THE VALUE OF VEHICLE-TO-GRID FOR THE SWISS ELECTRICITY SYSTEM

Ambra M. Van Liedekerke, ETH, Reliability and Risk Engineering, Leonhardstrasse 21, 8092 Zürich, Switzerland, +39 3319190549, avanliede@ethz.ch
Marius Schwarz, ETH, Energy Science Centre, Sonneggstrasse 28, 8006 Zürich, Switzerland, mschwarz@ethz.ch
Blazhe Gjorgiev, ETH, Reliability and Risk Engineering, Leonhardstrasse 21, 8092 Zürich, Switzerland, gblazhe@ethz.ch
Giovanni Sansavini, ETH, Reliability and Risk Engineering, Leonhardstrasse 21, 8092 Zürich, Switzerland, sansavig@ethz.ch

Overview

An increase in adoption of renewable energy sources (RES) and the electrification of energy-intensive sectors (heating and mobility sector) are essential ingredients of the decarbonization pathways. These changes will have a substantial impact on the electricity system. Possible solutions to reduce the burden on the electricity system include demand-side management (DSM) and vehicle-to-grid (V2G). The latter is a bidirectional interaction between electric vehicles and the grid, which allows to utilize the battery capacity to provide flexibility for the electricity system. In this study, we estimate the impact of V2G on the Swiss electricity system.

Methods

To compute the value of V2G for the Swiss electricity system, we use the Nexus-e modelling framework, which is a platform of interfaced high-resolution models for the techno-economic assessment of future electricity systems. Its investment module performs generation expansion planning and operations optimization for a desired simulation years (here 2030, 2040 and 2050) given detailed information of the available generation technologies and the Swiss transmission grid. We hereby assume that V2G is used for balancing supply and demand on a system level. We investigate two reference scenarios, one with and one without V2G, sensitivity analyses on restricted electricity trading (NTC30), developments in neighboring countries (TDE), high gas prices (Gas), and high levels of V2G available (XL). In all simulations we set the V2G variable operating and maintenance (VOM) costs to zero, to obtain an upper bound of the V2G value for the system.

Results

There are three main drivers for the value of V2G in the electricity system. First, charging the electric vehicle (EV) batteries during peak electricity generation time and discharging them at times with lower RES production or high demand leads to better exploitation of installed variable RES (VRES). Second, the added flexibility by V2G allows better exploitation of market price differences between hours and days. Third, V2G can help to avoid using expensive backup generators based on fossil fuels. We analyze the impact of V2G on electricity system costs, curtailment of VRES and electricity trading between Switzerland and the neighboring countries. Our results show that participation of EVs in V2G leads to electricity system costs decrease varying between 1.7 to 6.6 billion EUR for the 2020-2050 time frame (Figures 1 and 2). This translates into yearly cost savings up to 92 EUR per vehicle. The use of V2G as decentralized battery storage units allow the system to reduce curtailment by 18 to 71% (Figure 3). Additionally, imports and exports can be better planned and thus become more profitable.

Conclusions

In all scenarios, the introduction of V2G leads to economic benefits for the electricity system. The value of V2G depends on many factors, including the EV and V2G modeling assumptions and the developments in the surrounding countries. When V2G VOM costs are set to zero, the comparison between scenarios with and without V2G integration gives an indication of how much is worth paying for the V2G service (systems perspective). This should be compared to the V2G implementation costs and the necessary payment to EV owners. However, information and studies on these costs are scarce. In future work, we aim to assess the impact of V2G on CO2 emissions, the need for distribution grid expansions, and how the system costs are affected when V2G is participating in the reserves market.

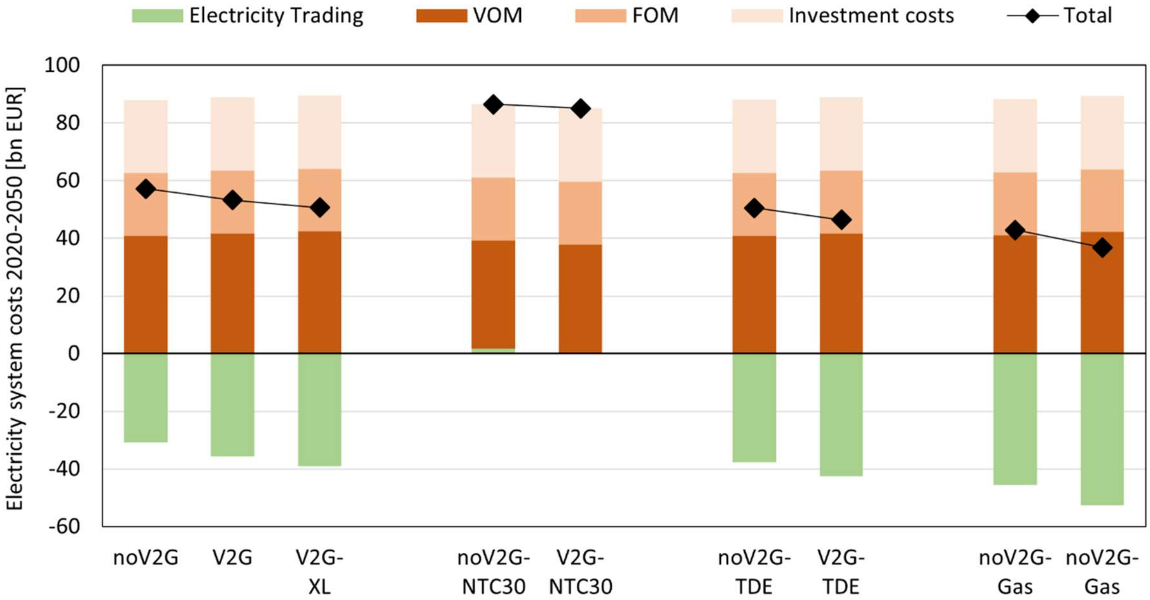

Figure 3. System costs broken down in VOM, flexible operation and maintenance (FOM), investment and trading costs.

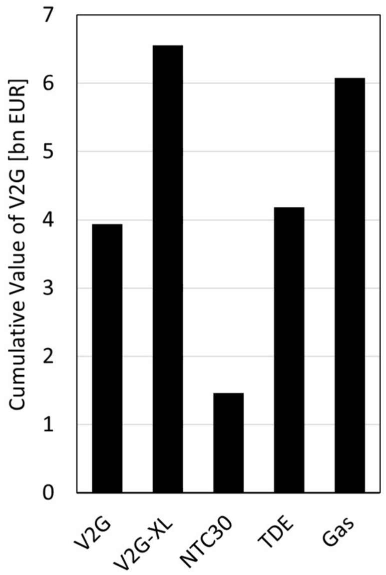

Figure 2. Total system costs.

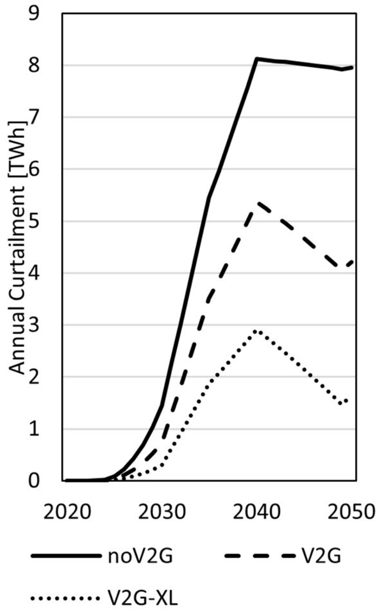

Figure 1. Annual curtailment.

References

Paris Agreement, United nations framework convention on climate change, Paris, France. https://ec.europa.eu/clima/policies/international/negotiations/paris_en.

Morales-España, G., Martínez-Gordón, R. and Sijm, J. (2022) "Classifying and modelling demand response in Power Systems," Energy, 242, p. 122544. Available at: https://doi.org/10.1016/j.energy.2021.122544.

Gjorgiev, B. et al. (2022) "Nexus-E: A platform of interfaced high-resolution models for energy-economic assessments of future Electricity Systems," Applied Energy, 307, p. 118193. Available at: https://doi.org/10.1016/j.apenergy.2021.118193.

Raycheva E, Schaffner C, Hug G. Nexus-e: CentIv module documentation. Tech. rep., Berne: Department of the Environment, Transport, Energy and Communication DETEC, Swiss Federal Office of Energy SFOE, Energy Research and Cleantech; 2020-11-27, http://dx.doi.org/10.3929/ethz-b-000471885.