Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

In cooperation with the CTI
Energy funding programme
Swiss Competence Centers for Energy Research
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Commission for Technology and Innovation CTI

Decarbonizing the Swiss Heavy-Duty Truck Fleet: Potential of Battery-Electric Vehicles

Heavy-duty trucks produce more than 11% of the transportation CO_2 emissions in Switzerland [BAFU 2017] and their mobility grows roughly twice as fast as the passenger mobility [ARE 2017]. Reasonably, the International Energy Agency calls for electrification of the heavy-duty freight vehicles. In this project, we explore the electrification potential of the heavy-duty fleet of Switzerland – to our knowledge such a study is done for the first time for an entire national fleet. Our research questions are under which conditions electrification of the heavy-duty fleet can be achieved and how the electrification of the fleet affects the CO_2 emissions caused by the heavy-duty trucks in Switzerland.

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Our Approach

Our main sources of data are GTE (Gütertransport-erhebung), a survey on Swiss heavy duty trucks and LSVA (Leistungsabhängige Schwerverkehrsabgabe), the performance monitoring system used to collect the heavy vehicle road tax. We take the vehicle usage profiles throughout the year from these datasets and translate them to energy demand profiles using our energy demand model. We design a battery electric powertrain for each heavy-duty vehicle and check if the new powertrain can satisfy the vehicle's energy needs for 365 days of the year. If a vehicle achieves all its missions throughout the year with the battery electric powertrain, it is electrifiable according to our model. From this, we formulate electrification/ decarbonization potentials using different assumptions of charging power, swapping technology and battery energy density to analyze possible scenarios of technology development in the future.

Maximum CO_2 Mitigation Potential

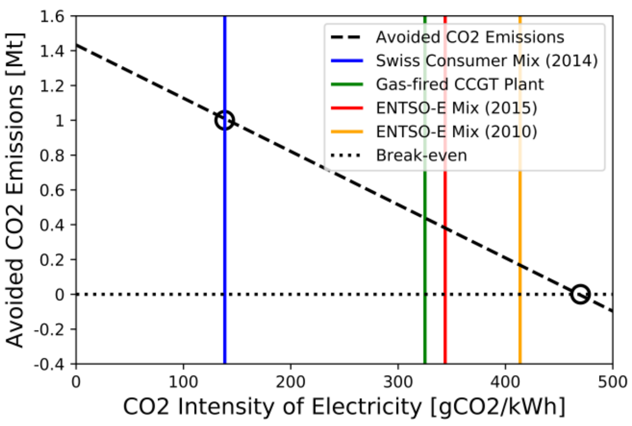

Figure 1: Avoided CO_2 Emissions against CO_2 Intensity of Electricity – Case: Whole Heavy-Duty Fleet is Electrified (BEVs)

Fig. 1 shows the CO_2 emissions avoided when the whole heavy-duty fleet in Switzerland is electrified and demonstrates that the origin of the electricity determines the CO_2 avoidance. With a CO_2-free electricity, 1.43 Mt CO_2 can be avoided, while this avoidance falls to only around 0.4 Mt when a CCGT (Combined Cycle Gas Turbine) plant or the ENTSO-E mix is used. The Swiss consumer mix offers a much better CO_2 mitigation potential compared to these two options.

Better Batteries

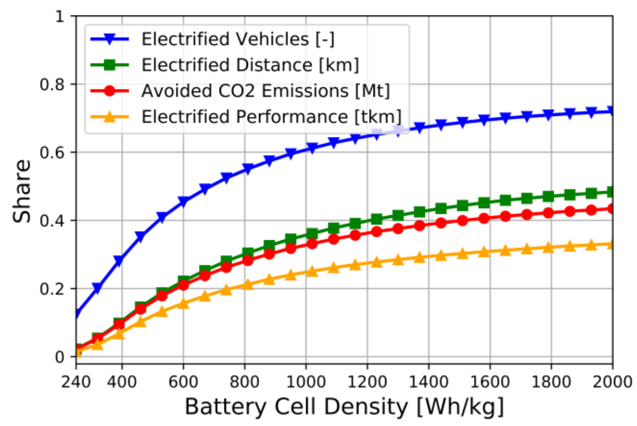

Figure 2: Effect of Battery Density on Electrification Potential and Avoided CO_2 Emissions – Battery Packaging Factor: 70%

Nowadays, the state-of-the-art batteries have battery cell densities around 240 Wh/kg. We investigated the effect of battery energy density beginning from this value up to 2'000 Wh/kg – an unrealistic value for the near future. This showed that even at 2'000 Wh/kg, only 70% of the vehicles were electrifiable and emissions were not even cut in half. The reason for this is not that not enough energy can be stored in batteries, but the power levels today (50 kW) are not sufficient to fully charge energy-dense batteries in the night.

Battery Swapping

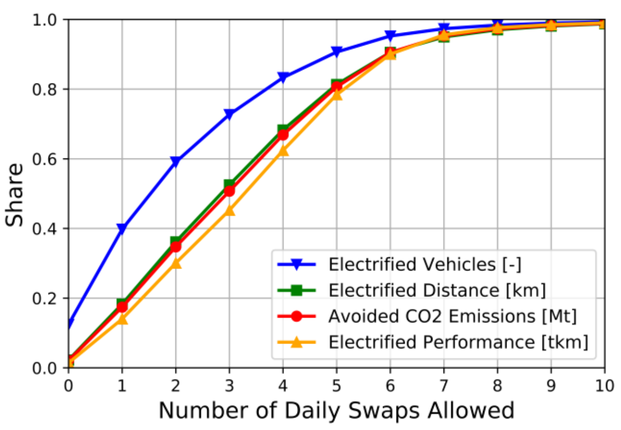

Figure 3: Effect of Swapping on Electrification Potential and Avoided CO_2 Emissions

The dramatic impact of battery swapping can be seen in fig. 3. With three daily swaps allowed, an avoidance of around 50% is achieved, while this avoidance level cannot be reached in the previous figure considering battery cell densities. On the other hand, this development will require thousands of batteries and many swapping stations around the country.

Better Batteries and Swapping

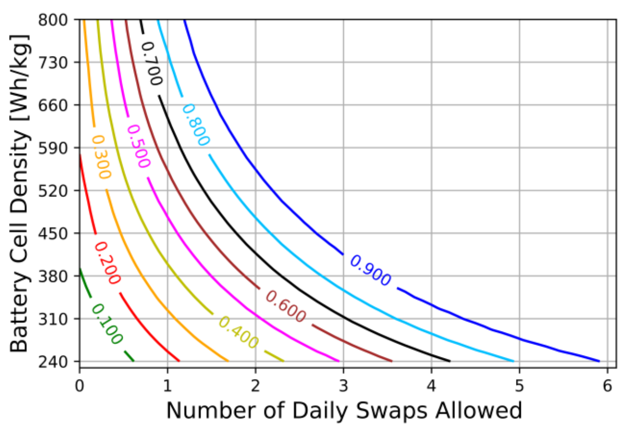

Figure 4: Effect of Battery Energy Density and Swapping on Avoided CO_2 Emissions (Both Together) – Isocurves show the share of Avoided CO_2 Emissions

Fig. 4 shows the cases when both developments occur concurrently. The hyperbolic trade-off curves show the trade-off between the number of swaps and the battery-cell density. For instance, two swaps a day and 315 Wh/kg are enough for 50% CO_2 avoidance – the same can be achieved by either with a density more than 2'000 Wh/kg (fig. 2) or 3 daily swaps (fig. 3).

Conclusion and Outlook

- **Batteries with high energy densities require a high-capacity grid connection** – a charging power of 50 kW will become limiting for batteries in the future.
- **Battery swapping increases the electrification potential** dramatically while this **creates the need for new infrastructure** (building battery swapping stations and storing thousands of batteries).
- **Using both battery swapping technology and better batteries can eliminate the range anxiety to a large extent** and make it possible to electrify the heavy-duty fleet in the future.
- Even if the heavy-duty vehicles are electrified**, the amount of avoided CO_2 emission depends heavily on the electricity mix used.**
- In the next step, the decarbonization study will be performed for **fuel cell and plug-in hybrid trucks**

References

[BAFU 2017]: Entwicklung der Emissionen von Treibhausgasen seit 1990 (2017)
[ARE 2017]: Perspektiven des schweizerischen Personen- und Güterverkehrs bis 2040 (2017)

About us

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LAV's energy systems group specializes in the technology assessment of energy conversion technologies and the analysis of interconnected energy ecosystems, including mobile systems and their supporting infrastructure(s). Further activities revolve around stationary power generation, in particular decentralized, biogenic CHP plants.