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Feasibility Study of Swedish-German Corridor with Electric Road System

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Abstract
This study examines a potential international corridor with Electric Road Systems (ERS) from Sweden via Denmark to Germany in the form of a case study. ERS use conductive or inductive technologies to enable energy transfer to electric vehicles while driving. The study aims to illustrate the challenges of a transnational ERS and to discuss potential implementation strategies. For this purpose, we first define relevant criteria to assess the usefulness of establishing an ERS corridor. Technical, economic, environmental, but also political-strategic criteria play a role here. Based on these criteria, we evaluate the ERS corridor using traffic flow analyses and derive recommendations as to what needs to be considered when designing a Swedish-German ERS corridor.

Research Questions
Electric road systems (ERS) enable power transfer to moving vehicles by means of overhead lines, rails or wireless technology. ERS constitutes a new type of technological system that is a paradigm shift compared to traditional refuelling at fuel filling stations. ERS offer the possibility to electrify long-distance heavy duty road transport, as well as busses and potentially also passenger cars, without using large batteries. ERS have the potential to reduce fossil fuel dependency, emissions of greenhouse gases, air pollutants and noise in urban environments, while increasing energy efficiency in the transport sector [1]. As a result, ERS are gaining importance in recent discussions about sustainable transport strategies. Although also cars can in principle use ERS, this work only covers heavy duty vehicle electrification by means of ERS.

In Sweden and Germany, in particular, there have been various research and development activities relating to Electric Road Systems (ERS) in recent years. Since 2017, there is a government agreement between the two countries with the aim of intensifying cooperation in ERS research.
Previous research has mainly focused on a better understanding of the individual aspects of ERS (technical system, standardisation, cost estimates, etc.). Now the first field trials are in operation and at least Sweden has developed a roadmap to decide on the implementation of ERS [2]. At the same time, many stakeholders stress the importance of a transnational approach to ERS, as lots of transports are international and generally, there is a strong integration in the European market.

This was the motivation for conducting a feasibility study for an exemplary Swedish-German ERS corridor. An important goal was to illustrate the challenges of a transnational ERS and to discuss potential implementation strategies. The core question for this conference contribution is the effect of a potential ERS corridor from Sweden via Denmark to Germany on electric mileage of heavy-duty trucks and corresponding environmental parameters.
Effects on cost, the acceptance of ERS among vehicle operators and manufacturers as well as the potential role a corridor could play in a broader international development of ERS have been analysed in the feasibility study, but are not covered in this contribution.

Methodology

First, we considered various potential corridor routes based on results from a traffic flow projection for year 2050 (see [3]). We chose a route from Hamburg via Lübeck, crossing the Fehmarnbelt between Puttgarden and Rødby and over the Öresund (Figure 1) with a total length of 424 km. Already today, this route is very important (using a ferry link over the Fehmarn Belt). It will become even more important in the future after realisation of the Fixed Fehmarn Belt Link. Then it will offer a purely land-bound and direct motorway and railway connection between the metropolitan areas of Hamburg, Copenhagen, Malmö, Goteborg and Stockholm and thus it will be a meaningful corridor for a possible ERS-connection between Scandinavia and Germany.

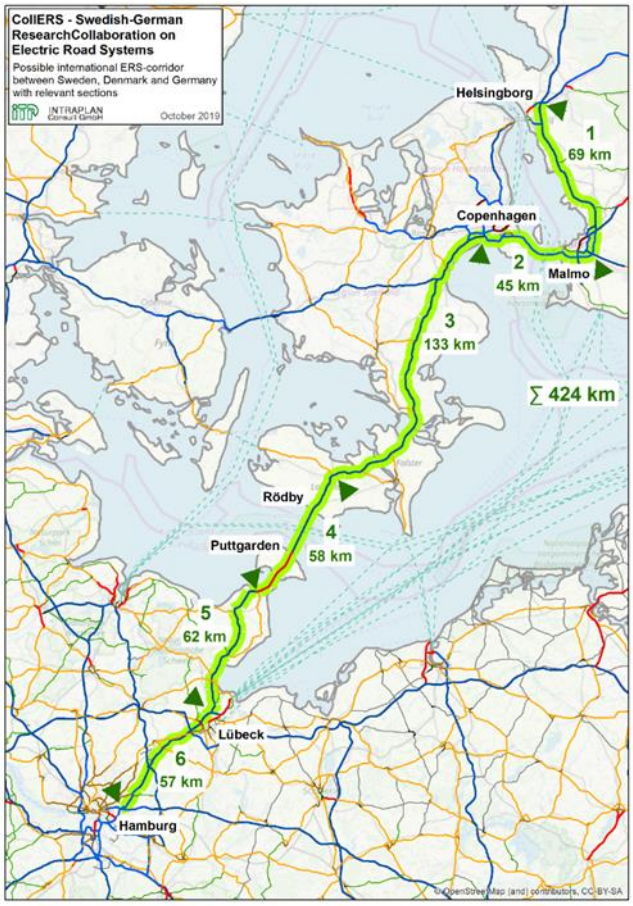

Figure 1: Chosen corridor route for the feasibility study

For this corridor route, aspects that could be relevant for the feasibility of a transnational ERS corridor in an early phase of ERS introduction in Europe are to be discussed. Relevant aspects can be classified into four groups:

- Electrification potential: Which electric mileage can be enabled by the chosen ERS infrastructure on the corridor?
- Environmental aspects: Which effects can be expected on key environmental indicators, most notably CO_2 emissions?
- Economic aspects: Can an ERS corridor pose a business case? Could it contribute to improvement of ERS economy in general?
- Political aspects: Would an ERS corridor implementation make sense from a political point of view?

In this abstract, we focus on the first two of those aspects. In order to answer the questions, we chose an approach based on traffic flow data for each of the six sections of the chosen corridor (see Figure 1). To determine the general suitability of a given traffic flow for operation with ERS vehicles, we considered the share of mileage on the ERS corridor with respect to the total mileage on a given origin-destination pair. If pre- and post-ERS distances were below 250 km, we assumed that the respective origin-destination pair in principle is ERS-suitable. It has to be observed that, for shorter overall trip distances, we can expect an increasing suitability for pure battery electric trucks. Generally speaking, there will be a trade-off between costs for the vehicle-side ERS components and costs for additional battery capacity. Future research needs to further investigate under which conditions regional freight traffic could benefit from lower operating costs by using an existing ERS.The calculations of CO_2 reduction potential are based on [4].

Results

Traffic data shows that a high number (45 %) of current heavy-duty traffic on the corridor would be suitable for electrification through ERS based on the start and stop destinations of transportation routes in this region. Simultaneously, the data also shows that there are some adjoining routes to the corridor with substantial traffic flows, for example north of Helsingborg, road E47 westward in Denmark, and south of Hamburg that could act as national ERS-networks which would amplify the desired effects and outcomes of ERS implementation in the EU.

If the ERS-suitable traffic on the corridor is electrified using hybrid vehicles that will run on electricity while on the ERS, around a third of all CO_2 emitted from heavy transportation on the corridor could be mitigated (Figure 2). This figure includes a well-to-wheel perspective, considering the expected country electricity mixes for year 2030. The mitigation potential is estimated to increase to up to 50 % if the ERS is powered entirely by renewable electricity and national ERS networks are present, increasing the number of ERS-suitable vehicles on the corridor. Apparently, the amount of mitigated CO_2 on the corridor is dependent on the source of electricity in the country supplying the ERS with power, making an ERS-corridor favourable in this region based on a high current share of renewables in the electricity mix in the Scandinavian countries, which is also projected to increase in all three countries in coming years.

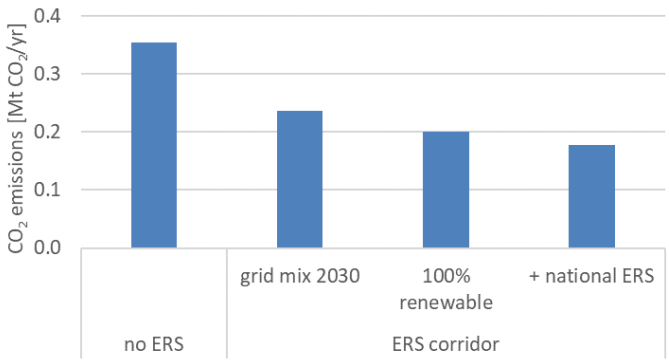

Figure 2: CO_2 emissions on the ERS corridor route (Well-to-wheel)

Currently there are problems with air quality in all three major cities along the corridor (Malmö, Copenhagen and Hamburg), although the traffic on the corridor is only contributing to this in a marginal way. Thus, installing an ERS would not improve the urban air quality along the corridor in a substantial way. However, if the vehicles are designed to also use their electric drive outside the ERS corridor (e.g. if they are equipped with a larger battery), the positive effect on air quality would be considerably higher.

The findings in this case study so far point towards implementing a rollout strategy for the ERS corridor in a series of stages as opposed to electrifying the entire corridor in one go. The proposed rollout strategy will initially focus on the ends of the corridor (Hamburg-Lübeck and Helsingborg-Malmö), which are characterized by shorter stretches that are heavily trafficked and could simultaneously serve as the foundation for the construction of national ERS-networks in both Sweden and Germany. This way, the first stage of ERS corridor will hopefully have a high CO_2-effectiveness along with enabling and strengthening similar national efforts. Peculiarities of the local markets and regulation should be observed, as well as country-specific priorities on decarbonizing road freight transport. Additionally, the identified ERS potential for medium distances will depend on the technical and cost development of battery trucks.
Within this feasibility study, a framework has been established which allows for an assessment and comparison of international ERS corridors in general. It is well-suited to investigate more comprehensive European roll-out strategies for ERS.

Acknowledgments

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