Mbabane hydrogen energy storage

Mbabane hydrogen energy storage

There is no established definition of LDES, but following Shan et al [3], this paper defines LDES technologies as "technologies that at minimum can provide inter-day applications." However, geographical constraints can limit the deployment of pumped hydro storage and compressed air energy storage, two well-known LDES technologies [3]. In contrast, PGP is not bound by similar restrictions and can be expanded at scale to address long-duration energy imbalances. Consequently, large-scale hydrogen PGP projects are rapidly expanding globally [8-10].

Informing hydrogen-related power sector investment planning and policy design requires a comprehensive examination of the competing roles of hydrogen as LDES and as an international energy carrier. However, there is a limited understanding of the role and needs of the international liquefied hydrogen trade in decarbonizing the electric power sector compared to domestic hydrogen production and use [13, 15, 16].

By comprehensively examining the use of hydrogen in Japan, this study can serve as a useful reference for other countries, particularly those facing similar energy transition challenges and anticipating the dual use of hydrogen in the power sector.

This study employs a robust modeling framework that integrates capacity expansion and hourly dispatch models within the platform known as solar and wind energy integrated with transmission and conventional sources (SWITCH). Developed as an open-source tool [33], SWITCH facilitates assessments of the profound impacts of high renewable energy penetration on electric power systems. Since its launch, SWITCH has evolved through diverse country-specific applications to the US, China, among others (e.g. [34-38]).

This study employs a comprehensive approach to exploring the impact of imported and domestic hydrogen on wholesale electricity costs and Japan"s generation mix across four scenarios: Base, No Hydrogen, Domestic Hydrogen, and Imported Hydrogen.

The Base scenario simulates the least-cost capacity expansion of the electricity system from 2025 to 2050, and encompasses both imported hydrogen and hydrogen storage deployment. Subsequently, an hourly dispatch analysis examines the energy storage operations and overall system reliability. The model assumptions are given in table 1.

The No Hydrogen scenario excludes imported hydrogen and hydrogen storage deployment, thereby providing a benchmark for assessing the impact of hydrogen on the electricity system. The Domestic Hydrogen scenario and the Imported Hydrogen scenario exclude either imported hydrogen or hydrogen energy storage, respectively, offering insight into the implications of relying solely on domestic or imported hydrogen.

This study calculates the changes in the generation, storage, and transmission capacity mix, along with total system costs, based on the least-cost pathways for each scenario. System costs are defined as the cost of generation and storage, plus incremental transmission investments (SI S1.4(1)). To enhance robustness, we have also conducted sensitivity analyses for critical factors, including imported hydrogen prices, hydrogen storage costs, domestic renewable energy costs, and battery costs for the Base Scenario.

The overview of scenario analysis and sensitivity assessment are summarized in table 2. Detailed model descriptions, descriptive statistics, and additional results are provided in the supporting information.

Our findings underscore the feasibility of achieving a zero-emission power system in Japan through substantial investments in renewables, hydrogen, battery storage, and transmission infrastructure. Together, solar and wind power constitute three-quarters (74.7%) of the least-cost electricity mix, necessitating a robust combination of clean, firm generation and various storage options to address their inherent variability across different timescales.