SWITZERLAND'S WINTER ENERGY GAP: THE ROLE OF STORAGE

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Overview

This project quantifies the thermal and electrical storage demand of Switzerland for 2035 and 2050, aiming to support the integration of solar and wind energy while ensuring system stability and supply security. By applying large-scale numerical modeling, we analyze the demand for additional storage capacity to address both seasonal and diurnal fluctuations in energy supply. In doing so, we also account for the anticipated significant increase of battery electric vehicles (BEVs), hydrogen systems, heat pumps, district heating capacity, etc. along with the demand-side management potential these advancements bring. The model's objective is to minimize the overall system costs.

An energy system heavily reliant on renewables like solar and wind faces the challenge of balancing their fluctuating, weather-dependent electricity feed-in. Switzerland, with its extensive use of hydropower, already has a potential storage capacity of several terawatt-hours in its water reservoirs. However, the necessity for additional storage to bridge intraday and seasonal gaps remains uncertain when considering a higher share of renewables in the electricity system, particularly in light of the European Union's and Switzerland's trade interdependency.

Currently, cross-border electricity trade with the EU occurs on a daily basis. However, challenges in negotiations could hinder future bilateral agreements. To address this uncertainty, this study incorporates several shock scenarios that partially or entirely restrict electricity and gas trade between Switzerland and the EU. These scenarios enable a detailed evaluation of the role and value of various technologies critical to the Swiss energy markets, especially storage technologies.

The findings of this study will assist policymakers in designing and implementing timely and effective support schemes, ensuring Switzerland's energy system is prepared for a sustainable, affordable and secure future.

Methods

To address the research question, the proven model "Future Electricity Market" (FEM) is updated and further developed. As a partial equilibrium dispatch and investment model, it is able to invest into several technologies in Switzerland, especially storage but also electricity generation technologies.

A central focus lies on the integration of flexible loads. These include, among others, heat pumps, battery electric vehicles (BEVs), hydrogen systems, and district heating, which can partially or fully shift their consumption to more favorable hours. In the optimization across various scenarios, including both shock and normal conditions, these have the potential to reduce the demand for additional storage.

Additionally, the scenarios used in this study account for:

- **Developments in the EU**: Based on the ENTSO-E Ten-Year Network Development Plan (TYNDP), uncertainties such as the expansion of gas and electricity infrastructure and future generation capacity are analyzed. These factors significantly impact Switzerland's trading capacities.

- **Regulatory developments in Switzerland**: Policies such as the Mantelerlass and the Energy Perspectives 2050+ lead to varying assumptions about renewable energy expansion. Additionally, the implementation of different limits on the net import can be explored just as much as different potentials for the hydropower expansion. Different scenarios also explore the flexibility potential of specific technologies.

A major improvement in this model is the more realistic depiction of electricity price fluctuations. As investment decisions are heavily influenced by hourly and seasonal price differences, these fluctuations are crucial for the economic evaluation of storages and their deployment.

Results

Without a detailed, model-based analysis, the necessity and extent of additional storage capacities required by Switzerland remain uncertain, particularly in light of the growing potential for demand-side management. This study elucidates the interactions between flexible demand patterns and storage technologies, highlighting their role in ensuring supply security and reducing reliance on fossil fuels.

The project's findings include:

- **Quantification of storage demand across time horizons**: This encompasses both electrical and thermal storage solutions. For example, thermal storage systems can exploit periods of low electricity prices to heat water, which can then be stored and utilized several hours later, thereby alleviating pressure on the power grid.

- **Evaluation of the market value of various storage technologies**: The economic viability and comparative advantages of different storage options are assessed.

- **Analysis of import dependencies and their influence on storage requirements**: The study examines Switzerland's reliance on energy imports and exports to neighboring countries and how this affects the need for domestic storage solutions.

These results provide a robust foundation for policymakers to design informed measures that facilitate the integration of storage technologies. This may include the strategic use of subsidies or regulatory adjustments to achieve the optimal quantity of storage at the appropriate time.

Conclusions

The results of this project establish a comprehensive foundation for evaluating Switzerland's storage demand within an electricity system predominantly reliant on renewable energy sources. By exploring various scenarios, the analysis identifies key drivers of storage requirements, such as the availability of load flexibility and dependency on energy imports.

These insights serve as a critical basis for developing and implementing appropriate market incentives and regulatory measures. Moreover, they offer valuable guidance for shaping the future design of the Swiss energy market and addressing challenges related to energy provision during winter months. Consequently, the findings make a significant contribution to the ongoing discourse on achieving a sustainable and resilient energy supply in Switzerland.