Drivers of Economic Wind and Solar Penetration in the United States

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Overview

Much has been made for the potential for wind and solar generation to supply cheap, CO_2-free electricity in the United States. It is common to see claims that electricity demand in the contiguous U.S. can be supplied 100% by renewable generation within the next 30 years, and at a delivered cost cheaper than today. It is equally common to see claims that variability will significantly limit the economic penetration of wind and solar, absent further subsidies and other policy support. Missing amongst the hyperbole from both sides is an understanding of what economic factors underpin the potential for penetration of renewable generation. Is it the relative investment costs of these technologies compared to conventional technologies that will drive penetration, as proponents argue? Or is the variability – the generation profile relative to load – that is the key driver, as detractors would have it?

Five economic drivers are often cited as being reasons for or against renewable penetration in the United States. These are: declining investment costs of new wind and solar, operating costs of conventional technologies, generation profile of each resource relative to load, availability of storage, and potential for inter-regional transmission. In this paper, we consider each of the five economic drivers from the hourly perspective. We create a sensitivity analysis varying each of the five factors as to understand which factors, or combinations of factors, drive or limit penetration of renewable generation. That allows us to answer questions such as what is the likely maximum economic penetration of renewable generation in the U.S. under a variety of economic conditions (including conditions that represent CO_2 restrictions on conventional technologies), and which is the most significant limiter to further penetration, which may indicate where further R&D is most needed. By bringing together five of the most often considered sensitivities to renewable penetration in a single, coherent, framework, using a state-of-the-art U.S. wide electric sector capacity expansion tool, we can comprehensively address some of the big questions about the potential drivers and limiters of renewable penetration in the U.S.

Methods

We use two economic capacity expansion models of the U.S. electric sector to understand the relative importance of the following economic drivers to wind and solar penetration:

1. Investment costs of wind and solar
2. Operating and fuel costs of conventional technologies (assumed to be gas for this analysis)
3. Generation profile of the variable technologues (including the load shape)
4. Availability of low-cost storage
5. Availability of inter-regional transmission

The two models used are varients of EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy Model (US-REGEN). One variant is a full inter-temporal dynamic investment/dispatch model of the U.S. electric sector, from 2016-2050. The other variant is a single year (2050) static equilibrium model with capacity rental and hourly dispatch. The use of the static model allows us to represent hourly storage operations and investment faithfully, something that is not currently possible in long-horizon dynamic models without chronology, which use a few representative hours for a single year. The use of the dynamic model enables a detailed transmission sensitivity to understand opportunities and challenges associated with trade interactions with adjacent markets. All other scenarios are run in both models, allowing 'like for like' comparison to the other scenarios within each modelling structure.

To test the robustness of our conclusions, we run the above scenarios in both a 'business-as-usual' framework (with no additional carbon policies beyond those already on the books), and a deep decarbonization framework, where we assume the electric sector has to achieve a 95% reduction in CO_2 emissions by 2050 vs. 2005. We then re-examine the relative importance of the five drivers under this decarbonization framework.

Results

Our modelling results find that the generation profile of renewable technologies is the single biggest driver of economic renewable penetration in the United States. Moving the profile of solar generation for example, so that peak solar generation coincides with peak load, can more than double economic solar penetration. The second biggest driver of renewable penetration is the operating costs of conventional generation, specifically natural gas prices, which would also be the channel by which most carbon policies would impact the electric sector. The importance of this driver is particularly demonstrated in the decarbonization framework. Investment costs of new renewable generation fall into third place in either the business-as-usual or decarbonization frameworks.

Storage is one option to shift the profile of renewable generation, by charging when renewable generation is high and load is low, and discharging when renewable generation is low and load is high. However, storage incurs losses, in addition to its own capital costs. We find that, under optimistic assumptions about both losses (10%) and capital costs ($25/kW), including storage does not greatly increase total renewable penetration in the United States, though it does change the ratio of installed solar to wind capacity.

The final driver we considered was inter-state transmission. The potential value of long-distance transmission is the ability to transcend time-zones, and mimic ‘shifting’ renewable generation by up to three hours by transmitting it across the United States to where load is currently high. We find, with optimistic costs for new transmission, and no consideration of siting constraints, that limited new transmission is built, and the option to build such transmission incents very little new renewable generation (less than 5% beyond the reference scenario).

Conclusions

Much attention has been paid to the dramatic fall in renewable capacity costs in the last decade, with many commentators citing this as reason to predict large quantities of new renewable generation in the United States. However, our research indicates that the profile of renewable generation, rather than the capital costs, is the single biggest driver – and thus the single biggest limiter – of economic deployment of renewable generation in the U.S., especially at higher variable renewable penetration levels. This suggests that the development of technologies that can compensate for, or shift the profile of renewable generation will be the most important driver of renewable deployment in the future. This is true whether future environmental policies are similar ot those today, or require deep decarbonization of the electric sector. Storage is one such technology, but our results suggest that even assuming only 10% losses and a cost of $25/kW, storage will not drive a large change in renewable penetration by itself, as it similarly exhibits decreasing marginal returns as deployment increases.