Energy storage for renewable energy capital

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Due to cost decreases1,2, renewable energy is experiencing greater use (https://). Many jurisdictions have policies in place to incentivize renewable use (). These policies are often intended to decrease the carbon-intensity of electricity production.

The role of energy storage in aiding the integration of renewable energy into electricity systems is highly sensitive to the renewable-penetration level3. California, for instance, is experiencing days during which demand is too low to accommodate all of the solar energy that is available midday4. This overgeneration-related renewable curtailment can be exacerbated by thermal generators having limited flexibility in how quickly they can adjust their production or how low their production levels can go5.

Thus, there is a need to optimize the operation of energy storage to achieve desired economic and environmental outcomes. Many studies optimize the operation and size of an energy storage system for a given grid application based on economic criteria26,27. Others propose optimization models for sizing and operating energy storage to minimize total electricity cost or to maximize investor profits28,29,30. Another set of studies model emissions and economic considerations in optimizing energy storage use31,32,33.

Our analysis of the cost reductions that are necessary to make energy storage economically viable expands upon the work of Braff et al.20, who examine the combined use of energy storage with wind and solar generation assuming small marginal penetrations of these technologies. Conversely, we examine their economics at significant renewable penetrations that are necessary for deep decarbonization of electricity production.

Our findings show that renewable curtailment and CO2 reductions depend greatly on the capital cost of energy storage. Moreover, increasing the renewable penetration or CO2 tax makes energy storage more cost-effective. This is because higher renewable penetrations increase the opportunities to use stored renewable energy to displace costly generation from non-renewable resources. Among the energy storage technologies that we consider, PHS and DCAES are deployed in more of the scenarios that we examine. This is due to the lower capital costs of these technologies. Other technologies see deployment under some scenarios. We also find that relatively modest reductions in the capital costs of other energy storage technologies can make them cost-effective for this proposed application.

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Even in the absence of renewables, deploying some energy storage technologies in Texas is cost-effective under higher emissions-tax rates. This is because the ERCOT system has a more mixed generation fleet, with both coal- and natural gas-fired units that have very different generation costs. Moreover, the differences in the carbon contents of coal and natural gas gives larger differences in marginal generation costs between coal- and natural gas-fired units with higher CO2-tax rates.

Annual renewable curtailment as a percentage of potential renewable production in California for the year 2012 in the base case with a 7.0-GW minimum-dispatchability requirement. Figure panels correspond to different wind- and solar-penetration levels, which are indicated at the left-hand side and bottom, respectively, of the figure. Source data are provided as a Source Data file

Annual renewable curtailment as a percentage of potential renewable production in Texas for the year 2012 in the base case with an 8.2-GW minimum-dispatchability requirement. Figure panels correspond to different wind- and solar-penetration levels, which are indicated at the left-hand side and bottom, respectively, of the figure. Source data are provided as a Source Data file

Consistent with real-world experience4, renewable curtailment is greatest in the spring. This is due to the spring having relatively low electricity demand and many days with good midday solar availability. California has experienced recentlyan increasing number of spring days on which these factors require solar curtailment.

Annual CO2 emissions (million ton) in California for the year 2012 in the base case with a 7.0-GW minimum-dispatchability requirement. Figure panels correspond to different wind- and solar-penetration levels, which are indicated at the left-hand side and bottom, respectively, of the figure. Source data are provided as a Source Data file

Annual CO2 emissions (million ton) in Texas for the year 2012 in the base case with an 8.2-GW minimum-dispatchability requirement. Figure panels correspond to different wind- and solar-penetration levels, which are indicated at the left-hand side and bottom, respectively, of the figure. Source data are provided as a Source Data file

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