ROAD FREIGHT DECARBONIZATION IN THE TEN-T NETWORK IN THE CONTEXT OF FUTURE ENERGY SUPPLY INFRASTRUCTURES

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Motivation

The introduction of zero-emission technologies has been particularly difficult in the transport sector. By now, it has become evident that the one key element along the pathway to a decarbonized transport sector is the implementation of battery-electric vehicles in the passenger car sector. This zero-emission technology has become the most favorable replacement for combustion engines and for the usage of fossil-based fuels. This can be motivated by the triangulation of the following three facts: (1) The prices of battery packs have been constantly lowering, making it the cheapest option of all zero-emission alternatives, and, moreover, also cost-competitive with combustion engines. (2) This technology is also significantly more efficient in its energy consumption, given the minor losses in well-to-tank energy transmission, when comparing the electricity production of renewables and transmission via the power grid to the extraction of oil, energy losses in refinery and in the energy transfer from tank to wheel (77% vs. 21%). (3) Current alternatives for diesel and petrol, including e-fuels and bio-fuels, are less attractive options due to the complex and energy-intensive processes behind the production of these, leading to high costs and limited availability.

While this pathway is more or less determined for the passenger car sector, as well as for light-duty cars, the implementation of zero-emission heavy-duty vehicles is still surrounded by more challenges which are primarily driven by the requirements in the speed of charging/fueling, driving range and cost-sensitivity. Following existing literature on this topic [1], there are two main technologies "competing": Battery-electric and hydrogen fuel cell vehicles. Because of the high maturity of battery-electric drive technology, many experts argue that this will be the main technology to be implemented in heavy-duty road transport. Simultaneously, many decarbonization scenarios project a high share of hydrogen fuel cell-powered trucks. One particular study that assumes a 55% share of heavy-duty transport fueled by hydrogen is dedicated to the planning of the future Hydrogen Backbone [2]. A strong argument supporting a high penetration of hydrogen in the fuel mix includes the range of hydrogen fuel cell vehicles which allows for a more flexible allocation of hydrogen fueling stations which can potentially decrease the transportation costs of the hydrogen between the production site and the refueling station - especially if it is located near or even directly connected to a hydrogen pipeline network.

The objective of this work is to identify if such spatially dependent opportunities will be able to make the application of hydrogen fuel cell vehicles cost-competitive and if so, identify under which conditions in routing, the availability of different hydrogen supply options, and other parameters (f.e. electricity price, carbon price, ...). This is applied to the Scandinavian-Mediterranean corridor which is part of the Trans-European Transport Network.

Method

To answer this research question, a model is formulated that includes the following functionalities:

- High geographical resolution: In order to analyze these local opportunities for the application of hydrogen fuel cell vehicles, the road network is represented on NUTS-2 level. Sensitivities are also conducted at NUTS-3 level, in order to explore the limitations of this geographic resolution.

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- Spatial flexibility: The coverage of fueling demand of a fleet traveling a certain route can be allocated in a flexible way. The location of the coverage of the energy demand thereby determines the allocation of a charging/fueling station. This way, infrastructure can be planned in the most efficient way and allocated with the consideration of local potentials.
- Modeling of the long-term developments in technological share: To observe, the resulting technological share in heavy-duty transport in regard to cost-optimality, the implementation of alternative technologies (battery-electric and hydrogen fuel cell) is observed within the time frame 2020-2050.

This model is graph-based and its main inputs are the infrastructures (f.e. current transport infrastructures, planned developments in hydrogen pipeline network), origin-destination travel demand, and various cost parameters, such as carbon prices and fuel prices.

The output of the model includes developments in technological share within the considered network and required capacities of charging and fueling infrastructure.

Results

Preliminary results indicate that within the studied area of the Scandinavian-Mediterranean corridor, most of the heavy-duty vehicles will be replaced by battery-electric trucks (see Figure 1). Hydrogen fuel cell technology is adopted for the transportation of merely 1% of total travel demand until 2050. Following these initial results, multiple sensitivities were tested in order to explore different potential leavers for the higher penetrations of hydrogen application:

- The delay in further battery technology improvement, causing battery-electric trucks to be a less attractive option.
- The earlier expansion of the hydrogen backbone, leading to early lower costs for hydrogen supply.
- The earlier drop in hydrogen fuel cell vehicle costs.

The results of studying these cases still consequences in a distinct transition to battery-electric vehicles, painting a similar picture of the transition as displayed in Figure 1.

This detected niche application of 1% in the results needs further studying and insights into the specific conditions of these applications.

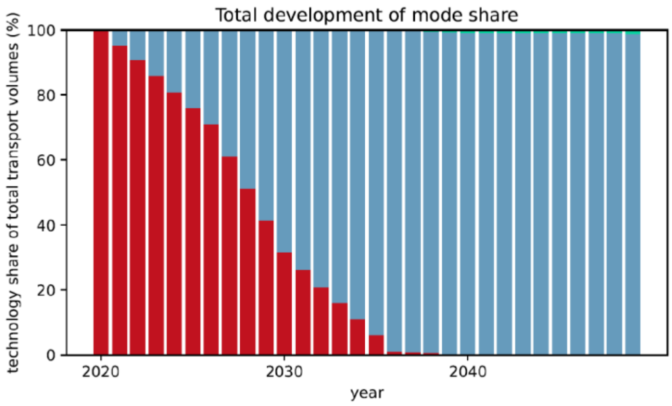

Abbildung 1: Development of in technology share in heavy-duty transport: diesel-fueled combustion engine(red), battery-electric (blue) and hydrogen fuel cell (green).

References

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