Regional Variation in Health and Financial Benefits of Energy Storage Deployment in US

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Overview

Energy storage occupies a vital role in unfolding the sustainable and renewable energy transition because it can facilitate solar and wind energy integration[1–3], enhance the flexibility and resilience of the electric grid[4,5], and reduce the greenhouse gas emissions and operation cost [6,7]. Many researchers have projected future capacity needs for energy storage based on optimization methods to minimize the cost and also meet various constraints like carbon emission budget[8–10]. However, such system-level optimization models may yield planning results that are not aligned with the potential financial benefits of private project develoeprs without appropriate market designs or policy incentives for new storage systems.

This paper will present the emission impact and expected profit from energy arbitrage of a marginal energy storage project in each state of the continental US under a reference development scenario projected by NREL. Then we will discuss how the regional distribution of these benefits deviates from the distribution of capacity planned in each state. Later, we will analyzed the emission effect from the marginal energy storage project.

Methods

The future scenarios of energy transition in the U.S. from 2022 to 2050 is based on a national study from National Renewable Energy Laboratory (NREL) and the results can be retrieved at https://cambium.nrel.gov/. We extract the information about future planned energy storage capacity in each state at each year, hourly generation of each resource , the emission factor of each resource, and the hourly marginal cost of the system. We assume the marginal cost of the system as the electricity price, calculate the energy arbitrage revenue based on the charging and discharging information, and estimate the revenue and the emission of a 1-MW storage system. The lifetime of the storage system is assumed as 15 years. When the lifetime exceeds 2050, we assume that the future years will stay the same as 2050. We identify the year that the project will have the highest revenue from energy arbitrage which proxy the financial attractiveness to project developers. Similarly, with the marginal emission rate from NREL's model result, we can calculate the emission caused by charging and discharging of the energy storage system in each state.

Results

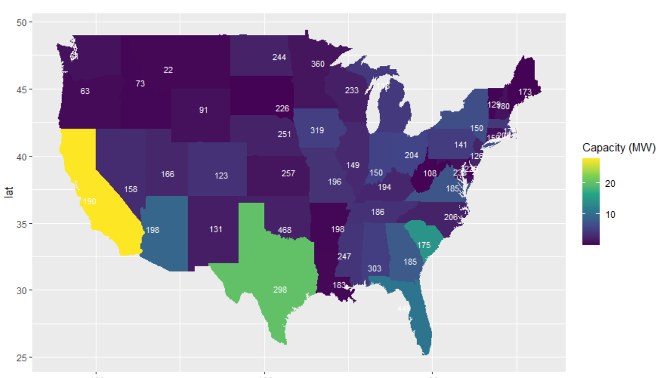

Figure 1 Capacity planned in each state (filled color) and expected revenue from energy storage system (numbers displayed in each state in $/MW) under a baseline scenario

Figure 1 shows the preliminary result displaying the maximum annual energy storage capacity during 2022-2050 in the fill color and the projected revenue from the energy storage project in the text on the map. The revenue is the maximum revenue of a single 15-year project could achieve over the period. We can tell that California and Texas will need the most energy storage capacity to support energy transition and maximize benefits of existing renewable energy development. However, the project developers may be attracted to invest in energy storage projects in Oklahoma and Florida as the energy arbitrage potential is greater than 400$/MW. The states in the middle or, more specifically, at the edge of the eastern grid show a relatively high revenue potential, but these states did not receive much attention in the policy discussion. The incentive for energy storage deployment might be essential to accelerate the energy transition. We would argue for a more differentiated incentive design considering the revenue potential and the capacity target in each state. The states like California and Texas may need more support to achieve their target. For states like Oklahoma and other states in the middle could utilize their large revenue potential to spur the economy and job growth.

From an emission perspective, as shown in Fig2, the project with maximum revenue potential may not align with the environmental benefits. The preliminary results show that the projects in the eastern states generally increase emissions while the projects in the west generally decrease emissions. It is mainly due to the timing of storage deployment and local generation mix. In the eastern states, the maximum project revenue occurs in the early years of the planning period with limited decarbonization. Due to the energy loss during storage and the higher emission factor when charging than the discharging, the storage operation increases the emission in these states, consistent with previous literature[11]. In the western states, the maximum appears a little bit later in the planning period when more renewable energy is installed. The storage could take advantage of the cheap, clean electricity; thus, the lifetime emission induced by storage becomes negative. The increased emission caused by energy storage did not impede our effeort to promote it but the public resources supporting it should not come from environmental perspective at the beginning period of the energy transition. The policy should also balance the environmental benefits and the private profits when guiding the storage deployment strategy.

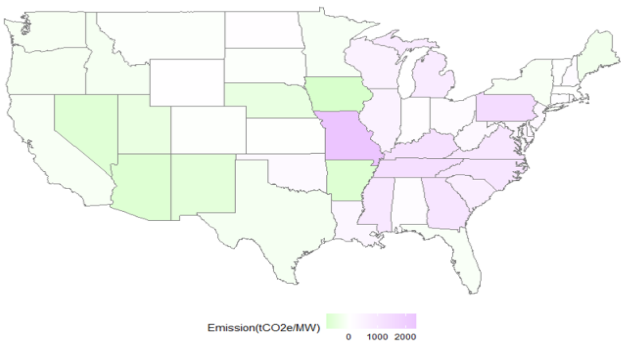

Figure 2 Emission induced by a margnial storage project in each state under the baseline scenario with maximum profit strategy.

Future analysis will incorporate three additional energy transition scenarios from the Cambium project, with different renewable costs and carbon budgets to achieve climate goal.

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