ELinGO

Electric Infrastructure for Goods Transport

Realisation and industrialisation

Work package 5

AUTHOR
Runar Søråsen Miles Ahead AS

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Content

Introduction

This chapter reports the findings from ELinGO's work package A5 "Realisation and industrialisation". The purpose of this work package is to identify required next step towards realisation of Electric Road Systems (ERS) and how Norwegian industry can take significant positions in this possible future market. The specific objectives of this work package:

- Identify potential value chains to realise ERS
- Identify possible revenue streams for all actors
- Identify knowledge and technology gaps that need to be closed to realise ERS
- Develop and strengthen triple-helix collaborations
- Plan for pilots and demonstrators bringing ERS closer to industrialisation

Business models and value network

Methodology

This section is based on results from individual workshops with the industry partners in ELinGO. The aim of these workshops was to:

1) Document the industry partners' current business models
2) Explore possible future business models for the industry partners in an ERS scenario[1]
3) Discuss possible future scenarios affecting their business, including new framework conditions (e.g. CO_2 funds), new technologies (e.g. synthetic fuel, hydrogen competitive, automation of road transport, 3d printing, ...), the transition from a product to a service economy
4) Identify barriers and critical framework conditions for realising ERS

The content of the workshops was also aligned with the needs from work package 4 to provided valuable input to task 4.4 (see Langhelle 2017). Due to confidentiality requirements the results from the individual workshops are not reported in this document. To discover and document the individual business models the Business Model Canvas (BMC) was employed. This is also called the Osterwalder model and is based on the doctoral work of the Alexander Osterwalder and is described in Osterwalder and Pigneur (2010). The BMC is show in Figure 1. The purpose of discussing possible future scenarios in the workshops was to motivate the participants to see an expanded opportunity room in an ERS future, and not being limited to the individual company's current business operations.

[1] In this context an ERS scenario means a future where ERS are put into commercial operation on key parts of the public roads network

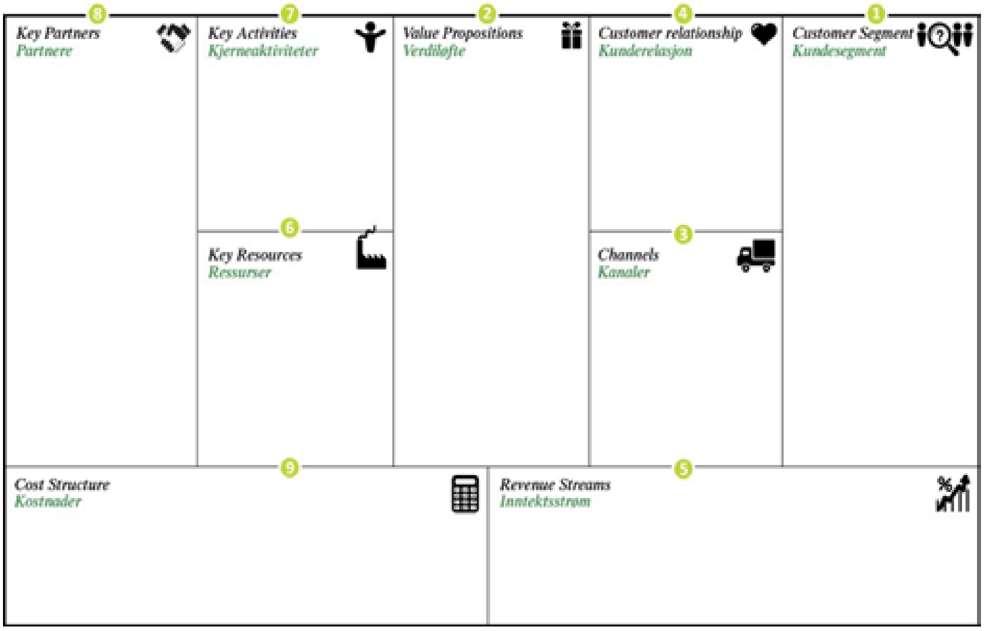

Figure 1: Business Model Canvas (BMC)

During autumn 2016 a total of 5 individual workshops were arranged:

- Infratek
- Lyse
- Volvo
- NHO Logistik og Transport
- Siemens

NHO Logistik og Transport is an association of Norwegian logistics and freight companies, and in this workshop both representatives from the organization's administration and some of its members were present: Posten/Bring, Logi Trans and Tine.

Value network

The collected outcome from the workshops were used to identify the value chains required to deploy and operate ERS. This is illustrated as a value network in Figure 2.

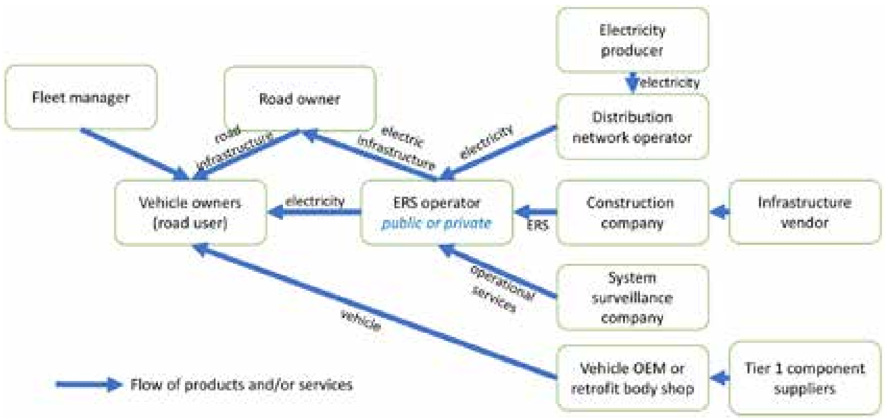

Figure 2: Value network for deployment and operating ERS

Critical framework conditions and key uncertainties

Critical framework conditions and uncertainties for realising ERS was identified in the workshops and are summarized below. This includes both the viewpoints of ERS operators/owners and ERS users:

- **Eco-friendly solutions must be competitive**
  - Vehicle
    - Existing benefits for electric cars must be maintained and extended to larger vehicles
    - CO_2 funds, or other support arrangements/incentives, must be established to compensate for additional costs of buying/operating eco-friendly vehicles
  - Infrastructure
    - Large discrepancies in the estimated investment costs for ERS
    - The CO_2 fund as currently planned will only support procurement of new vehicles, not building of infrastructure. Infrastructure might be supported by ENOVA
    - Existing electricity distribution regime with fees on peak power and compulsory investment contributions to strengthen electricity grid can potentially make investments in infrastructure very expensive – one proposal is to replace these mechanisms with specific tariff on electricity used for mobility
    - Deployment of ERS will contribute to strengthen the electrical power transmission backhaul. This provides value beyond the transport sector and will improve resilience of the electricity system and can be a trigger for introducing more renewable electric production in the grid
  - Logistic chains
    - ERS must be part of a seamless transport system where the same vehicles can be used on all routes with minimum demand for reloading
- **The ownership and responsibility for infrastructure must be clear**
  - Clear responsibilities with regard to outages, accidents and similar
  - The operational risks of carriers using the infrastructure should be reduced through compensation schemes during downtime (similar to what exists on railroad freight)
  - No private actors have been identified as infrastructure owners (except for smaller turn-key installations). Public-private partnerships may be viable where transporters, constructors and road owners establish a consortium
- **Payment solutions must be flexible and fair. Might be based on yearly subscription + use (km + kWh)**
- **The solutions must be available and proven in real-life before large scale deployment.**
  This requires establishment of demonstrators and pilots.
- **Stable and predictable regulatory schemes are a prerequisite for investments (for both infrastructure and vehicle owners)**

Value and revenue potential for ERS

Due to the large discrepancies in estimates regarding costs of deploying and operating ERS it is very difficult to provide a quantitative assessment of the revenue streams. The most up-to-date estimates are summarised in chapter X (results from work package A4). In the operational phase the revenue can be compared to current revenue from fuel. In Norway this amounts to 65 mill NOK yearly[2] In addition, comes road user charging generating a revenue[3] of more than 10 mill NOK. This illustrate that there is a large revenue potential when converting the transport system towards an ERS scenario. With reference to the value network in Figure 2 the vehicle owner in an ERS scenario pays for both electricity and access to road infrastructure. In the long term, when and if volume production is established, it is expected that the cost of electric vehicles adapted to ERS will cost less than both vehicles based on internal combustion engines and pure battery electric vehicles. This is both due to the cost savings expected by replacing complex combustion engines with simpler electric motors,

[2] *Vegkart for næringslivets transporter – med høy mobilitet mot null utslipp i 2050*, Sept 2016
[3] This includes both cars and heavy vehicles

and due to the fact that ERS enables smaller batteries compared to pure battery electric vehicles. This mean that in the future a larger share of the total cost of ownership for vehicles can be moved to the usage phase.

Payment solutions

Real world realisations of ERS will need some kind of payment system, both to pay for road use and energy consumed (electricity). This is extensively covered in Gustavsson et. al. (2015). One possible solution proposed by the vehicle industry (Håkan Sundelin, Scania and Richard Sebastyén, AB Volvo) is shown in Figure 3. In this system a gantry (to the right in the figure) validates the vehicles entering an ERS segment. The validation uses a vehicle ID to activate the segment. The electric road module (ERM) inside the vehicle registers the energy usage. The ERM is coupled to the tachograph[4] (TCO) which uses the fleet management system's (FMS) mobile telecom facilities to report energy usage to the ERS provider.

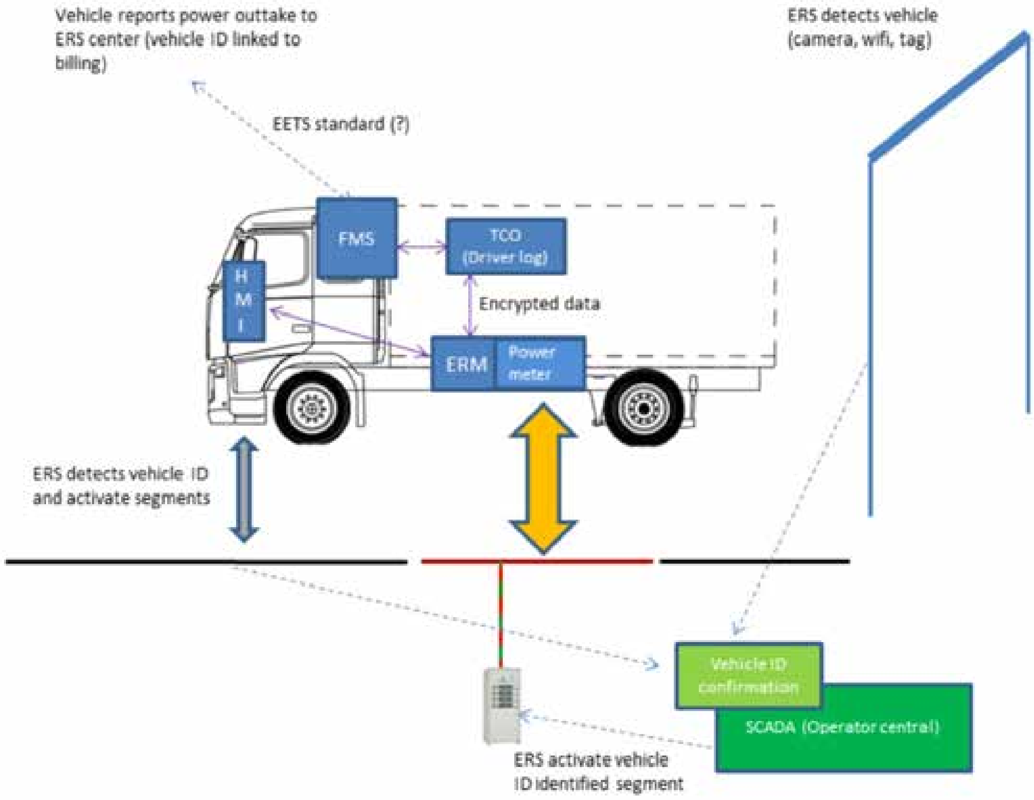

Figure 3: Proposed payment system by OEMs

The system as proposed relies heavily on systems typically only found in heavy vehicles (such as TCO and FMS). This limits duplication of functionality and reduces the system costs. For smaller vehicles such as private cars that system needs to be rolled-out separately. The proposed use of gantries for identification of vehicles entering the ERS segments increases the infrastructure cost. A similar, but less infrastructure requiring approach, is a GNSS based payment solution. Installed and certified on-board units can use available positioning services, such as GPS or Galileo, to implement the same functionality. The platform can detect entry to segments and report this to the infrastructure by legacy cellular mobile services. Gantries at the street may only be required for enforcement purposes and to verify the existence and correct usage of the on-board-units just like in current tolling applications.

4 The tachograph is mandatory in most heavy vehicles and is responsible for automatically recording speed and distance, together with the driver's activity, and is used for enforcing regulations related to speed and rest periods for professional drivers.

For ground based ERS, either conductive or inductive, the length of each segment will probably be much shorter compared to the overhead case, requiring frequent activation and deactivation of segments. In this case the validation and activation should probably be based on short range communication technologies to not overload the cellular network. This can either be ITS-G5 or even technologies with less communication overhead such as CEN DSRC or RFID.

Like for existing tolling systems, any commercial deployment of a payment system for ERS require that proper care is taken with regards to ensuring data privacy and security. Security measures need to both consider data breaches, potential loss of income, and operational disturbances due to hostile interventions.

Roadmap towards realisation and industrialisation of ERS

ERS technologies and technology readiness level

The ERS technologies considered in the ELinGO project can be classified in three groups: (1) Overhead conductive lines, (2) Conductive rails integrated in the road structure, and (3) Contactless power transfer from beneath the road surface. These technologies are at different maturity levels. A common method to describe the maturity of different technologies is to use technology readiness level (TRL). TRL defines maturity on a scale from 1 to 9 with 9 being the most mature technology. The method was introduced by NASA in the 1970-80's and was quickly adapted by the international space development community. The TRL scale has now spread to other communities, but with significant changes to the definition of the different levels. Horizon 2020 (EU's program for research and innovation) uses the following definition[5]:

TRL	Description
1	Basic principles observed
2	Technology concept formulated
3	Experimental proof of concept
4	Technology validated in lab
5	Technology validated in relevant environment
6	Technology demonstrated in relevant environment
7	System prototype demonstration in operational environment
8	System complete and qualified
9	Actual system proven in operational environment

Note that even if TRL can be used to compare maturity of similar (or substitute) technologies care need to be taken when considering systems of sub-systems. The TRL of the complete system will always have a TRL lower or equal to the TRL of the sub-system with the lowest TRL.

The table below compares the TRL of the different ERS technologies at the system level (for the contact-based solutions the TRL is in accordance to the findings in *Technology for dynamic on-road power transfer to electric vehicles*. The table only includes solutions that has been demonstrated at relevant power levels for heavy vehicles. The table also includes a list of identified knowledge and technology gaps that need to be closed to realise large scale deployment of ERS:

[5] See https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2016_2017/annexes/h2020-wp1617-annex-g-trl_en.pdf

	Overhead conductive lines	Conductive rails integrated in road	Contactless power transfer from road (inductive)
Suppliers and solutions	Siemens eHighway	Alstom APS for road, Elways, ElonRoad	Bombardier, KAIST
Current state of development	Demonstrated by Siemens on test-track since 2010. Demonstrated on public road in Sandviken, Sweden from 2016 (2 km, two vehicles) and Carson, California, USA from 2017 (1.5 km, three vehicles)	Alstom: Demonstrated on a test-track in cooperation with Volvo Elways: Open roads planned for 2018 ElonRoad: Demonstrated in laboratory	Bombardier: 800 m track supplying truck in Augsburg, Germany KAIST: least 6 busses which are currently in regular operation
Estimated TRL	6 - Technology demonstrated in relevant environment	ElonRoad: 3 - Experimental proof of concept APS/Elways: 4 - Technology validated in lab	Bombardier: 3 - Experimental proof of concept KAIST: 4/5 - Technology validated in relevant environment but only for busses
Identified gaps and uncertainties	Adverse Nordic costal climate	Adverse Nordic climate and winter maintenance. Activation of segments to ensure safety. Lifetime of rails and pick-up	Adverse Nordic climate and winter maintenance. Optimisation of segment lengths (road-side coils). Electromagnetic emissions within safety limits. Optimisation and choice of frequency. Compatibility with stationary charging solutions. Adaptability to different vehicle sizes

Table 1: Maturity and TRL of different ERS technologies

The TRL in the table above is relevant for the energy transmission systems. Regarding payment solutions no implementation and demonstration activities have been reported (in easily accessible publications). Some concepts have been formulated, thus a TRL of 2 is assumed. The individual sub-systems needed to realise payment solutions, i.e. distance based tolling (using GPS), power metering and communication technologies, all have TRLs close to or equal to 9, so it is expected that envisaged payment solutions can be elevated to a higher TRL quite easily.

In addition to elevating the TRLs of the different technologies, standardisation is of equal importance. Standards are needed to harmonise both interfaces and operational modes to ensure interoperability between components from different suppliers (both at roadside and vehicle side) and to enable a larger market of ERS solutions, facilitating cost savings through enabling volume production.

Project roadmap

Table 1 identified knowledge and technology gaps that need to be closed to realise large scale deployment of ERS, i.e. bringing one or more of the technologies to TRL 9. The basic buildings block has all been (at a minimum) validated in lab conditions but there are still a lot of development needed to industrialise and prove ERS in real life. The conductive technologies are the most mature, while for inductive solutions significant research efforts are needed (as listed in *Technology for dynamic on-road power transfer to electric vehicles)*. To reach commercial deployment of ERS both demonstrator and pilot activities are needed. In this context demonstration and pilot projects are defined as follows:

- Demo project – Projects that shows proof of the technology's feasibility and durability.
- Pilot project – Projects that shows the commercial relevance of the system, i.e. in use by actual end-users. Pilot project is typically of significantly larger scale compared to demo projects.

I.e. demo projects comes before pilot projects. To reduce the risk of both demo and pilot projects they both should both be designed with a gradually increase in scale, based on agreed milestones. The figure bellow outlines the steps needed to elevate ERS towards large scale deployment:

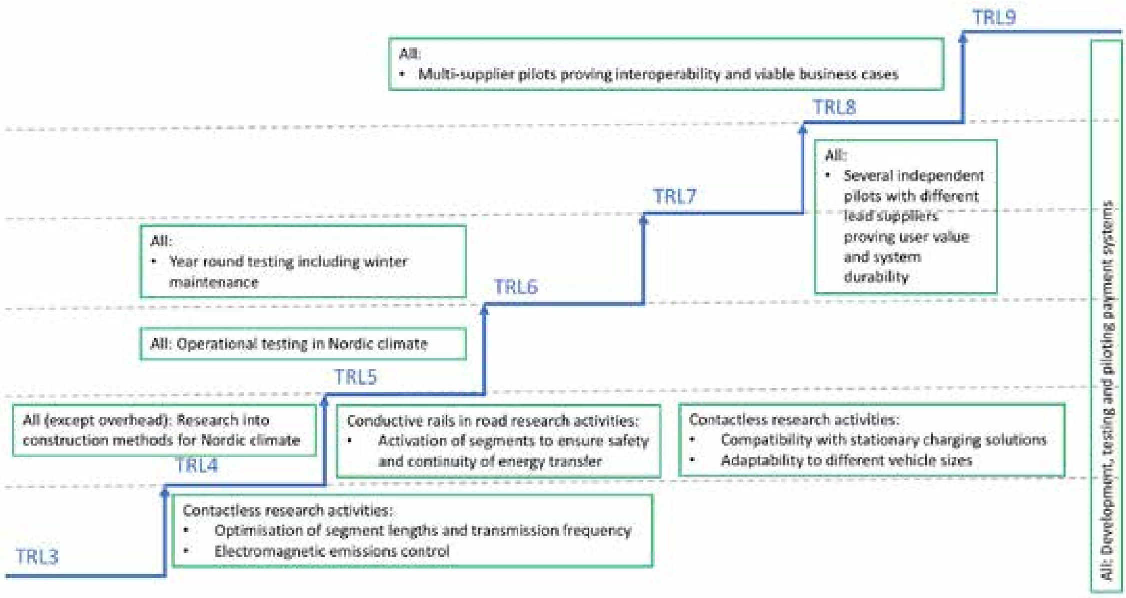

Figure 4: Steps needed to elevate ERS towards large scale deployment

The timeline for reaching the different TRLs are different for the different ERS technologies. The table below provides a best-case estimate of the year where a specific TRL can be achieved for each of the three major technologies[6]:

TRL	Overhead conductive lines	Conductive rails integrated in road	Contactless power transfer from road (inductive)
9	2022	2023	2024
8	2020 (requires piloting in multiple countries)	2021	2022
7	2019 (based on planned pilots in Germany/USA)	2020	2021
6	Completed	2019	2020
5		2018	2019
4		Completed	Completed
3			

Table 2: Estimated year of reaching specific TRL (best-case)

[6] The TRL level in this case is considered independent of standardisation activites, assuming that single-vendor systems can be deployed and proven at sufficient scale.

The table below summarises contemplated follow-up projects that has been discussed within ELinGO or Norwegian Electric Roads Cluster (none of these has been formally decided or initiated):

Type of project	Name	Description	Indicative target start date
R&D (KPN)	CERNoCC	Construction of Electric Roads for Norwegian Climate Conditions	2018
Test bed	Hell Arena ERS	Test and pilot area for new ERS solutions	2020
Pilot (Pilot-E)	Electric heavy vehicles between Vestby and Sande	ERS will be evaluated as one of the options	2021
Demonstrator	Sandmoen/Heggstadmoen/Torgård	ERS between major logistic hubs in Trondheim	2022
Pilot	Port of Oslo – Alnabru (see Sæther, 2017)	ERS between major logistic hubs in Oslo	2022
Pilot	Klemetsrud – Port of Oslo (see Sæther, 2017)	ERS between waste management centre and port of Oslo	
Pilot	EL39	Part of new ferry-free E39	2025
Pilot	Göteborg – Oslo	ERS on highly trafficked road	?

Triple-helix collaboration

One specific objective of ELinGO was to develop and strengthen triple-helix collaborations. In the project it was decided that the most sustainable way to develop such collaborations was through the establishment of an industry and innovation cluster. The main motivations for this decision was:

- ELinGO is a time-bound project and probably not big enough to succeed with industrialization and realization
- Norway needs an innovation arena where technical issues can be identified and where solutions can be developed in collaboration
- There is a need to continue the collaboration established in ELinGO to ensure the realisation of pilot and demo projects
- Establish a platform for nurturing public-private collaboration toward the goal of developing cost-effective solutions for a fossil-free future

Based on this the association *Norwegian Electric Roads Cluster* was established August 2017. Founding members were: Alstom, AtB, FourC, Hell Arena, Infratek, Multiconsult, Norsk Transformator, Siemens, Volvo, SINTEF, TØI, NTNU, University of Stavanger. The scope of this cluster is somewhat wider than the scope of the ELinGO project and includes all technology and means for integrating charging opportunities in road infrastructure. This is also reflected in the goal of the cluster:

> *Norwegian Electric Roads Cluster shall help Norwegian players to take leading positions in the transformation to fossil-free road transport and ensure green competitiveness in a global market.*

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18-0733 visuell.kommunikasjon@vegvesen.no