

Higher Stakes, Lower Gains: Analyzing the Revenue Cannibalization Effect of Renewable Energies in the Electricity Market with PyPSA-Japan2050 Model

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Background and Objectives Renewable energy sources, particularly solar and wind power, are increasingly significant in Japan's electricity market. As these renewable energies approach grid parity, their integration poses unique challenges, especially in maintaining their market value amidst increasing penetration. This paper addresses the revenue cannibalization effect, where the market value of renewables declines with higher market shares due to their intermittency and non-dispatchability. Our study aims to explore effective strategies for promoting renewable energies as primary power sources in Japan's electricity market post-grid parity.

Methods This study utilizes the PyPSA-Japan-2050 model, an optimal power dispatch model, to simulate and analyze the long-term effects of renewable energy integration in Japan. The model is based on minimizing electricity generation costs while considering system constraints such as demand, capacity, and stability. Key components include evaluating the impacts of enhanced carbon pricing policies and demand response mechanisms, like electric vehicle (EV) batteries, on the market value of renewables.

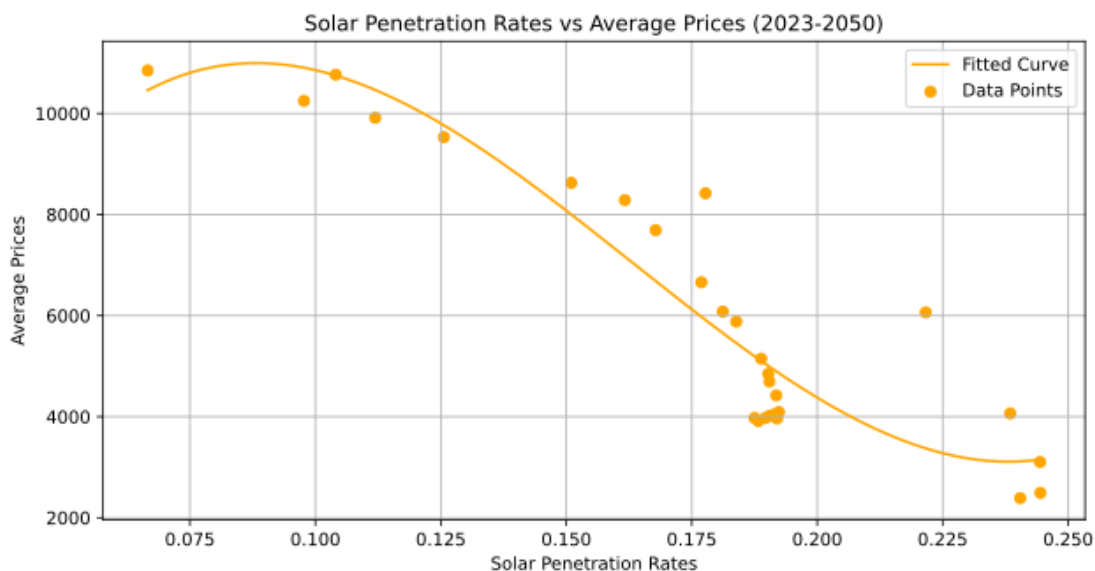


Figure 1 Simulated Results of Solar Penetration Rate and Average Market Prices (2023-2050)

Results Our findings confirm the presence of the revenue cannibalization effect in Japan's solar, offshore, and onshore wind sectors. As the penetration of these renewable energies increases, their market value declines significantly(see Figure 1). The study reveals that carbon pricing policies can mitigate this decline by making fossil-fuel-based electricity generation less cost-competitive(see Figure 2). Additionally, demand response mechanisms, such as integrating EV batteries into the power grid, can enhance the market value of renewables by balancing supply and demand, stabilizing energy prices, and alleviating the revenue cannibalization effect.

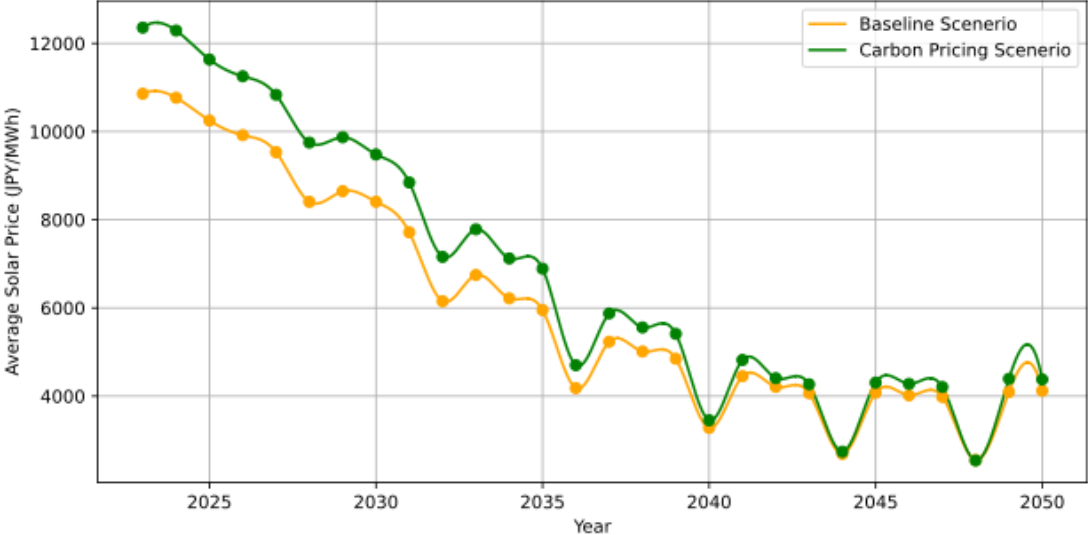


Figure 2 Comparison of Solar Market Prices under Carbon Pricing Policy with the Baseline Scenario

Conclusion This study highlights the critical role of policy interventions in sustaining the economic viability of renewable energies in Japan's electricity market. Carbon pricing and demand response mechanisms are effective tools for mitigating the negative impacts of high renewable energy penetration. Policymakers must adopt a multifaceted approach, combining market-based incentives and regulatory support, to ensure the successful integration and sustainability of renewable energies. These strategies are essential for achieving a sustainable and resilient energy future, which requires both technological innovation and adaptive, forward-thinking policy frameworks.