

IOWA STATE UNIVERSITY
Hexcrete Tower Project (DE-EE0006737)

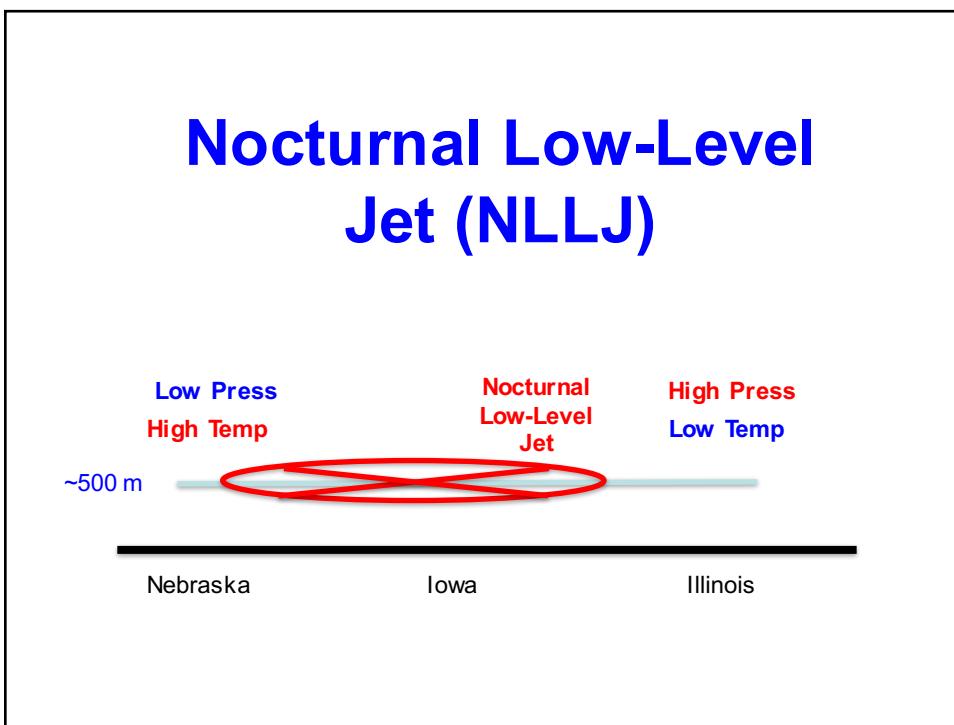
J.S. DEPARTMENT OF
ENERGY Energy Efficiency &
Renewable Energy
WIND & WATER POWER
TECHNOLOGIES OFFICE

Wind Energy Potential in the Midwest at Higher Hub Heights

Eugene S. Takle, Bin Cai, Sri Sritharan
(acknowledgement to the Iowa Energy Center for data from the Iowa Tall Tower Network)

Iowa State University

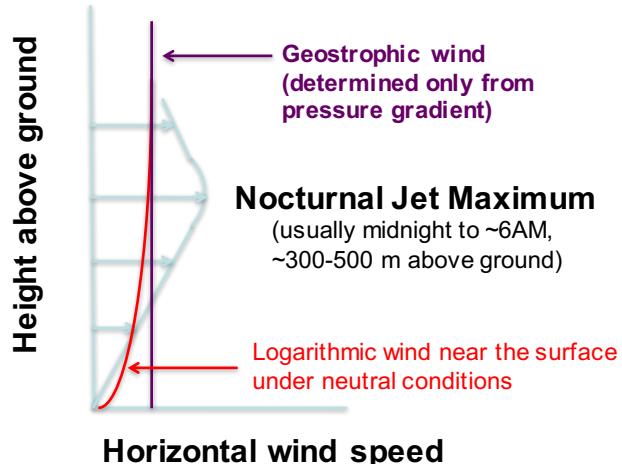
Hexcrete Commercialization Workshop
Denver, CO
June 23, 2016



Important slide!

Nocturnal Low-Level Jet

Although labeled as a “jet” the NLLJ is really a broad sheet of air of higher speed that may be only be 100-200 m thick but blanket the whole state of Iowa

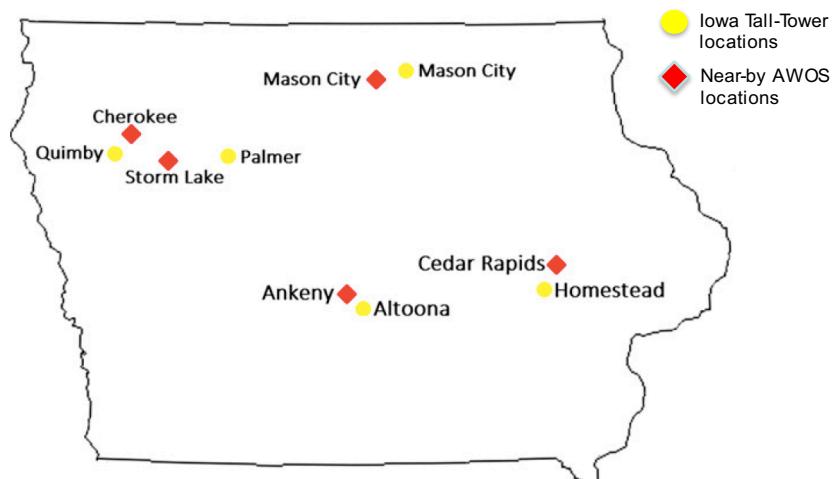


Horizontal wind speed

Note: when meteorologists plot data as a function of height they usually put height (independent variable) on the vertical axis

Iowa Tall-Tower Network

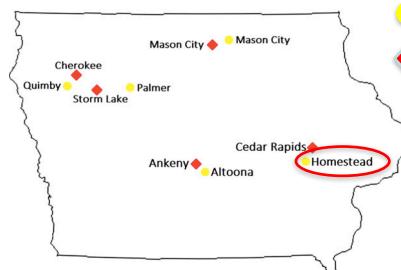
Data provided by the Iowa Energy Center



Walton, R. A., E. S. Takle, and W. A. Gallus, Jr., 2014: Characteristics of 50 – 200 m winds and temperatures derived from an Iowa tall tower network. *J. Appl. Meteor. Climatol.*, 53, 2387-2393. doi: <http://dx.doi.org/10.1175/JAMC-D-13-0340.1>.

Iowa Tall-Tower Network

Data provided by the Iowa Energy Center



Iowa Tall-Tower locations

Near-by AWOS locations

Data period: 11/30/2006 - 12/11/2008 (742 days)

10-minute average wind data (temperature, mean wind speed, wind speed standard deviation, wind direction, wind direction standard deviation) at 50 m, 100 m, 150 m, 200 m

Missing data

Height	Wind Speed _Daytime	Wind Speed _Nighttime	Wind Direction _Daytime	Wind Direction _Nighttime
50 m	1.33%	1.59%	13.33%	9.4%
100 m	3.65%	3.17%	37.75%	35.71%
150 m	4.46%	4.21%	13.68%	11.12%
200 m	30.85%	36.29%	40.71%	42.61%

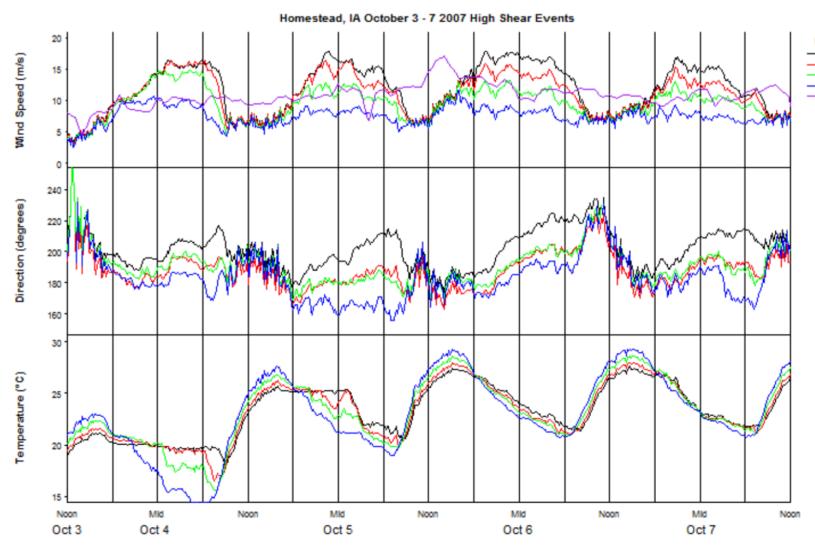
Walton, R. A., E. S. Takle, and W. A. Gallus, Jr., 2014: Characteristics of 50 – 200 m winds and temperatures derived from an Iowa tall tower network. *J. Appl. Meteor. Climatol.*, 53, 2387–2393. doi: <http://dx.doi.org/10.1175/JAMC-D-13-0340.1>.

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Diurnal Trend of Wind Speed, Direction, and Temperature



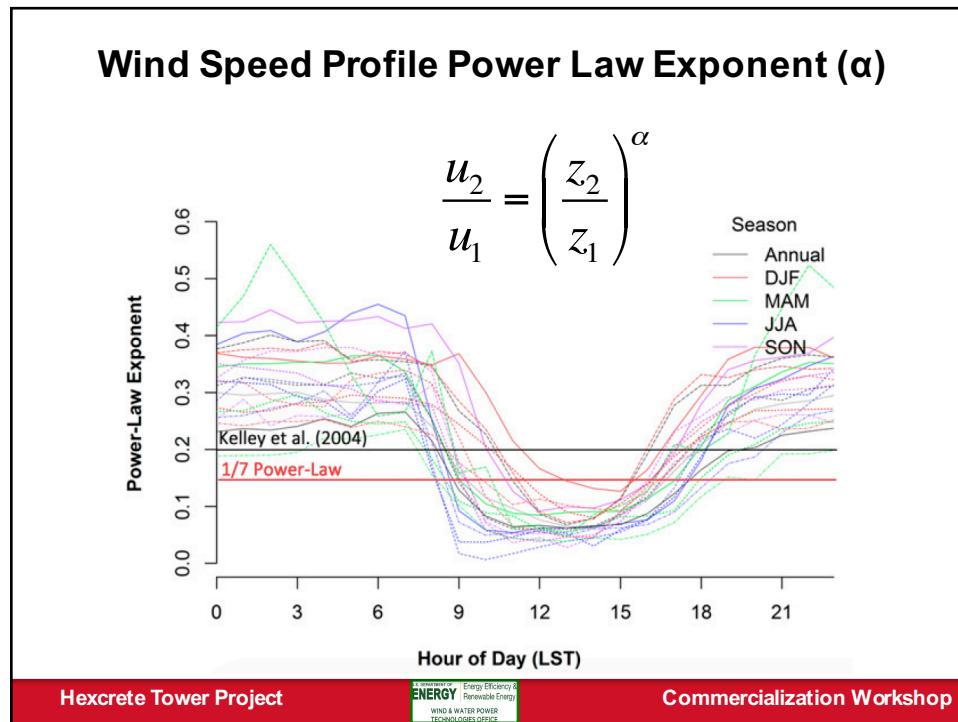
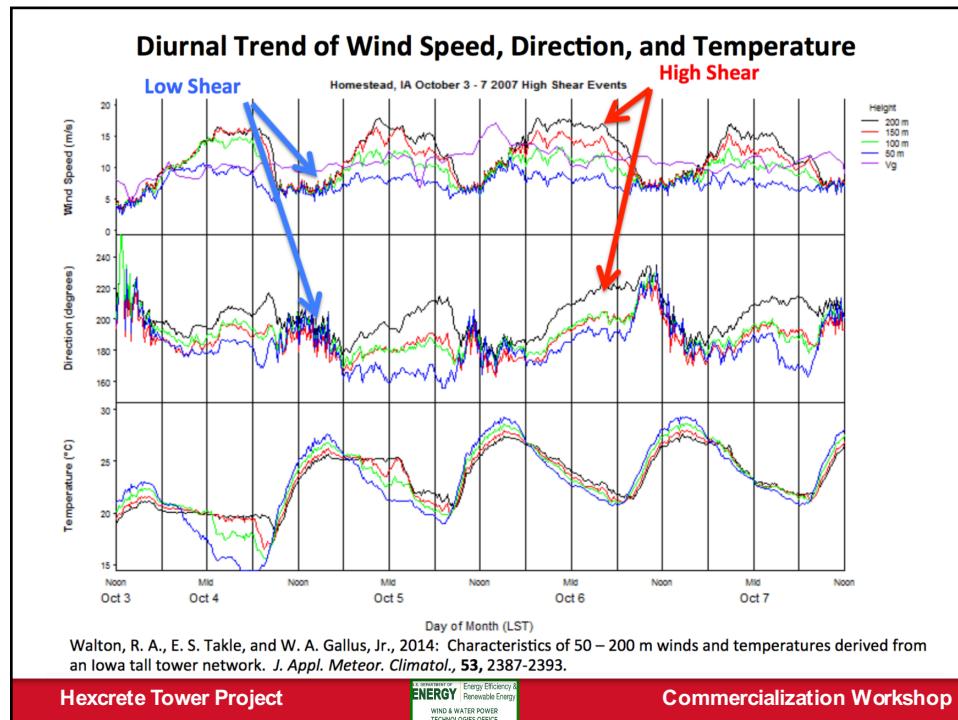
Day of Month (LST)

Walton, R. A., E. S. Takle, and W. A. Gallus, Jr., 2014: Characteristics of 50 – 200 m winds and temperatures derived from an Iowa tall tower network. *J. Appl. Meteor. Climatol.*, 53, 2387–2393.

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Annual Energy Production

$$AEP = \sum_{k=1}^{12} \left\{ \sum_{j=1}^d \left[\sum_{h=1}^{24} \left(\frac{\sum_{i=1}^m E(v_i)}{m} \right) * 6 \right] \right\} (1)$$

$$E(v_i) = P(v_i)p(v_i) \quad (2)$$

d: number of days for each month

m: number of available data points for each hour per month

v_i: 10_minute average wind speed

p(v_i): number of occurrence for wind speed v_i

P(v_i): actual power output at wind speed v_i

$$\text{Capacity Factor} = \frac{AEP}{\text{turbine capacity} * 8760} * 100\% \quad (3)$$

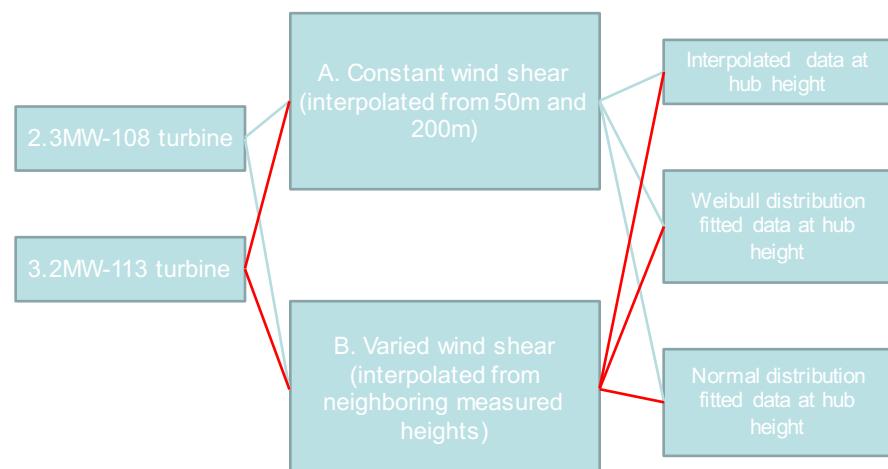
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Energy Calculation

12 Cases:

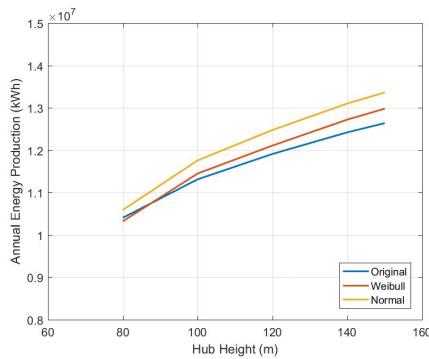


Annual energy production and capacity factor for the 2.3 MW turbine (preliminary results)

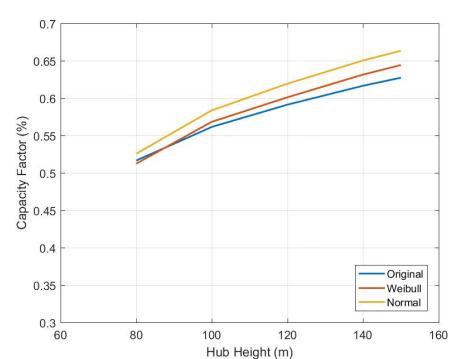
Hub height (m)	Annual energy production (kWh)			Capacity factor (%)		
	Original data	Weibull data	Normal data	Original data	Weibull data	Normal data
80 (baseline)	1.04E+07	1.03E+07	1.06E+07	52%	51%	53%
	1.13E+07	1.15E+07	1.18E+07	56%	57%	58%
100	+9%	+11%	+11%			
120	1.19E+07	1.21E+07	1.25E+07	59%	60%	62%
140	1.24E+07	1.27E+07	1.31E+07	62%	63%	65%
	+19%	+23%	+24%			

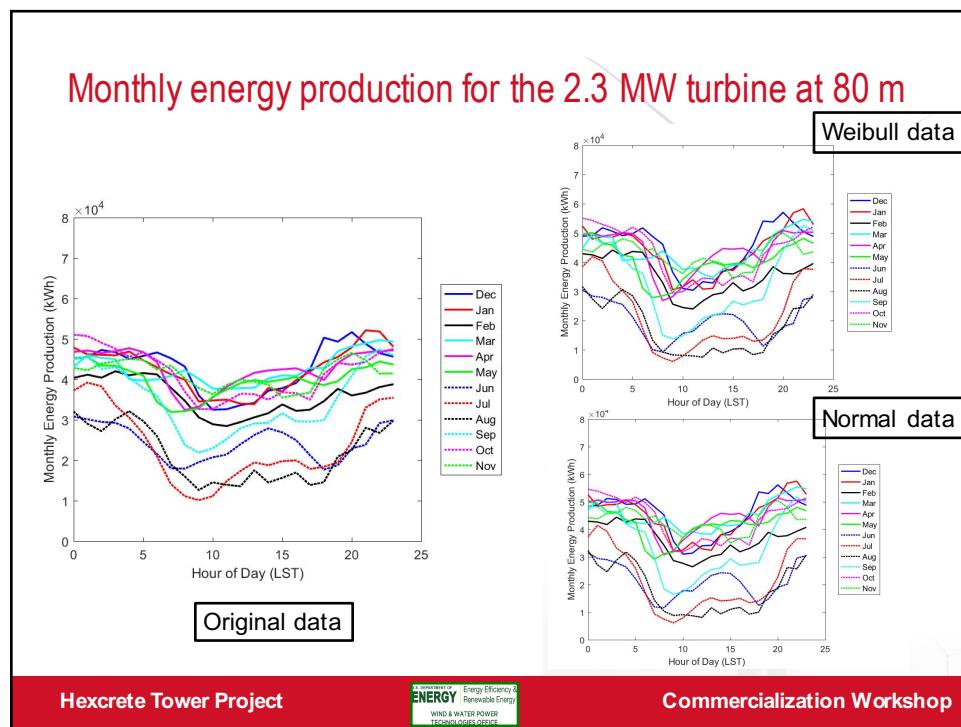
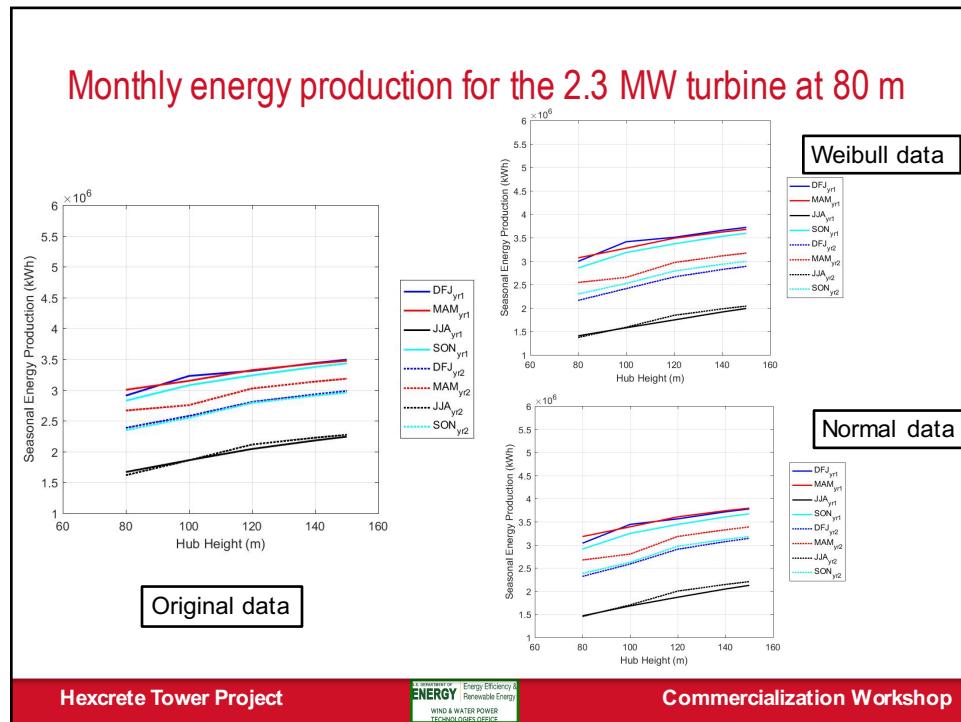
Annual energy production and capacity factor for the 2.3MW turbine

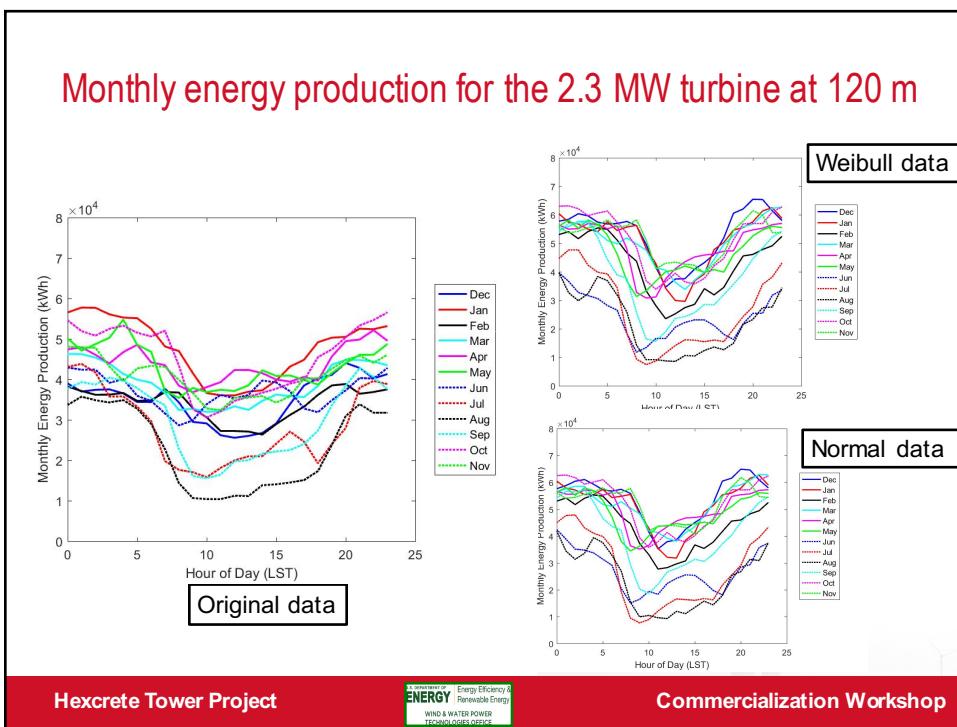
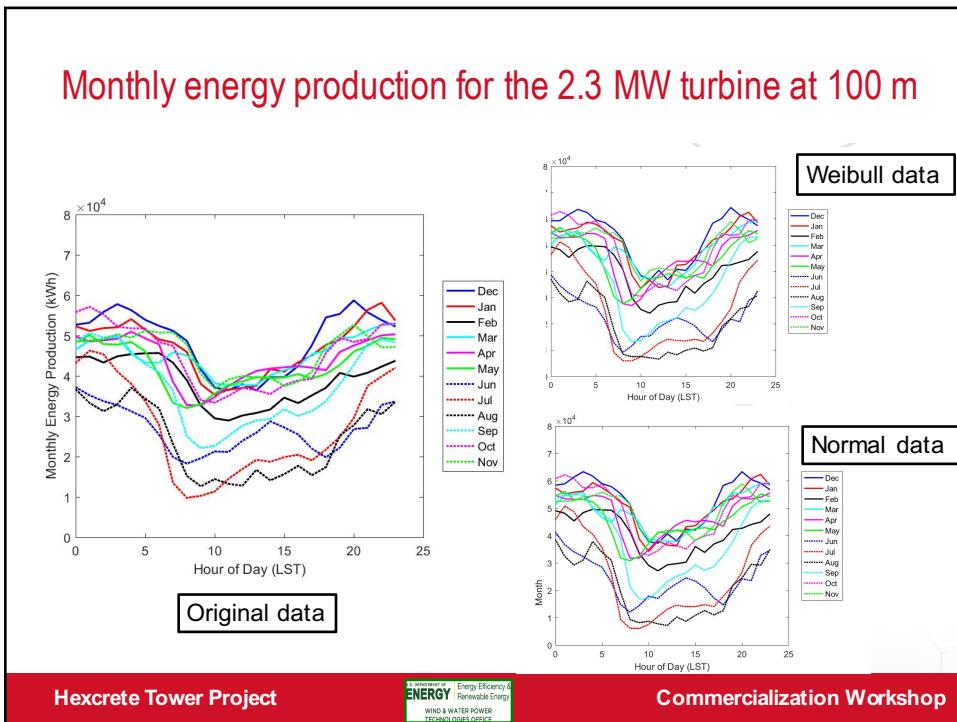
Annual Energy Production
Year 1

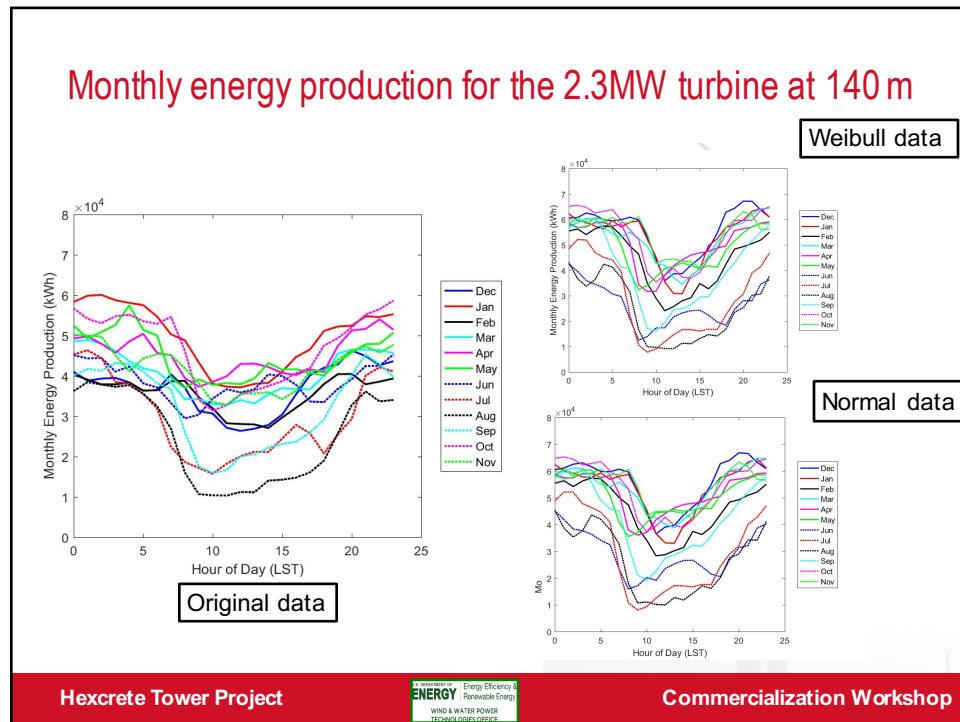


Capacity Factor
Year 1







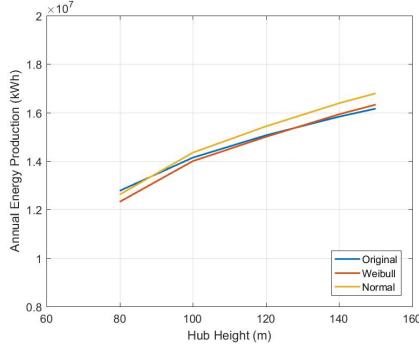


Annual energy production for the 3.2 MW turbine (preliminary results)

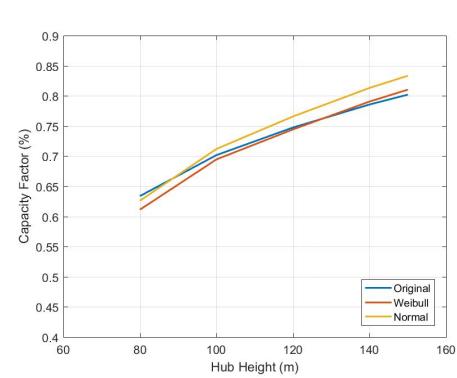
Hub height (m)	Annual energy production (kWh)			Capacity factor (%)		
	Original data	Weibull data	Normal data	Original data	Weibull data	Normal data
80 (baseline)	1.28E+07	1.23E+07	1.26E+07	46%	44%	45%
100	1.41E+07	1.40E+07	1.43E+07	50%	50%	51%
120	11%	14%	14%			
140	1.51E+07	1.50E+07	1.54E+07	54%	54%	55%
	18%	22%	22%			
	1.58E+07	1.59E+07	1.64E+07	56%	57%	58%
	24%	29%	30%			

Annual energy production and capacity factor for the 3.2 MW turbine

**Annual Energy Production
Year 1**

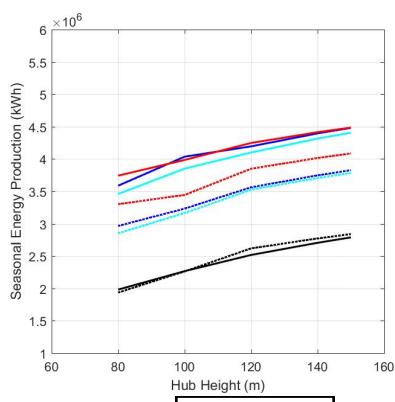


**Capacity Factor
Year 1**

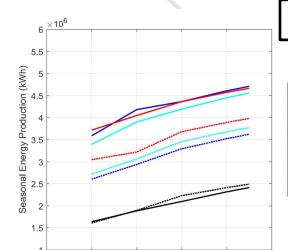


Seasonal energy production for the 3.2 MW turbine

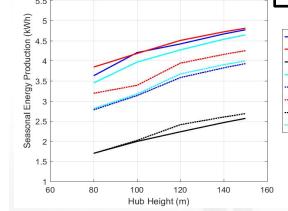
Original data



Weibull data



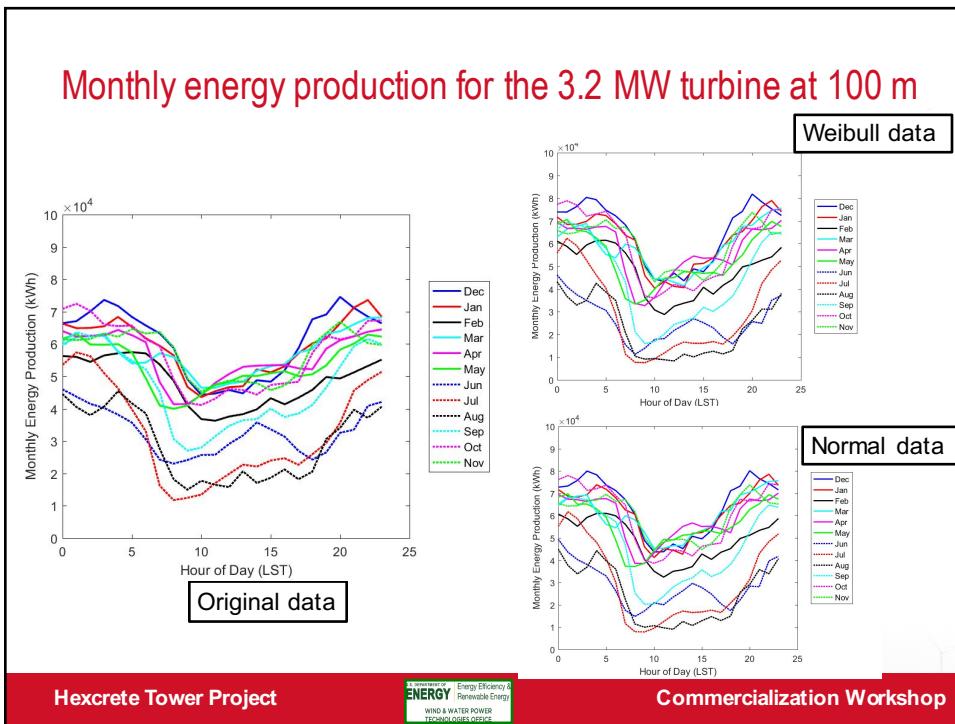
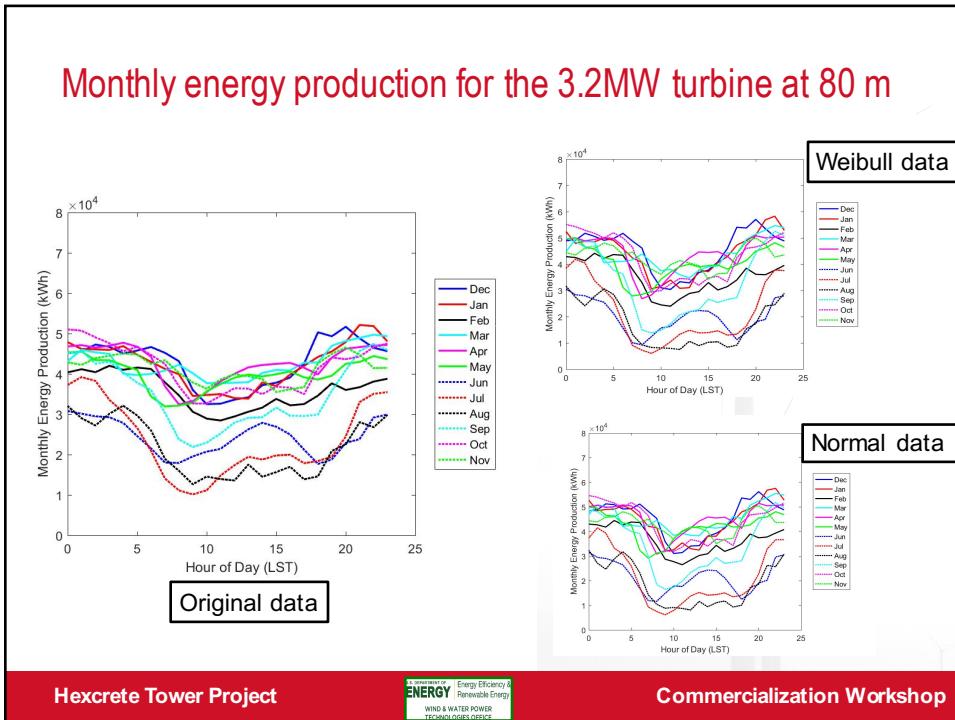
Normal data

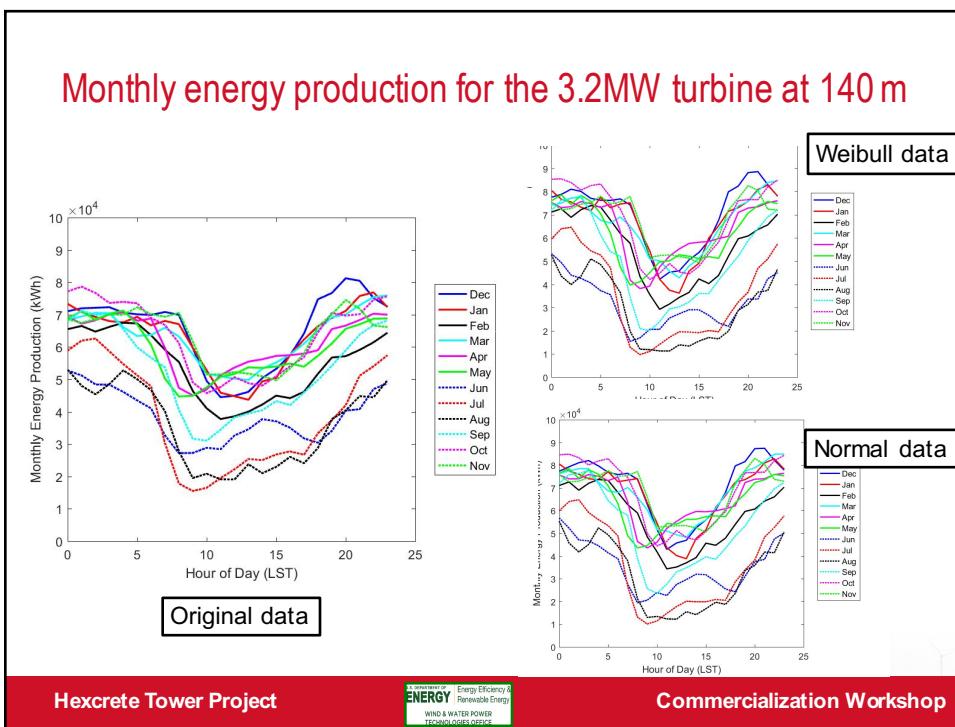
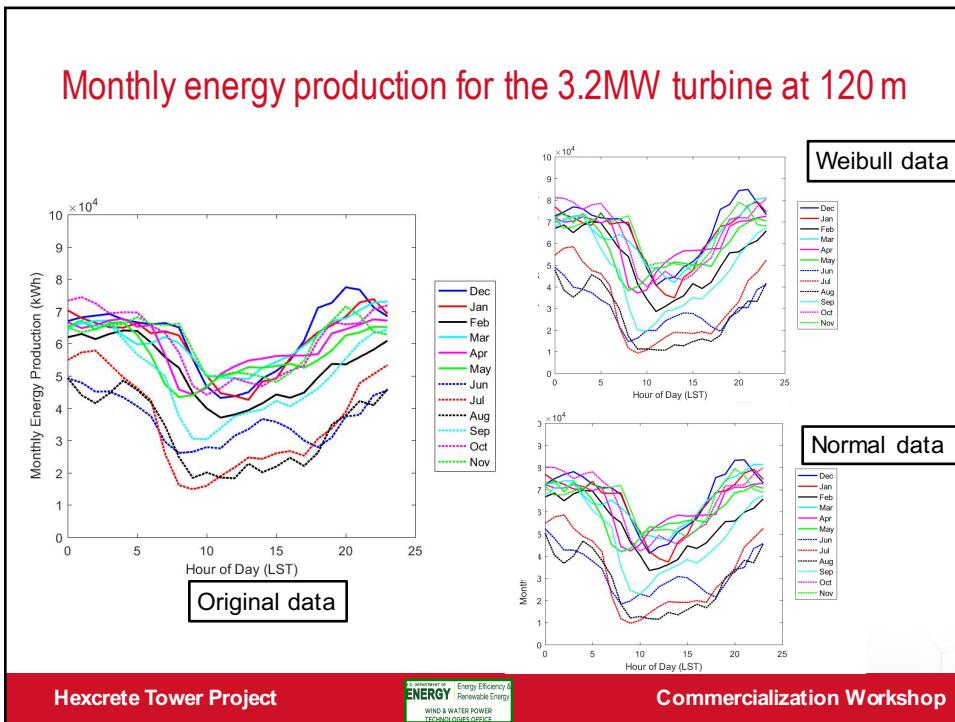


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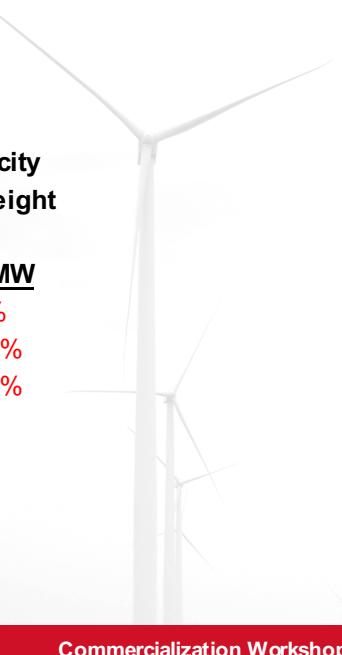




Important slide!

Summary

Height	% Increase in Capacity Factor over 80-m Height	
<u>Rated Power</u>	<u>2.3 MW</u>	<u>3.2 MW</u>
100 m	7.7%	8.7%
120 m	16.7%	17.4%
140 m	19.2%	21.7%



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