Wind Energy Potential at Six Locations in the Midwest US at Higher Hub Heights

Eugene S. Takle[1], Bin Cai[2], Sri Sritharan[2]
[1]Dept. of Agronomy, Iowa State University, Ames, Iowa, USA, gstakle@iastate.edu; [2]Dept Civil Engineering, Iowa State University, Ames Iowa, USA

Abstract

Higher winds, particularly at night due to the nocturnal low-level jet in the US Midwest, provide incentive to build wind turbines with hub heights above 100 m. Estimates of annualized energy production based on models and statistical methods in such conditions have high uncertainty. We use measured data at 100 m and above to demonstrate that increases of approximately 10% in capacity factor can be achieved with a 20 m increase in hub height.

Keywords: *Tall tower, Field measurement, Wind speed; Annual energy production, Levelized cost of energy*

Introduction

Higher winds, particularly at night due to the nocturnal low-level jet (NLLJ)[1,2] in the US Midwest, provide incentive to explore energy resources at 100 m or higher. Estimates of annualized energy production and capacity factor based on mesoscale meteorological models, the NREL WIND Toolkit [3,4], and statistical extrapolations from lower levels [2, 5] have large errors because of limitations in capturing characteristics of the NLLJ. We use tall-tower measurements at six locations in the US Midwest to evaluate wind resource potential above the conventional 80-m hub height of the current fleet of Midwest turbines. Results demonstrate that a 20-m increase in hub height can increase energy production by up to10%, which offers a significant incentive for using taller towers.

Methods

We use two years of 10-min data from 50, 100, 150, and 200 m recorded on tall towers at five Iowa locations - Quimby, Palmer, Mason City, Altoona, and Homestead – along with data from 130 m for a brief summer period at Rosemount, MN to estimate annualize energy production (AEP). Power output was obtained from two typical utility-scale turbines, a 2.3 MW turbine with a 108-m rotor diameter and a 3.0 MW with a 113-m rotor diameter.

Results

Diurnal variations of annually averaged wind speed show a strong tendency for higher winds at night than during daytime, with variations from location to location in Iowa. The MN data available represent only a summer period and not an annual average.

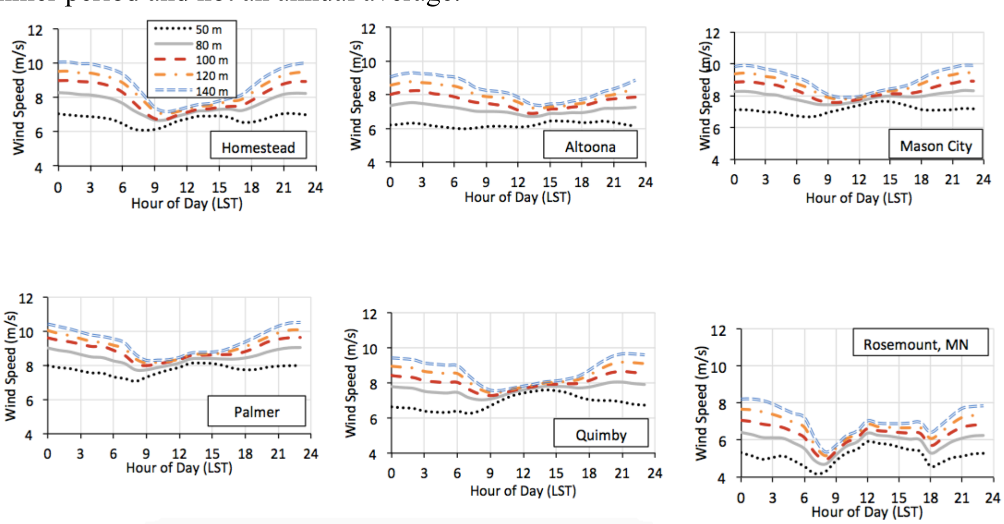

Fig. 1. Diurnal variations of average of wind speed at various heights for six Midwestern locations.

We use power curves for the 2.3 and 3.2 MW turbines to calculate AEP and capacity factors at 80, 100, 120, and 140 m (Fig. 2). These results demonstrate that tall towers in this region can enhance the capacity factor of wind turbines by 9, 12, and 17%, respectively for 100, 120, and 140-m towers over capacity at 80 m for a 2.3 MW turbine and 10, 15, and 20%, respectively for a 3.2 MW turbine.

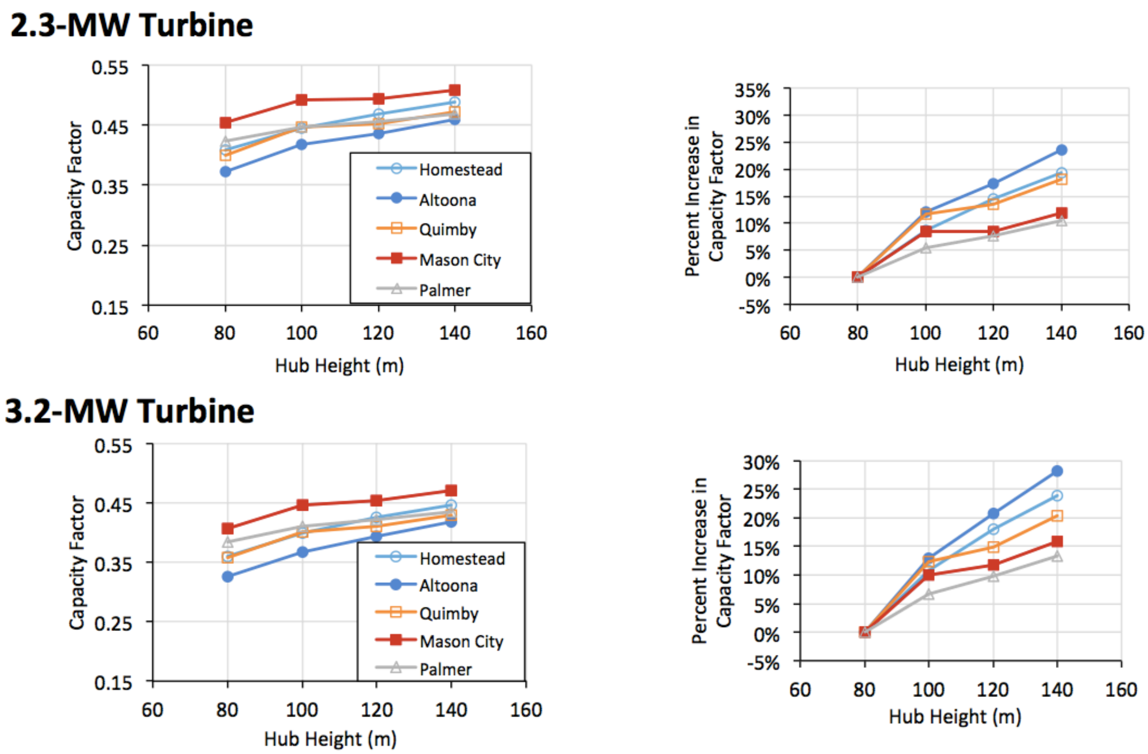

Fig. 2. Capacity factor (left) and percentage increase in capacity factor over those for 80-m hub height (right) for Siemens 2.3 MW (top) and 3.2 MW turbines (bottom)

Results for the MN tower data (not shown) for a limited July period show a 33% increase in capacity factor per 20-m increase in height above 80 m, although not representative of other months or an annual average. Analysis of a one-year dataset is in progress. NREL WIND Toolkit data for the Homestead, IA tower location for 2007 (all months) revealed good agreement for diurnal and seasonal cycles of wind speed. Toolkit nighttime winds agree well with measurements while daytime data showed a low bias.

Acknowledgement

Support provided by the EERE/USDOE DE-EE0006737, the Chinese Scholarship Council (Cai), Iowa Energy Center (IEC) grant OG-17-001, and the FaNTASTIC project NSF grant 1701278. Data provided by Siemens Corporation, IEC, and the U Minn. Eolos Wind Research Station.

References

1. Storm, B, and Basu, S, 2010: the WRF model forecast-derived low-level wind shear climatology over the United States Great Plains. Energies, 3, 258-276. DOI:10.3390/en3020258
2. Walton RA, Takle ES, Gallus WA. Characteristics of 50 – 200 m winds and temperatures derived from an Iowa tall tower network. *J. Appl. Meteor. Climatology* 2014; **53**, 2387-2393. http://dx.doi.org/10.1175/JAMC-D-13-0340.1
3. Draxl C, Hodge BM, Clifton A, McCaa J. The Wind Integration National Dataset (WIND) Toolkit. *Applied Energy* 2015; **151**: 355-366. http://dx.doi.org/10.1016/j.apenergy.2015.03.121
4. King J, Clifton A., Hodge B.M. *Validation of power output for the WIND Toolkit.* Technical Report, NREL/TP-5D00-61714. National Renewable Energy Laboratory: Golden, CO, 2014.
5. Kelley N, Shirazi M, Jager D, et al. *Lamar low-level jet project interim report.* Technical Report. NREL/TP-500-34593. National Renewable Energy Laboratory: Golden, CO, 2004. http://www2.mmm.ucar.edu/people/patton/documents/NREL-TP-500-34593.pdf