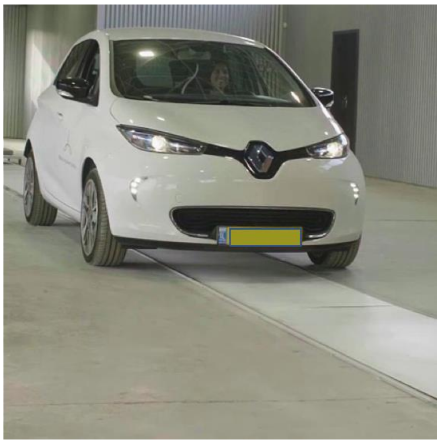
Swedish-German research collaboration
on Electric Road Systems



Real-world experiences of ERS

Best practices from demonstration projects in Sweden and Germany

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  - ifeu – Institut für Energie- und Umweltforschung Heidelberg
  - Fraunhofer IEE – Fraunhofer Institute for Energy Economics and Energy System Technology
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Additional information and resources can be found on the web:
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The pictures on the front page are courtesy of Region Gävleborg, eRoadArlanda, and Electreon, respectively.

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Introduction

Demonstration projects currently underway will test Electric Road Systems (ERS) along public roads and in real-life environments, addressing various legal, political, economic, and efficiency aspects of ERS. Public road tests provide decision makers and investors with a foundation for further investments that would bring ERS to commercial operation. The following table gives a summary of completed, ongoing and planned activities along public roads:

Name	**Location**	**Solution**	**Start of vehicle operation**	**End**
E16 Electric road[1]	E16 in Region Gävleborg, Sweden	Overhead lines	2016	2020
SCAQMD	Los Angeles County, USA	Overhead lines	2017	2017
eRoadArlanda[2]	Stockholm Arlanda Airport, Sweden	Rail	2018	2021
ELISA[3]	A 5, Germany	Overhead lines	2019	2022
FESH[4]	A 1, Germany	Overhead lines	2020	2022
Evolution Road[5]	Lund, Sweden	Rail	2020	2022 (estimated)
Smartroad Gotland[6]	Visby, Sweden	Wireless	2020	2022 (estimated)
eWayBW[7]	B 462, Germany	Overhead lines	2021	2024 (estimated)

At the time of writing, Sweden and Germany together represent the largest collection of real-world experiences in ERS: The Swedish Transport Administration has funded four demonstration projects along public roads in Sweden, and has also initiated planning of a full-scale ERS pilot. Similarly, in Germany there are two ongoing demonstration projects along public roads and the German federal government is funding the construction of one additional demonstration project.

The purpose of this report is to report best practices from

- *demonstrations of ERS technologies along public roads in Sweden, and*
- *procurement and the start of ERS demonstration projects in Germany.*

Readers in need of a state-of-the-art description of ERS, should refer to the CollERS report "Overview of ERS concepts and complementary technologies".

[1] https://www.regiongavleborg.se/regional-utveckling/samhallsplanering-och-infrastruktur/elvag/the-electric-highway-in-english/
[2] https://eroadarlanda.com/
[3] https://ehighway.hessen.de/
[4] https://www.ehighway-sh.de/de/ehighway.html
[5] https://www.evolutionroad.se/
[6] https://www.smartroadgotland.com/
[7] https://ewaybw.de/

Demonstration facilities in Sweden

In Sweden, four different ERS technologies have successfully been deployed for demonstrations along public roads. One demonstration has utilized overhead lines, two demonstrations utilize different kinds of road-based rails, and the fourth demonstration utilizes a wireless technology. All four demonstration projects are partially funded by Trafikverket, the Swedish Transport Administration. The demonstrations can be roughly characterised as follows:

- E16 Electric road: Overhead lines provided by Siemens along 2 km of motorway E16 in the vicinity of Sandviken in Region Gävleborg. Operation commenced in June 2016 and the project ended in April 2020. Three vehicles have been in operation for transportation of goods from various industries to the port of Gävle.

- eRoadArlanda: Conductive rail provided by Elways deployed in a 2 km stretch of the road 893 in the area of Stockholm Arlanda Airport. Operation commenced in April 2018. One electrified 18 tonne truck is in shuttle operation between Arlanda Cargo Terminal and the Rosersberg logistics area.

- Evolution Road: Conductive rails provided by Elonroad are being deployed along a street in the city of Lund in the Skåne Region. Operation commenced in June 2020 and an electrified bus is used as the demonstration vehicle.

- Smartroad Gotland: Coils for wireless power transfer provided by Electreon are being deployed along a route between Visby Airport and the city of Visby on the island of Gotland. An electrified medium-sized truck and an electrified bus will be used as demonstration vehicles. The truck has been tested on part of the route since March 2020 and full-scale operation is scheduled to start during the Autumn of 2020.

There are many similarities and differences between the four technologies. Each individual ERS technology will affect road construction differently. Trafikverket thus deemed it necessary to evaluate several ERS technologies to gain knowledge for a presumptive deployment in the future. Considerable amounts of knowledge and experience have been gained since the start of the demonstration activities in 2015, and it has attracted substantial interest from around the world. Progress of demonstration activities has been reported by Region Gävleborg[8] and eRoadArlanda[9]. The authors have followed all four projects closely[10] [11].

[8] https://www.trafikverket.se/globalassets/dokument/elvagsdokument/reg-gavle_e16_rapport.pdf (public report in Swedish)
[9] https://www.trafikverket.se/globalassets/dokument/elvagsdokument/eroads-arlanda_rapport.pdf (public report in Swedish)
[10] Magnus Lindgren, "Electric road system technologies in Sweden - Gaining experience from research and demo facilities", Proceedings of 8th Transport Research Arena TRA 2020.
[11] Martin G. H. Gustavsson and Magnus Lindgren, "Maturity of power transfer technologies for electric road systems", Proceedings of 8th Transport Research Arena TRA 2020.

Best practices from Sweden

1. The Swedish projects have succeeded with ERS operation and collection of valuable experiences from several technologies

The main purpose of the Swedish demonstration sites is to gain knowledge on how to build, operate, and maintain ERS. A secondary objective is to demonstrate various technologies. An important part of the Swedish government agenda has been *technological neutrality*, i.e. electrified roads are regarded as a concept where electricity is supplied to vehicles whilst the vehicles are in motion, and not regarded as a specific technology.

2. A process for pre-commercial procurement is needed when there are no mature products

The Swedish demonstration sites were procured through a so-called pre-commercial procurement that enables procurement at a time when there is no mature market for the required product or function. When it was launched in 2013, the first procurement of ERS demonstrations was the largest pre-commercial procurement in Europe. This type of procurement was considered suitable for ERS as no individual ERS technology had reached market maturity.

Two different pre-commercial procurements for ERS have been conducted and both have been divided into several phases. In each subsequent phase, the level of detail for the required documentation was increased, and thus the cost and effort increased for the interested consortia.

The first procurement started in 2013 and attracted interest from 11 consortia. In the first phase, the pre-qualification, all but one consortium passed. The pre-qualification phase was followed by an idea phase and required the delivery of a preliminary description. Four consortia passed the idea phase and were asked to deliver a detailed project description. For this phase, the consortia were each given funding of one million Swedish kronor. In the final phase, the assignment to gather knowledge of how to build, operate, and maintain an electric road system was granted to two individual consortia: E16 Electric Road managed by Region Gävleborg and eRoadArlanda managed by Rosersberg Utvecklings AB.

The second pre-commercial procurement was launched in 2018 and followed the same basic procedure except for the pre-qualification phase. In April 2019, two consortia remained and received authorization for the demonstration phase. The selected consortia are Evolution Road managed by Region Skåne and Smartroad Gotland managed by Electreon AB.

3. The suitable locations are limited by the requested delivery of knowledge

Considerations of the location of the ERS demo sites were part of the pre-commercial procurement. Each consortium proposed a location that was evaluated based on the possibility of bringing about answers to the questions specified in the pre-commercial procurement, i.e. the required knowledge. One section of questions is related to winter maintenance and operation. Each consortium needed to consider possible impacts on road users, public living near the demonstration site, authorities (local, regional and national), land use, cultural and natural environment.

4. The approval procedures were simplified and evaluated case-by-case

Necessary approval procedures from concerned authorities, such as environment, electrical safety and vehicles were investigated by each applicant, i.e. each demonstration project, and part of the overall project. The approval procedures for the research and demonstration projects were rather simple because they were limited in both space and time. Regarding the actual demonstration site, no road plan procedure was deemed necessary. Normally, the road plan procedure takes between one and three years to complete.

For all four demonstration projects, approval procedures have been evaluated on a case-by-case basis and often based on communication between concerned stakeholders. This has been a successful approach for research and demonstration projects with limited scope, but not recommended for a large-scale roll-out of electric road systems.

5. Involvement of stakeholders has been a key factor

Electric road system is a new form of infrastructure in the road environment. This will have an effect on the current legal system (approval procedures, road construction, maintenance, etc) and on other systems (rescue operations, environmental impact, landscape, etc). Involvement of stakeholders has been a key factor for each demonstration project. The stakeholders can be arranged into different groups such as approval authorities, direct and indirect partners, emergency services and the public. All of these stakeholder groups could significantly impede the demonstration projects on public roads and in the future, a roll-out of ERS, thus information to and from various stakeholders is highly important. Building electric road system is not the same as building road or rail infrastructure, but it has proven to be feasible with the involvement of stakeholders.

6. Construction along a public road is challenging

The construction of electric road systems, independent of technology, along a public road is more challenging as compared to enclosed test sites. Within an enclosed test site there is normally no interference with other road users and the environment including the roadbed and topography is controlled. It is advantageous, but not necessary, to have multiple lanes during the construction phase along a public road. With good traffic management, it is also possible to implement ERS on single-lane sections with limited disturbance.

7. Operation experiences from successful demonstrations are valuable but more verification is needed

Deployment of a temporary and spatially limited demonstration facility does not mean that it would be equally easy to build a permanent and large-scale field test or national deployment. A temporary facility can be built with manual and time-consuming exemptions. While a large-scale deployment would require a road plan, this was considered unnecessary for the temporary demonstration installations.

The type approval[12] of the hybrid and fully electric trucks equipped with a power receiver have been based on a national procedure, partly inspired by experiences from trolleybuses. Another example is the UNECE regulation 100 (2013) which stipulates that a vehicle that is physically connected to the grid is not allowed to move by the vehicle's own propulsion system. This regulation was not intended for ERS but will have an effect on conductive ERS. A large-scale deployment of ERS-compatible trucks has to be based on prescribed type approval procedures. In the demonstration sites, the trucks are rather unique entities that have been purpose-built. For a large-scale roll out the production capacity needs to be developed.

There are also systems needed in a large-scale deployment that have not been included in the demonstration projects. Three of the more important sub-systems are:

- Access control
- Energy metering and billing
- Autonomous safety systems

None of these sub-systems have yet been demonstration in an operational environment, i.e. along a public road and with vehicles in commercial operation. Safety is handled in the demonstration facilities, but it includes one layer of manual oversight, which is not practical in a large-scale deployment.

Overall, the first two demonstration projects have successfully showed that it is possible to power an electric truck from the road. However, additional verification is needed before any ERS is fully mature.

[12] https://ec.europa.eu/growth/sectors/automotive/technical-harmonisation/faq-auto_en

Field tests in Germany

So far, there have been mostly R&D projects on ERS systems in Germany. Live testing in Germany began on a test track operated by Siemens near Berlin (Groß Dölln), and were observed by a range of scientific studies, i.e. ENUBA and ENUBA 2. Currently, however, three German field tests (in Hessen, Schleswig-Holstein, and Baden-Württemberg) are in various stages of implementation. These are partially funded by the German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety (BMU). The projects can be roughly characterised as follows:

- ELISA (Elektrifizierter, innovativer Schwerverkehr auf Autobahnen): 5 km stretch of motorway A5 in the state of Hessen from exit Langen-Möhrfelden to exit Weiterstadt, i.e. between Frankfurt am Main and Darmstadt. Operation commenced in May 2019. Five vehicles are currently in operation and are utilized by different logistics operators.

- FESH (Feldversuch eHighway Schleswig Holstein): 5 km stretch of motorway A1 in the state of Schleswig-Holstein between Reinfeld and Lübeck. Approval of the overhead line system and delivery of the first truck took place in December 2019. Since January 2020 one truck is in operation.

- eWayBW (eWay Baden-Württemberg): Two parts (3.2 km and 750 m) will be electrified on the national road (Bundesstraße) B462. Construction started in June 2020 and the operation is scheduled to start in the beginning of 2021.

Experience with ERS in Germany is summarised in the following section based on these three field test projects. For this purpose, guided interviews have been held with a key person from each project. From these interviews, the following first conclusions and lessons learned have been identified by the authors.

Best practices from Germany

1. All three German projects are well on the way to start ERS operation and collection valuable experience

Around 10 km of overhead catenary line ERS systems have already been built within three German ERS projects and around 5 km more are being contracted. As of late 2019 one of the projects already started operation. The second project will follow early 2020 and the third will most likely start operation in 2021. Despite considerable challenges associated with the installation of such a new technology without standardised planning procedures, all three German projects are well on their way to start ERS operation along German roads.

All three projects have also implemented a research agenda along with the projects which are likely to collect valuable experience for future operation and roll-out stages. This research covers technical aspects in respect to the vehicle, road infrastructure and energy grid. Furthermore, environmental impacts, public acceptance, political/legislative considerations and appropriate logistics concepts are investigated.

2. The use of established overhead catenary lines currently supports rapid implementation

The ERS concept with overhead catenary lines used in all three projects has several qualities for field test projects, which have been beneficial in this early installation of ERS field trials. Since this system does not interfere with the road pavement itself, concerns of road authorities have been low. Furthermore, no full obstruction of the respective highway sections has been necessary. Thirdly, the technology is fairly simple and has been tested at railways for a long time. Technical challenges have thus been rather low, and no entirely new components have had to be developed. This background has enabled fast implementation in the trials. Even though other ERS systems may take more time to be developed, they nevertheless may have other advantages in the long run and should still be observed.

3. The location and surrounding area affect the planning process

The location and surrounding area affect the planning process in at least four different ways: First of all, population density and proximity to settlements has an influence on the general need for involvement of the local citizens and authorities. Concerns of citizens in respect to noise, traffic flow, views or potential environmental burdens can be expected to be higher and have to be taken more seriously in closer proximity to settlements.

Second, the existence of nature conservation areas needs to be taken into account. The test trials have been able to avoid these issues, partially by omitting critical stretches, but for larger ERS these issues need to be considered. This may also affect the potential need for compensating areas.

The third effect refers to the ownership of areas along roads. On motorways, the infrastructure can be built primarily on the area associated with the road — the so-called 5 metre space. On other road types, this has to be clarified in detail.

Finally, the organisational structure and experience of local authorities may affect the planning process, depending on the political support of the respective ERS route.

4. Challenges in the approval procedure

As the overhead line system is a new type of infrastructure component on motorways and national roads, the planning and approval procedures posed particular challenges. On the one hand, this led to a longer planning period than expected. On the other hand, the current implementation procedure cannot be directly transferred to a roll-out of the technology on a larger scale. In all three field test projects, no complete plan approval procedure was carried out. Instead, a preliminary assessment was carried out as part of an environmental impact assessment. As a result, the infrastructure can only be used temporarily. For permanent use, an additional planning approval procedure would have to be carried out.

5. Stakeholder consultation is necessary, but not a showstopper

Some sort of stakeholder consultation has been undertaken in all test trials. This includes the municipalities, grid operations, road authorities, nature conservation departments, the police, fire brigades and military (Explosive Ordnance Disposal). While some challenges in the planning process have been encountered, cooperation was generally experienced as positive. Citizens' concerns have been expressed mainly in respect to traffic hold-ups in the construction process. Also municipalities could be compensated if seriously affected by the ERS route. Concerns of other actors have decreased with the start of operation. Overall, stakeholder consultation is important and should be taken seriously. But stakeholder concerns have also been no showstopper for ERS in the case of the test trials.

6. Currently there is no (real) market and competition for the installation of ERS

A special situation has arisen in the tendering procedures: despite costly EU tenders, one bidder was now successful in all three tenders. In some cases, the bid was only submitted for certain sections of the route, the construction of which was expected to present fewer challenges. The current positive order situation of construction companies in question was cited as a possible reason for a low level of participation in the tendering procedures. Potential bidders would therefore avoid the risk of installing this new technology. A lack of competition could have a negative impact on the economic viability of the system in the event of a roll-out of the technology.

7. Flexibility in the tender description facilitates appropriate and realistic bids

Given that ERS technology does not require 100 % electrification of all roads, the field test projects have shown that certain flexibility in the tendering process could be advantageous at an early stage. This flexibility can, for example, give potential bidders freedom with regard to the selection of the specific route sections to be electrified. This allows potential bidders to assess for themselves how the challenges on site, e.g. by topography or aspects of landscape protection, such as the unique nature of a Flora Fauna Habitat (FFH) area, are to be assessed. This could lower the barrier to bidding and facilitate solutions at lower costs.

8. Challenges of constructing ERS also depend on road type and topography

The field test projects have shown that an important success factor is the selection of sections for installation of overhead contact line infrastructure. Part of this is the type and topography of the route. The fewer narrow curves and hills or depressions there are, the easier it is to implement electrification. On the other hand, it is advantageous to electrify sections with few engineering structures such as bridges and tunnels. However, the field test projects were able to show that this is also possible in principle. Furthermore, there are advantages in the construction phase if multi-lane roads are selected. An essential concern is that construction work along a single-lane road would result in extreme traffic disruptions. These disturbances can be minimized with good management of the construction work and the use of multi-lane roads.

9. Successful start of ERS field tests

While there have been delays in the planning and construction of the infrastructure in two field test projects for different reasons, the practical operation of ERS trucks along a public road has been successfully tested since May 2019. After initial difficulties with the first truck, which led to workshop visits, the trucks now have a high availability. Fuel consumption on the trucks' approximately 60 km-long journeys — of which 5 km are equipped with an overhead line — has been significantly reduced. Furthermore, important practical experience was gained, e.g. with a burning third party vehicle under the overhead line infrastructure.

10. Logistics operators are generally open towards testing ERS

There has been a general interest among several large logistics companies in testing the new technology. In one case a logistics company even initiated the field trial. In another case several companies were interested in participation, but the case could not be selected due to the limited number of vehicles. Therefore, it can be concluded that a sufficient number of logistics operators appear to be open to ERS and willing to get involved in test trials.