Advocating Battery swapping as a complementary solution for electrification of heavy transports

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Summary

- Battery electric heavy trucks (BEHT) are entering the market. The standard charging solution in Europe is cable based. The capacity of charging is moving towards fast, superfast and mega charging
- Cable charging of BEHT will in many scenarios not support the market needs as a single generic solution for electrification, it is not sufficient from a logistics, business, and efficiency perspective. We see a risk that cable charged BEHT will not reach a full market penetration, due to charging solutions and its limitations
- Building a large enough charging infrastructure fast enough, will be a challenge which will further reduce transportation companies willingness to invest in BEHTs
- Nor will electric roads be a solution for other than specific and limited applications. The infrastructure is extremely expensive and cannot be expected to cover more than a fraction of the roads and transport volumes
- Battery swapping is a market and customer oriented technical concept meeting the needs of the transportation companies. It also has many advantages regarding the electric grid, electricity distribution, simplifying the expansion and decreasing peak effect demand, offering fast “refueling” and lower total operational cost
- Building an infrastructure for battery swapping will be significantly less expensive, more flexible and can be done faster, than building a corresponding support for cable charging or electrical roads.
- The technique is in full operational and business use today. It is well studied and rolled out at high speed in China, where already a third generation of swapping stations are on the market. By 2025 Chinese operators will have established more than 25,000 battery swapping stations for passenger vehicles and more than 600 battery swapping stations for heavy trucks.
- From an operational perspective, there is no reason for choosing the fixed battery standard, there is simply no advantage to it. A truck with battery swapping can do everything a truck with fixed batteries can do, including charge by cable.

The main reason we are now heading down the one-way alley of cable-charging, is because of the strategy and business considerations of the European truck manufacturers, not because it is deemed a superior solution from a system perspective. And not because a national strategy or responsible authorities (Trafikverket and VTI) concluded it is the best strategy.

We are convinced that battery swapping as a concept will reach the European market within short, it´s already been introduced for passenger cars and machines for mining and other applications. We argue that European heavy truck manufacturers needs to prepare for this and that we as a society should not wait too long and invest too much in solutions that will risk being obsolete in a few years' time. And most of all, we cannot risk losing important time in reaching the climate goals!

Electrification of heavy transports may well be the most revolutionary and overthrowing process, since steam was introduced in transportation some 150 years ago. What since then slowly evolved into a globally integrated transportation system of enormous proportions, will now dramatically change in just a decade. The outcome is unpredictable, but it is a good guess that the transportation ecosystem will look dramatically different 10 to 20 years from now. Electrification, digitalization, AI and autonomous trucks and ships will be change agents in a transforming market where some investments and competence will be obsolete, old companies will disappear and new emerge. Kodak and Facit are well-known examples of how new technology and innovative companies can change everything. It is no secret that the competitive advantage for dominating truck manufacturers, to a large extend has been built on the diesel powertrain. Such competence and strength is now quickly devaluated and soon obsolete, which opens up for new fast growing actors, which Tesla and NIO are examples of.

With all this uncertainty we still need to act fast, climate change gives us no time to hesitate. From a political perspective we observe and appreciate a strong determination to act, however we miss a deeper analysis and a systemic view on the transportation system.

The slow process that has shaped today's transportation system, is not the result of a political strategy, it´s rather been an "evolutionary process" where companies, legislators and technology gradually has adapted and changed when new conditions and opportunities has developed. We believe that today's fast "revolutionary process" needs more of overall, systemic analysis and strategy. Action is important but so is direction, ability, and feasibility! The risk we run today is that we mistake large investments, intense activities, action plans, reports and talk, for progress. The vertical way of organization everything; legislation, authorities, municipalities, projects, companies etc, is now maybe the greatest threat to a successful electrification process. Lot´s of activities and money, is no guarantee to overcome that.

Maybe the most fundamental argument for a better electrification strategy, is that the logistics system needs to be efficient AND fossil free! Goods needs to be moved from truck to rail and see, filling rate needs to be high, and routing needs to be efficient. The driver of a truck is often the highest cost component and already today there is a growing shortage of qualified truck drivers. Hence, the exploitation of driver time must be optimized and well utilized. As must the usage of new, expensive electric vehicles. To build a new transportation system on conditions that vehicles and drivers idle time will increase, means the opposite. "Only 90 minutes charging time!" for 200-250 kilometers, is declared great, while in any calculation it will be a considerable loss. Increasing planning complexity by introducing planning for charging, will further decrease efficiency. Instead of optimizing logistics, we will

have to optimize the charging strategy. The performance of a new electric truck with a battery of 500 kWh able to charge at 1MW is of course impressive. But comparing a single electric truck with a diesel version, is not very relevant, when trying to change the transportation system. We need a more comprehensive and systemic analysis and strategy for electrification of heavy trucks! Cable charging as a single solution risks an overall lower logistics efficiency.

Finally, fossil free alternatives for heavy trucks has been around for a long time now, while companies, authorities and government constantly have been talking about great progress and bold targets. It all sounds fantastic, but in reality, fossil fuels still dominates and the market penetration of non-fossil alternatives has been slow. Not to lessen the efforts and the progress that has been made by a few companies and organizations really putting their mind to it, but in reality transportation is a business where short lead-times and low cost still rules. HVO or RME can be used in any diesel engine with little or no adaptation and the operation can go on as before, it is just a matter of cost. Electrification is totally different, introduced in scale, it will change a lot of today´s way of working. And it will be more expensive and less resource efficient, unless we manage to develop logistics to increase efficiency. So given the lack of success so far, the current electrification strategy is not reassuring.

Challenges of cable charging in short

- Does not answer to the full needs of transportation companies regarding range, uptime and flexibility
- Risk of reduced transportation efficiency
- Slow, inflexible and expensive development of infrastructure
- Fast and mega-charging will create electrical peak demands on the grid

Other solutions

Hydrogen is a technology in which many actors have great expectation. No matter hydrogen possibilities in the future, the technology and market availability is still lagging behind BEHT. If transportation companies now hesitate about the business feasibility with cable charged BEHT, it´s a significant risk they will wait for the hydrogen technology, which will delay the electrification process. For a transportation company hydrogen technology as such, has a great advantage over BEHT due to less weight, long range and less standstill. It´s therefore understandable if companies consider waiting, instead of investing in BEHT now. LBC, liquid biogas is also appreciated by Swedish transporters, much by the same reasons. It is equally fossil free, here it´s EUs roadmap about emission free road transports, that currently creates uncertainty.

In parallel electric roads are discussed and tested as a solution. With the same systems perspective on cable charging, we argue that electric roads do not have the potential to solve anything significant. It´s extremely expensive and would only be a solution for trucks operating back and forth on the main highways. In most fleets there is a need for flexibility to insure resource efficiency and trucks often operate on different routes. To bound single trucks for operations on certain roads, including how far they can travel leaving the electric road, will complicate matters. There is a lot of technical studies and costly experiments on

electrical roads, but so far, we have not seen any systemic analysis of how this technology will fit in a future electrified transportation system. From a technical perspective it´s an interesting concept which anyone who has been playing with electric racetracks as a kid, can relate to. But from a systemic perspective we do not believe it´s a solution of relevance.

The concept of battery swapping (BS)

BS as an alternative to cable charging of BEHT, means the truck simply exchange an empty battery for a fully charged and get on it´s way again in a few minutes. Much the same as you do with electrical hand-tools and have been doing with electrical forklifts since long. Basically the same type of truck is used with the only difference the battery is not fixed to the body, but can be lifted off and replaced in an atomised BS-station. A BS vehicle may be charged via cable as any BEHT, which makes it flexible according the needs of the transportation company.

Battery size can be adapted to current needs, which means vehicles do not need to carry excess battery capacity to handle a “worst case”, resulting in higher paying load. In the system as a whole the total battery capacity will for the same reason be less, even though the number of batteries will be slightly higher (1.2 batteries/vechicle), in comparison to a cable-charging system

For a transportation company where fleet management, efficiency and business are crucial, there are several obvious advantages with BS. From a network perspective BS is also favourable due to charging of batteries in the swapping station is done at low effect and peaks are avoided. Slow charging is also positive for battery health which has a great impact, since approximately 50% of the vehicle value emanates from the battery. Finally the infrastructure for a swapping station is less space consuming than building large parking-lots for charging trucks and installing fixed grid capacity.

The development in China

The modern story of battery swapping starts with Tesla establishment in 2002. Few people know that Tesla designed their car for battery swapping and established one fully automated station between San Francisco and Los Angeles. Finally, they choose to commercialese cable charging. As Tesla was the first electric car there was no market, no cars and thus low demands for charging. The entire focus was on cars.

The Israeli Better Place took on the idea and developed fully automated battery swapping stations, collaborated with Renault in designing 600 electric cars for their system. Also, this time the timing was not right, and the market was not in place, and the main barrier was that OEMs did not want to open the full car architecture control. Better Place collaborated with several partners, also in China. The rapid development of electrical cars and the escalation of sales volumes made Chinese actors early realize the consequences on charging infrastructure and demands on the energy supply and grid system. Thus, the Chinese actors chose battery swapping as a complementary system solution to established cable charging. Now China is taking the lead in this direction.

Our research shows that by 2025 China will have set up 25,000 battery stations for passenger cars and 600 for heavy trucks. From 2021 one Chinese car manufacturer (NIO) has established a battery swapping system in Norway and 92% of their customers chose battery as service solution, meaning they buy the car and lease the battery with full capacity flexibility. By 2023 several heavy trucks manufacturers intend to establish operation in Europe based on battery swapping technology.

Link to report from Sweden China bridge-project: https://logistikia.se/publikationer/1076/

Our proposed scenario

The province of Östergötland is an important logistical region in Sweden. For over a year, a number of parties have collaborated to increase the regional capacity in the electrification of freight transport in the province of Östergötland and south of Sweden. With the initiative "Snabbspår Östergötland" a strong environment for establishing broad and thorough pilot projects for electrification of freight transport, has been established. We are well prepared to scale this initiative to it's full potential, in steps establishing the first European demonstrator for the battery swapping technology.

Specifically, a group of 15 organisations have agreed to set out for a commercially oriented pilot project to establish and operate battery swapping stations in the region to start with, and expand to cover south of Sweden in steps. The parties are all organizations with highly set climate goals and consider the solution with BS as a potentially important enabler to reach those goals under commercially acceptable conditions. Together, the parties represent major parts of the established logistic eco-system – Large transport buyers, carriers, energy producers and grid operators, in combination with strong support from academic research, province and local authorities and a regional network that includes both companies, municipalities and region Östergötland local government.

We have elaborated a scenario where in 4 steps a battery swapping infrastructure with 40 stations can be developed in 2-3 years, covering the south of Sweden, an area which counts approximately 80% of registered heavy trucks today. In China the cost of a battery swapping station equals 25 MSEK corresponding to a total investment of around one billion SEK for a Swedish network. In this context it is a rather small investment. The roll-out scenario is briefly outlined below.

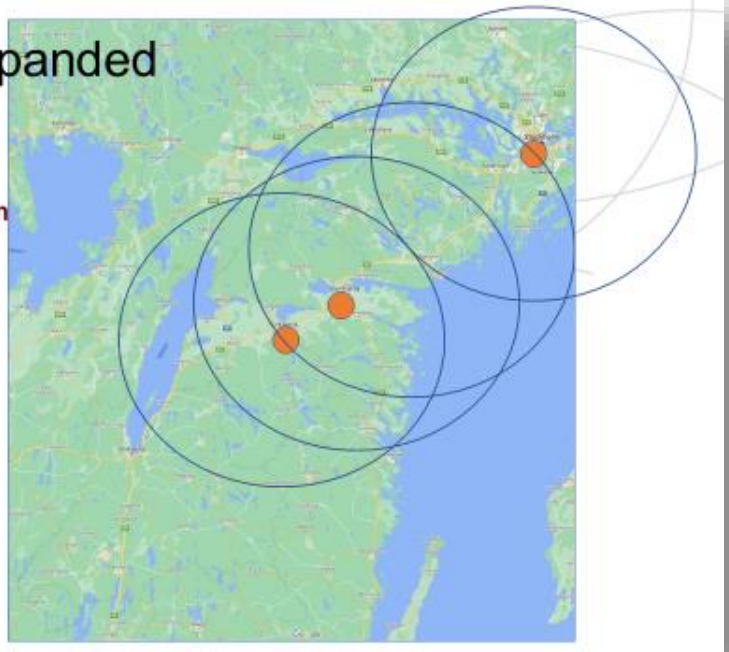
Initial setting and expanded

Östergötland – Stockholm freight commuter

Linköping, Norrköping and Stockholm battery-swapping stations

Operational range 200km between swapping stations

- Initial setting 10 trucks
- Expanded 30 trucks



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Stockholm - Jönköping

7 swapping stations
150 trucks in local and regional traffic

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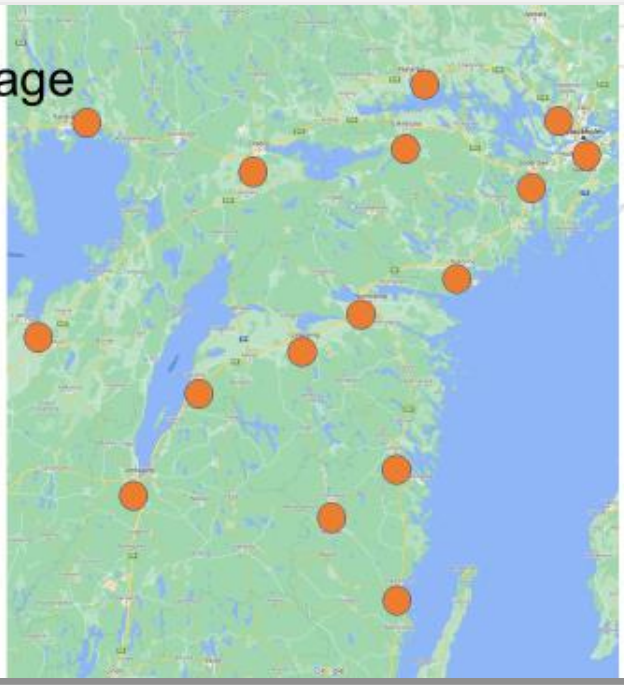
East Sweden coverage

Covering Region Östergötland+
16 Swapping station, 400 trucks



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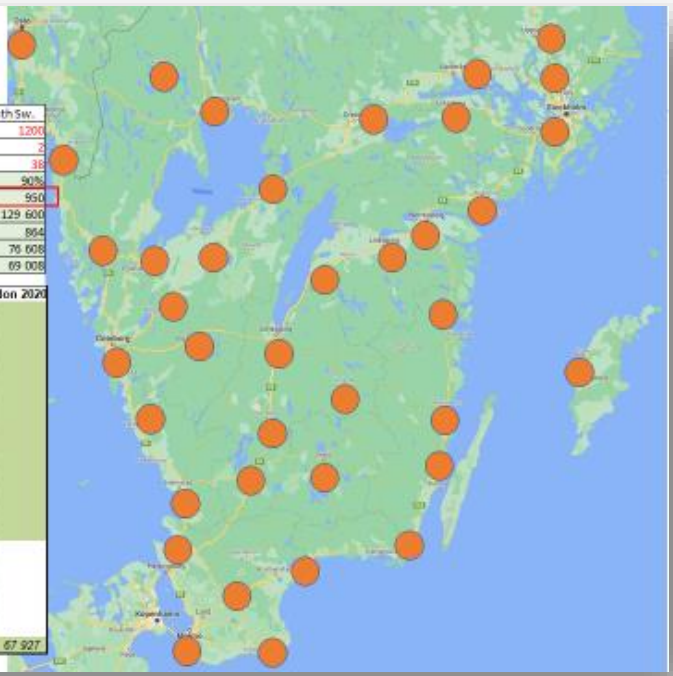
South of Sweden

38 swapping stations, 1200 trucks

Project phase	Start	Expanded	Sthlm-Jkpg	Österg.+	South Sw.
No of trucks	10	30	150	400	1200
No of swaps/truck and day	3	2	2	3	2
No of swapping stations	1	3	7	16	38
Capacity usage swapping stations	10%	29%	61%	71%	90%
Investment bs stations (MSEK)	75	75	175	400	950
Total MWh usage/year	1 080	3 240	16 200	43 200	129 600
Gross revenue swaps/year (MSEK)	7	22	108	288	864
Gross profit swaps/year (KSEK)	50	151	1 764	10 752	76 608
Net profit swaps/year (KSEK)	-550	-449	364	7 552	69 008

Swapping capacity per station	70
Average power cons. (kWh/km	1,2
Average km/day and truck	300
kWh/swap	180
Investment per swapping station (MSEK)	25
Price/swap	1200
Operational days/year	300
Cost/kWh (charging) SEK	3
Gross profit/swap	840
Yearly op. cost/swapping station (KSEK)	200

Län	Tunga fordon 2020
Stockholms län	13 950
Uppsala län	2 656
Södermanlands län	2 019
Östergötlands län	3 648
Jönköpings län	3 532
Kronobergs län	2 065
Kalmar län	2 282
Gotlands län	674
Blekinge län	1 031
Skåne län	12 046
Hallands län	2 880
Västra Götalands län	13 809
Värmlands län	2 750
Örebro län	2 595
Västmanlands län	1 992
Dalarnas län	3 166
Gävleborgs län	2 837
Västernorrlands län	2 568
Jämtlands län	1 779
Västerbottens län	2 749
Norrbottens län	3 300
Summa	84 326 67 927



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