An Empirical Analysis of the US Generator Interconnection Policy

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March 2022

The transition to a low-carbon electricity grid will require massive investment in wind and solar-powered electricity generation. An obstacle to this investment is an electricity transmission policy that was designed for fossil fuel generators rather than renewable energy. This paper studies the interconnection process, which new generators use to connect to existing transmission infrastructure. This process is one of the most time-consuming and costly steps before a generator goes online. Increasing the rate at which renewable energy generators complete the process from the current 15 percent to the fossil fuel completion rate of 32 percent has the potential to double the amount of renewable energy capacity the US adds each year.[1]

The interconnection process works as follows. A generator wishing to connect to the transmission grid joins a waitlist known as the "interconnection queue". The generator then undergoes a series of engineering studies that determine whether the new generator will overload the grid ("violation"), what new equipment (such as new transmission lines) is needed to resolve the violation, and what the cost of this equipment and its installation will be ("interconnection cost"). Each subsequent study provides more certainty about the final cost. Generators in the queue must pay for the studies to remain in the queue, and they can drop out of the process at any time. After the final study, the generator can connect to the transmission grid by paying the interconnection cost, or it can leave the queue.

From an economic perspective, the current queuing process is far from optimal. In many cases, new generators must pay the entire cost of the transmission upgrades they trigger even

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[1] These withdrawal rates were calculated using Berkeley Lab's data on completed and withdrawn interconnection requests from 2000-2020. These data cover five regional transmission organizations (CAISO, ISO-NE, MISO, NYISO, PJM), which collectively serve the Northeast, Midwest, and most of California. For more on these data, see Rand et al. (2021).

though existing and future generators also benefit. According to Gregory Wetstone, president of the American Council on Renewable Energy, "Today's grid interconnection policies are largely analogous to requiring the next car entering a crowded highway to pay the entire bill for a needed lane expansion" (Hale 2021). High numbers of study requests also lead to delays, even though most studies are done for projects that eventually drop out of the queue.

We study the market design of the interconnection process using a novel data set on the costs of interconnection. We hand collect these data for the PJM grid operator. We focus on PJM because it has the most comprehensive public records of any US regional transmission organization. PJM serves 65 million people in parts of the Mid-Atlantic, Midwest, and Southern United States (PJM 2021). Thus far, we have collected data from 1,072 out of the 6,462 requests for interconnection in PJM.

The data first show that high interconnection costs predict withdrawals and that a long queue increases wait times. Our data show a large and positive correlation between the interconnection costs revealed in a study and the decision to withdraw. The average interconnection cost revealed in the first study (conducted soon after a generator joins the queue) is 0.73 million dollars per MW for all generators, while this cost for completed generators is 0.19 million dollars per MW. We also find a 10 percent increase in the queue size reduces the probability a generator completes the interconnection process in a given month by 6 percent. Furthermore, renewable generators have higher interconnection costs and longer wait times than similarly sized fossil fuel generators.

We also find evidence for a geographical cost externality across projects. We show that generators applying for interconnection near a recently completed generator have lower costs of interconnection. We estimate the interconnection cost reduction associated with the completion of a project within 10 miles in the past five years to be 0.12 million dollars per MW. Presumably, these generators made upgrades to the transmission network, thus reducing the cost for future connections. Consistent with this explanation, we find this pattern is driven by completed generators with high interconnection costs.

We next develop an empirical model of queuing to study the incentives of potential generators. We model withdrawal decisions as an optimal stopping problem, and we develop a tractable queuing equilibrium concept that allows for the non-stationarity we see in the data. Using the model, we simulate the impact of three counterfactual policies. The first is a direct subsidy for interconnection costs for renewable generators. The second is to speed up the delivery of studies. The third is to reallocate interconnection costs across projects. Specifically, we simulate the effect of having later generators in a geographic area subsidize the first project in that area.

Preliminary results show that directly subsidizing interconnection costs and re-allocating costs across generators are most effective at reducing withdrawals. If the subsidy for interconnection costs is 0.15 million dollars per MW (about 20 percent of the mean interconnection cost estimate from the first study), the completion rate for renewable generators rises from 17 percent to 26 percent. We see a similar increase for the cost-reallocation policy, which is about half as costly for the government. For generators entering the queue from 2011-2017, the subsidy and cost-reallocation policies would have resulted in an additional 4-5 GW of renewable energy capacity.[2] Both policies result in longer wait times for completed projects because fewer projects withdraw from the queue. On the other hand, increasing the speed of study deliveries by 10 percent increases the completion rate for renewables from 17 percent to 19 percent, but reduces the waiting time by only 6 percent, as generators are more willing to wait for studies that arrive more quickly.

This paper is the first empirical study on electricity market entry to carefully account for the effects of interconnection queues. Although the interconnection process has received some attention in research on energy policies (e.g., Gergen et al. (2008), Alagappan et al. (2011)), it has been rarely studied in the economics literature, likely due to a lack of data. We also contribute to the market design literature by studying queue design in a novel and important market. The interconnection queue features both "peer effects" (Epple et al. (2018), Allende (2019)) and dynamic agents (Gandhi (2020), Agarwal et al. (2021), Waldinger (2021), Verdier & Reeling (2021), Liu et al. (2021)), forces have not been explored jointly in the prior literature. Finally, we contribute to an extensive literature on the relationship between long-term investment in renewable energy capacity and environmental policies.

[2]For comparison, the entire US added 11.6 GW of utility-scale, renewable energy capacity in 2017 (calculation based on data from US Energy Information Administration Form 860).

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