Energy in the Transportation System

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How would the ideal electric vehicle (EV) charging network look in the Swedish context, and how many EV batteries will there actually be in the future? While these questions hold significance, definite answers continue to elude us. They are, however, linked. With each charging technology, there is a connection to the desired battery sizes. Simply put, convenient charging processes can often reduce the stress of not having enough driving range to cover the entire journey in one charge.

The message is loud and clear: global climate change is calling for urgent action, all sectors and countries included. Notably, the transport sector ranks as the second-largest contributor to yearly greenhouse gas emissions worldwide, even making it to the top of the list in Sweden. One of the main contenders to cut the emissions from transports is electrification, which effectively eliminates tailpipe emissions. Nevertheless, this solution presents its own set of challenges. Two key concerns associated with electric vehicles (EVs) are battery sizes and charging availability. After all, vehicles are more than just modes of transportation; they are instruments of mobility. This purpose has to be upheld, ensuring that traveling from point A to point B without worrying about the driving range is not an issue. To alleviate such anxieties and foster widespread EV adoption, a combination of factors is vital. A battery with sufficient capacity and a robust charging network together form a recipe that can effectively soothe EV range anxiety - essentially, the fear of getting stranded due to insufficient power.

The most commonly encountered ways of charging today are fast and slow cable charging, with electric road systems (ERS) and battery swapping (BS) as two of the contenders. ERS commonly revolves around dynamic charging while driving, whereas BS offers a rapid switch of discharged batteries for charged ones. A swap takes 3 to 6 minutes for both cars and trucks, significantly shorter than its fast charging (FC) counterpart. It is a mature technology that has gained significant ground in China, but has not yet reached large-scale deployment in Europe. A prerequisite for BS is a battery stock in the swapping stations. Batteries of different sizes can be offered, and instead of being a property of the driver, they are owned, maintained, and eventually recycled by BS operators. Some of the merits related to this is that the battery charging can be monitored to reduce battery wear and strain on the power grid. When the batteries are not needed for swapping services, the stations can instead function as energy storage units capable of reversing the energy flow back into the grid. This is particularly useful in the Swedish setting, as more renewable and intermittent energy is introduced into the power mix. The core of this thesis is to uncover the total battery capacity required in a transportation system where BS serves as the main charging technology. This has implications for aspects such as overall battery costs and material consumption. The focus is, therefore, the development of a BS system model, of which the total energy need is measured, and compared to corresponding figures of FC and ERS scenarios.

A MATLAB model was formulated, representing a BS system with capacity to meet the charging demands of a synthetic population of cars and trucks on long trips. Locations and charging needs were predetermined by the input data, while the BS system dimensions were established based on current technology and earlier studies. The total energy need in terms of battery capacity was found and compared to the outcomes of the other charging scenarios. Lastly, a sensitivity analysis of the BS model was conducted to verify the model's robustness, where the impact of the input parameters considered most uncertain on selected results was investigated.

A BS system designed to cater to the majority of all charging needs in a day comprises 150 swapping locations for cars and 29 for trucks. The number of BS stations per site varies depending on the projected traffic flow in the area. The findings show that, when comparing the total energy needs of a BS and an FC scenario, the differences are minimal. BS, introducing additional batteries in the swapping stations, results in an overall energy increase of 0.4% for the car fleet and 7.8% for the truck fleet. A more substantial reduction is observed in the ERS scenario, where studies have shown a total reduction of 60% when compared to an equivalent FC scenario.

What the future holds for the Swedish charging infrastructure remains undefined. The feasibility of BS as the primary charging technology for long journeys depends on several critical factors. Among these, the main obstacle is the lack of unified standards, as it affects upfront costs, utilization rates, and customer satisfaction. The compatibility between vehicles and BS operators may be the deciding factor in whether BS becomes a staple in the charging landscape or not.