The Performance of U.S. Wind and Solar Generators

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Executive Summary

The levelized cost of electricity (LCOE) implicitly treats every kilowatt-hour (kWh) of electricity generated as equally valuable regardless of when it is produced. A number of authors have argued on theoretical grounds that to compare dispatchable and non-dispatchable technologies properly, nodal spot prices should be used to value the generation of non-dispatchable facilities. Thus a wind or solar facility that produced electricity that was considerably more valuable than average might be worth building even if its LCOE was somewhat above that of an alternative baseload technology.

To learn how the value of generation from U.S. wind and solar plants compared to the average nodal spot prices they faced, I asked all seven U.S. Independent System Operators (ISOs) for two years of hourly generation and nodal spot price data, centered on 2011, for a small, representative sample of wind and solar generators. (Coverage was limited to the ISOs, which serve about 2/3 of U.S. load, since there are no nodal spot prices in areas they do not serve.) I was able to obtain data on only nine solar facilities from three of the ISOs. The wind sample included 25 facilities, with at least three in each of the ISOs. I obtained two full years of data for most wind generators, but samples for all the solar generators were somewhat shorter.

Analysis of the price data yielded interesting results. All of the price series were right-skewed (the mean exceeded the median), and all had heavier-than-Gaussian tails. Average prices in 2011 varied by more than a factor of two across ISOs, and average coefficients of variation varied by more than a factor of seven. The average correlation between prices in adjacent hours differed substantially among the ISOs, as did the average correlations between prices in the same hour in adjacent days. The highest of the latter correlations was only 0.50. In only one ISO was the price range among plants in our sample less than $1.00/MWh close to half the time, while in three the price range exceeded $10.00/MWh more than 35 percent of the time.

My initial focus was on what, following Hirth (2013), I term *value factors*: the ratios of the output-weighted average spot price each facility faced to the unweighted average price. I also examined other performance measures, including capacity factors and several measures of intermittency. Perhaps the most important finding of the study was the general observation that most performance measures studied varied substantially within and between ISOs, and some varied substantially over time. No two wind or solar generators are alike, and averages, particularly national averages, can be misleading.

Thus, for instance, wind capacity factors in 2011 varied from 19 percent to 43 percent, and solar capacity factors varied from 7 percent to 25 percent. Wind value factors averaged 0.88, with a range from 0.39 to 1.14. Solar value factors averaged 1.16, with a much smaller range of 1.08 to 1.23. All these statistics varied little between the early and late periods in our data, but the substantial cross-section variation makes clear the inefficiency of state subsidy regimes, notably most Renewable Portfolio Standard (RPS) programs, that restrict the siting of wind and solar generators. A uniform nationwide RPS program (or feed-in tariff) would produce substantially more renewable generation per subsidy dollar.

All but three of the 25 wind plants in our sample produced more per hour at night than during the day, and all but four produced less on average during peak-price hours than at other times. Differences in these ratios were significantly correlated with differences in wind plant value factors. All solar plants generated more on average in peak-price hours than at other times, but the ratio of average peak-hour generation to average generation at other times varied from 1.1 to 2.3 in our small sample. Differences in this ratio helped explain differences in solar plant value factors.

All generators outside New England, where negative bids were not allowed, faced negative spot prices in at least 18 hours in 2011, and nine faced such prices in more than 500 hours. Wind plants outside New England produced 49 percent more on average in hours with negative prices than in other hours and shut down on average in only 8 percent of the hours with negative prices. Solar plants on average shut down in only 17 percent of daytime hours with negative prices. Generation when the spot price is negative is value-destroying; it occurs in large part because RPS regimes and the federal production tax credit that has subsidized wind generation reward all covered generation equally, regardless of when and where it occurs. It would clearly be better to subsidize generation only when its marginal value (as measured by the nodal spot price) is positive or, even better, to make the subsidy rise with the spot price.

To get a rough sense of these generators' contributions to system capacity, I examined capacity factors during peak-price hours. The 2011 values for wind (22 percent) and solar (20 percent) facilities were nearly identical, but the range for wind plants (8 percent to 46 percent) was more than twice as wide as the range for solar plants. Eighty percent of the cross-section variation for wind plants and 23 percent of the cross-section variation for solar plants was within, not between ISOs. Treating all wind or all solar generators the same for capacity market or capacity planning purposes within an ISO is clearly problematic. In addition, these peak-period capacity factors varied substantially between early and late periods, and an important fraction of the corresponding variance was between ISOs.

Substantial, relatively stable differences in hour-to-hour and day-to-day output variability were present in our sample, and a major component of that variation was at the ISO level. Even though coping with such variability can be costly, existing subsidy programs provide no incentive for generators to select sites with stable wind or predictable insolation. A new measure of ISO-level reductions in output variability from geographic averaging was developed; applying it to our sample revealed substantial reductions on average, particularly in hour-to-hour variability, with notable differences among the ISOs.

All but two wind plants in our sample had at least 300 hours with zero output in 2011, almost always during the day and when the spot price was positive. While three of the ISOs had more than 100 hours during which none of their wind plants generated, three others had fewer than 20 such hours. The null hypotheses that the incidence of zero-output hours was independent among plants within each ISO were all strongly rejected. Solar plants rarely produced zero output during the day or even output less than half the average output of adjacent hours or the same hour on adjacent days.