Ultra Low Carbon Electricity Systems:
Intermittent (Renewables) or Baseload (Nuclear and CCS)?

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Overview

The EPA Clean Power Plan sets an interim goal for states to reduce carbon emissions collectively by ~32% by 2030. The states, in turn, are tasked with devising State Implementation Plans to reduce carbon emissions by a specified amount. It is apparent by the quantifications in the Clean Power Plan as well as the rhetoric of the states that plans will attempt to minimize costs (at least from the State's perspective) for the given goal—32% by 2030. We examine in this research whether this philosophy will lead to the lowest system level costs under increasingly stringent carbon constraints in the distant future.

We examine the effect of an increasingly stringent carbon constraint because it has an effect on the utilization of the low carbon generators. Neither wind, solar, nor baseload can perfectly match the diurnal or seasonal demand patterns for electricity, and storage is expensive. Therefore, there is a risk that whatever technology is implemented today will not be as cost effective as envisioned because it may not maintain full utilization. We find that as carbon constraints become increasingly aggressive, the effect of utilization dominates whichever type of generators minimize system level costs. Therefore, more aggressive carbon constraints tend to favor higher utilization generators as the least cost option rather than the systems with the lowest LCOE, which assumes full utilization. To summarize, it is currently thought that wind, solar, and (low carbon) baseload generators increase in costs in that order. However, under very aggressive carbon constraints, the priority cost minimization may be reversed due to correlation with load and the higher utilization offered by the latter technologies.

Methods

We constructed an hourly economic dispatch model of the ERCOT electricity system to find how increasing aggressive carbon constraints affect low carbon utilization and in turn system costs. Hourly demand and hourly wind production from 2012 was downloaded from the ERCOT website. Hourly solar production was modeled using 10 different locations in Texas using NREL's Solar Advisor Model (SAM). We assumed that wind, solar, and baseload generators have an equivalent load carrying capability (ELCC) of 25%, 50%, and 95%, respectively, with the ELCC contribution of wind and solar generators decreasing at higher penetrations. We assumed that the value of ELCC was $330/MW-day.

Results

The results from this study are shown in Figure 1 below. We assumed that the cost of low carbon baseload technology was $100/MWh and that wind and solar cost less according to the delta indicated. A delta of $15/MWh or $30/MWh assumes that wind and solar costs $85/MWh or $70/MWh. For storage, we assumed that both demand side management and a Tesla Powerwall would be available in every home. Demand side management is modeled to operate like two batteries—one mimicking peak shaving and the other sustained load shifting that can last up to 12 hours. DSM is assumed to have a total capacity of 50 GWh and a peak capacity of 9 GW. We also assumed that every home in Texas would have a Tesla Powerwall. Each Powerwall has a storage capacity of 7 kWh and a capacity of 2 kW. This equates to system wide battery storage capability of 17 GW and 60 GWh. With DSM and the Tesla Powerwall together, the collective "battery" of the system is 110 GWh.

Figure 1 shows that the least cost generators (wind and solar) essentially make up the majority of the low carbon energy at requirements below ~60%. However, with increasing requirements for low carbon energy beyond 60%, low carbon baseload technologies become increasingly competitive because of their ability to maintain higher utilization. Furthermore, the cost minimizing amount of renewables on the system decreases with requirements for more low carbon energy, implying that whatever is most cost effective today might not actually be leading to the most cost effective system in the future, even if it has lower costs.

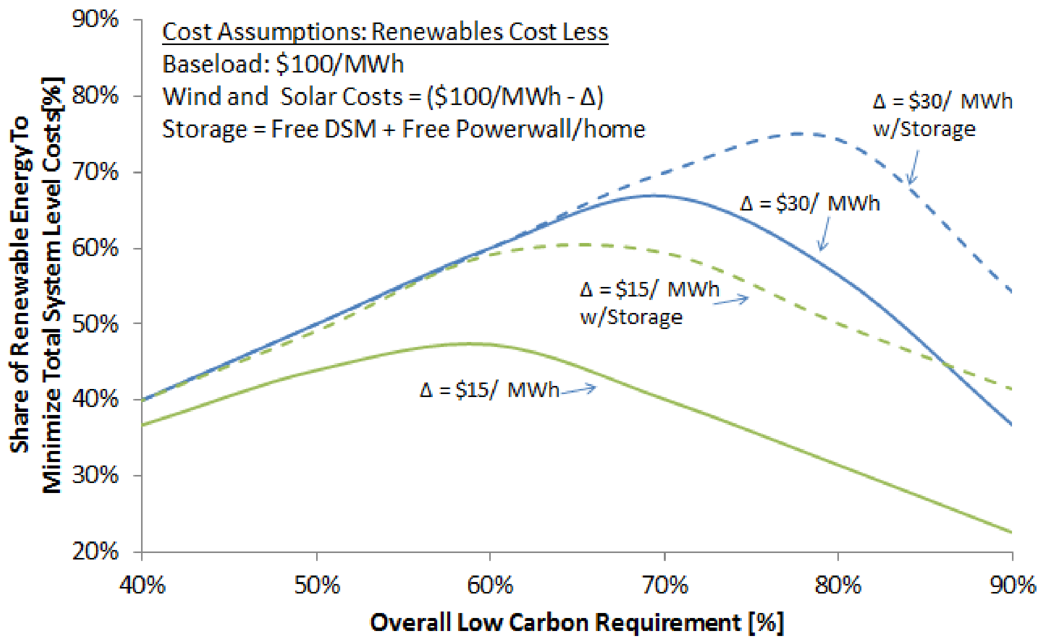

Figure 1: Cost Minimizing Combinations of intermittent and low carbon baseload technologies under increasingly aggressive requirement for low carbon energy.

Conclusions

There are three main takeaways from this research. In order of decreasing importance, the future make-up of the grid will be dependent on: 1) the cost of renewable energy vs. baseload energy, 2) the stringency of the carbon cap, 3) the presence of batteries. Figure 1 shows that assumed costs still dominate. However, with increasing stringency of the low carbon energy required, the insufficient coincidence of intermittent generators with demand leads to decreasing utilization as the technology scales. This means that renewable energy can have a low levelized cost yet still have higher system level costs. The presence of storage does increase the utilization of renewable energy, but not as much as one might think. Intermittent dominated systems tend to have seasonal oversupply and undersupply issues, and storage cannot store seasonal surpluses. Storage also increases the utilization of baseload generators which may oversupply at night and during the winter. We conclude that the debate between intermittent and baseload is still a function of costs with low carbon stringency increasing the importance of utilization and thus decreasing the competitiveness of renewables.