OPTIMIZING THE USE OF CURTAILED POWER IN THE ELECTRIC GRID

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Overview

Over the past decade, decreasing costs and strong government incentives have propelled a more than forty-fold increase in installed solar power capacity worldwide, from 9 gigawatts (GW) globally in 2007 to 390 GW in 2017. Installed wind power capacity has increased almost six-fold over the same period. Concurrently, however, several major electricity markets have also seen an increase in both solar and wind power curtailment—the shutting down of electricity production from these generators because the system cannot integrate it. In the first four months of 2018, the California Independent System Operator (CAISO) was forced to curtail more than 210 Gigawatt hours of wind and solar power, and CAISO is expecting these levels of curtailment to increase as more renewables are installed in pursuit of the state's ambitious renewable energy goals.

Methods

We develop a large-scale optimization model of the CAISO generation and transmission system to quantitatively assesses the spatial and temporal risks of renewable power curtailment. We ground this model in a large, empirical historical record of curtailment. We further analyze how to transform curtailment risks into benefits by developing techno-economic models of the likely cost and performance of a suite of technologies that could exploit the curtailed generation in California, namely direct air capture, power to gas, or utility-scale batteries. Our optimization model sheds light on the location and scale of technology deployment, and its economic effects on the wider system.

Results

Our results suggest that CO_2 removal occurs through two methods. The vast majority is supported by curtailed energy, and this curtailment is done mostly through direct air capture technologies, which are responsible for the removal of more than 1.5 million tons of CO_2 per year. A smaller amount of CO_2 removal is supported in areas with characteristically negative locational marginal prices (LMPs). Ten percent of the CAISO system has LMPs negative enough to support carbon removal technologies, though these would operate intermittently and at high marginal cost. In total, these technologies would remove more than 1.6 million tons of CO_2 annually, which is equivalent to removing approximately half a million cars from the road.

Conclusions

The results of our investigation allow both energy system modelers and policy makers to begin considering the up-side of curtailment, which is rightly considered to be a major challenge to the power system. Moreover, we show how a range of novel climate change mitigation strategies can produce fairly substantial benefits. If climate change mitigation becomes a bottom-up endeavor, as appears likely, these novel strategies could work alongside traditional policy instruments as we seek to deeply decarbonize the global energy system.