GRID INTEGRATION OF SOLAR-PVAND ELECTRIC VEHICLES: ANALYSING THE ECONOMIC BENEFITS OF SMART CHARGING FOR CORPORATE PROSUMERS

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Overview

Switzerland has embarked on an ambitious plan to decarbonise power supply and electrify road transportation. The government targets a significant increase of electric vehicle (EV) uptake to reach a 91-99% market share by 2035, along with the aggregated build-out of 2 million home-place and public EV charging points by the same year. The increase in electricity demand from Switzerland's EV strategy will be substantial (+7.3 TWh expected for 2035). Managing this growth properly is important to avoid challenges for grid stability. In parallel, the the Swiss regulatory also foresees a significant increase in variable sources of renewable electricity, notably 30 TWh of solar PV generation by 2035. How can Switzerland's dual transition towards high shares of EV and PV be managed in a user-centric and grid-friendly way, unlocking synergies rather than multiplying challenges? Looking at the typical patterns of solar PV generation and EV charging, workplace charging emerges as a key yet under-researched piece in the Swiss energy transition puzzle, as well as across the broader EU landscape.

In recent years, bidirectional charging has been gained increased policy traction as teachnically feasible solution to support the grid integration of variable renewable energies (VRE) EVs alike. In effect, while previous studies have examined the technical feasibility of so-called 'vehicle-to-grid' (V2G) technology, only a few focused on the economic viability of different business models built upon this innovation, with a minor share targeting interacting effects with VRE generation on-site for corporate energy consumers. This study addresses this gap with the following question: To what extent investments in solar-powered V2G charging infrastructure yield tangible economic benefits for corporate energy consumers in Switzerland? To address this question, we conduct a longitudinal economic assessment of 38 company investments in smart and V2G charging infrastructure for workplace use, and of the changes induced by such an investment on the financial performance of their other investments in solar PV systems. Results will allow to inform better-calibrated policy support measures to incentivise greater uptake of smart/V2G charging solutions in tandem with solar PV applications.

Methods

To this aim, we first calibrated a sample of companies operating a solar PV system in their building's roottop or adjacent premises, and who were willing to partake in our study via data-sharing purposes. Importantly, company selection was done following the selection criteria of:

- Large nominal power of rooftop area (i.e. PV installation size) relative to electricity consumption,
- Preferred geolocation for suburban/rural areas (as opposed to city centre),
- Daytime work commute patterns of employees (as opposed to nighttime or fully home-based), and
- Low capture rates from electricity tariffs.

The selection criteria yielded a final sample of 38 corporate energy consumers. Data sourcing from the final sample consisted on the following parameters:

- Annual grid electricity consumption profiles, disaggregated into 15-minute intervals.
- Electricity and power tariffs for each 15-min. interval of grid electricity consumption.
- Annual solar PV generation profile, disaggregated into 15-minute intervals.
- Feed-in-tariff (FiT) prices for surplus solar electricity sold back to the grid

The analytical procedure consisted of a comprehensive lifecycle financial assessment. The primary focus of the effort was assessing whether investment costs for V2G charging are justified based on the economic and financial benefits accrued from company investments in V2G charging infrastructure. To this effect, for each of the 38 companies, the procedure started with an initial estimation of cashflow changes stemming from the acquisition, maintenance, operating, degradation, and amortisation costs for both technology investments combined (solar PV system + V1G/V2G charging units). From this, a set of financial key performance indicators (KPIs) was estimated for each company profile, consisting of the net present value (NPV), internal rate of return (IRR), and oayback period (PBP) of the original solar PV investment. In a second step, data on the total cost of ownership (TCO) of

V2G charging infrastructure was computed into the analysis of the key economic parameters of the solar PV system, in order to assess the extent of difference in each one of them. This allowed to obtain quantifiable estimates of changes in the solar PV system's TCO derived from the net economic benefits of V2G charging infrastructure investments, in terms of total net increases in a) the amount of solar energy self-consumed, and b) the avoided grid electricity costs (i.e. increased cost-savings). In a third step, we conducted different scenario analyses to estimate the effects of a) flexibility premiums, and b) different policy instruments (e.g. investment subsidies, tax exemptions) on the financial KPIs of the clean energy investments under investigation.

This analytical procedure allowed to conclusively determine – on a 'case-by-case' basis and for each of the 38 corporate energy consumer profiles – whether the TCO of V2G charging is justified based on the relative economic gains obtained from their solar PV investments under current market conditions (flat tariff rates) as well as under a more dynamic price setting (ToU tariffs); and therefore whether it is economically reasonable for each company to undertake (or not) such an investment.

Results

Three scenarios were utilised in the economic evaluation to determine the attractiveness of investing in bidirectional charging infrastructure. The findings indicate that the financial results are generally poor, with all three financial metrics (NPV, IRR and PBP) presenting economically unattractive outcomes. The high costs of bidirectional charging stations, which are significantly more expensive than standard charging stations, substantially contributed to the poor financial results. However, despite these financial drawbacks, companies benefited from substantial non-monetary advantages. The companies analysed reduced their reliance on grid electricity from approximately 64.0% to 32.2% on a median basis and increased self-sufficiency with their own PV electricity from 36.0% to 67.8% (median).

The analytical outputs indicate that, given the existing market parameters currently in place, investing in bidirectional charging stations is financially unattractive in Switzerland, whereas solely investing in on-site PV systems is substantially more economically appealing. However, it is worth noting that companies with an electricity demand of >50'000 kWh already showed a positive NPV over the investment period analysed. Nevertheless, the non-financial benefits of having both a PV system and V2G charging stations are significant. Companies can benefit from reduced reliance on externally produced electricity by 64.2% on average, while simultaneously reducing the risk of volatile energy prices.

This last consideration highlights that V2G technology could still make commercial sense, especially in a scenario of rising and increasingly volatile electricity prices since 2023. The dataset used in this analysis shows a notable increase in energy costs, with day tariffs rising by 24.4% and night tariffs by 13.2% between 2022 and 2023. This observation is in line with what has been reported by the Swiss government, which observed price increases by 24% for Swiss companies during this period on a median basis. From 2023 to 2024, this price increased further by about 18%.

In light of these contextual developments, we note how despite the financial challenges reported from our results, the increased self-sufficiency and reduced reliance on grid electricity underscore the potential long-term value of V2G technology combined with self-generated solar power for Swiss companies. However, it will re rather unrealistic to expect capturing such value in the future, without a drastic reduction of the capital costs from V2G charging technology in Switzerland

Conclusions

Our initial results serve as an empirically-validated information source supporting the investment decisions of corporate energy end-users in the process of assessing the business case for partaking in solar V2G charging at work.

Furthermore, the novelty of examining the interacting effects of different clean tech. investments on the investment considerations of corporate energy consumers will contribute a more refined understanding of the potential venues through which to assess the investment risks of 'focal' innovations (e.g. V2G charging) when their adoption is contingent upon the performance of other 'complementary' technologies (e.g. solar PV) as well as more dynamic market arrangements (e.g. dynamic pricing for arbitrage gains and/or flexibility service provision). As such, they make an important contribution to both industry actors and policymakers, in Switzerland and abroad.

Finally, our analysis serves as an empirically-validated knowledge resource informing both managerial strategies and policy measures for PV-EV convergence, allowing to comparatively assess the suitability of different support schemes to lower investment risk for smart EV charging infrastructure.