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The impact of Production Tax Credits on the profitable production of electricity from wind in the U.S.

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ABSTRACT

A spatial financial model using wind data derived from assimilated meteorological condition was developed to investigate the profitability and competitiveness of onshore wind power in the contiguous U.S. It considers not only the resulting estimated capacity factors for hypothetical wind farms but also the geographically differentiated costs of local grid connection. The levelized cost of wind-generated electricity for the contiguous U.S. is evaluated assuming subsidy levels from the Production Tax Credit (PTC) varying from 0 to 4 ¢/kWh under three cost scenarios: a reference case, a high cost case, and a low cost case. The analysis indicates that in the reference scenario, current PTC subsidies of 2.1 ¢/kWh are at a critical level in determining the competitiveness of wind-generated electricity compared to conventional power generation in local power market. Results from this study suggest that the potential for profitable wind power with the current PTC subsidy amounts to more than seven times existing demand for electricity in the entire U.S. Understanding the challenges involved in scaling up wind energy requires further study of the external costs associated with improvement of the backbone transmission network and integration into the power grid of the variable electricity generated from wind.

1. Introduction

Wind power offers a potentially important renewable low-carbon source for electricity in the U.S. Wind power in the U.S. grew at an annual average rate of 39% from 2005 to 2009 (AWEA, 2010). By the end of 2009, the cumulative installed capacity had reached a level of close to 35 GW (AWEA, 2010), corresponding to approximately 22% of total global capacity (WWEA, 2010). A recent study by the U.S. Department of Energy (US-DOE) suggested that as much as 20% of total U.S. demand for electricity could be supplied by wind as early as 2030 (US-DOE, 2008).

A number of studies concluded that apart from the system integration challenges, wind resources in the U.S. are more than sufficient to supply the present and projected future demand for electricity in the U.S. (Elliott et al., 1991; Hoogwijk et al., 2004; Lu et al., 2009; NREL and AWS-Truewind, 2010). Lu et al. (2009), using assimilated meteorological data from the U.S. National Aeronautics and Space Administration (NASA), concluded that the potential for wind at a height of 100 meters from the contiguous 48 states exploited by turbines operating at capacity factors (CFs) in excess of 20% could supply as much as 16 times current total demand. A recent joint study by the U.S. National Renewable Energy Laboratory (NREL) and AWS-Truewind estimated that wind-generated electricity at 80 m for areas with gross capacity factors (CFs) in excess of 30% would supply as much as 8 times current U.S. electricity demand (NREL and AWS-Truewind, 2010).

These and other previous studies, however, were directed mainly at quantifying the technologically feasible wind energy excluding only areas of low wind and areas judged unsuitable for wind farm development. In practice, a combination of location related economic factors must be taken into account including generation cost, the marginal cost of electricity in competing local power markets, and the financial incentives from government subsidies. For example, small-scale wind projects might still be competitive in the northeast where electricity prices are relatively high and where incentives are in place for development of renewable energy, even though wind resources are not as strong

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as in the Great Plains states. On the other hand, it may be difficult to site a large wind farm in the northeast U.S. due to population density, geography, and the existence of areas judged off-limits to development. The distinction is analogous to the concept of "resources" versus "reserves" pertaining to oil, natural gas, and coal. Resources define the amount of potentially recoverable fossil fuel, whereas reserves identify the subset of resources deemed technologically and economically viable for extraction. Wind reserves are contingent thus on economic conditions, as well as on wind resources and current technologies. It is important to determine whether the wind energy can provide an economically viable alternative to more conventional sources of electricity.

The federal production credit tax (PTC) provides an important subsidy for the development of wind power in the U.S. A qualified wind farm can receive an income tax credit of 2.1 ¢/kWh, adjusted for inflation, for the first ten years of operation. The PTC was established under the Energy Policy Act of 1992 to stimulate renewable technologies for electricity generation. Since its first scheduled expiration in mid-1999, the PTC has been renewed seven times, usually for only one or two years at a time. The current PTC was extended to 2012 under the American Recovery and Reinvestment Act of 2009 (ARRA 2009). In the absence of price on carbon emissions, much of the growth of wind power in the U.S. in the past decades can be attributed to PTC, as well as renewable portfolio standards (RPS) adopted by many states (Wiser, 2007). The cycle of expiration and extension of the PTC subsidy however has resulted in a boom-bust pattern for the development of wind power in the U.S. (Wiser, 2007; AWEA, 2010). Barradale (2010) pointed out that the volatility of investment in the wind sector was driven mainly by uncertainty about the PTC. A longer-term extension of PTC could have had important benefits in terms of costs for development of wind energy and for efficiencies in the entire supply-chain (Wiser, 2007). Assuming that a long-term and stable PTC policy is enacted, the question arises as to how the economic feasibility of U.S. wind power would be influenced by the specific level of the PTC subsidy.

This paper investigates the economic feasibility of the onshore potential for wind energy given the current PTC subsidy, accounting for geographic and demographic differences across the contiguous U.S. The first step in the analysis is to evaluate the technical potential for wind power for the contiguous U.S. without consideration of financial constraints (i.e., the resource). The study is distinguished from previous work in which it takes advantage of high-resolution spatial and temporal wind data derived from assimilated meteorological fields compiled by NOAA (Benjamin et al., 2002). Spatial analysis tools in Geographic Information System (GIS) are applied to identify regions technically suitable for turbine deployment. Following this, a spatial financial model for U.S. wind projects, building on the technical model for wind potential, is developed and applied to explore the profitability and competiveness of wind-generated electricity in the local power market. The GIS-based financial model developed in this study provides a useful tool to study quantitatively the impact of PTC on the profitability of wind power in the U.S. while integrating considerations of wind resources, technology, and finance. The economically feasible potential for wind-generated electricity (i.e., the reserve) in the contiguous U.S. is explored specifically considering PTC subsidies varying from zero to double current levels.

Following this introduction, the evaluation of onshore wind resources and the assumptions involved in the choice of geographical constraints are described in Section 2. The spatial financial model for U.S. wind projects and the key parameters defining this model are discussed in Section 3. Results are presented in Section 4 with concluding remarks in Section 5.

2. Onshore wind resources and geographical constraints

The purpose of this section is to evaluate the technical potential for wind power resources in the contiguous U.S. The results will be used as input to the spatial financial model described in Section 3. Wind data for the present analysis are derived using assimilated meteorological fields, RUC-20 (the 20-km resolution version of the Rapid Update Cycle assimilation system), developed for 2006 by the National Centers for Environmental Prediction (NCEP) of the National Oceanic and Atmospheric Administration (NOAA) (Benjamin et al., 2002). Meteorological fields are reconstructed in RUC-20 through an optimal analysis of results from the state-of-the-art mesoscale numerical forecast model combined with measurements from a comprehensive variety of sources including surface stations, weather balloons and aircraft, and satellites. RUC-20 provides a record of hourly wind speeds with a spatial resolution of 20 kilometer (km) by 20 km for the North American region. There are 50 vertical model layers in the RUC-20 and each model layer contains the wind activities in both longitudinal and latitudinal directions. Wind speeds at an elevation of 100 m are interpolated from data over the first five model layers of RUC-20. Electricity generation from wind is estimated assuming a network of land-based GE 2.5-MW turbines (GE, 2006), a model representative of current technology on the international market. Deployment is restricted to areas that are not forested, built-up, or ice-covered (Lu et al., 2009), and excludes regions with slopes greater than 20% (McElroy et al., 2009) and areas designated as national or state parks. The combination of the above exclusions identifies regions unsuitable for wind turbine installation, as indicated in white in Fig. 1.

We assume that the spacing between individual turbines in a typical wind farm is equal to nine rotor diameters in the downwind direction and five rotor diameters perpendicular to the prevailing wind ($9D \times 5D$), slightly larger than the spacing adopted in prior studies (Archer and Jacobson, 2005; Dvorak et al., 2010; Lu et al., 2009). The rotor diameter, the diameter of the circle swept by the three turbine blades, is 100 m for the wind turbines (GE-2.5 MW) considered in this analysis (GE, 2006). Thus, each turbine requires a setback area of about 0.45 km^2. Overall power loss due to turbine wake effects with the spacing proposed here is taken equal to 10% (Kempton et al., 2007; Masters, 2004). The data flow and assumptions for this analysis are summarized in Fig. 2.

The output of wind-generated electricity from each RUC-20 grid cell over the contiguous U.S. is calculated using the power curve provided by the wind turbine manufacturer. Power production is estimated for every hour over the course of 2006, then aggregated for the whole year to generate a spatially distributed map of the net capacity factors (CFs), as shown in Fig. 1.

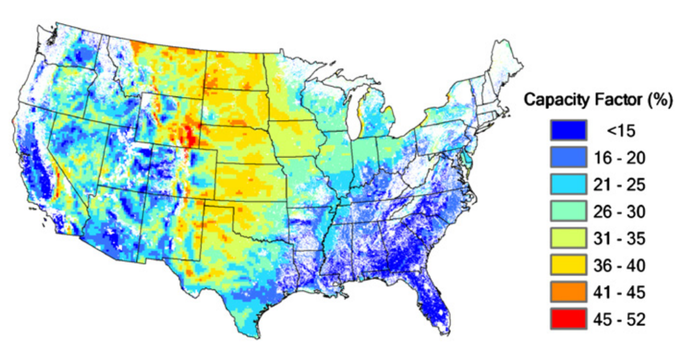

Fig. 1. Spatial distribution of net capacity factors evaluated for deployment of 2.5 MW turbines on the contiguous U.S.