Marius Schwarz, ETH Zurich

Title: Addressing integration challenges of high shares of solar photovoltaics with battery storage, electric vehicles and time-varying electricity pricing

Abstract: The transition towards renewable energy and electric vehicles offers the potential to decarbonize both the power generation and the transportation sector, accounting for over 60% of global primary energy demand. However, the large-scale integration of solar photovoltaics, the most prominent renewable after wind, is beginning to challenge existing electricity systems. First, solar photovoltaics aggravates sharp system-wide load changes and, in turn, increases the need for fast-ramping generation capacity. Second, it reduces the demand for electricity supply from the grid, causing an increase in electricity prices as grid costs are recovered over smaller volumes of electricity. Battery storage and electric vehicles can play an important role in the large-scale integration of solar photovoltaics. Battery storage mitigates the first integration challenge of solar photovoltaics by flattening the system-wide load but elevates the second by increasing self-consumption behind-the-meter. Electric vehicles increase the volumes of electricity due to their immense charging loads and provide storage capacity to address sharp system-wide load changes. However, the amount of capacity electric vehicles can provide depends on when they are connected to the grid and how they are charged. In the face of the complex interplay between individual technologies and an existing electricity system, policymakers need to re-evaluate policies to address integration challenges. In this paper, we investigate how different electricity-pricing strategies, particularly time-variant pricing, shape the diffusion of the technology triad i.e., solar photovoltaics, battery storage and electric vehicles and, in turn, affect grid reliability and electricity prices. To do so, we develop an agent-based model of the technology triad market in California between 2005 and 2030. We focus on California as it is one of the first regions affected by system-wide challenges associated with the integration of solar photovoltaics; and will become even more affected as it strives for a carbon-free electricity grid by 2045. Agent-based modelling allows us to quantify multi-actor, multi-technology, and multi-policy dynamics. Our results show that electricity-pricing strategies affect the diffusion of battery storage, and shape the impact electric vehicles have on integration challenges of solar photovoltaics. Time-variant pricing makes it profitable to store surplus electricity in off-peak hours and self-consume it in on-peak hours, resulting in an uptake of battery storage. Also, time-variant pricing triggers charging of electric vehicles increasingly during off-peak hours. In turn, both more battery storage and smarter charging of electric vehicles support the large-scale integration of solar photovoltaics.