REPORT

Business and financing models for infrastructure when electrifying heavy duty road transports.

(Affärs- och finansieringsmodeller för infrastruktur vid elektrifiering av tunga vägtransporter)

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Preface

This study was done to create a basis for discussions around new businesses and financial models for the future electrified road system aimed for heavy duty road transports with different stakeholders. It has been a challenging work as the general knowledge about such road systems is quite low, our work has therefore been partly educational. The cost analysis and model has been discussed in a large extend in the group, but the outcome we believe will be helpful for further decisions for new interesting business and financing models for future electric road systems.

Projektengagemang has been responsible for the project. Ann Segerborg-Fick has been project leader and Per Ranch acted as senior advisor.

The work on different models was led by KTH Fredrik Lagergren. Stefan Tongur, KTH/INDEK supported the work.

Göran Lundgren, GL add Wise, who has a long experience from both Vattenfall as senior manager and Arlandabanan as CEO, has been advisor to the project.

The front animation is used by courtesy of Ashley Bruce, www.eqdigital.co.uk

Summary

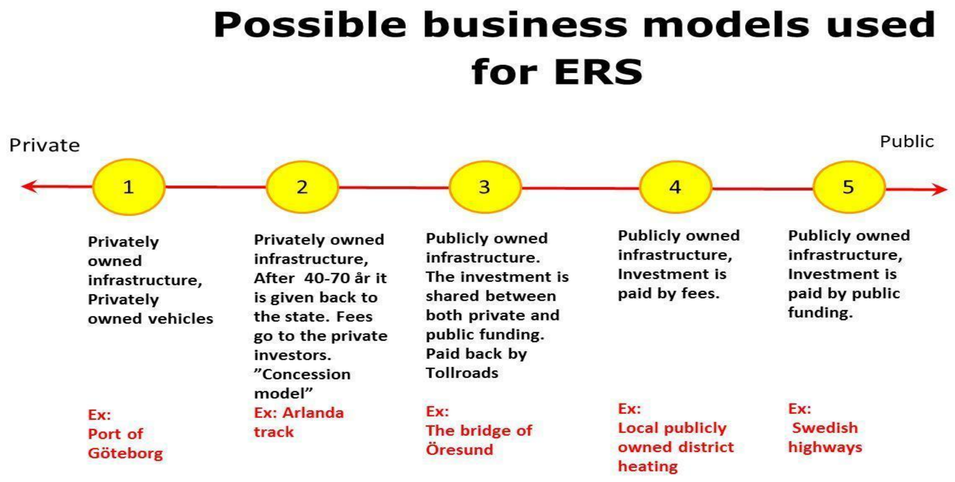
Sweden has a goal to have a fossil free transport system 2030. To be successful in reaching that goal, Sweden has to find innovative solutions. Electric road system (ERS) is one example of an innovative but realistic solution. ERS will reduce emissions and has a potential to be self-supportive within heavy duty road transports. Such systems could be interesting for new investment like Public Private Partnership (PPP). This study uses business models as tools to look deeper into PPP arrangements for ERS in heavy duty transportation.

This study has looked into

- Different business models for ERS
- Description of business model scenarios, qualitatively and quantitatively
- Visualization of a model used for sensitivity analysis
- Stakeholder knowledge and points of views regarding ERS
- Report from a visit to the ERS demo project in Los Angeles, USA

Five models are presented, from fully privately owned to fully publicly owned ERS cases.

1. ***All private, fee-based***
2. ***Private concession, fee-based***
3. ***Joint venture between public and private investors, fee-based***
4. ***Publicly owned fee-based infrastructure***
5. ***Publicly owned, tax paid infrastructure***



There are several considerations to be made in the selection of a business/financing structure for an ERS. The model selected should:

- Create and add new ideas to ERS development

- Provide new insights, knowledge or experiences, i.e. around usage pattern and take-up among the users.

- Be able to expand to many different situations

- Involve more than one actor

The unique characteristic of the ERS is that it is both an infrastructure – in fact two: the road itself plus the electric distribution system, and a constant energy feed. In addition to these complexities there is also a need for specially adapted vehicles. The ERS is both a fixed infrastructure and a moving vehicle. In open system, where vehicles from many different owners/operators use the ERS, there is a need for individual measuring and billing for the energy used. Simultaneously electric energy is cheaper than fossil fuel or gas. The energy efficiency is also higher compared to internal combustion engines.

These findings point out preference for our model 3, the consortia model involving many different financiers as the model for ERS. It could also be model 4, the publicly owned and fee based model. The other models are either too narrow in scope or too expensive for the tax payers.

A calculation model in a spreadsheet is included for sensitivity analysis to visualize the different opportunities that are available when it comes to business and financing models and applications. The spreadsheet should be used for testing cases of interest and only as an advisory document. It still conveys good understanding of different ERS road scenarios.

Interviews of different stakeholders for an ERS application are part of the study. The purpose of the interviews was to

- Inform about the ERS concept and different business models
- Get the different stakeholders' point of views regarding ERS
- Understand their interest to get involved in the future technology development
- Create an interest to contribute to a demonstration project

There were a big interest for ERS among the stakeholders but very few had any deeper knowledge in the area. Most of the interviewees thought it will become reality, but in the future. The more knowledge they gained the more interested they became. This means that there are big educational needs for seminars, workshops etc. to get a common understanding in the society for future ERSs. Their most concerns among the interviewees were

- Cost
    - Vehicles
    - Infrastructure
- Timing, this is for the future
- Technologies
- The total business case
- Public perception (overhead lines are very visible)
- Environmental consequences

The interviewees also got involved in the business model discussion and they showed large interest for lower energy cost and less environmental impact, like CO2 emissions. But the emission reduction must be at least 50% lower to create acceptance for a higher price for the transportation services.

At the very end of our work, we went on a study tour to USA to become acquainted with the group in Los Angeles who already has decided to go along with a demo project for ERS, with Siemens system (overhead lines) and one Volvo hybrid truck amongst others. The decision and responsibility for realization lies with the AQMD (Air Quality Management District) which is a governmental local body who is responsible for the South Coast air quality. Air quality is really the driving force; to lower emissions substantially towards zero emissions on some heavy traffic road stretches. ERS was, for the time being, the only solution according to their early studies. They were not so concerned about the price of the infrastructure. “price will go down”. The public perception regarding overhead lines is their most important concern as is also, in the long term, the safety of the system. They were very interested in our work in Sweden and suggested that we start collaboration. The common issues to discuss should be:

- Grid impact studies
- Standardization
- Business models
- ERS cost
- Public perception
- Parameters to be measured during the demo test (NREL)

We warmly recommend the Swedish Agencies to initiate such discussions as there will be many hurdles that are good to share along the way to Electric Road System for heavy duty transports.

Introduction

The electrification of roads and trucks is an on-going phenomenon with several activities in Sweden and globally. Several technologies are being considered for electrifying the road and several different actors from varies industries and agencies are participating in the different activities. One common name adopted in Sweden for this phenomenon is the Electric Road System, ERS. In USA it is named as way side power. In this report, RES will be used and we refer to Electric Road System for heavy duty road transport only.

The transition towards the ERS has been described as a technology shift and a new technological paradigm. The technical challenges of changing from the internal combustion engine and fossil fuels to an integrated ERS have been described as massive but manageable over time. Instead, many studies have pointed out that business model aspects are crucial for the deployment and success of the ERS. There is a need for more knowledge in understanding how private and public actors could relate to each other when it comes to investments, risks and revenues. This could guide agencies and private actors in decision-making regarding future ERS activities.

The purpose of this study is to highlight the role of business models for ERS through different scenarios. This report continues by introducing the role of business models and the transition towards the ERS. Five scenarios are described qualitative and also quantitative trough calculations where the calculations can be used for fingerprinting the opportunities for future investments in ERS. A visit to California, Los Angeles was important as the local government already have planned for an ERS demoproject and there are lot to learn and find new collaborations. Finally, interviews have been done with different Swedish stakeholders to locate where the knowledge is for ERS and how different stakeholders look upon their own situation and business when ERS is introduced. To summarize, the study will cover:

- The role of different business models for ERS
- Description, qualitively and quantitatively, five business model scenarios
- Visualization of a model used for sensitivity analysis
- Stakeholders knowledge and point of view regarding ERS
- Report from ERS demo project in Los Angeles, USA

Goal for the study

The overall goal of the study is to develop and elucidate the business and financing models as tools when make decisions on next step towards commercialization of ERS after the demonstration phase. Five business models are studied and all are applied on ERS concept. The goal is to find models to that will be used to reach fossil free heavy duty road transports 2020.

The transition towards the Electric Road System, ERS

History of electrification of road transport

In the year of 1900, 4200 automobiles were sold and 38% were electrically powered. 22% were powered by gasoline and the rest by steam (Husain, 2011) The long charging time of the battery and the reach of the electric vehicle was a problem already then. Hybrid vehicles, using both electricity and gasoline, were also developed at this time (around 1900).

ASEA developed an electric truck and the technology was then used by the Swedish company Sea, founded by ASEA. In the 1930s and 1940s, Sea was the largest producer of electric vehicles in Sweden. During this period of time, a technology was also used where trucks and busses were supplied continuously with power through contact lines while they were moving. Such a system was used in Stockholm for two decades with a start in 1942. Even though the interest for electric vehicles declined in Sweden after the Second World War, systems with a continuous power transfer to buses, trolleybuses, were widely used around the world until the 1970s. Today, there are approximately 350 trolleybus systems in the world with a vehicle fleet of approximately 40,000 busses. Since the year of 2003, there is a trolleybus system in Landskrona. Except mining applications, systems with trucks with continuous power supply when in motion are however not in commercial use in Sweden today.

The conventional road system

The conventional and established transportation system has developed organically over the past century into an essential part of modern society and is strongly connected to economic growth. Vehicles based on the internal combustion engine (from now on called ICE) technology, emerged as the dominant design in the beginning of the 20th century. In the 1920s, ICE trucks based on the diesel engine technology emerged as an alternative to gasoline driven otto engines. Trucks fuelled by diesel were better suited as diesel fuel had a higher energy density diesel engine was more durable with higher torque than gasoline engines.

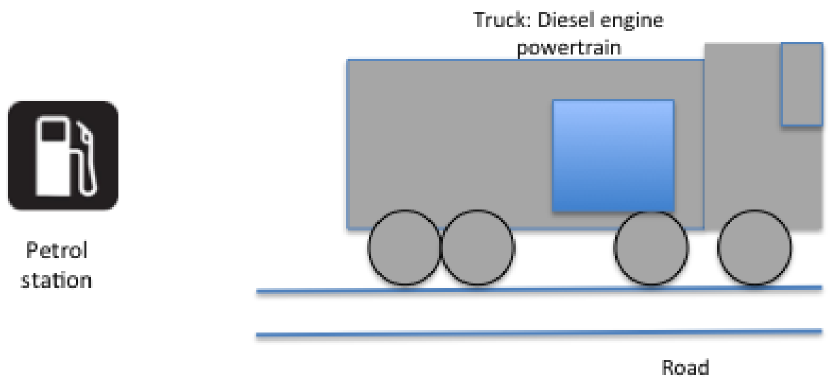


Figure 1. Autonomy subsystems in the conventional road system.with on board energy storage

Three subsystem are needed to make transportation durable (see fig. 1):

- fuel stations
- ICE based vehicles
- roads

Each subsystem has developed similar standards between the interfaces. For example, trucks could drive on roads in most regions and countries, while being able to tank the similar fuel in the same market place. Consequently, each subsystem has developed into an industry that is path dependent. Further, users and policy makes have also become locked in to the diesel engine technology.

The road transportation system currently is considered as locked-in to fossil fuel energy and ICE technology but there are several driving forces for new technologies.

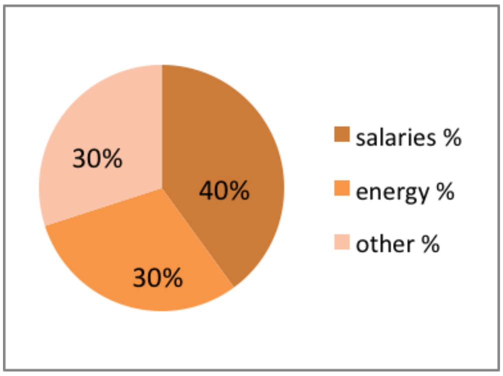


Fig. 2 Cost distributions for haulage contractor companies within long-distance transport

One of the main driving force is the price of the fuel, which has a large impact on the profitability for the transportation company (see figure 2). But also an increased concerns of climate change and energy security of supply is important. All these issues give a demand for more energy efficient technologies that reduce fuel costs and cause less greenhouse emissions. So far, there have been two alternatives to fossil fuels: keeping the ICE but shifting to alternative fuels (such as biofuels) or shifting to an electric power train. Alternative fuels have demonstrated commercial viability but have lacked in the capacity to satisfy the fuel demand in the transport sector. Electric powertrains and hybrid vehicles have not proved commercial viability at a large scale for trucks because of their low battery capacity. Electrifying roads and transferring power vehicles from an external fuel source has emerged as a realistic scenario to solve the challenges of the conventional transportation system.

ERS - A new technological paradigm

The ERS can be described as electrified roads supporting dynamic power transfer to the vehicles. ERS has the following subsystems (see fig. 3):

- power grid and stations
- power transfer technology
- the road
- ERS based vehicles

The basic principle is to power an electric engine within the vehicle from an external power source that is built into the road infrastructure. The electrical power is transmitted while the vehicle is in motion through a pick up, picking up power from below or above assembled to the vehicle.An example is the trolley bus. The roads would be accessible for both vehicles with ERS-propulsion as well as conventional fossil fuelled vehicles. Further on, the ERS-vehicles would be equipped with a small battery and a potentially smaller diesel engine to allow a flexible system where vehicles could drive outside the electric road network on conventional roads.

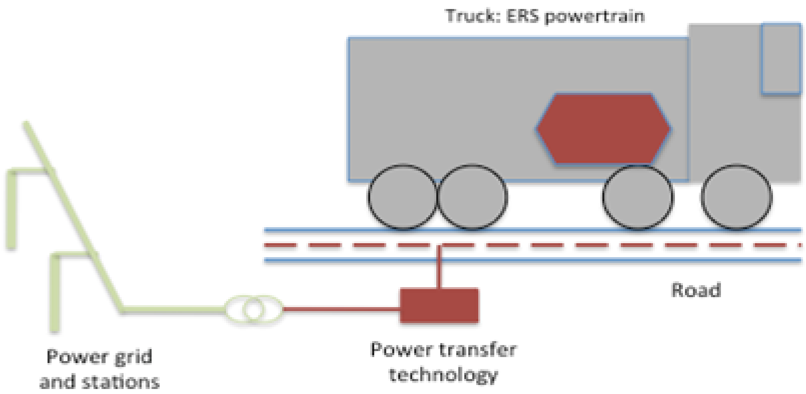


Figure 3. Integrated subsystems in the electric road system

While the basic principle for the ERS is dynamic power transfer technology from the road to the vehicle, the technological standard for transferring power is not developed yet. Currently there are three main concepts in electrifying the roads: over-headline, conductive underneath or inductive. Each technology has it cons and pros and is developed and marketed by different firms. Most of these firms are from the railway industry and could be considered as new entrant to the road transportation system.

The ERS could be an enabler for the integration between the transportation system and other systems such as information and communication technology (ICT) and electric smart grid. ICT technology could be helpful for the vehicle to communicate with other vehicles to avoid crashes and enable automated technologies, such as platooning (platoons decrease the distances between cars using electronic coupling) and could be integrated with the electric grid for metering and billing of the electricity use.

Stakeholders' implications

For **truck manufacturers**, power electrification could be seen as a body builder (building application on the truck chassis). This means that the truck should manage electrification independent of which power transfer technology that becomes the standard. However the vehicle will be more integrated with the infrastructure in the new system compared to the conventional road system, as it needs to be developed and connected with the other subsystems. A shift to ERS would require the truck manufacturers to acquire new competencies and new business models.

Petroleum firms will most probably continue to play a significant role with ERS (electrified roads and batteries would not be able to supply the whole road transportation system). The role of these firms could however change, from being the dominating fuel supplier, to a secondary fuel supplier. They could also start new applications, such as quick charging and battery swapping.

Construction firms need to ensure safety and durance in controlling the construction and properties of the electric roads.

State and agencies aim to reduce environmental impacts, oil imports and increase energy efficiency by switching from fossil to electric fuel. All other stakeholders have pointed out that the state and agencies have a key role as facilitators when it comes to investing in infrastructure. The loss in oil taxes and currency savings from oil imports as well as the large initial investments in new infrastructure could require new national and international policies and business models.

The users of the ERS could benefit from higher energy efficiency in the vehicles compared to diesel engine trucks and thus potentially lower fuel costs. ERS could also constitute an image and brand value to be more environmental friendly than other alternatives.

Road power technology firms could be firms in the railway industry or entrepreneurs. Railway companies have long experience in designing, producing and delivering complete railway systems, including infrastructure and intelligence.

Power companies produce electricity through different energy sources, e.g. fossil fuels, nuclear and renewables. The traditional way of making money is to sell electric power per kWh to households and companies. In the ERS scenario, electricity will be the new primary vehicle fuel, which opens a new market for the power companies.

Business models for Electric Road Systems

What is a business model?

The term business model has a long history. It was first mentioned in an academic journal article in 1957 (Osterwalder et.al 2005) and as early as 1954 in a management book (Drucker, 1954). Business models were used as a modelling tool of business in the computer field and system modelling in the beginning of the 1970´s. Previous management scholars defined other concepts, similar to business model, such as “business idea”, and “service management system”. The interest has increased for business models development as the IT technology developed. Most management researchers agree that the concept is about how **business creates value** and it is an important unit of analysis, relevant for both management theory and practice.

A business model is defined through the elements of *value proposition*, *value creation* and *value capture*

- **Value proposition** defines what the added value is for the user (and describes what the firm proposes to sell and to whom (Chessbrough, 2010).
- **Value creation** is defined by two components; a firm’s strategic resource, which consist of the core competences, strategic assets, and core processes; and the value network or value chain, which outlines the firm´s suppliers, partners and coalition that complement the firm´s resources

- **Value capture** describes the revenue model and how the business generates its sales revenue.

A business model is not a strategy, but the implementation of strategic choices or the complement of a strategy use an analogy. To illustrate what a business model is and how it differs from strategy and tactics, the design and building of the car represents the strategy, the car itself represent the business model and the driving of the car represents the tactics.

"Different automobile designs have different specific logics of operation - conventional engines operate quite differently from hybrids, and standard transmissions from automatics - and create different value for their 'stakeholders,' the drivers e.g. small car or SUV. Automobiles are made of parts - wheels, engines, seats, electronics, windshields, and the like. To assess how well a particular automobile works - or to create a new one - one must consider its components and how they relate to one another, just as, to better understand business models, one needs to understand their component parts and their relationships." (Casadesus-Masanell & Ricart, 2010, p.197)

Business models could be used to analyze relationships between several stakeholders in a value network.

Public-private business models in infrastructure

The concept of business model has spread from the private sector to the public sector. The concept has been used to find innovative ways of providing infrastructure, such as roads, railways, water, energy and telecoms. The implications of using the concept when designing business models that include public actors is that the value proposition, value creation and value capture between different actors differs, in contrast to traditional public business models.

Private actors with business models for traditionally public services are not new phenomena. During the development of new infrastructure technologies in the 19th century (e.g. railways, telegraphs, telephony and electricity systems), private firms were competing to find a appropriate business models for technological innovation. For example, the development of the lighting system came from the business model innovation from Edison to sell power plants and lighting network as a service to the public authorities. Another example is AT&T whom in the 1880s developed a business model for long-distance telephony by providing the service through a large, vertically-integrated and centrally managed bureaucracy (Davies et.al., 2010).

Over time, these business models failed in attracting the required investments that were needed to expand the infrastructure. Since the infrastructure of transport, water, energy and communications were considered as the overhead capital o the economy and the basis for nations growth and prosperity, these infrastructures were transformed to "natural monopolies" under public ownership or private regulation (Chandler, 1977).

In recent decades, the boundaries and responsibilities of public infrastructure have been blurred and reshape as previously public activities have been transferred to the private sector (Graham & Marvin, 2001). Further, management tools form the private sector has been widely deployed in the public sector through a market-driven governance style. The ambition is to improve quality of public sector services.

With an increased outsourcing of activities from the public to the private sector, governments have become more dependent on private sectors´ finance as well as technical and market knowledge.

Three major changes in infrastructure provision have generated new business models (Davies et.al., 2010)..

1. The public sector providing infrastructure has faced outsourcing activities through privatization or joint venture. Privatization means that both the costs and revenues are in private hands. Though concession contracts the private actors has the responsibility and authority to provide the service for a limited contract period. Joint-venture contract mean that the private and public actors share responsibilities and ownership for the delivery of services (Li & Akintoye, 2003).

2. The public authority responsible for the infrastructure service could transfer the risk to private actors, share the risk or retain the risks. In this way, the public authority could manage different types of uncertainties. The contracts could be through contracts such as PFI and PPP.

3. New organizational forms and transactional relationships between the public authorities and private partners are being developed, moving from short term to long rem relational contracts. These contracts often build on trust and could reduce risks that are involved infrastructure provision for both parties.

ERS– calculations and sensitivities as a tool for business models

The project has developed a relatively simple calculation model to visualize the basic financial potential of electrification of heavy transports and be able to do a sensitivity test for different parameters. The calculations carve out a niche of the road transports and show a snap shot of a year (beyond 2020) when an electrified road is established and the market share into the high regularity heavy long haul segment on that road is significant. As it does not consider the market share and build-up over time and ignores the first difficult years it is clearly not an investment model (and does not express discounted cash flow values). The purpose is rather to illustrate if there is a future 'steady state' situation which can be attractive enough on market terms to further analyze the build-up, the road to get there, as well as the future possible roles of new players, who are not currently involved in the road infrastructure. In fact, a second spreadsheet calculation model illustrates the effects on various players, including a possible road electricity infrastructure owner as well as tax consequences.

The model essentially reflects the differences, the deltas, as compared to today's world by adding electrification to a road of significant length (e.g. Stockholm-Malmö). The source of revenue is the avoided cost for conventional fuel, i.e. diesel fuel (including taxes). The costs are associated with electricity in terms of direct electricity costs (including taxes) as seen at the power whole sale market, grid costs for current network, the electrical infrastructure costs to and on the road as well as the additional costs in the vehicles for pantographs etc. The model is static in the sense that it calculates the consequences of a set of assumptions, not least market share and volumes (as opposed to a dynamic model where costs and prices would generate the volumes from their economic attractiveness).

The basic question the calculations are trying to illustrate is the following: Are the revenues, i.e. the reduction of the costs for diesel sufficient to pay for all electrification costs?

In a base case of assumptions, which are deemed reasonable and provided there is high market share in the long haul market, the answer is basically: yes, electrification can then just barely pay for itself.

We have always assumed that the vehicles will pay for the use of the electrical infrastructure per usage, either per km of electric road travelled (tool road) or/and the electricity infrastructure per kWh. We have also assumed that this price is set so there is a net profit for the vehicles; otherwise they are not likely to use the ERS. On the other hand, with such 'pricing policy' usage and market share can be assumed to be high. This means that revenues in our calculations and examples first will cover the cost of electricity and the cost of the vehicles, thereafter the electrical infrastructure cost. A key observation from the calculations is that the total electrification cost of the vehicles is small in relation to the costs of electrification infrastructure, which means that the 'road price' for the ERS will appear to be high, in the order of 1 SEK/km. This shall be compared to the diesel cost of 4,8 SEK/km.

Another observation is that the value of the reduction of CO2 calculated on the basis of the cost of emission rights in the European trading system is small (the CO2 tax for diesel is a significantly higher number).

A certain number of sensitivity variations further illustrate which are the key and crucial assumptions.

Some basic assumptions and variations

Economic life time: 40 years for infrastructure (annual O&M cost 2,5 % of investment), 4-6 years for electrical equipment in vehicles (same as vehicle). Variations show that economic life of infrastructure is only moderately sensitive (e.g. 30 years)

Interest: 2 % + inflation (CPI), but can be higher for vehicles

Infrastructure investment: 10 MSEK/km, which may be on the low side. Variations show that this is very sensitive, 10 % increase can just barely be absorbed.

Vehicle cost: 500 kSEK (additional for electrification)

Diesel cost: 12 SEK/liter (incl taxes, CO2 fee). Variations show that this is very sensitive, since all revenues come from avoided cost for diesel

Electricity cost: 0,30 SEK/kWh (taxes and grid cost is additional). Variations show little sensitivity since the biggest part of the total electricity cost is the road infrastructure cost, the cost of power itself is only 15-20 %.

Share of electric vehicles show that this is sensitive since usage (and thereby avoided costs for diesel) is directly related to share of vehicles.

The calculation below is useful for overall discussions around sensitivity and profitability from perspective of different stakeholder in ERS.

Electric Road Simulation					
	Scenario:	**E 4**	**Scenario:**	**E4**	
			Traffic		
Input Infrastrucure	**Infrastructure**		Road Length	558	Kms
Investment Cost per Km	10	MSEK / Km	Whereof Electrified	90	%
Economic Life Time - Depreciation Period	40	Years	Electric Road Length	502	Kms
Average Consumer Price Increase - CPI	1,5	% / Year	No of Truck Passages In + Out / 24 Hours	4200	Trucks / 24 Hrs
Borrowing Interest - CPI + X %	2,0	% + CPI	Whereof Heavy Trucks	80	%
Borrowing Interest	3,5	% / Year	No of Heavy Truck Passages	3360	Trucks / 24 Hrs
Annuity - annual cost: Depreciation + Interest	468	TSEK / Year	Whereof Long Haul Passages- Start to End	75	%
Maintenace as a % of the Investment Cost	2,5	% / Year	No of Heavy Long Haul Passages	2520	Trucks / 24 Hrs
Total Cost per Km - Infrastucture	718	TSEK / Year	Heavy Long Haul Kms / 24 Hrs	1265544	Kms / 24 Hrs
			Long Haul Days / Yr	365	Days / Yr
Input Vehicle (All costs exclude VAT)	**Energi & Co2**		Heavy Long Haul Kms / Yr	461,9	Million Truck Kms/Yr
Diesel Total Cost	12,00	SEK / Litre	Electric Vehicle Share	32	%
Diesel - Product Cost	6,90	SEK / Litre	Electric Road Use	147,8	Million Truck Kms/Yr
Diesel - Energy Tax	2,08	SEK / Litre			
Diesel - CO2 Tax	3,02	SEK / Litre			
Power Fixed Cost	0,30	SEK / Kwh			
Power Energy Tax	0,29	SEK / Kwh	**Infrastructure Contribution**		
Power Variable Cost	0,30	SEK / Kwh	Electric Road Use	147,8	Million Truck Kms/Yr
Power Infrastructure Transfer Cost	1,30	SEK / Kwh	Power Infrastructure Transfer Benefit	307,5	MSEK / Yr
Power Total Cost	2,19	SEK / Kwh	Infrastructure Cost - E-Road Lenght x Annuity	-360,7	MSEK / Yr
Effeciency Factor - El. Power vs Diesel	2,5	Times	Infrastructure Contribution	-53,3	MSEK / Yr
Energy Content / Litre Diesel	10,0	Kwh			
Consumption - Diesel / 10 km	4,0	Litre / 10 km	**Truck Fleet**		
Consumption - Energy /10 km (Diesel Vechicle)	16,0	Kwh / 10 km	Kms / Truck / 24 Hrs	1000	Kms
Co2 / liter Diesel	2,41	Kgs / litre	Whereof on Electrid Roads	60	%
			Net Kms / Truck / 24 Hrs	600	Kms
Total Cost Diesel / 10 km	48,00	SEK /10 km	Days in Use / Yr - Each Truck	260	Days
Total Cost Power / 10 km	35,09	SEK /10 km	Total Electrified Kms / Truck / Yr	156000	Kms / Yr
Energy Saving / 10 km	12,91	SEK /10 km	Vechicles Required	948	
Energy Saving / km	1,29	SEK / km			
			Carrier´s Contribution		
			Energy Savings - E-Road use x Saving/km	190,9	MSEK / Yr
			Hybridization Cost - Cost x No of vehicles	-138,5	MSEK / Yr
Input Hybridization	**Hybridization**		Carrier´s Contribution	52,4	MSEK / Yr
Hybridization Investment Cost / Vechicle	500	TSEK			
Economic Life Time - Depreciation Period	4	År	**Scenario Result**		
Borrowing Interest - CPI + X %	2,0	%	Infrastructure Contribution	-53,3	MSEK / Yr
Borrowing Interest	3,5	%	Carrier Contribution	52,4	MSEK / Yr
Annuity - annual cost: Depreciation + Interest	136	TSEK / Year	**Result**	**-0,9**	MSEK / Yr
Maintenace Cost / Vechicle	10	TSEK / Year	CO2 Saving	142494	Metric Tons / Yr
Total Cost Vechicle Hybridization	146	TSEK / Year			

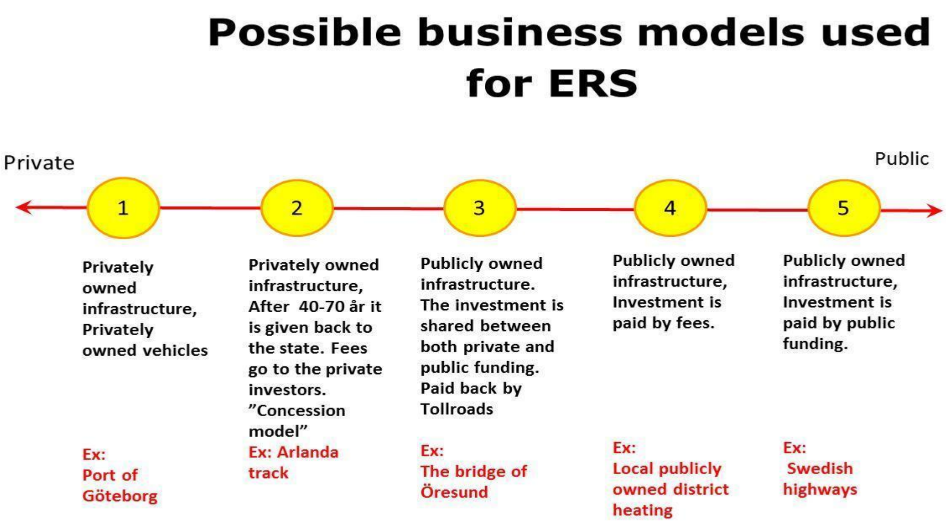
The main sensitivity challenges are: investment cost for infrastructure, number of truck passages In + Out / 24 Hours, long haul passages- start to end, long haul days/year and the share of electric vehicles which the calculation shows.

Five models that could be used for Electric Road Systems

Below are five examples of business models for Electric Road systems. They range from an “all private” enterprise to a tax-paid, public road. However, there is a difference between ordinary road financing systems and electric road systems in the sense that the electric road system also provides the energy for the transport. On ordinary roads the fuel is handled separately from the road by oil companies and their infrastructure for gas stations. One can say that there are two separate infrastructure systems at work to get the fossil-fuel transportation system to run.

In an electric road system, these two systems operate together and may be integrated. The vehicles must also be adapted to these new technologies which increase the cost of vehicles. The electric road system possibility also challenges the conventional road financing models since it also embrace the operating cost of the energy used to perform the transportation.

In the following are five different archetypical models for financing various infrastructure installations described and discussed for their potential in ERS. The five types range from an all-private, fee based system to an all public tax based system and variations in between. All of these archetypical models are in use for various infrastructure systems, although not always for financing of roads.



1. All private, fee-based

The all private fee based system has no funding or other involvement from government or other public spending of money. Instead it is operated as a commercial enterprise with a private funding of the infrastructure and a fee for utilizing the facility. There are examples of private railways, private roads and harbors that have this business model.

Within such an operation there might be room for other private entrepreneurs that perform various auxillary services paid for by the infrastructure owner or the users of the facility. In a harbor area, several private maintenance companies and ship management companies can operate on the grounds of the harbor owner.

The actual business/pricing models can be fixed or in relation to usage of the facility. Typically a combination of fixed fees and moving rates are used. In the early days of railroad in Sweden foreign investors which had experience with the railway technology built many private railroads connecting smaller cities and towns. Often a group of investors with local connections agreed to finance and set up the railway company and its operations. One drawback for society was that different standards were established which became obstacles for a larger system development. Another obstacle was that the private investors could not cater for large projects connecting many cities or longer distances because they simply did not have enogh financial resources. The state limited its operations to the creation of a backbone system connecting all the smaller private railways with a larger network. IN the 1930ies the state changed strategy and gradually took over the ownership of nearly all local railways and changed all equipment, railroads etc into one single standardized technology. This change, in turn, was the start of a rapid increase in travel and volume of goods transported since the standardization meant lower prices for transport and faster connections.

Transferred to modern day and the ERS it is easy to foresee a similar pattern of development: Private investors establishing private roads with different technology solutions and standards for the technology for transferring power to the vehicle. Initially It would probably be shorter distances within or close to existing installations say between a harbor and a mine, or between two industrial areas in the same way as the first private railroads enabled industrial development that had previously been held back due to poor transport systems.

The advantage with this all private model is that it can be tried and tested without any economic involvement from the tax payers. It can be seen as something like a test project. New actors can also enter with other technologies, ideas and business models and experiences from earlier systems lead to further developments.

One drawback is that different standards might evolve and ther may also be difficulties to scale up the system. Another drawback is that the privately funded systems will probably be short distance and for a specific use which may hamper further expansion of the system as was the case with railways until the state engaged and took control of the whole system.

2. Private concession, fee-based

Another type of model is the similar to the all private model, but has some distinct differences. In this model the state grants an exclusive licence for the company that build the ERS to build, own and operate for a limited number of years. When the license expires the ownership including the infrastructure is transferred to the state.

This is the case with nearly all hydro power stations in Norway. The young Norwegian state of the early 2000 century had very limited funds for investments in infrastructure and energy. Instead they chose a solution in which claimed ownership of many streams and waterfalls which they in turn granted a licence for private investors to build dams and create hydro power plants. These licences have had a very long life since some of the contracts had an expiriation date fifty to a hundred years into the future. (I am not aware of whether the licences has been terminated or prolonged.)

The core idea is that the state grants an exclusive right to somebody else to invest and erect an infrastructure to be used on the state property. When applied to ERS this model is somewhat appealing since it limits the risk for the tax payers money and it creates a business case for the private investor with a fixed end date. This means that the risk of not getting the money invested back within a set time frame is made clear. After the expiration date the state can choose to reclaim the licence or put it up for auction. The state can also include new terms or requirements which may steer away from the problem of different standards evolving in different roads

This same type of licence of operating an infrastructure is also used in the british railway system where different actors bid for the different operational licensees. One drawback is that the licencing includes a private party which requires a profit to be made which makes the systems more costly compared to an investment made by the tax payers.

For ERS with overhead transmission, this solution may be appealing since the state-owned roads can continue to be managed by the state, while the ERS with overhead transmission can be operated by a licensee under terms stated by the road authorities. Thereby the road administration can keep the overall management of the road while getting the electric infrastructure raised by a private operating company that takes the whole risk of the system. I.e. Tax payers money are not spent on the new technology. If the system works, the ownership of the system may be transferred to the state at some point in the future.

3. Joint venture between public and private investors, fee-based

The Öresund bridge connecting Denmark and Sweden was built by a joint-venture group consisting of several different public and private actors. The Swedish and Danish state has one claim each in the consortia while local government in Copenhagen also is involved together with private investors and companies involved in the bridge building. The loans required to build the bridge are going to be repaid by the users of the bridge, Trucks, busses, cars and railway.

The fact that the states back the project with financial guarantees means that the credit cost is reduced compared to a situation where a private company would be the lender.

In many countries with toll roads and high-way fees this financing model is common. One example is France where a whole industry of 10+ different companies own and operate fee-based motorways. Often with shared ownership between private financing and public entities (regional and national) There are even motorway companies listed on the stock exchange in Portugal (Brisa) and Australia (Riverside).

This model would possibly also be applicable to ERS roads using a fee-based system for operating a toll road equipped with ERS, one fee for drivers not using the ERS and another fee for users using the ERS. The advantage of using this model is that public and private financiers can operate alongside each other. The project has a limited risk since a clear income model is used (toll) and the concept is recognized among investors worldwide. This model also opens for a wide range of investors: private companies, pension funds, local municipalities, private investors etc.

The characteristic of such an investment is that the risk is limited to variations of the volume in traffic since the cost are to a large extent fixed.

4. Publicly owned fee-based infrastructure

One variation of the fee-based idea is to only allow a publicly owned entity to invest in the infrastructure. There are reasons and arguments for this solution – in Sweden all main roads are owned by the national government and/or municipalities and there is a resistance and hesitation towards giving up this principle. There are no toll-bridges within Sweden, only between Denmark and Sweden and between Norway and Sweden. There is an ongoing discussion on applying fees for roads and other infrastructures. So far there are only congestion charges in Stockholm and Gothenburg.

There are other examples of publicly owned fee based infrastructures: the railroad network is owned by the Swedish transport administration, harbors are owned by municipalities and operated as commercial companies, district heating networks are owned and operated by municipalities as well as private owners and also the transmission grid for electricity is owned by a publicly owned grid company. All of these infrastructure owners are financed by fees collected from the users of these infrastructures.

The model for ownership and financing is thereby clear and common: a publicly owned entity, municipal or national, owns the infrastructure organized as an administration or as a company. The operation and further expansion of the infrastructure is thereby financed by the users and additional users through fees, and not by tax payers money, although the initial investment is often funded or guaranteed by tax payers. The connection and public ownership reduce the risk for lenders which reduce the cost of capital. In some cases there is also a somewhat diffuse regulation of the fees to be limited to cover the cost to maintain the quality of the infrastructure as well as some expansion. However it is difficult to regulate this in a general manner.

One could imagine using this model e.g. to build and operate an ERS within a city as well as along the main roads in Sweden. However, the initial investment would draw much cash from the tax payers as well as challenging the current idea that all road infrastructure should be financed by tax payers money rather than by fees. ON the other hand, one can argue that only the users using the ERS should be paying for it and not the whole society.

5. Publicly owned, tax payed infrastructure

The conventional Swedish financing model for road infrastructure is that tax payers money is invested in roads and other infrastructure. One argument for this idea is that all of society benefits from better transportation opportunities and reduced cost for transporting goods and people.

If this would be the option for financing the ERS it would be put in line among all other infrastructure investments waiting. Since the new technology also requires the vehicles to be adapted to the ERS and probably the number of such vehicles would be limited, it is difficult to foresee that this investment would be prioritized before e.g. a railroad project or a conventional high way project.

The priority between the different investments in transport infrastructure is ususally based on a cost-benefit calculation where all the projects are ranked according to best utility and lowest cost. Since the number of potential users is small in the beginning the benefit for society is low at the outset and thus this type of system will have a lower priority.

Which model to be selected for a test?

There are several considerations to be made in the selection of a business/financing structure for an ERS. The model selected should be:

- Creative and add new thought to the ERS development
- Be able to obtain new insights, knowledge or experiences, i.e around usage pattern and take-up among the users.
- Have the potential to be expanded to many different situations
- Involve more than one actor

The unique characteristics of the ERS are that it is both an infrastructure – in fact two: the road itself plus the electric distribution system, and a constant energy feed. In addition to these complexities there is also a need for specially adapted vehicles. The ERS is thus partly a fixed infrastructure and a moving vehicle.

The financing needs are thus: the road, the fixed electrical installations, the onboard equipment and the energy used by each vehicle. The last part means that there is a need to measure the energy used by each vehicle and charge the user for the energy used. Although in all private systems it may be enough to measure the energy at the input to the system and not measure each vehicle individually. In open system where vehicles from many different owners/operators use the ERS there is a need for individual measuring and billing for the energy used. On the other hand, electric energy is cheaper than fossil fuel or gas. The energy efficiency is also higher compared to internal combustion engines.

For a test installation there is also a knowledge building demand beside the obvious

This points to the third model, the consortia model involving many different financiers or perhaps model 4, the publicly owned and fee based model.

Using the calculations from this report a case regarding a fee-based joint venture can be illustrated:

Assume that a large scale project is developed in which the main road E6 is converted into an ERS for 90 % of its length which equals to 1350 kilometres of electric road. A joint venture consortia is set up with the different stakeholders entering as co-financiers and the contribution from the national road administration consist of a licence given to the consortia to install ERS infrastructure in the form of overhead lines above the right lane of the road in both directions. The licence should state that ordinary non-electrified traffic must not be hindered from using the road.

The total investment for the ERS infrastructure is approximated to 10 MSEK/km which equals 13.5 billion SEK. The yearly cost of the infrastructure including maintenance is estimated to be 970 MSEK.

In addition to this cost there is also the cost of energy provided through the ERS which is approximated to be around 0,90 SEk/kWh.

The trucks running on the road also have to equipped with technology to utilize the ERS which is approximated to be around 500 TSEK which equals 146 TSEK/Year.

The fee structure is one fee for using the ERS and another fee for the energy used. The ERS is thus a kind of toll road where you pay per kilometer used plus the amount of kilowatt hours used. Thus a “light” truck will pay the same road toll as a heavy vehicle but different amounts for the energy used.

In a case where all heavy traffic is using the ERS the road price would be 22 SEK per 10 km while the energy price would be 0,90 SEK/kWh. Assuming that a truck use 16 kWh per 10 km this equals to 14.4 SEK/10 km in electric energy cost.

A truck that e.g. runs a distance of 200 km would thus pay 440 SEK in road fee for using the ERS and 288 SEK for the 320 kWh it uses. In total 760 SEK for the whole distance. The extra cost of equipping the truck with ERS-equipment is estimated to be SEK 8,60 / 10 km. (assuming the cost to be 146 TSEK/year and operating 170 000 km per year) In total SEK 892 for the whole journey or SEK 44,6 per /10 km. This should be compared with a diesel truck with an operating cost of 48 SEK / 10 km, which equals 960 SEK for the whole distance. The benefit is thus SEK 68 for the whole distance or 3,4 SEK/ 10 km. However, this benefit will be shared between the financiers of the ERS and the truck owner.

The case above included some assumptions that must be analyzed a bit further. First, the calculation is based on cost coverage. The road price is actually the lowest price acceptable for the ERS-consortia in order to cover its cost. In reality the price must be higher to cover for risk and profits for the financiers.

Second, the assumption of a 100% market share of the ERS-technology is unrealistic. In this case, the breakeven point is a 87,5% for the ERS. (The break even point is calculated as the lowest volume of traffic that share the cost for the ERS +electric energy + on board equipment up to the point where the cost equals the cost of driving on diesel fuel alone. This cost level would make it pointless for using the ERS, at least from an economic aspect.) Is the market share lower it will be difficult to cover the cost of the infrastructure without raising the fee so high that driving on diesel fuel will be cheaper. The market share is based on the rate of 443 million truck kilometers / year which is the current traffic volume. This volume consists of trucks from different companies and with different routes. Some truck operating firms use their trucks on many different routes and spend very few kilometers on this road while others may have a dominant part of their traffic on this road. It is difficult to obtain statistics on the variations and whether a 87,5% market share is realistic or not. The average distance a truck runs per year has been assumed to 170 000 km/year.

Given the case above, one can see that there are several different parties that can and should be involved. Large truck operators/logistic firms that operate many trucks using this road a lot could naturally be involved in the financing of the road system since it reduce their cost of operation.

Other financiers of toll roads, e.g. private equity companies pension funds etc can fund this infrastructure since it requires a large capital investment with a steady yield. The risks are limited to the buildup of traffic volume and the market share rate of ERS-technology on board the trucks. The latter can be increased through marketing, financing campaigns etc. The volume increase can to some extent be predicted.

Another development could be to impose a road fee for all heavy traffic using the road. This would change the competition for the benefit of trucks using the ERS. Consider a truck fee of 10 SEK/ 10 Km for all truck running on diesel plus the fees above for the vehicles using the ERS. In doing so, the ERS owner would receive large amounts in road fees plus the additional fees from the users of the ERS.

This solution would a) increase the revenue from the traffic, b) making the ERS viable at a lower conversion ratio, maybe around 50% of the traffic need to be run by converted trucks. C) a cost increase for diesel trucks which would increase the speed of the conversion since it would be economically attractive. If a tollroad is introduced for all trucks without ERS, then the profitability total will increase and it will be profitable to change to an ERS truck. This shows that the solution is road tolls.

Interviews of ERS stakeholders in Sweden

The main purpose of interviews of the different stakeholders

- To inform about the ERS concept and different business models
- Get the different stakeholders point of view regarding ERS
- Understand their interest to get engaged in the future technology development
- Inform and create an interest to contribute to a demonstration project

After a short presentation of the subject in a technical matter and a description of our five business models a few questions was asked:

- Is ERS an alternative for your business?
- How would your business concept look like in a ERS for the large highways?
- Is the reduction of CO2 sufficient driving force for ERS?
- Are you interested to further discuss to be involved in a demo project?

The following categories of organizations were interviewed:

Category	**Organisation**
Energy	Power Circle
	Vattenfall
HD vehicles	Scania
	Volvo
Transport supplier, Haulage contractors	Schenker
	DSV
	PostNord
	Sveriges åkerier
Logistic solutions	Logistikregion Örebro
Customers	Göteborgs hamn
Retail chain	IKEA
	ICA

Conclusions from the interviews

There was a great interest to meet us and gain knowledge of ERS. Our first impression of the interviews was that there exists a general lack of understanding of electric roads and electrification of heavy transports. Even though all included parties were familiar with “Elvägar”, very few felt that it was of their concern. Many of the involved argued that it was a question of infrastructure and that it does not require the attention of them as a specific stakeholder. After a long discussion around ERS and what it could lead to in the future the general approach to the subject changed and the interviewed became more positive. To reduce the total cost of energy use has a large impact of the total business of transport as ~30% of their total cost is for fuel. To lower total cost is of main importance for transport companies today. The environmental aspect weighed heavily for some of the participants, for example CO2-emissions. The emission reduction needs to be substantial, at least 50% to be interesting for a business case.

The economy of a haulage contractor is poor, sometimes less than 2% profit. Therefore the extra cost with hybridization of the vehicle seems to be a big hurdle. The problem they also foresee is how the infrastructure will be financed and how it will develop as the pay back for the vehicles only starts when a long enough stretch of the road is electrified.

The main concerns regarding ERS was:

- Cost
    - Vehicles
    - Infrastructure
- Timing, this is for the future
- Technologies
- The total business case

ERS is for the future therefore not all interviewed seemed to be at all concerned. They have very little knowledge about the technologies and how it could influence their business. Our finding is that most of the interviewed are getting more and more interested as they gain more knowledge. This tells us that already now start workshops and seminars to increase the base of knowledge for all stakeholders who will be involved in ERS in the future. This pro-active approach will the technology to come forward much quicker if knowledge is spread in an organized way than through "rumors" that are missing basic facts. Some are worried that the introduction of overhead lines can be a problem as it is extremely visible. If the people know the reason and the background of building ERS, the negative issues could be less. This is to avoid unnecessary draw backs in an early stage of the use of ERS.

Below are the main content of the interviews.

Energy companies

Electricity companies are very interested in electrification of transports as a new market and they have made all lot of activities to support the conditions for electrified transports on roads. The experiences from these activities can be used to improve the regions of Sweden to take the next step to create real business opportunities for industry and government. The focus has so far been on personal cars but the concept can expand towards heavy duty transports.

Smart grids are getting more and more important when transports on roads are electrified. Today, the electric grids are conservative and not accommodated to new areas of use. A very interesting project for ERS is the Sydvästlänken done by Svenska kraftnät. The focus of SydVästlänken is to boost the alternating current grid and to improve reliability of the Swedish base grid. The connection is also very important to expand renewable energy by expanding the wind power electricity production.

- Northbound, an alternating current grid is built to connect to the Swedish base grid in Hallsberg.
- Southbound, a direct current grid is connected to the Swedish base grid in Hurva.

Fig ? shows the stretch of Sydvästlänken

Sweden is expected to have surplus of electricity and therefore it is interesting to find new businesses for the electricity. ERS could be one of them and it will drive the expansion of smart grids and renewable energy production.

Heavy duty vehicle companies

The Swedish vehicle companies are all preparing for ERS by big efforts in the R&D. The vehicle companies are interested to take a deeper look into electrification of the whole transport system. They have already worked a long time with hybrization of the vehicles and the largest hurdle so far is to find good enough efficiency in the batteries. The truck companies are also looking into system solutions in the applications like forestry and mining where electrification of transport may be interesting in the future.

The doubts lay in the business concept and how the haulage contractors will get their money back in the extra cost of the vehicles like hybridization and catenaries and who will pay for the infrastructure? Maybe an incentive for the extra cost for the equipment could be an idea to encourage the use of an ERS system.

In a longer term perspective, the vehicle companies will be part of the electrification of transport and already today they work together with technology companies like Siemens, Bombardier and Alstom.

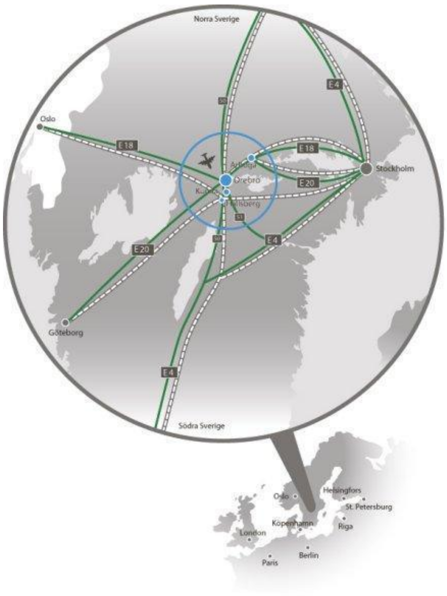
Today there are around 1600 hybrid busses, a combination of an electric and a diesel engine, already delivered around the world. A hybrid bus or truck can be used more or less without changes in the ERS. This means that the technology hurdles for the vehicle companies are relatively small to overcome.

The companies are positive to get involved in a demoproject to demonstrate the use of heavy trucks on electric roads. A demoproject will give answer on many questions and will increase the knowledge for all stakeholders involved. Therefore it is important to use an open technology. If so, standards can slowly be developed to be able to create a future international business and market for ERS.

Logistic centers

Through cooperation between Hallsberg, Kumla, Örebro och Arboga the Swedish ”heart of logistics” is created. It is a region of tradition of being a center for logistics with a University education specified in logistics for example. All the areas below could be of interest for future ERS:

- Dry port
- Kombiterminals
- E18, E20, Bergsslagsdiagonalen
- Dump for risk waste
- Railway node
- Airport



The group is very interested to develop the region around Örebro to a national logistic center. The knowledge around ERS is low but the interest is high as they already today has a railroad shuttle between Goteborg and Örebro. To combine this with ERS could be a very interesting application. It could also be useful to electrify different parts of the region to keep the logistic together. A discussion around business models led to that they were interested in both investing in ERS and also make a tolling system, all this to increase the attractiveness of the region. All involved wanted to be involved in a demoproject.

Haulage contractors

The Swedish haulage contractors has a turnover of 108,3 MSEK, which is around 4 percent of GNP and employ 86 000 people. There are more than 10 000 individual contractors. For most of the companies, there are very little knowledge about ERS and its opportunities. The conclusion is that they are positive if ERS gives the contractors a better economic situation. It is difficult to add on extra cost as the contractors are already under pressure economically and exposed to competition. The willingness to change is there and also the willingness to get engaged in a demoproject. The discussion around business models was mostly related to extra cost that was possible for the contractors and the payback time. Today the contractors are fighting with profitability and have a hard time to focus on future issues.

It is hard for the transport companies to condition the haulage contractors as long as the contractors do not get paid for a increased investment in the vehicles. Euro6 was not a problem as because everybody knew far in advance and was able to plan for the change. At the same time, Euro6 became legislation and all competitors had common ground rules throughout EU.

The most important for the contractor is ”total cost of ownership”. Is it enough with lower operation costs? Is the best technology used? How will the second hand value become for the vehicle? All these questions need answers to understand better how they could benefit from ERS. The vehicle has a deprecation time is 8-10 years.

They described the introduction of Volvo MDE (Methane Diesel) hybrid vehicle as an example of new technology. It was difficult as it cost more than 400 000 SEK extra. The government decided to subsidy the vehicle with 170 000 SEK/vehicle. It did not help to get the vehicle to the market as the infrastructure was not there for LNG (methane). Many of the haulage contractors believe in LNG as it exists in the whole EU but it is important to have a system that cover more than Sweden as the companies are in whole Europa.

Electric and hybrid vehicles also mean that the vehicles become heavier and therefore the driver needs more skills and a more advanced driver license, C-driver license which is more expensive and harder to achieve.

If the hybrid vehicles are profitable to be used in the ERS, somebody has to do the investment for the infrastructure. One idea is that the government could give a loan for the investment to get in place. Is the amount of ERS too few, nobody will invest in hybrid vehicles as the profitability only come when many stretches are electrified. When the vehicles are profitable there could be a payback system for the governmental loan.

How do we calculate decrease of CO_2 emissions from transport? Not in absolute numbers. If you buy a company then the CO_2 increases. Shall you use tonkm? Then the customer mix is essential, what kind of goods that is delivered. Big, heavy and short distances is much better than light goods on long distances. Shall you calculate the costumers emissions or the emissions from the truck? The problem is how to allocate the emissions. Today there is a CEN standard which is good for calculating CO_2 emissions. The most important is that everybody use the same system and calculations so the measurements can be compared.

The transport companies are working with ”triangle” Malmö – Stockholm, Göteborg – Stockholm, Malmö – Göteborg. It is called line traffic and they go to logistic centers with a distribution net for smaller vehicles that exist in all bigger cities. Line traffic goes shuttle traffic to every center and that traffic can be of interest for ERS in the future. Haulage contractor could join a demoproject but the proposal has to be more concrete. They wish that at least Sweden decides what should be used. Alternative fuels is a mess today and so is the regulatory system

Ports

Ports usually have shuttle traffic that could be very useful for ERS. For example the port of Göteborg, the largest port in Scandinavia with 11 000 ships/year, has its own shuttle traffic with trucks that are 48 m and weigh 120 ton. The fuel consumption is 1-2l/km. This application would be a very interesting stretch for ERS. Today there are less than 10 trucks/day but the volumes are increasing. The port is very interested to get involved in demoprojects as it would give the port a positive image.

Retail chains

with a couple of the leading retail brands in Sweden as well as one leading international brand has been carried out. We will not disclose the brands because the answers varies extremely much depending upon how the interviews were carried out and for how long the interviewed person/organisation has been aware of the ERS concept. The conclusion is that the longer a person has been aware of the ERS concept the more positive the person is. Another observation is how the information process affects the interviewed person. Rather predictable, a personal meeting using “professional sales” methods resulted in a more positive attitude towards ERS than a unpersonal email interview. This is a bit frustrating since we did a quite extensive research to identify the person in charge of transport strategies and policies. Below are some of the answer we got in response to our core questions:

Is ERS an alternative for your business?

- Yes - ERS is definitely an alternative for our business, if this alternative existed, we would compare it with other alternatives and we are willing to pay a premium for fossile free transports.
- YES - ERS is of interest to ensure our business operation in the long term - we are extremely dependant on transports.
- No - we don’t believe in ERS at all, especially not in Sweden because of the small and widespread population making the infrastructure extremely expensive. Great Britain or Holland is better suited for ERS.

How would your business concept look like in a ERS for the large highways?

- Our business concept will not be affected at all of ERS since all our transports are outsourced to haulage subcontractors
- We believe our offering to end users can benefit from a fossile free alternative and that the end user are willing to pay for it.
- We don’t see ERS this in Sweden within the foreseeable future.

Is the reduction of CO2 a sufficient driving force for ERS?

- Yes, if the CO2 reduction is big and the consumer is willing to pay for it.
- No, we think energy price and supply is a stronger driver
- No, except in a catastrophic scenario where nations are forced to drastically reduce emissions

Are you interested to further discuss to be involved in a demo project?

- Yes, we are interested to be involved
- Yes, we are interested to be a part of the demo project
- No, we are not interested but we want to be informed about progress.

Study tour USA, Electrified roads

The Californian governmental organization Air Quality Management Department for Eastern Pacific (AQMD) is the air pollution control agency for all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties, the smoggiest region of the U.S. They are committed to protecting the health of residents, while remaining sensitive to businesses. AQMD has had many studies and reports how they can reduce, going towards zero emission vehicles to transport goods from L.A and Long beach ports. There is a freeway, “710”, 17 miles long that has extremely high traffic frequency of heavy duty transport and passes many residential areas, 30 000 heavy duty trucks/day. Today, AQMD only finds one solution to reach zero emission traffic and that is the ERS. They have therefore decided to use the Siemens system with both battery and hybrid trucks.

The purpose of the study tour was to learn more about the activities in California regarding ERS by visit the partners who were closely related to the Port of Los Angeles demo project for electrification of heavy duty trucks. The project was already in the planning phase and completion phase of a startup when we visited. It is run by AQMD. The consultancy company Gladstein is the project manager to put the project together and ensure realization. Transpower will rebuild the trucks and the local governmental body Metro Los Angeles , who is owner and responsible for all highway within L.A, have started the I-710 Corridor project to aim at developing solutions to improve air quality and public health, safety, and the design of the existing freeway.

In the study we report from the different discussions we have drawn the conclusion that a useful collaboration could be in the following areas:

- Grid impact studies
- Standardization
- Business models
- ERS cost
- Public perception
- Parameters to be measured during the test (NREL)

AQMD (Air Quality Management District) South Coast

www.admg.org **(** 21865 Copley Dr ▫ Diamond Bar, Los Angeles CA 91765)

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AQMD has a clean fuel program of 10-12 M$/year. The work that is funded is research but focusing on implemented research and demonstrations. For example will they introduce battery buses, to start with 6-8, into the L.A area and the buses are taken from BYD in China. They also work with stationary fuel cells for electricity production that could eventually go into transport. The feed stock is hydrogen but also waste gas from different biological sources. In L.A it is a lot of focus on CNG for transport as they have natural gas surplus. The argument for gas is "It is better and cheaper than diesel". The source is also landfill gas but there is a problem for ICE because of the contaminant SiO_2 which comes from the cosmetic products like shampoo and soap. Waste water sludge is also used to make methane.

AQMD are very interested in electrification of transport and their driving force is zero emission on a local level. They are most concerned about particles and NO_x, especially from diesel engines and demonstrate a plug in hybrid truck to be used in the city. They have also ERS could also be a solution, AQMD has looked into many technologies such as taking electricity from underneath like induction (MAGLite) or conductivity (Volvo system was mentioned). The only technology applicable today is the overhead lines and catenary already known from trolley buses has the highest priority now. AQMD has just signed a contract with Siemens and their system together with a hybrid truck from Volvo as sub-contractors to electrify one mile of the Almeria road where the trucks shuttle from the port to the railway station. AQMD is also signing up to use different trucks, one will be the Volvo diesel hybrid truck, another is a fuels cell hybrid truck. A third one is based on CNG-hybrid and a forth will be pure electric. This is to test if the electric truck can leave the electric line for at least 30 miles without ICE to ensure zero emissions. The system they have decided is an open system which is important for the demonstration part. The demo project will only cover one mile but the future thinking is to electrify 17 miles, freeway 710. Siemens is very interested to deliver their system for the whole route. Today, Metro is the owner of the system and so far the investment will be public funding. No discussions at AQMD around different business models and how the investment could be funded but there is a budding interest for this issue.

They are not worried regarding safety as they already have a quite extensive system for light weight rail which is run by electricity. The heavy trains for goods are run by diesel in USA.

The first thing to be done now is to make an environmental study for building the infrastructure. Responsible for that is The Southern Interior Construction Association (SICA). The responsibility for the infrastructure is the governmental California department of transport, Caltrans. A lot of information has to be gathered for the environmental report which could be used in a collaboration with Sweden.. The time table is to start in September and to be finalized in 6 months. The construction is planned to start in May 2014.

Electricity in California is mostly imported (from other US states), 40%. CA produces around 5-8% renewable electricity and the rest is made out of natural gas. No coal is used. The peak production is 55 000 MW. An estimate is that CA uses 45 000 MW at the most which means that there is around 10 000 MW left for transport. The problem is the charging system with much higher prices when peak hours. Consequently the electricity is much more expensive than diesel fuel during peak hours and the economic incentive to use electricity is not there. If CO_2 had a value, the situation could be different but so far there are only discussions around carbon emission trading but not yet effectuated. California is driven by local emissions and has a federal mandate to reduce particulates and NOx until 2023. The only way to do that in a short time is to electrify parts of the transport system according to AQMD..

The meeting with AQMD ended positively and a closer collaboration and sharing of information will be of interest to avoid common mistakes when planning and realization of the demoprojects. Standardization has high priority. It is important to start early to set common grounds and parameters. An ISO standard for electrification of heavy duty vehicles would be interesting to work with together.

Metro

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Gateway cities

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Jerry.R.Wood, consultant

Council of governments

Metro is working mainly with environmental studies for all transports in the area of L.A. They work together with Caltrans and other governmental bodies. Adrian has an assignment to look into the ports and the environmental effects of transporting goods to and from ports. Within the L.A area there are two of the largest ports in the world, L.A port and Long Beach port, and the traffic is extremely heavy. The ports transport 14 million teu/year and are planning to expand to more than 40 million teu/year. This means that there are 30 000 trucks/day on the port roads already now which will increase heavily. The most important road is the Freeway 710, a stretch of 17 miles that goes through the whole city. On one side there is the railway track and on the other side you find people`s houses. So it is a delicate issue as the local pollutions are increasing and the disturbances from heavy trucks with heavy congestion and noise.

The plan for the road is to use zero emission trucks, either electrification or fuel cells. The trucks are also supposed to go outside this zone for around 30 miles with zero emissions, which will be a challenge for the OEM. Metro is looking into how to commercialize the stretch. Tolls are discussed and also subsidiaries to make zero emissions technologies come true. No trucker wants to invest in a 200 000 $ hybrid truck today if there are not good enough incentives. The government has good experiences from subsidies to change technologies and habits. A few years ago they decided that all trucks in the port area should have the best environmental standard available (which was not the case before). The government put 200 million $ for incentives and also strong regulations to make it happen. Now all trucks in the area have the highest emissions control possible, like Euro 6.

The Metro Board of Directors has recently initiated a program to explore the use of Public-Private Partnerships (PPPs) to accelerate delivery of highway projects. The overall purpose of the PPP highway program initiative is to establish an approach on how to identify, assess and implement projects using private sector participation, with the overall goal of accelerating Metro's delivery of highway projects in Los Angeles County. The initiative was recently introduced to accelerate transit projects in Los Angeles County. At the same time, the Board adopted a policy to combine long term countywide sales tax revenue with alternative project delivery and financing methods for highway projects.

Metro is also discussing which technology that would fit the best. All want to have the electricity from underneath but have not yet found a useful and possible technology for that. They are very interested in the Swedish Slide in project and would appreciate to get some type of report if possible.

GNA Gladstein, Neandross &Associates

www.gladstein.org

Patrick Couch, Project Director

GNA is a consultancy company and they work very closely with AQMD on the Siemens project. Patrick had just finalized a meeting with the AQMD board where it was decided to write a MoU to get started on the project. Now Patrick is waiting for a clear signal to get started on the environmental study. The plan is to start now and finish the study within at most 6 months. After that the plan is to start build and 2015 the system should be up and running.

GNA has made a cost analysis study, which showed that the catenary with overhead lines is the most cost effective way to electrify trucks to get zero emissions. Conductivity from under, which Volvo had shown, is not safe enough. Induction is hard to use and not enough is known. Overhead lines are very similar to trolleybuses and they are standardized which is a very good start.

Patrick thinks that the demo project will start and maybe lead to new projects but only for niche markets. He does not think it will be a solution for general long distance transport of goods for a long time in the US.

The railroad companies own their trucks and it is hard to get them to invest in more expensive trucks like hybrids if not necessary.

The public perception when new technology is introduced is very important and we could help each other with this. The demo project needs to include this issue in a serious and thorough way to ensure that the technology used is not turned against the users. The discussion about overhead lines is a reality and overhead lines are not popular especially if the benefits are not very clear. Patrick suggested that we worked together on this issue.

NREL- National laboratory will measure different parameters from the whole demo project and make a report of the results. The parameters used could be of interest and could be discussed between Sweden and US to have a common idea what are will be important specifications for the final projects.

The final goal for all involved in the US project is to have zero emission greenhouse gases 2050.

GNA is interested in cooperation in different fields like

- Grid impact studies
- Standardization
- Business models
- ERS cost
- Public perception
- Parameters to be measured during the test (NREL)

We also had a short fuel discussion and natural gas is the future fuel for USA because there is so much of it. The Gladstein company will also build a DME plant together with Obreon. Volvo will also be involved. The feedstock will be natural gas to start with. The plant will be finalized 2014 (5 tons/day) (http://www.oberonfuels.com/2013/06/07/oberon-fuels-brings-production-units-online-launching-the-first-north-american-fuel-grade-dme-facilities/).

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TransPower's mission is to develop and commercialize advanced power generation and conversion technologies that improve efficiency, reduce fossil fuel consumption, and improve the environment.

TransPower is committed to the success of the partnership with Siemens to demonstrate the catenary power system for trucks, even though they foresee some issues that need to be addressed for widespread use of such a system to become possible. These issues include galvanic isolation of the catenary power source, which could require expensive additions to the equipment needed on every truck using such a system, along with the environmental and permitting issues associated with any catenary infrastructure. Time will tell whether sufficient funding will be committed to resolve these issues and enable broad use of the technology. TransPower believes catenary propulsion is one of several zero-emission technologies worth pursuing for large trucks, and are glad to be in a position to become involved with a few of these various efforts. TransPower very much looks forward to working with Swedish projects to test and evaluate catenary systems in Sweden and to discussing other relevant technologies.

Rebuilt of a Kalmar Cargotec truck to electric truck

Battery pack for a heavy duty truck

Attachements

1. Execute Contracts to develop and demonstrate Catenary Zero emission goods movement system
2. Zero Emission Vehicles: Emerging Technologies for Trucks and Goods Movement

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Elektrifiering av E4 Södertälje-Helsingborg – översiktlig samhällsekonomisk kalkyl Grontmij AB Mattias Haraldsson

Lokalisering-, intressent- och finansieringsutredning för en demomiljö av elvägar.
Juni 2013 Per Ranch, Projektengagemang AB

http://studentarbeten.chalmers.se/publication/175334-comparative-lca-of-electrification-alternatives-for-long-haul-trucks-the-case-of-iron-ore-powder-tra