***Electric mobility in Switzerland: how many Teslas can the system deal with?***

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## Overview

As envisaged by the Energy Strategy 2050, Switzerland aims to reduce greenhouse gas (GHG) emissions by 80-90% by 2050. This ambitious goal presupposes decarbonization of the transportation sector which A suitable approach is to increase the share of electric vehicles (EVs) in the transportation sector. However, deployment of EVs and corresponding additional electricity demand will affect electricity markets and particularly market prices. The main goal of this paper is to quantify the interactions between electric mobility and electricity markets in Switzerland in 2030 and 2040.

## Methods

In this paper, we extend Swissmod (Schlecht & Weigt, 2014), a customized dispatch model for Switzerland and Central European electricity markets, with an electric mobility model that takes into account the particular characteristics of electric vehicles and the resulting new demand patterns. In order to obtain customized data on Swiss reality, two other models were linked to our model framework. Data regarding electricity generation mix and consumption developments are provided by the Swiss TIMES energy system model (STEM)(Kannan, Panos, Kober, & Luh, 2019), while detailed transportation patterns of EVs are developed by BedDeM (Nguyen & Schumann, 2020). This paper focuses on analyzing the effects of alternative charging behavior, namely instant and smart charging, on the electricity system outcomes such as European and Swiss electricity prices, charging costs, and revenues of hydropower plants in Switzerland. In instant charging behavior, the EV owners connect their vehicles to the grid right after every trip and let the batteries get fully charged, if possible. With smart charging, the EV owner allows a planner to assign the charging time to minimize the operational costs of the electricity system while assuring that the battery is charged enough for the next trips.

## Results

 Results indicate that even though Swiss electric mobility has rather minor effects on the average European indices (e.g., average price), Swiss EVs and their charging behavior have a noticeable effect on Swiss prices. For instance, compared to having no Swiss EVs, instant charging in Switzerland increases the average Swiss prices by around 3.7% and 14.1% in 2030 and 2040, respectively. In contrast, smart charging in Switzerland increases the average Swiss prices by only around 3.1 % and 1.6%compared to no EV casein 2030 and 2040, respectively.

The effect of charging behavior on the EV’s charging cost is considerably higher than its effects on average Swiss prices. More precisely, implementing smart charging leads to considerable savings on EVs’ charging costs. For instance, in 2040, implementing smart charging leads to an average charging cost that is on average almost half as much as if instant charging is implemented. In other words, choosing the smart charging approach over instant charging may lead to not only considerable system-wide improvements (such as lower market prices) but also direct profits for the EV owners which may be around 70 and 239 million CHF annually in 2030 and 2040, respectively. Such saving potentials indicate that there is a profitable business case for private aggregators who manage the charging behavior of EVs and participate on their behalf in the wholesale electricity markets.

Given the importance of hydro energy in Switzerland, we also analyze the effect of EVs on hydro plants. Revenues of Swiss hydropower plants are affected by charging behavior. Comparing average revenues in the no mobility case with the case with mobility shows that all hydropower plants on average benefit from increased consumption in Switzerland caused by the entrance of EVs. Hydro plants benefit more under instant charging since instant charging drastically increases peak hour prices, which are the periods in which dam plants focus their generation.

## Conclusions

In this paper, we quantified the effects of charging patterns on electricity markets. We showed that a smart charging pattern has a huge potential to reduce not only charging costs but also the consumption costs in the whole electricity sector. However, achieving such savings requires regulatory and technical adjustments that allow for the implementation of smart charging.

## References

Kannan, R., Panos, E., Kober, T., & Luh, S. (2019). *Updates on transportation module and development of STEM elastic variant*. (July).

Nguyen, K., & Schumann, R. (2020). A socio-psychological modal choice approach to modelling mobility and energy demand for electric vehicles. *Energy Informatics*, *3*(S1), 1–18. https://doi.org/10.1186/s42162-020-00123-7

Schlecht, I., & Weigt, H. (2014). *Swissmod A model of the Swiss Electricity Market Swissmod - A model of the Swiss Electricity Market*. (April).