to baseline				0,42%			0,26%	0,31%	1,05%			
Emissions in Traffic GER 2030	148	In relation to baseline				2,07%			1,26%	1,55%	5,20%			

Table 3 - GHG emissions and savings in Germany due to ERS in 2030, 2040 and over the duration from 2020-2030. Sources: Wietschel, et al. (2017, pp. 1, 199-202); Jöhrens, et al. (2020, pp. 33, 38-40, 55); Hacker, et al. (2020b, pp. 157-164, 211-212); Kemmler, et al. (2020, p. 24).
Results from the baseline scenario are set in relation to total emissions in Germany in different sectors in 2015 and 2030. For Wietschel, et al. upstream and downstream emissions were netted and set in relation for C-BEVs.

A. General Introduction to all interviews:

Motivation and Objective of the Interview

The ambitious climate protection goals of the EU and the German government for the year 2030, with a perspective of climate neutrality by 2050, make rapid decarbonization of all economic sectors inevitable.[16] In the transport sector, this development is progressing by far the slowest compared to other sectors.[17] Especially in heavy-duty transport, the choice of economical alternative propulsion technologies is severely limited. While BEV-Trucks are still sufficient for medium distances of 200-300 km, this option is not available for long-distance transport due to significantly higher battery weights.[18] The joint research project AMELIE 2 has therefore set the task of testing the viability of electric road systems, e.g. in the form of an overhead line, and of creating and validating possible stakeholder models for this. The following guideline-based interview will take place in this context. This document therefore structures the interview and documents the results of the interview.

Methodology and Research Questions

As an established method of qualitative empirical social research, guideline-based interviews offer the possibility of targeted data collection. The possibility to ask questions during the interview or to deepen specific topics also gives the format a special flexibility. The overarching research questions of the interview primarily serve to validate the stakeholder model as well as to assess the market ramp-up and are therefore:

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[16] BMU (2016): Klimaschutzplan 2050 - Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung. Link: https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_bf.pdf. European Commission (2020: Proposal for a Regulation of the European Parliament and of the Council establishing the Framework for achieving Climate Neutrality and amending Regulation (EU) 2018/1999 (European Climate Law) Link: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0080&from=EN.

[17] Kemmler et al.: Energiewirtschaftliche Projektionen und Folgeabschätzungen 2030/2050 - Dokumentation von Referenzszenario und Szenario mit Klimaschutzprogramm 2030. p. 69. Prognos (2020). Link: https://www.bmwi.de/Redaktion/DE/Publikationen/Wirtschaft/klimagutachten.pdf?__blob=publicationFile&v=8

[18] Hacker et al.: StratON - Bewertung und Einführungsstrategien für oberleitungsgebundene schwere Nutzfahrzeuge. S.89. Öko-Institut (2020). Link: https://www.oeko.de/fileadmin/oekodoc/StratON-O-Lkw-Technologievergleich-2018.pdf.

Market ramp-up:

- What are the overarching challenges associated with the market ramp-up of electric road systems and their GHG footprint, and how can these be addressed?

Stakeholder model:

- What challenges does Alstom S.A. associate with this stakeholder model?
- Can the presented stakeholder model be transferred to the French or European level from the perspective of Alstom S.A. or to what extent could there be a need for adaptation in this regard?

The following guideline includes 3 sections. Further details on individual questions can be found in the sections below.

B. Specific Interviews

Interview 1: Alstom

Interview with Patrick Duprat, Electric Road Program Manager at Alstom S.A. on 06.04.2021

Section 1: Addressing and personifying the respondents / general introduction to the view of the respondent on the topic

Research Question		Structure	
	Introduction	Question	Answer
Introduction	• Presentation of the interviewer • Usage of the results (We are recording) • Presentation of topics • Procedure		
Which industry/research project do the respondents belong to? In which industry/research project do the respondents work?	• Introduction of the interviewee	1.1 Could you please briefly introduce yourself at the beginning of the interview? We are particularly interested in the extent to which you are involved in the construction and operation of electric road systems.	
What are the respondents' views on ERS?	There are various approaches to implementing the transformation of the mobility sector. In addition to ERS, there are other potential technologies for decarbonizing heavy goods traffic.	1.2 Do you consider the introduction of electric road systems to be a relevant topic for implementing the mobility transition?	• Yes, they are • In the end there can be a mix, several solutions will be on the market

Section 2: The market ramp-up of ERS

Research Question		Structure	
	Introduction	Question	Answer

	The introduction of electric road systems is a complex task that poses both regulatory and economic challenges.	2.1. What aspects of a political, economic or regulatory nature do you consider to be central to enabling the timely introduction of electric road systems?	• all of these aspects are essential • importance of business-cases • requires investments and strong political will • no legal aspects which block the process, however there is some adaptation of the regulation needed, will develop with the introduction of the technology
	In Germany, in addition to three existing pilot projects, a decision on the large-scale roll-out of ERS is to be made in 2025.	2.2. How does this process play out in France? Should ERS also be established in France, what problems might occur and when can their introduction be expected?	• Pilot projects are expected (sometime soon, no specific answer) • French task force on ERS (cooperation with Sweden & Germany)
What are the overarching challenges associated with the market ramp-up of electric road systems in nation states and the EU and how can they be addressed?	Although establishing ERS at the national level may also make sense from an economic point of view, implementing the system within the framework of the European core network corridors and the TEN-T is most likely advantageous from an organizational, economic and political perspective.[19]	2.3. What challenges do you expect regarding the introduction of ERS in the EU and how can they be addressed? 2.4. What other political hurdles can be expected at the EU level and how can they be addressed? 2.5. What option to establish ERS do you consider more likely: a) A top-down process, e.g. via a binding EU regulation b) A bottom-up process, where some member countries establish the technology and others follow, possibly due to economic and ecological profitability and general spillover effects	• biggest challenge to decide for one of the technologies • second step will be the standardization • EU-Commission has to participate in financing ERS, especially in the beginning of the construction (no specific answer to question) • A top-down process is necessary, as non-standardized ERS among the EU will cost more and be impractical for speditions (on further request if he considers top-down **likely**, he repeated, that he considers it necessary for the success of ERS)

[19] Wietschel et al.: Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw. Fraunhofer ISI. P.247-250.

What are the advantages and disadvantages of existing variants of ERS?	Currently, there are three variants of electric road systems. They can be introduced either in the form of an overhead line, a conductor rail or through an inductive system. Some publications emphasize the high Technology Readiness Level (TRL) and the comparatively low costs of the overhead line system.[20]	2.6. Which technology is preferred by Alstom S.A. and why? 2.7. In case different ERS-variants are introduced in different EU countries: How does Alstom S.A. assess their interoperability and what additional costs could be involved? 2.8. Which level (size/length, number of vehicles) of testing would be sufficient to allow a major expansion of an ERS? 2.9. Apart from Technical Readiness Level (TRL) and Total Cost of Ownership (TCO) - which other criteria of is most important?	• problems with regard to heavy traffic (PAN break, catenary line break) at catenary systems • conductor rail preferred • inductive system not enough to recharge heavy trucks • conductor rail can be used by different vehicles, e.g. passenger cars as well; however there is not a big market for this; light duty vehicles are more interesting here • Does not believe in interoperability, too difficult and expensive (volume/weight/cost) to supply a vehicle with different devices and technologies (e.g. PAN for catenary line and conductor rail), not realistic, even if feasible • ERS as backbone of decarbonized long-distance freight • Most important is to demonstrate the system can demonstrate high power (MW) and "stress" (safety etc.)-capability, not length • Business case, Safety, Acceptance, Regulation, Availability of System, State investments

Section 3: The Stakeholder Model

Research Question		Structure	
	Introduction	Question	

[20] Ibid. p. 69; Hacker et al.: StratON- Bewertung und Einführungsstrategien für oberleitungsgebundene schwere Nutzfahrzeuge. p.82.

How can we ensure interoperability on the European level?	There are three basic technological approaches that provide possible solutions for supplying ERS and they are at different levels of market maturity. Against this background, it is conceivable that European countries could opt for different systems in different forms, which are not interoperable or are even incompatible with each other, especially since there is currently no legal obligation for states to comply with existing or future standards.	3.1 Which steps should be taken on a European level to ensure an interoperable system? 3.2 Do you see possible solutions with regard to ensuring different ERS (e.g. overhead contact line or inductive systems) will at least be compatible?	• EU Commission should step in and select solutions that fit all technological approaches (see 2.7) • Question omitted (see 2.7)
Legal classification of ERS in France	In the professional public and in the practice of the authorities, the view prevails that at least the physical part of an ERS (as distinct from the electrical power grid) is part of the road on which it is built. This ensures its safe integration into the road space in planning and operation. At the same time, it is thus included in road financing, which has already been made subject to European regulation by Directive 1999/62/EC (infrastructure costs Directive). The integration of the ERS into the infrastructure costs directive would have the advantage of a pre-existing European legal framework into which the different road financing systems of the Member States can fit without creating interstate barriers in contradiction to the idea of trans-European transport networks. At the same time, the infrastructure costs would be shared equally by all road users in heavy goods traffic, so that the emitters of harmful greenhouse gas emissions could easily co-finance the infrastructure to reduce them (polluter pays principle)	3.3 Would an ERS infrastructure in France be part of the highway and thus be regulated by the law on highways/road infrastructure? 3.4 Would the ERS/overhead lines as a traction power network be considered part of the general energy supply network? 3.5 Who would be legally responsible for the ERS infrastructure in France? (State, private, PPP) Who would possibly operate the network? 3.6 Would there be only one, or two separate operators for the ERS infrastructure and traction power network? 3.7 How would the infrastructure be connected to the local electricity distribution network? 3.8 What are your considerations with regard to possible billing systems?	• Probably yes, but no detailed information due to early stage of ERS-exploration in France (also: no expert for law) • Probably not (see 3.3) • full concession • privatized • details not yet defined • not yet defined • different solutions possible • no considerations made so far
The view and perspective from a truck operator's point of view	Logistic companies run their business at narrow margin levels and therefore react cost-sensitive.	3.9 If an ERS could offer economic benefits to them why hasn't there been more support from Logistic associations in order to bring ERS forward?	• uncertainty for further planning • Vehicles and infrastructure needed • OEMs (original equipment manufacturer) do not support ERS so far

Interview 2: Autobahn GmbH des Bundes

Interview mit Herrn Dominik Gurske, Projektingenieur bei der Autobahn GmbH des Bundes am 15.04.2021

Abschnitt 1: Ansprache und Personifizierung der Befragten / allgemeiner Einstieg zur Einstellung der Befragten zum Thema (offener Teil)

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**
Einleitung	• Vorstellung des Interviewers • Verwendung der Ergebnisse (wir würden das Interview gerne aufzeichnen) • Themenvorstellung • Ablauf		
Welcher Branche/welchem Forschungsprojekt gehören Befragte an? In welcher Branche/welchem Forschungsprojekt sind Befragte tätig?	• Vorstellung des Interviewten	1.1 Könnten Sie sich zu Beginn des Interviews bitte kurz vorstellen? Besonders interessant ist für uns, inwiefern Sie sich mit der weiteren Errichtung und dem Betrieb von ERS beschäftigen und welchen primären Herausforderungen sie in diesem Zusammenhang bei der Autobahn GmbH sehen.	
Wie stehen die Befragten zu ERS?	Zur Umsetzung der Mobilitätswende gibt es verschiedene Ansätze. Neben ERS gibt es noch weitere denkbare Technologien zur Dekarbonisierung des Schwerverkehrs.	1.2 Halten Sie die Einführung elektrischer Straßensysteme für ein relevantes Thema zur Umsetzung der Mobilitätswende?	• Im Blick auf Schwerlastverkehr kaum ohne ERS möglich. PKW-Elektrifizierung durch Batterien, bei Gütertransport nicht möglich (auch da Gewicht und Volumen der Batterien ein relevantes Kriterium sind) • H2-LKW? Ergänzen sich ggf. zu O-LKW, da Brennstoffzelle statt Dieselmotor Teil des Hybridsystems sein kann.

Abschnitt 2: Der Markthochlauf von ERS

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**

Welche übergeordneten Herausforderungen sind mit dem Markthochlauf elektrischer Straßensysteme verbunden und wie können diese angegangen werden?	Die Einführung elektrischer Straßensysteme ist eine komplexe Aufgabe, die sowohl von regulatorischer als auch wirtschaftlicher Seite Herausforderungen mit sich bringt.	2.1. Welche Aspekte politischer, wirtschaftlicher oder regulatorischer Natur halten sie für zentral, um eine zeitnahe Einführung elektrischer Straßensysteme zu ermöglichen?	• **Planungssicherheit**: Politik muss hier entscheidende Weichen stellen, um klare Signale zu senden, wohin die Reise gehen soll. Dann kann die Wirtschaft nachziehen. • **Normen und Standards** müssen erstellt werden. Dies ist extrem wichtig. Bspw. wo gehört welches Bestandteil hin (E-Highway als Teil des Fernstraßennetzes und damit klarer Regelung der Planung). • **Wirtschaftliche Aspekte** Anreize und Signale der Politik zur Zusammenarbeit zw. Öff. Und Priv. Wirtschaft sind nötig.
	Neben existierenden Pilotprojekten soll 2025 eine Entscheidung zum großflächigen Roll-Out von ERS getroffen werden.	2.2. Halten sie diesen Startzeitpunkt (2025) für realistisch? Sollte dies nicht der Fall sein, wann erwarten sie den Startzeitpunkt? Falls vorhanden, ziehen sie gerne Vergleiche zu anderen (möglicherweise vergleichbaren) Projekten, mit denen sie in Kontakt gekommen sind.	• Aus Sicht der Oberleitung ist der Plan realistisch. Erfahrungen werden aktuell bereits in verschiedenen Projekten gesammelt
Wie können die aktuellen Ausbaupläne eingeschätzt werden und wo verortet sich die Autobahn GmbH in diesem Kontext?	Pläne zum Ausbau einer Oberleitungsinfrastruktur bestehen bereits über die drei Pilotprojekte FESH, ELISA und eWayBW hinaus. Bis 2025 sollen zudem 300km Pendelstrecke elektrifiziert werden. Folgt danach eine Roll-Out-Phase, könnten nach einer vom Verkehrsministerium in Auftrag gegebenen Studie[21] schon 2030 2000 km Autobahnstrecke elektrifiziert sein.	2.3. Halten sie diese Ausbaugeschwindigkeit für realistisch? 2.4. Für den Fall, dass der deutschlandweite Ausbau von ERS auf ein Kernnetz von knapp 4000km ab 2025 erfolgt: Wann rechnen sie mit einer Fertigstellung des Baus? (Eine Schätzung kann hier genügen) 2.5. Welche Verfahrensschritte bei der Errichtung der ERS-Infrastruktur werden von der Autobahn GmbH als besonders relevant erachtet? 2.6. Welche Herausforderungen und potenziellen Problematiken ergeben sich damit für	• Noch keine konkreten Gespräche. ELISA 1 zeigt, dass 10km in einem Jahr errichtbar waren, auch die 300km bis 2025 sind **unter Einsatz entsprechender Ressourcen** und mit dem entsprechenden **politischen Willen** realistisch. • Bis 2030 sehr ambitioniert, kommt auf den Willen an, aber kann schnell gehen. • Ambitioniert, aber könnte nach obigen Annahmen schon **2035** fertig sein. Voraussetzung sind wieder **politischer Wille** und **angemessene Ressourcen**. • ELISA 1: Vorteil von „Zubehör“ zur Autobahn. Hier ist die Frage nach der Planfeststellung sehr wichtig. Bei dreistelliger Zahl von Stakeholdern könnte Planfeststellung sehr wichtig werden. • Sie gehen davon aus, dass bei mehr (ca. 100km) eine Planfeststellung nötig ist? • Ja, da reicht vermutlich 1 Stakeholder, der „querschießt“ und daher sollte man nicht davon ausgehen, dass die Planfeststellung immer entfallen kann. • Herausforderung: Entsprechende Strukturen innerhalb der Autobahn GmbH müssen geschaffen werden. Das Thema muss größer aufgenommen werden.

[21] Nationale Plattform Zukunft der Mobilität (NPM): Werkstattbericht Antriebswechsel Nutzfahrzeuge -Wege zur Dekarbonisierung schwerer Lkw mit Fokus der Elektrifizierung. Dezember 2020, S.15. Abrufbar unter: https://www.plattform-zukunft-mobilitaet.de/wp-content/uploads/2020/12/NPM_AG1_Werkstattbericht_Nfz.pdf.

		die Autobahn GmbH? Welche Lösungsansätze werden ggf. verfolgt?	• Laufende Projekte, SH und BW bringen weitere Perspektiven mit (jetzt auch Autobahn GmbH), d.h. weiteres Know-How ist vorhanden. Rechtliche Herausforderungen sind dann abzustecken. • Umweltverträglichkeitsprüfung im Rahmen des Planfeststellungsverfahrens, aber auch in ELISA 1/3 gemacht, dabei FFH Gebiete etc. ausgeschlossen. • Dauer ca. ein Jahr für ein Planfeststellungsverfahren, was ist Ihre Erwartung für den Zeitrahmen? • Unklar, kein Wissen vorhanden. • Prinzipiell könnte es ein Mehrjähriger Prozess werden, aber Vorteile, wenn die ERS auf der Autobahn und nicht Bundesstraßen gebaut werden.
Welche wirtschaftspolitischen Instrumente könnten zur Unterstützung und Stabilisierung des Markthochlaufs von ERS sinnvollerweise zum Einsatz kommen?	Neben dem Infrastrukturausbau ist für einen erfolgreichen Markthochlauf von ERS auch das Marktumfeld für Speditionen und Hersteller zentral. Ein politischer Rahmenplan, der Planungssicherheit schafft und die Wirtschaftlichkeit des neuen Systems unterstützt, wird daher von vielen Akteuren als zentral erachtet. Gerade Subventionen, wirtschaftliche Förderungen, sowie Abgaben könnten in diesem Kontext eine Rolle spielen.	2.7. Welche regulatorischen und wirtschaftspolitischen Instrumente könnten aus ihrer Perspektive primär zum Einsatz kommen? 2.8. Wie stehen sie zu einer Strompreis- oder Mautkostenerleichterung in der Anfangsphase des Markthochlaufs von ERS?	• Förderungen sind ein wichtiges Instrument. Bei ELISA: Speditionen leasen die LKW zu Marktüblichen Konditionen (d.h. konventionelle LKW). Eine Etablierung über Preis ist nicht vorstellbar. • Solange Risiken nicht abschätzbar und Konkurrenz sich nicht ähnlich verhält, ist eine Förderung nötig. Aktuell Unternehmen die „gerne an Forschungsprojekten Teilnehmen“, o.ä. • Ja, besonders am Anfang; auch wenn ggf. bereits eine TCO-Betrachtung positiv ist, ist es gerade am Anfang wichtig zu fördern um die Technologie zu etablieren. • CO2/Steuern/…? à CO2-Preis wird vermutlich positiv einwirken. • Blick ebenfalls auf EU-Umland nötig, um hier dieselben Technologien und Standards zu nutzen: E.g. bei 80% „Elektrifizierung“ ist eine europäische Interoperabilität nötig. • Fahrzeugzulassung: aktuell 40t, Pantograph und Batterie wiegen ~1,7t, Ausnahmeregelung erlaubt Zusatzgewicht, wodurch keine Sonderprüfung besteht.

Abschnitt 3: Das Akteursmodell

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**
Wie fügt sich die Autobahn GmbH in das Bild des Akteursmodells zur Gewährleistung eines reibungslosen, operativen Betriebs der ERS-Infrastruktur ein?	Die ERS-Infrastruktur würde nach dem Akteursmodell als staatliche Infrastruktur durch die Autobahn GmbH betrieben, als Teil der Straße staatlich aus dem Bundeshaushalt errichtet und über die Maut gegenfinanziert.	3.1. Entspricht die Rolle des ERS-Betreibers in dem vom IKEM entwickelten Akteursmodell den Vorstellungen der Autobahn GmbH des Bundes bzw. ist dies aus Sicht der Autobahn GmbH realisierbar? 3.2. Welche Herausforderungen sieht die Autobahn GmbH hinsichtlich des Betriebs der Oberleitungsinfrastruktur im Kontext der Autobahn?	• Aus ELISA-Perspektive und Verkehrszentrale Deutschland ist das auch das Modell, was für realistisch gehalten wird. Aus gesamt-BA GmbH keine Aussage. • **Sicherheitsaspekte:** Störfallmanagement, Abschaltung des E-Highway bei Rettungseinsätzen, etc. à Schulung von Feuerwehr/Verkehrszentralen à **Einzelne Verkehrszentrale für ERS**, die zentralisiert und dafür geschult wird ist Option. Aber: Speziell wenn mehrere Abschnitte genutzt werden, könnte dies zu Kapazitätsgrenzen an den Verkehrszentralen führen. Daher entweder ein Ausbau der Kapazitäten

		3.3. Welche Herausforderungen bestehen aus Ihrer Sicht im Hinblick auf die Errichtung eines Wettbewerbsmarktes mit verschiedenen Strom- bzw. Mobilitätsanbietern in der ERS-Infrastruktur? 3.4. Welche Herausforderungen sehen Sie im Hinblick auf etwaige Sicherheitsaspekte beim Betrieb von ERS?	oder Schaffung (einzelner) Verkehrszentralen. à **Vergleich Bahn:** Bahn hat eigene Teams, aber Abschaltung aufgrund eines Unfalls passiert. Prinzipiell ist von häufigeren Abschaltungen als bei der Bahn auszugehen, zumal auch lieber einmal mehr abgeschaltet wird, bevor doch was schief geht. Störfallmanagementtrupps wären sinnvoll. Im ELISA-Fall ist die Verkehrszentrale D das „Störfallmanagememt Team". • **Verkehrliche Aspekte:** Rettungshubschraubereinsatz, Großraumtransporte (aktuell Sperrung der 1. Fahrspur für Großraumfahrzeuge und lediglich zwischen 2 Anschlusstellen) • Ggf. via Nutzer, die Verträge mit Versorgungsunternehmen abschließen und eigenständig für die Nutzung der Oberleitung agieren. • Nach kurzer Beschreibung des Akteursmodells: Akteursmodell prinzipiell gut, gesonderte Verträge mit Stromlieferanten, dadurch die Genehmigung bekommen zum Anschluss an die Oberleitung. Daraus ergibt sich die Frage: Wie stimmen sich Betreiber und Lieferant ab, und wie ist zu kontrollieren, dass jeder einen Vertrag abschließt. Aktuell 100% Förderung des Stromes, wobei alle Nutzenden AGBs zustimmen, „Stromerschleichen" in dem Sinne daher nicht möglich. • S.o.
	Der Betrieb der elektrischen Anlage ist der Autobahn GmbH als Teil der Straße zugeordnet. Die Expertise in diesem Bereich ist bei der Autobahn GmbH voraussichtlich begrenzt.	3.5. Würde die Autobahn GmbH diese Expertise im eigenen Haus aufbauen, oder an private Unternehmen (Netzdienstleister) auslagern?	• Bei ELISA 1: Planung die Expertise auszulagern, aber mangels Interesses von Anbietern gescheitert, daher im eigenen Haus die Expertise gesucht und gefunden. Aber; bei Längeren Abschnitten vermutlich etwas in Richtung PPP.
Welche Lösungsstrategien für aktuelle rechtliche und organisatorische Probleme im Zusammenhang mit Errichtung und Betrieb von ERS werden verfolgt?	Eine Einschränkung der Einbeziehung von privaten Unternehmen ergibt sich derzeit noch aus § 5 Abs. 2 Satz 3 InfrGG (Begrenzung auf 100 km). Dies ist voraussichtlich zu kurz für einen sinnvollen Betrieb.	3.6. Welche Privatisierungsmodelle kommen hierbei aus Sicht der Autobahn GmbH vorzugsweise in Betracht? 3.7. Wie schätzt die Autobahn GmbH die Realisierbarkeit einer Sonderregelung im InfrGG für die Vergabe des ERS-Betriebs ein?	• Aktuelle Analysen im Sinne der Begleitforschung wird noch durchgeführt. Kooperation von privaten und staatlichen Institutionen vorzustellen. • Verfügbarkeitsmodell? Ja, dieses ist bspw. eines der diskutierten Modelle, aktuell im Projekt ähnliche Verfahren ggü. Siemens. • Man müsste denen, die die Entscheidungen treffen klar machen, dass es eine „notwendige" Entscheidung ist, dieses zu zulassen, dann ist eine Änderung / Sonderregelung vermutlich möglich.
	Alle öffentlichen und privaten Interessen, die öffentliche oder private Belange Dritter oder öffentliche Belange aus dem Zuständigkeitsbereich dritter Behörden betreffen, sind in	3.8. Die Richtlinien für die Anlage von Autobahnen (RAA) sind ein wichtiges Regelwerk für den Entwurf und Bau von Autobahnen. Welche Regelwerke und Regulierungen	• Fernstraßengesetz – Paragraph 1 („Zubehör" zur Fernstraße bereits genannt) [weitere nicht direkt]

	einem Planfeststellungsverfahren zu berücksichtigen, zu bewerten und gegeneinander abzuwägen. Die technische Sicherheit ist durch den Träger der Straßenbaulast bereits nach § 4 FStrG sicherzustellen, so dass sie im Planverfahren nur in Abwägung mit anderen Belangen und als Bewertungsmaßstab in der Abwägung eine Rolle spielt. Grundlegende Belange der technischen Sicherheit einer Oberleitungsanlage an Autobahnen werden daher in Regelwerken gelöst und sind nicht Gegenstand der Fachplanung.	sind in diesem Bereich darüber hinaus in Bezug auf ERS zu beachten? 3.9. Welche Belange werden aus Sicht der Autobahn GmbH durch den Ausbau einer Oberleitungsinfrastruktur zusätzlich betroffen? (Einbeziehung von Natur- und Wasserschutzbehörden?)	• Diverse Regularien wie für passive Schutzeinrichtungen (RPS), Rettungsdienst Handlungsanweisungen, Tätigkeitsbeschreibungen im Straßenbetriebsdienst. Div. weitere Dinge, hier ggf. noch mal detaillierte Diskussion • Weitere Punkte dazu: o DIN 1076: Abnahme der Oberleitung, hier Definition verschiedener Bauwerkstypen, hier fehlen bspw. noch Elemente wie „Oberleitungsmasten“ etc. o Ortsfeste Elektrische Anlagen (DIN VDE 0100-0105), automatische Abschaltung bspw. wie bei der Bahn auch noch Sicherheit Erdkabel, Regelwerke zu passiver Schutzeinrichtung klären. BASt hatte bei ELISA einfach die höchste Schutzstufe gewählt. Bei ELISA 3 Reduktion auf H2 (Richtlinie für passiven Schutz) o VOB ggf. anzusehen für das Verfahren mit dem Ziel die Oberleitung als Bauwerk zu definieren. • Trassenbetreiber, Natur- Wasserschutzbehörden (speziell, falls die Planfeststellung nicht entfällt), Belange weiterer Fachbereiche bspw. bei Brückenbauwerk, e.g. was passiert, wenn die Leitungen nicht „durch die Brücke“ passt? Die Bahn, wenn im Bereich der Strecke eine Neubaustrecke der Bahn geplant ist. Betreiber von Freileitungen, die die BAB kreuzen und daher keine Freileitung zulassen. Ggf. Kommunen mit Ihren Entwässerungsanlagen. Einbeziehung der „Streckenanreiner“ („Tank und Rast“) im Bauprozess.
	Bei konfliktarmen Vorhaben kann ggf. auf eine Planfeststellung verzichtet und eine Plangenehmigung erteilt werden. In manchen Fällen kann die Planfeststellungsbehörde sogar ganz auf Planfeststellung oder Plangenehmigung verzichten.	Wie beurteilen Sie die Notwendigkeit von Planfeststellungsverfahren oder ggf. (lediglich) Plangenehmigung im Hinblick auf die Errichtung von ERS?	• S.o.

Interview 3: Bundesverband Güterkraftverkehr Logistik und Entsorgung (BGL) e. V.

Mit Jens Pawlowski, Leiter der Hauptstadtrepräsentanz des BGL am 31.03.2021

Abschnitt 1: Generelle Einstellung der Befragten zum Thema

	Aufbau	
Einführung/Ansprache	**Frage**	**Antwort**
Zur Umsetzung der Mobilitätswende gibt es verschiedene Ansätze. Neben ERS gibt es noch weitere denkbare Technologien zur Dekarbonisierung des Schwerverkehrs.	1.3 Halten Sie die Einführung elektrischer Straßensysteme für ein relevantes Thema zur Umsetzung der Mobilitätswende?	• Ja, Mobilitätswende / Anforderungen des Klimaschutzrahmenplans können nur durch Vielzahl an Technologien umgesetzt werden (BEV, H2, OLI etc.) • Ergebnisse der Tests auf Pilotstrecken primär • Bedarf kann noch nicht hinreichend abgeschätzt werden, da noch nicht genügend Fahrzeuge auf dem Markt vorhanden sind; Insb. im Langstreckenbereich aber sinnvoll

Abschnitt 2: Potenzielle Problematiken im Zusammenhang mit der Einführung von ERS

	Aufbau	
Einführung/Ansprache	**Frage**	**Antwort**
In ihrem Jahresbericht 2019/2020 weisen sie darauf hin, dass eine CO_2-Abgabe ohne technologische Alternative nur den Speditionsbetrieb verteuert ohne positive Klimaeffekte zu bewirken.[22] Neben Abgaben besteht aber auch das wirtschaftspolitische Instrument der Subventionen. Diesbezüglich könnten Maut- und Strompreiserleichterungen sowie Kaufprämien für den Markthochlauf von Lkws mit alternativen Antrieben eine Option sein.	2.1. Wie stehen sie zu den genannten Subventionsmöglichkeiten und welche Probleme könnten aus ihrer Sicht (neben der Kostenbelastung des Staatshaushalts) damit einhergehen? 2.2. Verschiedene Subventionsinstrumente bringen verschiedene Vor- und Nachteile mit sich. Haben sie bezüglich der Art der Subventionen Präferenzen?	• Neue Technologien als Risiko, daher Motivation notwendig à Mauterleichterung als Anreiz • Mehrinvestitionen dürfen keine „erstickende“ Wirkung haben, • Dreiklang; Überkompensation zunächst möglich (Mautanreiz und Förderprämie/Kaufanreiz) • Keine spezifischen Präferenzen, relevant ist, dass Speditionsbetrieb wirtschaftlich und praktikabel bleibt und dass Planungssicherheit besteht
Im BGL-Jahresbericht 2019/2020 weisen sie darauf hin, dass ein strategischer Fahrplan zur Einführung alternativer Antriebe und die damit einhergehende Planungssicherheit zentral für die Güterverkehrsbranche sind.[23]	2.3. Was sind aus ihrer Perspektive die zentralen Aspekte eines solchen strategischen Fahrplans um eine bestmögliche Planungssicherheit zu gewährleisten?	• Langfristige Planbarkeit notwendig, da Fahrzeuge Im Nah- und Fernverkehr teilw. 10 Jahre im Einsatz • Skepsis gegnüber Batterie für Fernverkehr in 2030 mit ausreichender Reichweite, Ladekapazität und Praktikabilität (auch wenn MAN sagt sie entwickeln etwas derartiges)

[22] BGL – Bundesverband Güterkraftverkehr Logistik und Entsorgung: Jahresbericht 2019/2020. S. 37. Abrufbar unter: http://www.bgl-ev.de/images/downloads/ueber/jahresbericht/BGL_Jahresbericht_2019_2020.pdf.
[23] Ebd., S.38.

Verschiedene Studien haben eine insgesamt neutrale bis negative Haltung von potenziellen Kraftfahrzeugherstellern sowie von Speditionsunternehmen ergeben.[24] Als Begründung wurden primär Bedenken gegenüber potenziellen Kosten sowie aufgrund von mangelnder Planungssicherheit angegeben.	2.4. Wie schätzen sie die Einstellung innerhalb der Kraftverkehrsbranche gegenüber ERS ein?	• Einstellung in der Branche eher skeptisch • Ideologische Scheuklappen sollen vermeiden werden, da nicht viele alternativen vorhanden • Zeitplan eng, es muss nicht in zu vielen verschiedenen Bereichen entwickelt werden, Fokus und Konzentration hier notwendig, Problem hier wieder, dass politisch keine Planungssicherheit besteht
	2.5. Was könnte zur Verbesserung der Einstellung der genannten Marktteilnehmer gegenüber ERS beitragen? Was gilt es hierbei zu beachten?	• Planungssicherheit. Wirtschaftlichkeit, muss in die logistischen Abläufe passen • Diesel Lkw flexibler, Oberleitungs-Lkw kann nicht genauso flexibel eingesetzt werden (Nahverkehr und nächtlicher Langstreckenverkehr) • Kleinere Unternehmen können sich keine ganze Palette an Fahrzeugen zulegen, die auf verschiedene Zwecke passen • Praktikabilität • Leasing: die meisten Unternehmer leasen die Fahrzeuge auch jetzt schon, Problem: Diversität dennoch notwendig
	2.6. Wie stehen diese Aussagen im Vergleich zur BGL-Haltung ggü. den parallel diskutierten alternativen PtL-Kraftstoffe bzw. Brennstoffzellen hinsichtlich Kosten und Planungssicherheit?	• wirkliche Lösungen erst Ende der 20er Jahre verfügbar • PtL/Bio-Gas werden ebenfalls berücksichtigt • Nur Tank-to-Wheel Betrachtung, nicht Well-to-Wheel, Vorkette nicht mit einberechnet (Kyoto-Protokoll), auf Nachfrage zugestimmt, dass unter klimatechnischen Gesichtspunkten eine TtW-Betrachtung nicht sinnvoll ist, aber dass es in dem Sektor Gang und Gäbe sei Bedeutet effektiv Greenwashing/Schönrechnerei
	2.7. Wie stehen Sie zu solchen, für die Einsatzgebiete optimierten, Konfigurationen?	• BEV: Hohe, unpraktikable Batteriegewichte werden voraussichtlich nicht verschwinden, Lithium/Seltene Erden-Nachfrage übersteigt Angebot, Verfügbarkeit zukünftig fraglich à Preisexplosion? Zudem Umwelt/Soziales Problem bei seltenen Erden

[24] Fraunhofer ISI: Der eHighway aus gesellschaftlicher Perspektive - Erkenntnisse zur sozialen Akzeptanz und den Akteuren rund um Oberleitungs-Lkw-Systeme in Deutschland und Europa. Abrufbar unter: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cce/2020/2020-Bericht-Akzeptanz_BOLD_eHighways.pdf; Wietschel et al.: Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw. Fraunhofer ISI, 2017. S.217ff.

	2.8. Welche Unterstützung und Flexibilität wünschen Sie sich seitens der Infrastrukturen und der Fahrzeuge?	• Orientiert an Performance des Diesel • Infrastrukturen sind zentral, Unternehmen werden keine Umwege in Kauf nehmen, dezentrale Infrastruktur dringend notwendig, mögl. Auch auf Betriebshöfen der Unternehmen
Die verschiedenen Dekarbonisierungstechnologien gehen mit Ausnahme von PtL mit teilweise erheblichen technischen oder finanziellen Änderungen einher.	2.9. Wo liegen die „Schmerzgrenzen", die ggf. durch Subventionen, regulative Anpassungen bzw. Nachteilsausgleiche hinsichtlich Gewicht (insbes. für große Traktionsbatterien), Fahrzeugkosten (v. a. BZ-Fahrzeuge) oder Bauraum gelindert werden müssten?	• Diesel Lkw- Performance als „Schmerzgrenze", damit Risiko eingegangen wird, da keine Investitionssicherheit gegeben ist, muss zudem „überfördert" werden, möglichst hohe Anreize (ggf. degressiv über Verlauf des Markthochlaufs) • Anreize können über Mauterleichterungen/nEHS gesteuert werden (dabei aber Doppelbelastung der beiden Systeme ausschließen) → Nationaler Emissionshandel ist kontraproduktiv und kein geeigneter Anreiz, da er wettbewerbsverzerrend wirkt, weil er nur nationale Unternehmen trifft in einem stark grenzüberschreitend funktionierenden Transportmarkt. Daher Mautanreiz oder EU-Emissionshandel

Abschnitt 3: Der Markthochlauf von ERS

	Aufbau	
Einführung/Ansprache	**Frage**	**Antwort**
Die Einführung elektrischer Straßensysteme ist eine komplexe Aufgabe, die sowohl von regulatorischer als auch wirtschaftlicher Seite Herausforderungen mit sich bringt.	5.1. Welche Aspekte politischer, wirtschaftlicher oder regulatorischer Natur halten sie für zentral, um eine zeitnahe Einführung elektrischer Straßensysteme zu ermöglichen?	• Kaufanreize • Infrastruktur • Planungssicherheit • Praktische Probleme: wie versichert man ein solches Fahrzeug, Wartung • welche Sicherheitsfragen sind zu beachten (Havarien, Unfälle)
Neben existierenden Pilotprojekten soll 2025 eine Entscheidung zum großflächigen Roll-Out von ERS getroffen werden.	5.2. Halten sie diesen Startzeitpunkt (2025) für realistisch? Sollte dies nicht der Fall sein, wann erwarten sie den Startzeitpunkt? Falls vorhanden, ziehen sie gerne Vergleiche zu anderen (möglicherweise vergleichbaren) Projekten, mit denen sie in Kontakt gekommen sind.	• Später darf diese Frage nicht geklärt werden, da sonst keine Planungssicherheit und Investitionssicherheit • Soweit keine besseren Alternativen am Markt vorhanden

Pläne zum Ausbau einer Oberleitungsinfrastruktur bestehen bereits über die drei Pilotprojekte FESH, ELISA und eWayBW hinaus. Bis 2025 sollen zudem 300km Pendelstrecke elektrifiziert werden. Folgt danach eine Roll-Out-Phase, könnten nach einer vom Verkehrsministerium in Auftrag gegebenen Studie[25] schon 2030 2000 km Autobahnstrecke elektrifiziert sein.	5.3. Halten sie diese Ausbaugeschwindigkeit für realistisch? (Eine Schätzung kann hier als Antwort genügen) 5.4. Welche Herausforderungen und potenziellen Problematiken ergeben sich damit für die Speditionen? Welche Lösungsansätze werden ggf. verfolgt?	• Eher unrealistisch: langwierige Planungsverfahren, generelle Skepsis • Zudem sind andere Fragen wie z.B. Parkplätze noch nicht geklärt • massiver Wettbewerb mit mittel- und osteuropäischen Speditionen im mittelständischen Segment; diese Unternehmer dürfen durch Klimaschutzmaßnahmen nicht aus Markt gedrängt werden; • Problem: Co2-Handel nicht wettbewerbsneutral, sollte über Maut reguliert werden, gebietsfremde Transportdienstleister müssen mit einbezogen werden

[25] Nationale Plattform Zukunft der Mobilität (NPM): Werkstattbericht Antriebswechsel Nutzfahrzeuge -Wege zur Dekarbonisierung schwerer Lkw mit Fokus der Elektrifizierung. Dezember 2020, S.15. Abrufbar unter: https://www.plattform-zukunft-mobilitaet.de/wp-content/uploads/2020/12/NPM_AG1_Werkstattbericht_Nfz.pdf.

Interview 4: Contargo GmbH & Co. KG

Interview mit Kristin Kahl, Sustainable Solutions Management beim Logistikunternehmen Contargo GmbH & Co. KG vom 04.05.2021

Abschnitt 1: Ansprache und Personifizierung der Befragten / allgemeiner Einstieg zur generellen Einstellung der Befragten zum Thema (offener Teil)

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**
Einleitung	• Vorstellung des Interviewers • Verwendung der Ergebnisse (Wir würden gerne aufzeichnen) • Themenvorstellung • Ablauf		• Contargo: Logistikdienstleister, der 25 Terminals im Hinterland der Seehäfen betreibt, über 40 Schiffe und über 850 LKW im Einsatz, d.h. alle Container vom Seehafen bis zum Terminal (auch mit Schiff), „letzte Meile“ mit LKW (200-250km). E-LKW wurden von Rhenus gekauft, Oberleitungsfahrzeuge sind geleast.
Welcher Branche/welchem Forschungsprojekt gehören Befragte an? In welcher Branche/welchem Forschungsprojekt sind Befragte tätig?	• Vorstellung des Interviewten	1.4 Könnten Sie sich zu Beginn des Interviews bitte kurz vorstellen? Besonders interessant ist für uns, inwiefern Sie in das ERS-Pilotprojekt ELISA eingebunden waren und welche zentralen Herausforderungen sie im weiteren Ausbau von ERS sehen.	• Lange auf LKW „Elfondo“ gewartet, war okay, da gut kommuniziert. LKW kamen im Abstand von 2-3 Wochen. 1x im Monat Austausch allgemein, 1x Fahrer wöchentlichen Austausch. • Herausforderung, welche Technologie sich im Fernverkehr durchsetzt. Prinzipiell 3 alternativen: a. BEV, b. BEV-O, Hybrid-O, c. FC-LKW Hier ist die Entscheidung schwierig. BMVi will bis 24/25 Entscheidung treffen. • BEV stehen sehr hohe Energiemengen bereit für Schnellladung, O-LKW: Infrastrukturbedarf hoch FC-LKW: noch energiebedürftiger, Wissenschaftlich: BEV-Hybrid vermutlich sinnvoller, H2 aber importierbar

Wie stehen die Befragten zu ERS?	Zur Umsetzung der Mobilitätswende gibt es verschiedene Ansätze. Neben ERS gibt es noch weitere denkbare Technologien zur Dekarbonisierung des Schwerverkehrs.	1.5 Halten Sie die Einführung elektrischer Straßensysteme für ein relevantes Thema zur Umsetzung der Mobilitätswende?	• Sinnvoll, wenn oberleitungsgebundene BEV-Hybride hergestellt werden, da Laden während der Fahrt praktisch und Batterien kleiner. • Außerdem: Ausbau von Stromtrassen entlang der Autobahn direkt möglich. Egal wie, auf den Autobahnraststätten werden hohe Ladeleistung benötigt. Netzausbau muss entsprechend vorangetrieben werden.

Abschnitt 2: Der Markthochlauf von ERS

Forschungsfrage		Aufbau	
	Einführung/Ansprache	**Frage**	**Antwort**
Welche übergeordneten Herausforderungen sind mit dem Markthochlauf elektrischer Straßensysteme verbunden und wie können diese angegangen werden?	Die Einführung elektrischer Straßensysteme ist eine komplexe Aufgabe, die sowohl von regulatorischer als auch wirtschaftlicher Seite Herausforderungen mit sich bringt.	5.5. Welche Aspekte politischer, wirtschaftlicher oder regulatorischer Natur halten sie für zentral, um eine zeitnahe Einführung elektrischer Straßensysteme zu ermöglichen?	• Entscheidung welche Technologie gefördert werden sollte und am sinnvollsten ist. Frage, was am besten ist. • Anfangsphase: Förderung des Investments wichtig: Förderung für OEMs besteht, hier müssen weitere Förderungen für Käufer her. Die 80% Mehrkostenförderung mit 1,3€ Mrd. ist nicht ausreichend, da nur 5.000-6.000 LKW damit gefördert werden können. Aber Auswirkung auf die OEMs bedenken, da diese ein Interesse benötigen, den Preis zu senken. Hier eine degressive Ausgestaltung. • Auswirkungen auf die Batterie immer teurer, aber muss sich über die laufenden Kosten refinanzieren. Ggf. hier einfach die Diesel-Subventionen reduzieren. Gemäß Euro-Vignette zero-emission Reduktion auf 75% der Mautkosten

	Neben existierenden Pilotprojekten soll 2025 eine Entscheidung zum großflächigen Roll-Out von ERS getroffen werden.	5.6. Halten sie diesen Startzeitpunkt (2025) für realistisch? Sollte dies nicht der Fall sein, wann erwarten sie den Startzeitpunkt? Falls vorhanden, ziehen sie gerne Vergleiche zu anderen (möglicherweise vergleichbaren) Projekten, mit denen sie in Kontakt gekommen sind.	• Ja, definitiv, eigentlich auch schon 23/24.
Wie können die aktuellen Ausbaupläne eingeschätzt werden?	Pläne zum Ausbau einer Oberleitungsinfrastruktur bestehen bereits über die drei Pilotprojekte FESH, ELISA und eWayBW hinaus. Bis 2025 sollen zudem 300km Pendelstrecke elektrifiziert werden. Folgt danach eine Roll-Out-Phase, könnten nach einer vom Verkehrsministerium in Auftrag gegebenen Studie[26] schon 2030 2000 km Autobahnstrecke elektrifiziert sein.	5.7. Halten sie diese Ausbaugeschwindigkeit für realistisch? 5.8. Für den Fall, dass der deutschlandweite Ausbau von ERS auf ein Kernnetz von knapp 4000km ab 2025 erfolgt: Wann rechnen sie mit einer Fertigstellung des Baus? (Eine Schätzung kann hier genügen)	• Machbar wäre es vermutlich, da der Betrieb bei der Errichtung nicht sonderlich eingeschränkt ist. • Exploration: 2035, aber eigentlich sollte das schnellstens passieren, da die LKWs besser fahren sollten. Daher könnte auch 2030 möglich sein – alternativ könnte BEV-Technologie den Platz von ERS einnehmen.
Welche wirtschaftspolitischen Instrumente könnten zur Unterstützung und Stabilisierung des Markthochlaufs von ERS sinnvollerweise zum Einsatz kommen?	Neben dem Infrastrukturausbau ist für einen erfolgreichen Markthochlauf von ERS auch das Marktumfeld für Speditionen und Hersteller zentral. Ein politischer Rahmenplan, der Planungssicherheit schafft und die Wirtschaftlichkeit des neuen Systems unterstützt, wird daher von vielen Akteuren als zentral erachtet. Im Anbetracht von häufig einstelligen Margen im Speditionsbereich und einem nennenswerten Technologierisiko, das mit der Einführung alternativer Antriebe einhergeht, können gerade Subventionen, wirtschaftliche Förderungen, sowie Abgaben eine Rolle spielen.	5.9. Welche wirtschaftspolitischen Förderungen sind im Rahmen von ELISA für Speditionen zum Einsatz gekommen? 5.10. Betrachten sie diese Instrumente auch für einen deutschlandweiten Ausbau als geeignet? Welche regulatorischen und wirtschaftspolitischen Instrumente könnten aus ihrer Perspektive alternativ zum Einsatz kommen?	• Unklar, da das Fahrzeug zu „normalem" Preis im Vergleich zu Dieselfahrzeugen genutzt werden konnte. • Mögliche politische Instrumente? • Wenn wir von 2025 sprechen, wird die Förderung für die Anschaffung der Fahrzeuge eigentlich schon weg sein. Wenn 2025 die Elektrofahrzeuge nicht günstiger sind, haben wir ein Problem.

[26] Nationale Plattform Zukunft der Mobilität (NPM): Werkstattbericht Antriebswechsel Nutzfahrzeuge -Wege zur Dekarbonisierung schwerer Lkw mit Fokus der Elektrifizierung. Dezember 2020, S.15. Abrufbar unter: https://www.plattform-zukunft-mobilitaet.de/wp-content/uploads/2020/12/NPM_AG1_Werkstattbericht_Nfz.pdf.

			• Die OEMs brauchen aber klare Ansagen, um die Preise aus zu senken. D.h. die Degression der Förderung muss klar deklariert sein. Frühzeitig muss planerisch klar sein, wie die Förderplanung funktioniert.
Was sind die ausschlaggebenden Faktoren für die „Stimmung“ bzw. die Akzeptanz gegenüber ERS innerhalb der Speditionsbranche?	Untersuchungen zur speditionsseitigen Akzeptanz von ERS haben ergeben, dass ein überwiegend neutrales bis negatives Meinungsbild in der Branche vorherrscht.	5.11. Aus ihrer Perspektive als Speditionsvertreterin: Welche Gründe können sie für das nüchterne Meinungsbild innerhalb der Branche identifizieren? Welche Punkte sind aus ihrer Sicht die relevantesten?	• Mangelndes Wissen ist ein großes Problem. Weil: „Elektrifizierung auf der Autobahn ist doch nicht nötig, gibt doch die Bahn“ – aber LKW doch sehr flexibel und Bahn an Kapazitätsgrenzen. Laden während der Fahrzeit ein großer Vorteil. Aber E-Fahrzeuge in der Nutzung bisher nur eher theoretisches Problem, da wenig Fahrzeuge. • Vorteil hier: Das Unternehmen macht Projekte, die sinnvoll erscheinen und auf die Zukunft ausgerichtet sind. Nicht wissen und nicht kennen ist ein Problem. Frage ist besonders, wie schaffen „wir es unsere Subunternehmer“ mitzunehmen? Anschaffungskosten müssen sinken, um klar zu machen, dass das passiert. „Viele träumen noch vom Diesel“ aber eigentlich ist es viel angenehmer (aus der Erfahrung) mit den E-LKW zu fahren. • Skepsis bzgl. deutschem Einzelweg? Nein, es muss ein europäisches Projekt sein, GB geht stark voran, aber die anderen EU-Länder müssen auch dabei sein.

Abschnitt 3: Das Akteursmodell

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**

Wie fügen sich die ERS-Nutzer (Speditionen) in das Bild des Akteursmodells zur Gewährleistung eines reibungslosen, operativen Betriebs der ERS-Infrastruktur ein?	Die ERS-Nutzer würden nach dem Akteursmodell nur mit dem Mobilitätsanbieter (mit Abrechnungsdienstleister) in Kontakt kommen. Dieser würde weitere Verträge und Zahlungsströme mit dem Stromlieferanten und dem Mautsystembetreiber nach dem Single-Point-of-Contact-Prinzip, ähnlich zu aktuellen All-in-one Tankkartenkonzepten abwickeln.	6.1. Entspricht dieses Konzept ihren Vorstellungen als Spedition? 6.2. Welche Herausforderungen sehen sie hinsichtlich der Nutzung und im Betrieb der Oberleitungsinfrastruktur im Kontext der Autobahn? 6.3. Welche Herausforderungen sehen Sie im Hinblick auf etwaige Sicherheitsaspekte bei der Nutzung von ERS?	• Entscheidend ist das Gesamtpaket der Kosten. Mautreduktion für Zero-Emissions am geeignetsten. Transparenz muss vorhanden sein. Eine Wahl zwischen den Lieferanten wäre schön, aber Kosten sollten nicht deutlich steigen. Landung des Rettungshubschraubers muss gewährleistet sein. Sonst keine nennenswerten Probleme gesehen: Abschaltung der Leitung im Falle eines Unfalls ist gutes Tool.
Welche Herausforderungen und Ansprüche stellen Sie an die ERS-Infrastruktur?	Es ist zu erwarten, dass Nutzer der ERS-Infrastruktur bestimmte Aspekte bei der Nutzung priorisieren oder andere ggf. als weniger wichtig berücksichtigen.	6.4. Welche sind für sie zwingende Bedingungen, um die ERS-Infrastruktur attraktiv für eine Nutzung zu machen? Wären sie bspw. auch bereit, den Fahrstrom zu zahlen? 6.5. Im aktuellen Konzept ist ein Single-Point-of-Contact vorgesehen. Wie wichtig ist dies für Sie? Wäre bspw. auch die Trennung von Maut- und Fahrstromabrechnung vorstellbar? 6.6. Wäre es für Sie wünschenswert, zwischen verschiedenen Fahrstromanbietern auswählen zu können, oder würden Sie ein reguliertes System mit einem einzelnen (staatlichen) Betreiber bevorzugen?	• Das „bisschen Strom“ macht es nicht aus, das wichtige ist, wie man die Transporter „sauber“ bekommt und wie die Kunden da agieren. Diese müssen das einpreisen. Variable Kosten sind selbstverständlich. • Technik muss funktionieren, momentan häufige Inspektionen, aber das ist in Ordnung bis jetzt. • Single-Point of Contact ist gut (s.o.). • Solange Transparenz besteht, ist staatliche Kontrolle okay. Speziell hinsichtlich der Kosten sollte hier genauer aufgepasst werden.

Interview 5: Kisters AG

Interview mit Herrn Markus Rahe, Solution Area Manager bei der Kisters AG am 20.04.2021

Abschnitt 1: Ansprache und Personifizierung der Befragten / allgemeiner Einstieg zur Einstellung der Befragten zum Thema (offener Teil)

Forschungsfrage		Aufbau	
	Einführung/Ansprache	Frage	Antwort
Einleitung	• Vorstellung des Interviewers • Verwendung der Ergebnisse (Wir würden gerne aufzeichnen) • Themenvorstellung • Ablauf		
Welcher Branche/welchem Forschungsprojekt gehören Befragte an? In welcher Branche/welchem Forschungsprojekt sind Befragte tätig?	Vorstellung des Interviewten	1.6 Könnten Sie sich zu Beginn des Interviews bitte kurz vorstellen? Besonders interessant ist für uns, inwiefern Sie sich im Job mit Abrechnungssystemen in der Energiewirtschaft und ggf. dem Mautsystembetrieb beschäftigen. Außerdem würde uns interessieren welchen Zusammenhang zu elektrischen Straßensystemen und Mautsystem sie sehen?	• Markus Rahe, 17 Jahre bei Kisters, Solution Area Manager Sales, Alle Schnittstellen außer Leittechnik • Abrechnung E-Wirt: Wir beschäftigen uns mit allem vor der Abrechnung, d.h. Berechnungen der Datensätze, Vorbereiten der Abrechnung, ggf. auch Übergabe an den Kunden • E-Mobilität: Abrechnung perspektivisch interessant.
Wie stehen die Befragten zu ERS?	Zur Umsetzung der Mobilitätswende gibt es verschiedene Ansätze. Neben ERS gibt es noch weitere denkbare Technologien zur Dekarbonisierung des Schwerverkehrs.	1.7 Halten Sie die Einführung elektrischer Straßensysteme für ein relevantes Thema zur Umsetzung der Mobilitätswende? 1.8 Welche Relevanz sehen Sie im Vergleich zu Wasserstoff-LKW oder reinen BEV?	• Einführung e-Mob generell sinnvoll, auch ERS haben da ihren Platz, aber Akzeptanzproblem gegeben, interessant, hängt aber ggf. an der Sichtbarkeit und dem Widerstand der Bevölkerung. • Stromschiene realistischer? Nicht detailliert beschäftigt, aber alles was sichtbar ist, bleibt schwierig. • Relevanz: - H2-Technologie wird von Interviewtem als die Zukunft erachtet. Ggf. kostengünstiger zu betreiben. BEV vermutlich Schwierigkeiten beim LKW-betrieb.

Abschnitt 2: Der Markthochlauf von ERS

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**
Welche übergeordneten Herausfor-derungen sind mit dem Markthochlauf elektrischer Straßensysteme verbunden und wie können diese angegangen werden?	Die Einführung elektrischer Straßensysteme ist eine komplexe Aufgabe, die sowohl von regulatorischer als auch wirtschaftlicher Seite Herausforderungen mit sich bringt.	2.1 Welche Aspekte politischer, wirtschaftlicher oder regulatorischer Natur halten sie für zentral, um eine zeitnahe Einführung elektrischer Straßensysteme zu ermöglichen?	• Rechtliche Grundlagen zuerst aus politischer Perspektive. Wirtschaftlichkeit zu Anfang schwierig, speziell für Speditionen à Förderungen. Nutzen aufgrund der geringen Streckenverfügbarkeit anfangs beschränkt. Deregulierung muss (in späterem Stadium) sein, ähnlich zu E-Wirtschaft
	Neben existierenden Pilotprojekten soll 2025 eine Entscheidung zum großflächigen Roll-Out von ERS getroffen werden.	2.2 Halten sie diesen Startzeitpunkt (2025) für realistisch? Sollte dies nicht der Fall sein, wann erwarten sie den Startzeitpunkt? Falls vorhanden, ziehen sie gerne Vergleiche zu anderen (möglicherweise vergleichbaren) Projekten, mit denen sie in Kontakt gekommen sind.	• Ausbau Ladeinfrastruktur und SM zeigt zeitliche Probleme, prinzipiell möglich, aber es müssen klare Vorgaben und Gelder dafür kommen. Wenn man will, ist es realisierbar
Wie können die aktuellen Ausbaupläne eingeschätzt werden und wo verortet sich Kisters in diesem Kontext?	Pläne zum Ausbau einer Oberleitungsinfrastruktur bestehen bereits über die drei Pilotprojekte FESH, ELISA und eWayBW hinaus. Bis 2025 sollen zudem 300km Pendelstrecke elektrifiziert werden. Folgt danach eine Roll-Out-Phase, könnten nach einer vom Verkehrsministerium in Auftrag gegebenen Studie[27] schon 2030 2000 km Autobahnstrecke elektrifiziert sein.	2.3 Halten sie diese Ausbaugeschwindigkeit für realistisch? (Eine Schätzung genügt hier als Antwort) 2.4 Welche potenziellen Probleme (z.B. im energiewirtschaftlichen Bereich) können beim Markthochlauf von ERS als bremsende Faktoren erwartet werden? Welche Verzögerungen sind in diesem Zusammenhang erwartbar?	• Nicht einschätzbar, Bauchgefühl: das kann passen, wenn der politische Wille und entsprechende Gelder da sind. Bahn kann in ähnlichen Dimensionen bauen, daher vergleichbar.

[27] Nationale Plattform Zukunft der Mobilität (NPM): Werkstattbericht Antriebswechsel Nutzfahrzeuge -Wege zur Dekarbonisierung schwerer Lkw mit Fokus der Elektrifizierung. Dezember 2020, S.15. Abrufbar unter: https://www.plattform-zukunft-mobilitaet.de/wp-content/uploads/2020/12/NPM_AG1_Werkstattbericht_Nfz.pdf.

		2.5 Angenommen, ERS werden großflächig eingeführt: Sieht die Kisters AG darin einen potenziellen Betätigungsbereich? Bestehen schon konkrete Pläne zur Betätigung im Bereich ERS? 2.6 Welche Herausforderungen und potenziellen Problematiken ergeben sich damit für die Kisters AG? Welche Lösungsansätze werden ggf. verfolgt? 2.7 Welche Herausforderungen sehen sie im weiteren Ausbau erneuerbarer Energien? 2.7.1 Rückfrage: Smart Energy Lösung – Auto-Speicher inkl. Flexibilität; realistisch, dass das kommt und wann?	• Schwer einzuschätzen, aber primär rechtliche Aspekte sowie Widerstand aus der Bevölkerung als Bremsfaktoren erwartet, Vergleich zu Nord-Süd-Trasse und wie das Projekt mit privaten Klagen überzogen wird • Konkrete Pläne nicht, aber: Energiewirtschaftliche Daten sind Kernthema: Zähler, Leitungssteuerung, Datenabruf/-leitung/ etc. Aktuell keine Vorbereitung, typischerweise 3 Jahre Vorbereitungszeit in der Softwareentwicklung • Leitsysteme können komplette Netze steuern, Fehler müssen detektiert werden,… Einschätzung der Verbraucher eher schwierig. Frage, wie werden die Verbräuche gemessen?... Hardwareverfügbarkeit und Betreibermodell müssen vorher vorliegen. • Netzstabilisierung ist ein Thema der Kisters, speziell das hier eine Herausforderung bei den Prognosen, Wind, Verschattung (Wolken), Einsatz von Biomasse, etc. Ausbau entsprechender Speicher ist notwendig. • Ja, sehr wichtig und für diesen Fall bereits Software vorbereitet, aktuell in der Schweiz im Test, da in Deutschland Verträge ungünstig. Kisters steuert dort die Ladevorgänge von außen. In Deutschland kann dies noch länger dauern, da Rechtslage schwieriger.

Wie wird die weitere Entwicklung des Strommix in Deutschland eingeschätzt?	– Neben dem Infrastrukturausbau spielt für die Emissionsbilanz von ERS-Lkw auch der Emissionsfaktor des Strommix eine Rolle. Dieser befindet sich seit 2014 in Deutschland in einem fallenden Trend, der sich in den letzten Jahren noch beschleunigt hat.[28] Im ersten Halbjahr 2020 wurde ein Rekordwert von 55,8% erneuerbaren Energien am Strommix erreicht.[29]	2.8 Wie schätzen sie die weitere Entwicklung des Strommix in Deutschland bis 2030 und perspektivisch bis 2050 ein? 2.9 Kann der fallende Trend der letzten Jahre beibehalten werden?	• 55,8% vermutlich wieder, 2050 sehr sicher >80%, fallender Trend weiter realistisch • Ja

Abschnitt 3: Das Akteursmodell

Forschungsfrage		Aufbau	
	Einführung/Ansprache	**Frage**	**Antwort**
Wie fügt sich die Kisters AG in das Bild des Akteursmodells zur Gewährleistung eines reibungslosen, operativen Betriebs der ERS-Infrastruktur ein?	Das vorgeschlagene Akteursmodell setzt darauf, dass der Betrieb des ERS ähnlich zu Stromnetzen durch einen ERS-Betreiber (hier die Autobahn GmbH) durchgeführt wird. Verschiedene Mobilitätsanbieter bieten den ERS-Nutzern dann auf den ERS-Strecken verschiedene Stromtarife an, unter welchen diese wählen könne. Hierbei bestehen verschiedene Herausforderungen seitens der Erfassung und Abrechnung von Verbrauchs- und Einspeisedaten.	3.1 Welche Herausforderungen sehen sie für die Erfassung der Daten?	• Sicherstellen: Welche Energieverbrauch zu welchem Lieferanten, ohne festen Übergabepunkt schwierig. Daher muss Messung und Datenspeicherung in den Autos erfolgen. Das ist vermutlich die größte Herausforderung; Manipulationssicherheit? Messungen vielleicht Koppeln an die Mautstationen. Ggf. über Streckenpauschalen abrechnen und via Fahren der Kilometer. Zudem: Netzentgelte vereinfachen wäre für Abrechnung vorteilhaft.

[28] Icha, Petra, und G. Kuhs. "Entwicklung der spezifischen Kohlendioxid-Emissionen des deutschen Strommix in den Jahren 1990-2018." S.15. Umweltbundesamt (2019).
[29] Pressemitteilung Fraunhofer ISE: Nettostromerzeugung im 1. Halbjahr 2020: Rekordanteil erneuerbarer Energien von 55,8 Prozent. Abrufbar unter: https://www.ise.fraunhofer.de/de/presse-und-medien/presseinformationen/2020/nettostromerzeugung-im-ersten-halbjahr-2020-rekordanteil-erneuerbarer-energien.html.

	Die Stromeinspeisung in das ERS erfolgt an den Unterwerken, wo sich je ein geeichter Zähler befindet. Zudem soll in jedem Fahrzeug ein Zähler angebracht werden. Die Informationen zum Strombezug (kWh, Ort des Bezugs) sollen via Mobilitätsanbieter an den ERS-Betreiber weitergeleitet und mit dem Strombezug an den Unterwerken abgeglichen werden, wobei der ERS-Betreiber einen Auffang-Bilanzkreis führt und die Verlustenergie bereitstellt.	3.2 Halten Sie das vorgeschlagene Verfahren aus Ihrer Sicht für geeignet um die Stromkosten korrekt den ERS-Nutzern in Rechnung zu stellen? 3.3 Sehen Sie Einrichtung des Auffang-Bilanzkreises beim ERS-Betreiber an der richtigen Stelle? 3.4 Stellt die Datenerfassung und -übermittlung aus Ihrer Sicht eine besondere Herausforderung dar? (Warum ja / nein?)	• Einschränkungen s.o.; Manipulationssicherheit, etc. • Ja, erscheint sinnvoll • Datenerfassung bereits oben (in den Geräten, Übermittlung vermutlich via Mobilfunk). Technische Herausforderung nicht größer als sonst, GSM-Module würden dies erlauben. • 15min daten und noch genauer sind übermittelbar.
	Neben den Strombezug-Bezogenen Kosten, sind ebenfalls Netzentgelte für vorgelagerte Netzebenen zu entrichten. Hierzu soll für jeden Mobilitätsanbieter durch den ERS-Betreiber anhand der bezogenen Energiemenge der jeweilige Anteil ermittelt werden und den Mobilitätsdienstleistern in Rechnung gestellt. Die Netzentgelte soll nach diesem Vorschlag dabei der ERS-Betreiber schulden, die Mobilitätsbetreiber zahlen diese anteilig an den ERS-Betreiber.	3.5 Ist dieses Vorgehen aus Sicht der Kisters grds. umsetzbar, oder wäre ein anderes Verfahren (z.B. Netzentgelte als Teil der Infrastrukturkosten, die über die Maut abgerechnet werden) vorzugswürdig?	• Über kWh abrechnen (leistungsgerecht), in andere Systeme integrieren bringt meistens mehr Aufwand als Nutzen
	Der Mobilitätsdienstleister kann sich im Rahmen des vorgestellten Akteursmodells ebenfalls eines Abrechnungsdienstleister bedienen, welche die Datenübermittlung übernimmt und als Single Point of Contact zum Kunden agiert, sowie auch den Messstellenbetrieb der On-Bord-Units (OBUs) auf den LKW übernimmt.	3.6 Welche Herausforderungen sehen Sie im Rahmen des Messstellenbetriebs? 3.7 Welche Herausforderungen sehen Sie bei der Abrechnung der bezogenen Energie durch den eLkw?	• Keine. Messtellenbetreiber eigenständige Marktrolle in D. Daher müssen nur die Standardschnittstellen genutzt werden und weiterverteilt werden. • Solange Daten ordentlich übermittelt werden, ist das nur noch eine Frage der sauberen Bilanzierung. Abrechnung „nur noch aufschreiben“, das Datenmanagement muss korrekt sein.

		3.8 Welche Datenströme sind aus Sicht der Kisters AG im Akteursmodell notwendig, um eine effiziente Abrechnung zu ermöglichen?	• Daten sollten zu ERS-Betreiber und zum Mobilitätsdienstleister gehen („Messdatenverantwortlicher“), damit die Abrechnungen für alle funktionieren. Bspw. zur Netzentgeltabrechnung und Stromabrechnung.
Welche Rollen sehen Sie, kommen für die für die Kisters AG perspektivisch im Akteursmodell in Frage?	Das Akteursmodell sieht auch andere für den operativen Betrieb von ERS relevante Akteurspositionen vor. Diese umfassen u.a. den Mobilitätsanbieter, Abrechnungsdienstleister und EETS-EEMS-Anbieter.	3.9 Bitte geben Sie eine persönliche Einschätzung, wo Sie Möglichkeiten für die Kisters AG aufgrund ihrer Erfahrung in der Energiewirtschaft sehen.	• Rolle in der Ressourcenbereitstellung, Leitungssteuerung, Auswertung und Abholung der Daten, Messstellenbetreiberlösung. Netzentgeltberechnungen möglich, Kisters kann sich vorstellen einen entsprechend großen Teil der „Lieferkette“ zu übernehmen. Aussteuerung und Detaillösungen im technischen sind deutlich komplexer als ökonomische Aufgaben, da bspw. Lastprognosen und Spitzen.

Interview 6: Spedition Hans Adam Schanz GmbH & Co. KG

Interview mit Christine Hemmel von der Hans Adam Schanz GmbH & Co. KG am 28.04.2021

Abschnitt 1: Ansprache und Personifizierung der Befragten / allgemeiner Einstieg zur generellen Einstellung der Befragten zum Thema (offener Teil)

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**
Einleitung	• Vorstellung des Interviewers • Verwendung der Ergebnisse (Wir würden gerne aufzeichnen) • Themenvorstellung • Ablauf		
Welcher Branche/welchem Forschungsprojekt gehören Befragte an? In welcher Branche/welchem Forschungsprojekt sind Befragte tätig?	• Vorstellung des Interviewten	1.1 Könnten Sie sich zu Beginn des Interviews bitte kurz vorstellen? Besonders interessant ist für uns, inwiefern Sie in das ERS-Pilotprojekt ELISA eingebunden waren und welche zentralen Herausforderungen sie im weiteren Ausbau von ERS sehen.	• Christine Hemmel, seit 2015 mit Schwester Geschäftsführerin der Spedition Schanz, gegründet von Uropa • Hauptsitz bei Darmstadt, 75 MA, 35 Fahrer, größtenteils „Sonderausstattung" Nationaler Fern und Nahverkehr, Großkunde DAB
Wie stehen die Befragten zu ERS?	Zur Umsetzung der Mobilitätswende gibt es verschiedene Ansätze. Neben ERS gibt es noch weitere denkbare Technologien zur Dekarbonisierung des Schwerverkehrs.	1.2 Halten Sie die Einführung elektrischer Straßensysteme für ein relevantes Thema zur Umsetzung der Mobilitätswende?	• Relevanz: Ja, auf jeden Fall, Teil der sichtbar ist, getestet wird und funktioniert. Speziell als Transportunternehmen noch nicht gewagt zu investieren, da nicht am Markt verfügbar. Oberleitung eine Chance, nicht die einzige. • Welche weiteren Antriebe? - Gas getestet; aktuell wartend auf H2, bei BEV alleine Reichweite nicht ausreichend; Hybrid besser aktuell. Umstieg auf Gas?

			- Projekt zur Reduktion der Dieselkosten, allerdings keine deutliche Minderung - Keine CO_2-Hintergründe

Abschnitt 2: Der Markthochlauf von ERS

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antwort**
Welche übergeordneten Herausforderungen sind mit dem Markthochlauf elektrischer Straßensysteme verbunden und wie können diese angegangen werden?	Die Einführung elektrischer Straßensysteme ist eine komplexe Aufgabe, die sowohl von regulatorischer als auch wirtschaftlicher Seite Herausforderungen mit sich bringt.	2.1. Welche Aspekte politischer, wirtschaftlicher oder regulatorischer Natur halten sie für zentral, um eine zeitnahe Einführung elektrischer Straßensysteme zu ermöglichen?	• Staat muss eine klare Richtung vorgeben: Wohin soll gegangen werden. Hin- und her ist gerade ungünstig. Unklar, in welche Technologie zu investieren und was ausgebaut werden soll. • Planungssicherheit und Förderung muss notwendig sein (Diesel LKW 80k) Hier ist die Frage, ob die Zusatzkosten gefördert werden.
	Neben existierenden Pilotprojekten soll 2025 eine Entscheidung zum großflächigen Roll-Out von ERS getroffen werden.	2.2. Halten sie diesen Startzeitpunkt (2025) für realistisch? Sollte dies nicht der Fall sein, wann erwarten sie den Startzeitpunkt? Falls vorhanden, ziehen sie gerne Vergleiche zu anderen (möglicherweise vergleichbaren) Projekten, mit denen sie in Kontakt gekommen sind.	• BG: Wie viele km / Strecken / wären für Sie notwendig? Ausbauplanung realistisch ab 2025; Bau der Oberleitung ist schnell, Abhängigkeit besonders von den Zulassungsverfahren und politischem Willen.
Wie können die aktuellen Ausbaupläne eingeschätzt werden?	Pläne zum Ausbau einer Oberleitungsinfrastruktur bestehen bereits über die drei Pilotprojekte FESH, ELISA und eWayBW hinaus. Bis 2025 sollen zudem 300km Pendelstrecke elektrifiziert werden. Folgt danach eine Roll-Out-Phase, könnten nach einer vom Verkehrsministerium in Auftrag gegebenen Studie[30] schon 2030 2000 km Autobahnstrecke	2.3. Halten sie diese Ausbaugeschwindigkeit für realistisch? 2.4. Für den Fall, dass der deutschlandweite Ausbau von ERS auf ein Kernnetz von knapp 4000km ab 2025 erfolgt: Wann rechnen sie mit einer Fertigstellung des	• Kommt drauf an (siehe 2.2), aber vermutlich machbar. • 2035, wenn die Geschwindigkeit beibehalten werden kann.

[30] Nationale Plattform Zukunft der Mobilität (NPM): Werkstattbericht Antriebswechsel Nutzfahrzeuge -Wege zur Dekarbonisierung schwerer Lkw mit Fokus der Elektrifizierung. Dezember 2020, S.15. Abrufbar unter: https://www.plattform-zukunft-mobilitaet.de/wp-content/uploads/2020/12/NPM_AG1_Werkstattbericht_Nfz.pdf.

	elektrifiziert sein.	Baus? (Eine Schätzung kann hier genügen)	• Logistische Relevanz für Spedition: Fahrzeuge sind fahrergebunden, Shuttleverkehr, teilweise Begegnungsverkehr in Nürnberg, andere fahren eher ins Rheinland. Welcher Fahrer, welches Fahrzeug → Prinzipiell vor allem klassische Autobahnnetze. Hybrid wird ggf. bestehen.
Welche wirtschaftspolitischen Instrumente könnten zur Unterstützung und Stabilisierung des Markthochlaufs von ERS sinnvollerweise zum Einsatz kommen?	Neben dem Infrastrukturausbau ist für einen erfolgreichen Markthochlauf von ERS auch das Marktumfeld für Speditionen und Hersteller zentral. Ein politischer Rahmenplan, der Planungssicherheit schafft und die Wirtschaftlichkeit des neuen Systems unterstützt, wird daher von vielen Akteuren als zentral erachtet. Im Anbetracht von häufig einstelligen Margen im Speditionsbereich und einem nennenswerten Technologierisiko, das mit der Einführung alternativer Antriebe einhergeht, können gerade Subventionen, wirtschaftliche Förderungen, sowie Abgaben eine Rolle spielen.	2.5. Welche wirtschaftspolitischen Förderungen sind im Rahmen von ELISA für Speditionen zum Einsatz gekommen? 2.6. Betrachten sie diese Instrumente auch für einen deutschlandweiten Ausbau als geeignet? Welche regulatorischen und wirtschaftspolitischen Instrumente könnten aus ihrer Perspektive alternativ zum Einsatz kommen?	• Fahrzeug ist maut- und stromkostenbefreit. Aktuell: O-LKW ist geleast, daher Komplettpaket. Langfristig: hängt davon ab, wie die Abrechnung erfolgt, aktuell rechnet sich der O-LKW, aber nur, da Pilot und nicht real. • Möglicherweise Vorgaben von Kunden zum CO_2-neutralen Transport, oder gesetzliche Vorgabe zum Anteil CO_2-neutralen Transportes; Ohne Förderung keine Integration der Technologien möglich
Was sind die ausschlaggebenden Faktoren für die „Stimmung“ bzw. die Akzeptanz gegenüber ERS innerhalb der Speditionsbranche?	Untersuchungen zur speditionsseitigen Akzeptanz von ERS haben ergeben, dass ein überwiegend neutrales bis negatives Meinungsbild in der Branche vorherrscht.	2.7. Aus ihrer Perspektive als Speditionsvertreterin: Welche Gründe können sie für das nüchterne Meinungsbild innerhalb der Branche identifizieren? Welche Punkte sind aus ihrer Sicht die relevantesten? 2.7.1. Fynn: Nur wirtschaftliche und sicherheitstechnische Aspekte diskutiert, oder	• Eindruck bestätigt; Akzeptanz eher niedrig bei den Kollegen. • Reaktionen/Vorstellungen anderer Speditionen: dass 3-4km mit Oberleitungen ausgestattet werden ist komisch. Häufige Fotographie des Fahrzeugs, Diskussion bzgl. Sicherheit, Hubschrauberlandung, … • Aufklärung der Bevölkerung muss sein, Vorteile darstellen, dass es verstanden wird.

		auch Einsatzfähigkeit in Europa und international? 2.7.2. Fynn: Was sind hauptsächliche Gründe dagegen? Finanzierung?	• Andere Unternehmer viel International unterwegs. Das System wird aber nicht nur deutsch gedacht, andere Länder arbeiten auch daran. Zudem hat Spedition Schanz keine Einschränkung durch die Technologie erfahren – durch Laden unter der Oberleitung kann „jederzeit“ bei voller Nutzlast gefahren werden. BEV, die 10h Laden müssen, sind keine Option, wegen Nachtverkehr. • Eigentlich keine Gründe, manchmal Finanzierung der Infrastruktur. Aber in Realität: O-Lkw Effizienter als THG-arme Konkurrenz.

Abschnitt 3: Das Akteursmodell

Forschungsfrage		**Aufbau**	
	Einführung/Ansprache	**Frage**	**Antworten**
Wie fügen sich die ERS-Nutzer (Speditionen) in das Bild des Akteursmodells zur Gewährleistung eines reibungslosen, operativen Betriebs der ERS-Infrastruktur ein?	Die ERS-Nutzer würden nach dem Akteursmodell nur mit dem Mobilitätsanbieter (mit Abrechnungsdienstleister) in Kontakt kommen. Dieser würde weitere Verträge und Zahlungsströme mit dem Stromlieferanten und dem Mautsystembetreiber nach dem Single-Point-of-Contact-Prinzip, ähnlich zu aktuellen All-in-one Tankkartenkonzepten abwickeln.	3.1. Entspricht dieses Konzept ihren Vorstellungen als Spedition? 3.2. Welche Herausforderungen sehen sie hinsichtlich der Nutzung und im Betrieb der Oberleitungsinfrastruktur im Kontext der Autobahn? 3.3. Welche Herausforderungen sehen Sie im Hinblick auf etwaige Sicherheitsaspekte bei der Nutzung von ERS?	• Konzept super, je einfacher, desto besser. • Funkenflug bei Kälte kann andere Verkehrsteilnehmer erschrecken, Abrechnungssystem sollte so einfach wie möglich sein, Wahl des Stromlieferanten zur Bestpreisfindung vorteil-haft • Nicht alle Strecken schnell anfahrbar durch Rettungskräfte, sollte bei Planung berücksichtigt werden.
Welche Herausforderungen und Ansprüche stellen Sie an die ERS-Infrastruktur?	Es ist zu erwarten, dass Nutzer der ERS-Infrastruktur bestimmte Aspekte bei der Nutzung priorisieren oder andere ggf. als weniger wichtig berücksichtigen.	3.4. Welche sind für sie zwingende Bedingungen, um die ERS-Infrastruktur attraktiv für eine Nutzung zu machen? Wären sie bspw. auch bereit, den Fahrstrom zu zahlen?	• Ja, Fahrstrom wird natürlich zu zahlen sein. Zuverlässiger Betrieb zwingend nötig, d.h. „2 Wochen Wartung und kein Strom“ ist ggf. schwierig. Wirtschaftlichkeit muss unter allen Umständen aber gegeben sein.

		3.5. Im aktuellen Konzept ist ein Single-Point-of-Contact vorgesehen. Wie wichtig ist dies für Sie? Wäre bspw. auch die Trennung von Maut- und Fahrstromabrechnung vorstellbar? 3.6. Wäre es für Sie wünschenswert, zwischen verschiedenen Fahrstromanbietern auswählen zu können, oder würden Sie ein reguliertes System mit einem einzelnen (staatlichen) Betreiber bevorzugen?	• Antworten auf 3.5/3.6: s.o.