

COLLEGIATE
WIND
COMPETITION
2021

SITING
HARDWARE
REVIEW 2





SITING PROJECT DEVELOPMENT

TEAM LEAD: BRITTANY TAGA

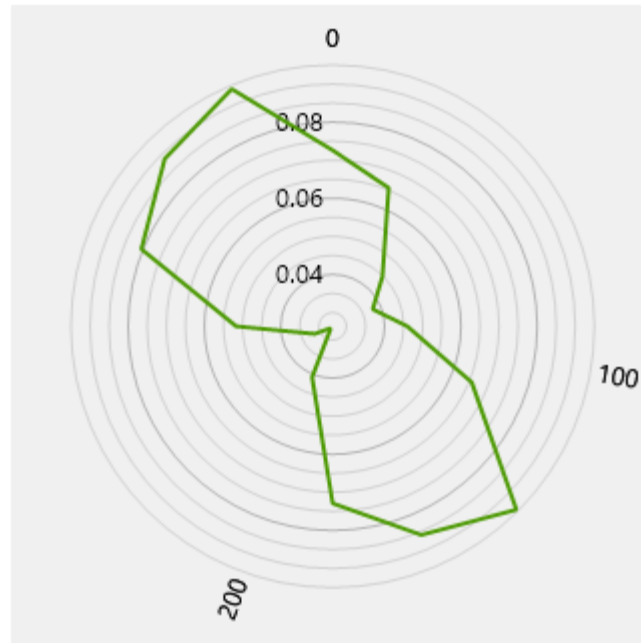
NAVEEN VIDANAGE, AARON ZEEK, TORE CADEMAN AND NATALIE MCDONALD



PROGRESS

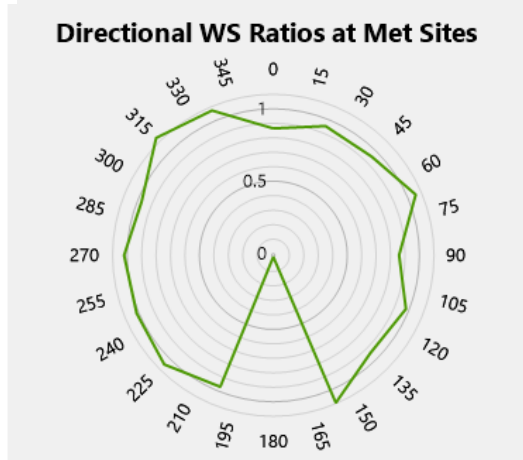
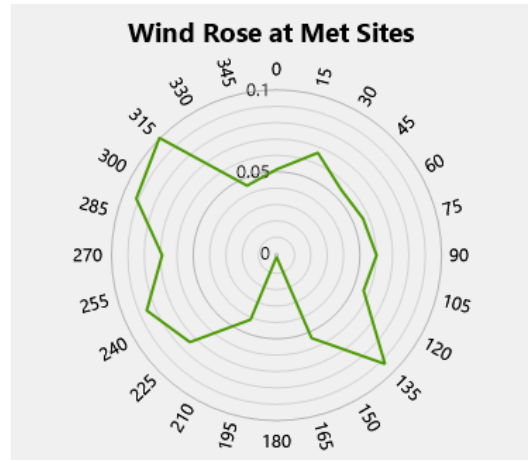
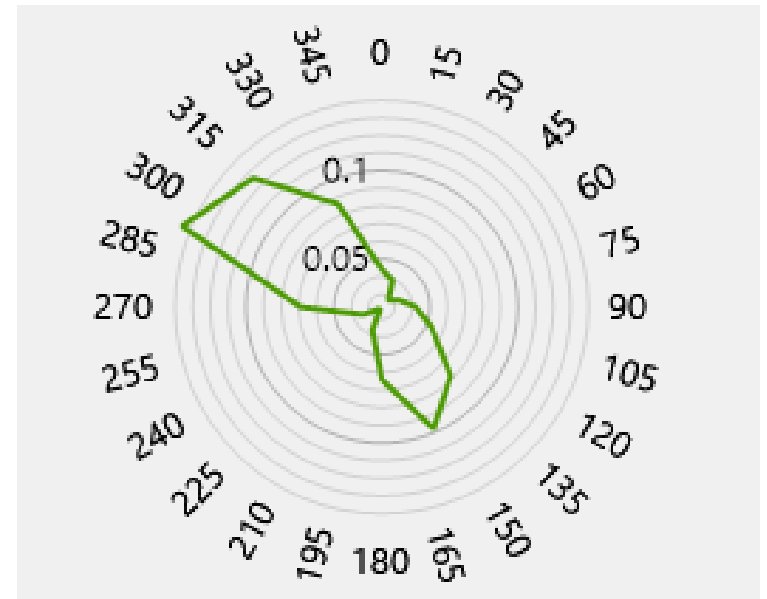
- Continuum software problems being solved
 - Team is currently simulating final site
 - Wind flow analysis
 - Turbine placement
- County ordinances and policies are being evaluated
- Currently reaching out to multiple corporations for more information regarding siting
- Finances are being secured
- Land being secured
 - Trying to contact landowner
 - Creating a lease document

WIND ROSE



WS/WD vs. WD

Wind Rose ▾



CONTINUUM CONTINUED...

- In Continuum we still need the power, thrust coefficient, and velocity to be able to generate an effective power curve.
- We originally based our power data off the available power equation rather than the power produced by the turbine. The overall power has yet to be determined for each model.

$$P_{avail.} = \frac{1}{2} \rho A v^3 C_p$$

- The equations used for finding thrust, and thrust coefficient are shown below.

$$T = \frac{1}{2} \rho A U^2 [4a(1 - a)] \quad C_T = \frac{T}{\frac{1}{2} \rho V_0 A_t}$$

WIND PROSPECTOR

- For Continuum's simulations Brittany and I both generated wind data.
- I ran 80 Meter tower height wind data and Brittany ran 100 meter

Generated in Wind Prospector			
File Name: 80 Meter Data	Long	-102.588501	
WS Units	Lat	45.07149124	
Date & Time Stamp	Velocity (mps)	Wind Direction	Air Temperature C
1/1/2012 0:00	11.89	305.43	1.52
1/1/2012 0:05	11.7	305.15	1.38
1/1/2012 0:10	11.69	304.76	1.26
1/1/2012 0:15	11.96	304.67	1.16
1/1/2012 0:20	12.53	305.5	1.09
1/1/2012 0:25	13.14	306.84	1.06
1/1/2012 0:30	13.52	307.43	1.02
1/1/2012 0:35	13.59	306.88	0.95
1/1/2012 0:40	13.49	306.04	0.87
1/1/2012 0:45	13.45	305.35	0.81
1/1/2012 0:50	13.5	304.69	0.74
1/1/2012 0:55	13.64	304.23	0.67
1/1/2012 1:00	13.85	304.18	0.59
1/1/2012 1:05	14.1	304.43	0.5
1/1/2012 1:10	14.31	304.9	0.42
1/1/2012 1:15	14.35	305.43	0.35
1/1/2012 1:20	14.27	305.89	0.29
1/1/2012 1:25	14.18	306.17	0.23
1/1/2012 1:30	14.04	306.21	0.18
1/1/2012 1:35	13.81	305.94	0.14
1/1/2012 1:40	13.51	305.18	0.09
1/1/2012 1:45	13.16	303.98	0.03
1/1/2012 1:50	12.88	302.84	-0.04
1/1/2012 1:55	12.74	302.49	-0.13
1/1/2012 2:00	12.81	303.39	-0.22
1/1/2012 2:05	12.95	304.9	-0.31
1/1/2012 2:10	13.14	306.11	-0.38
1/1/2012 2:15	13.21	306.62	-0.44
1/1/2012 2:20	13.14	306.58	-0.49
1/1/2012 2:25	13.03	306.47	-0.54
1/1/2012 2:30	13.02	306.65	-0.59
1/1/2012 2:35	13.09	307.19	-0.64

Figure 5: 80 Meter Data

Generated in Wind Prospector			
File Name: brit1	Long	-102.615	
WS Units	Lat	45.06995	
Date & Time Stamp	Velocity (mps)	Wind Direction	Air Temperature C
1/1/2012 0:00	11.05	304.37	-1.88
1/1/2012 0:05	11.09	304.58	-1.9
1/1/2012 0:10	11.11	304.93	-1.92
1/1/2012 0:15	11.09	305.28	-1.94
1/1/2012 0:20	11.05	305.47	-1.96
1/1/2012 0:25	10.98	305.59	-1.98
1/1/2012 0:30	10.94	305.69	-2
1/1/2012 0:35	10.88	305.56	-2.03
1/1/2012 0:40	10.79	305.3	-2.05
1/1/2012 0:45	10.7	304.81	-2.07
1/1/2012 0:50	10.57	304.21	-2.1
1/1/2012 0:55	10.45	303.55	-2.12
1/1/2012 1:00	10.32	302.94	-2.14
1/1/2012 1:05	10.19	302.39	-2.16
1/1/2012 1:10	10.1	301.94	-2.19
1/1/2012 1:15	10.03	301.54	-2.22
1/1/2012 1:20	9.99	301.33	-2.25
1/1/2012 1:25	9.96	301.45	-2.29
1/1/2012 1:30	9.93	301.84	-2.32
1/1/2012 1:35	9.88	302.4	-2.35
1/1/2012 1:40	9.85	303.12	-2.39
1/1/2012 1:45	9.8	303.83	-2.42
1/1/2012 1:50	9.74	304.37	-2.46
1/1/2012 1:55	9.67	304.88	-2.5
1/1/2012 2:00	9.61	305.24	-2.53
1/1/2012 2:05	9.55	305.68	-2.57
1/1/2012 2:10	9.46	306.08	-2.6

Figure 6: 100 Meter Data

Table 1: Perkins county monthly averages

Perkins county Climate Monthly averages

Month	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperatures	Hi -3°C Lo -10°C	Hi -2°C Lo -9°C	Hi 6°C Lo -2°C	Hi 12°C Lo 3°C	Hi 19°C Lo 9°C	Hi 26°C Lo 15°C	Hi 31°C Lo 19°C	Hi 29°C Lo 18°C	Hi 24°C Lo 14°C	Hi 13°C Lo 5°C	Hi 6°C Lo -1°C	Hi -2°C Lo -8°C
Avg. Wind Speed (m/s)	5	4.7	5	5.5	5.2	4.7	4.7	4.7	5	5.2	5	5
Avg. Precipitation (mm)	12	19	29	47	72	57	49	31	25	30	14	16
Average Humidity	82%	78%	73%	63%	61%	59%	50%	49%	48%	57%	63%	78%
Avg. Cloud Cover	49%	48%	48%	43%	37%	26%	20%	19%	21%	32%	34%	46%
Barometric Pressure (mb)	1021	1021	1017	1014	1013	1011	1012	1012	1014	1016	1018	1020
Average Dry Days	17	15	14	13	14	14	16	17	21	20	22	18
Avg. Precip. Days	3	3	8	12	15	14	11	11	8	7	3	4
Average Snow Days	12	12	9	6	1	0	0	0	0	3	5	10
Average Fog Days	4	2	4	2	1	1	0	0	0	1	1	3
Average UV Index	1	1	2	3	5	6	7	6	4	3	1	1
Avg. Hours of Sun	191	209	260	304	375	415	445	418	342	287	245	202

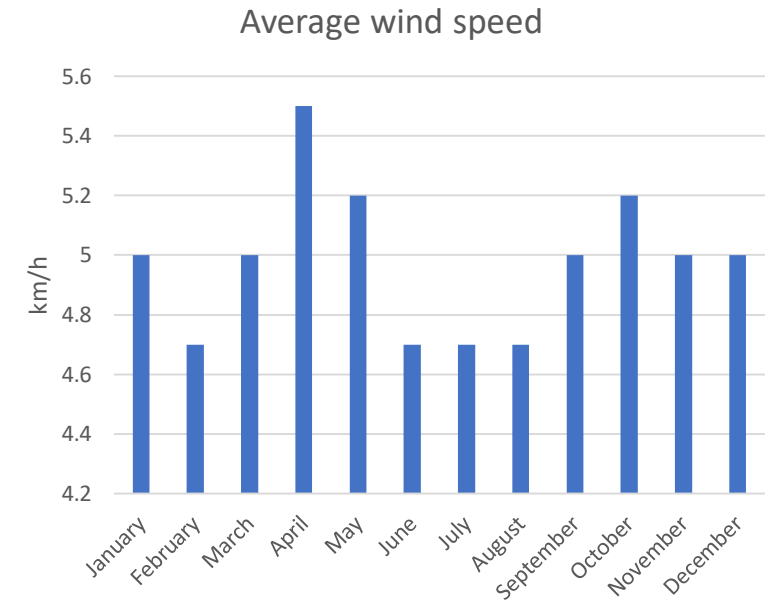


Figure 9: Average wind speed

[1]F. Weather WX, "Perkins County SD Climate Averages, Monthly Weather Conditions", WeatherWX.com, 2021. [Online]. Available:

<https://www.weatherwx.com/hazardoutlook/sd/perkins+county.html>. [Accessed: 24- Feb- 2021].

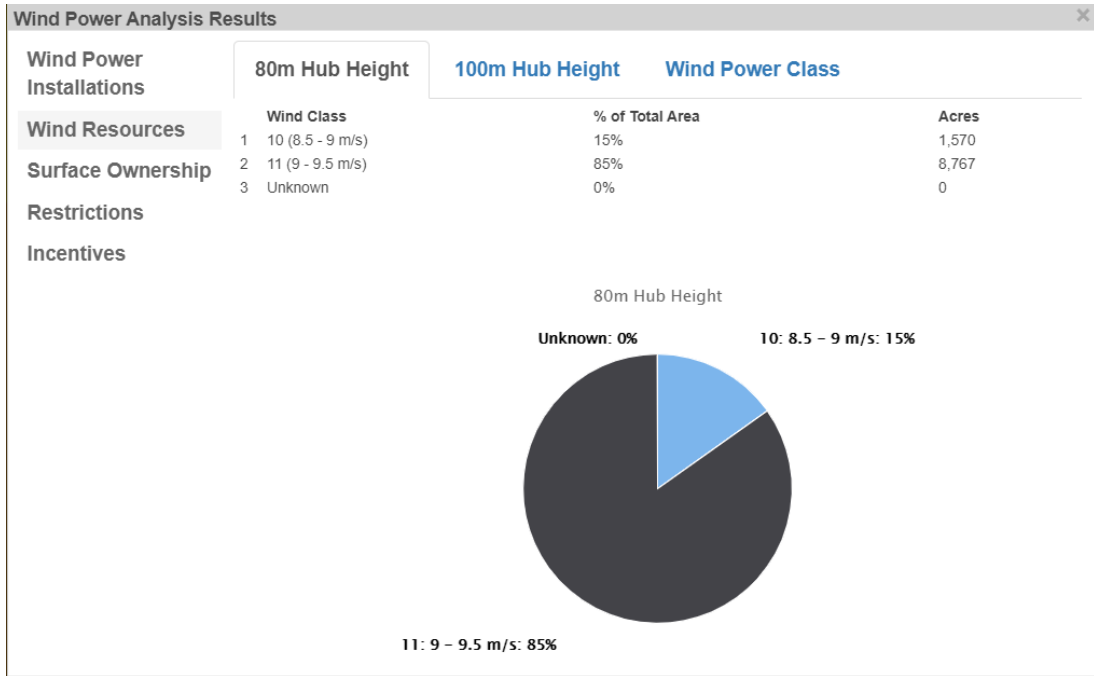


Figure 10: 80m wind power analysis

80m hub height on site location

Wind class(m/s)	%total area	Acres
1 8.5-9	15%	1570
2 9-9.5	85%	8767
median		
	8.75	1.3125
	9.25	7.8625
Average wind speed	9.175	

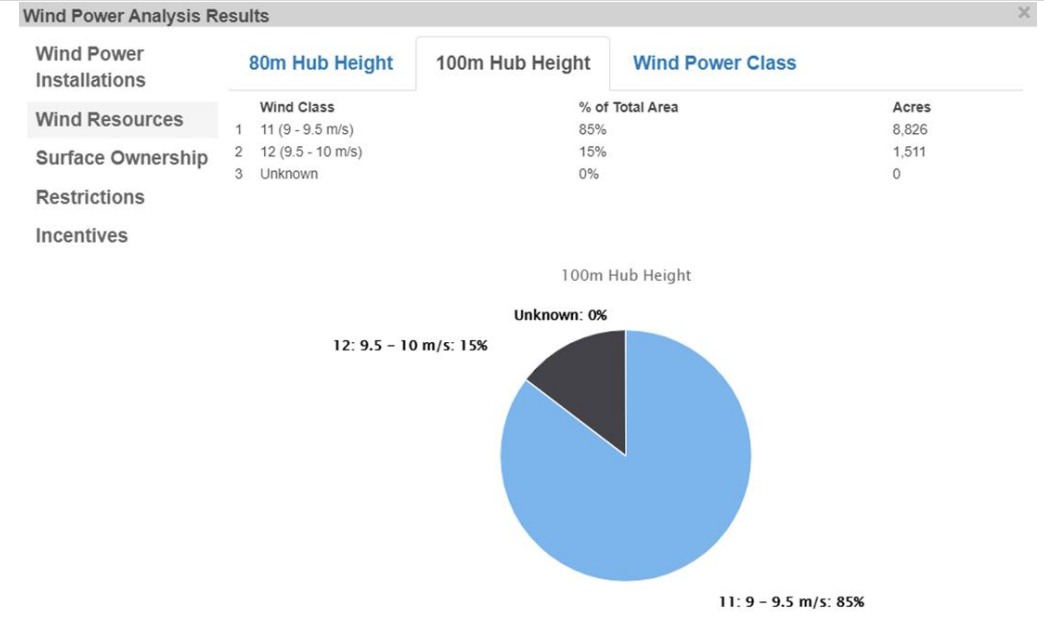


Figure 11: 100m wind power analysis

100m hub height on site location

Wind class(m/s)	%total area	Acres
1 9-9.5	15%	1570
2 9.5-10	85%	8767
median		
	9.25	7.8625
	9.75	1.4625
Average wind speed	9.325	

Table 2: IEC wind turbine classes

Wind turbine Class	I	II	III
V average (m/s)	10	8.5	7.5
Turbulence intensity	A	0.16	
	B	0.14	
	C	0.12	

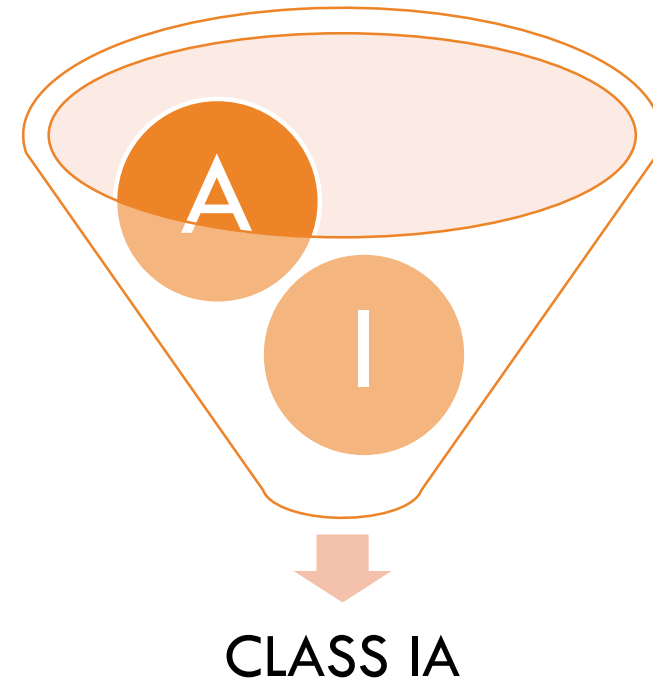
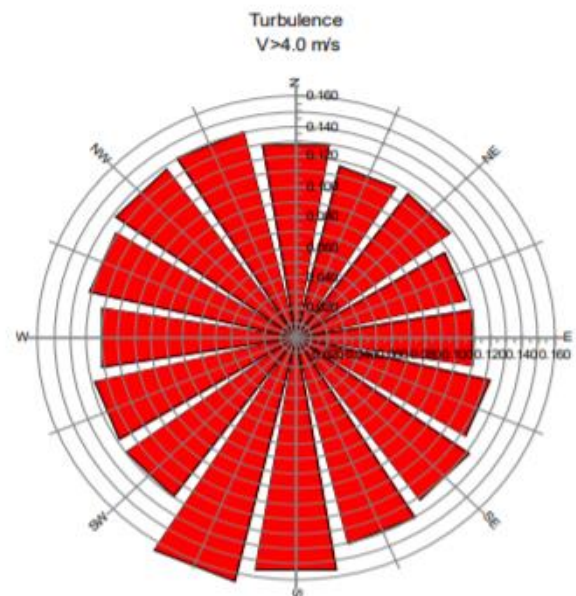
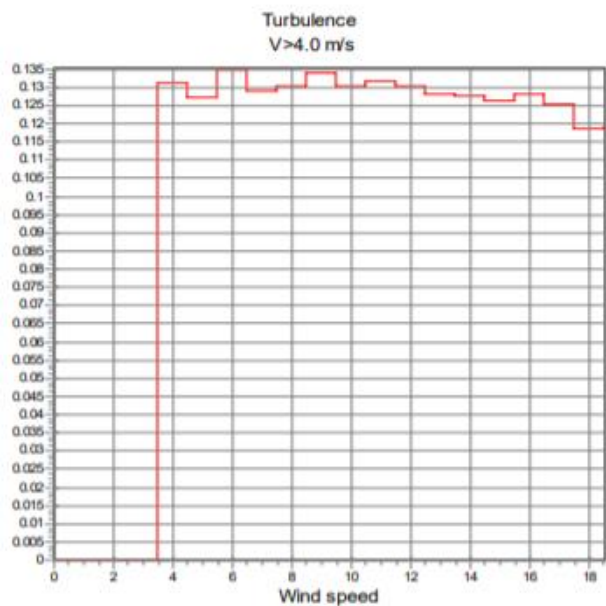
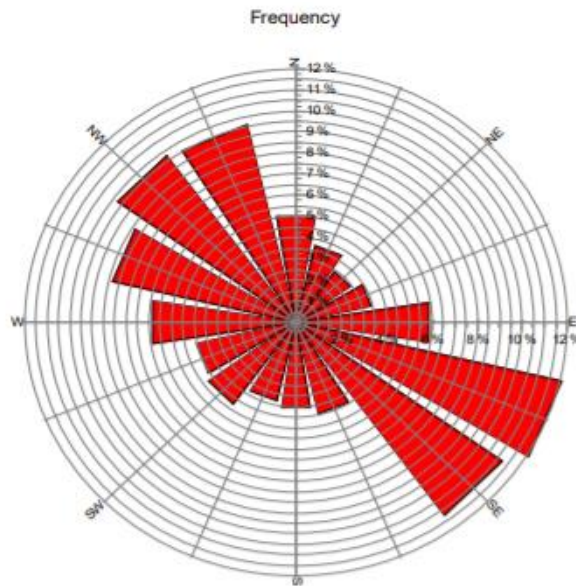
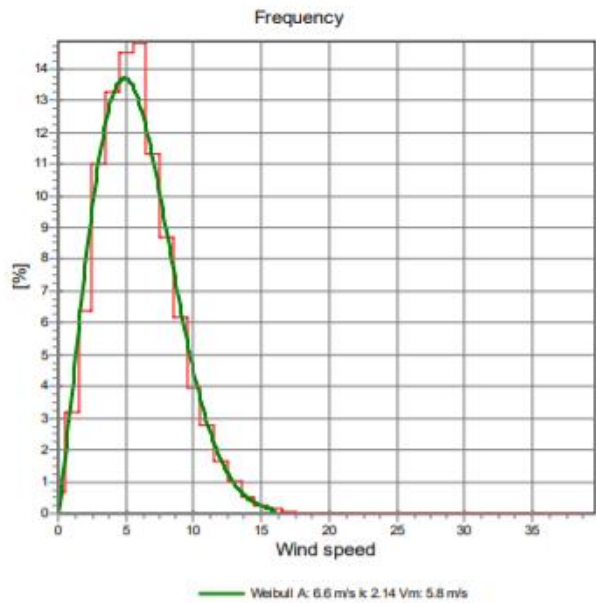


Figure 12: Anemometer Data (Wind Speed, Direction) for Beresford, South Dakota



V112-3.45

Power output:
3.450kW

Swept area:
9852m²

Hub height: 94m



SG 3.4-132

Power output:
3.465MW

Swept area:
13685m²

Hub height:
101.5m



SG 5.0-132

Power output:
5MW

Swept area:
13685m²

Hub height: 84m



SG 5.8-155

Power output:
6.6MW

Swept area:
18868m²

Hub height:
102.5m

Results

```
%80m hub height data  
h1 = 80;  
v1 = 9.175;  
  
%100m hub height data  
h2 = 100;  
v2 = 9.325;  
  
A = (log(v2)-log(v1))/(log(h2)-log(h1))  
  
A = 0.0727
```

Wind shear coefficient

Figure 13: shear coefficient calculation

Maximum power coefficient

Maximum Tip speed ratio

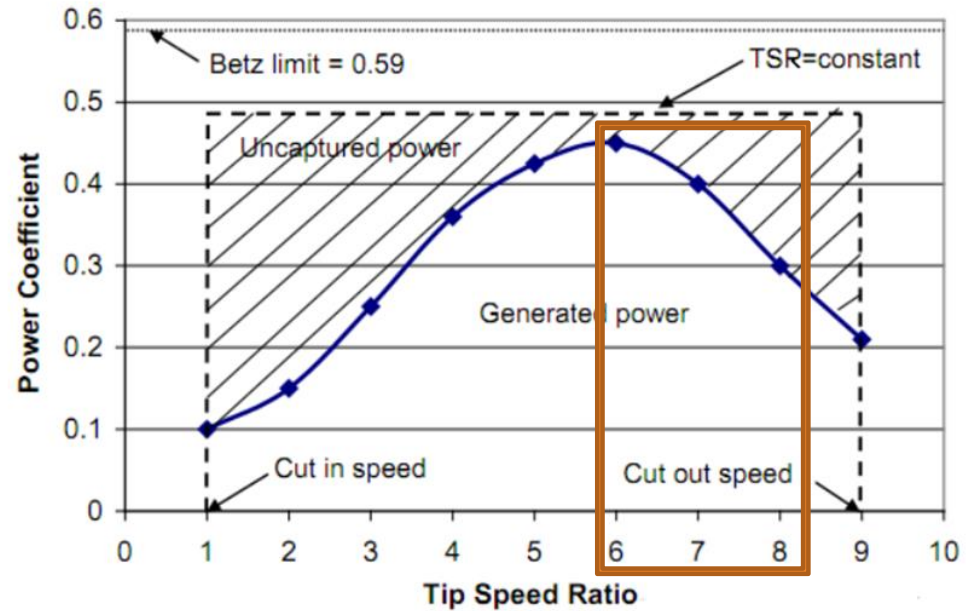


Figure 14: tip speed ratio and maximum power coefficient

Vestas V112-3.45 MW

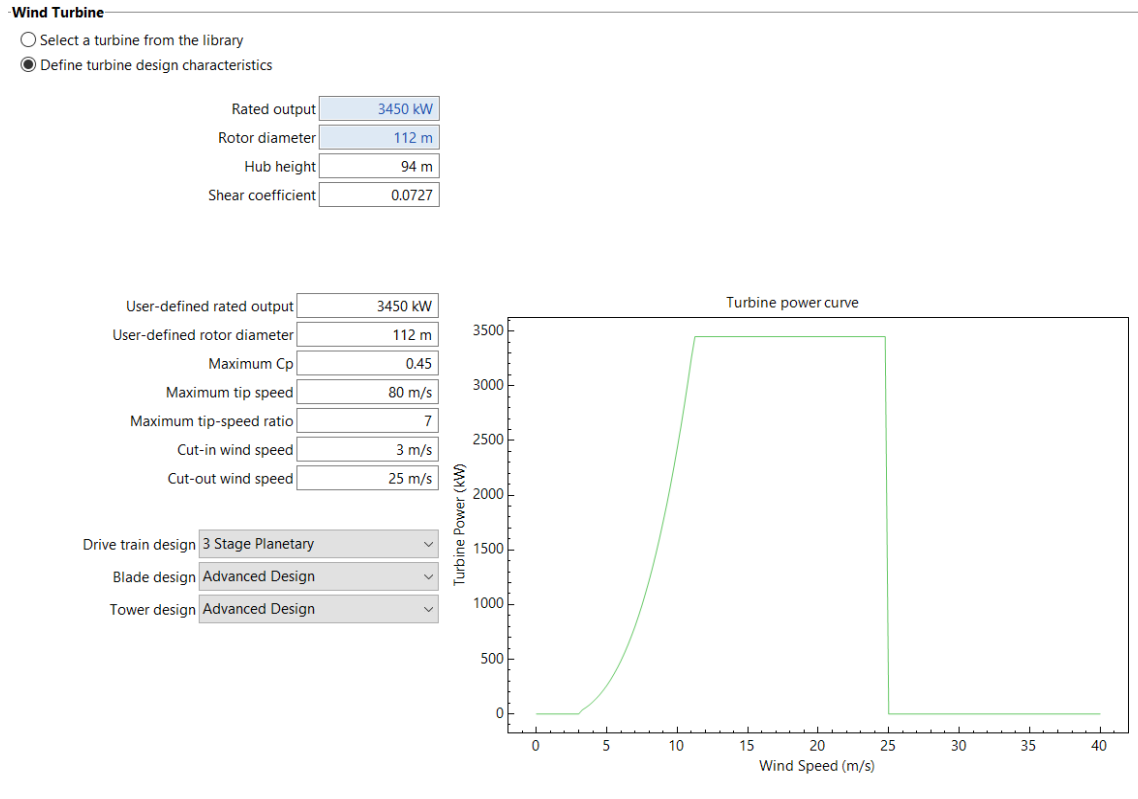


Figure 15: Power curve by shear coefficient

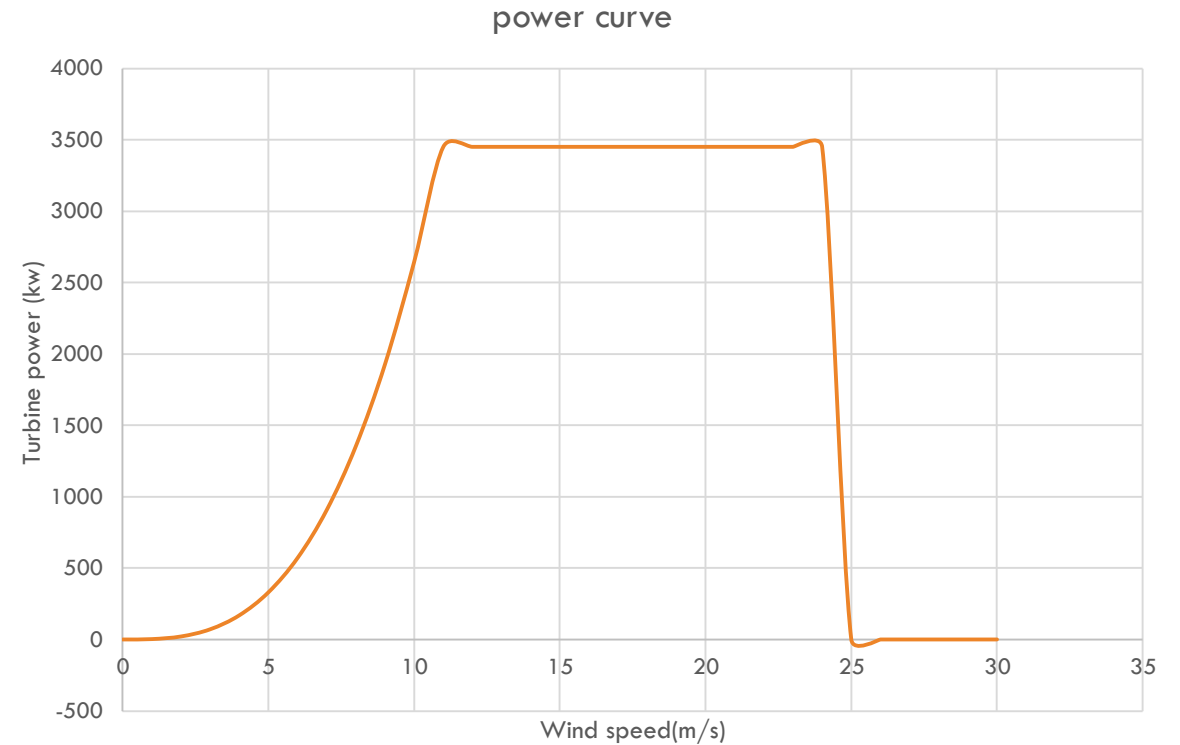


Figure 16: Power curve by thrust coefficient

LEVELIZED COST OF ENERGY (LCOE)

Table 2: LCOE Calculator

Data	Vestas V112- 3.45 MW	Siemens Gamesa SG 3.4-132
Annual Energy AC (year 1) (kWh)	2.478 E8	3.07037 E8
Annual Gross Energy (kWh)	3.0182 E8	3.72884 E8
Annual Energy with 95% Probability of Exceedance (kWh)	1.98687 E8	2.46183 E8
Annual Energy with 90% Probability of Exceedance (kWh)	2.09468 E8	2.59542 E8
Average Wind Speed (m/s)	7.33065	7.40502
First year kWh/kW (kWh/kW)	2565.22	3178.44
Levelized Cost of Energy (\$/kWh)	0.0843095	0.0680436

Table 3: Project Revenue

Revenue	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Total Revenue (USD)	0	0	0	0	0	0
Property Tax Net Assessed Value (USD)	130,410,000	130,410,000	130,410,000	130,410,000	130,410,000	130,410,000

**PROJECT REVENUE
FOR SIEMENS
GAMESA SG 3.4-132**

- Merchant Plan
- Site 7
- SG 3.4 - 132 had a lower LCOE
- Maximum Number of Turbines -28

Table 4: Project State Income Taxes

Project State Income Taxes	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
EBITDA (USD)	-4,709,250	-4,826,981	-4,947,656	-5,071,347	-5,198,131	-5,328,084
Interest Earned on Reserves (USD)	-8,264	38,184	84,637	131,097	177,563	224,036
Total State Tax Depreciation (USD)	23,922,222	38,388,456	23,255,394	14,170,046	14,154,892	7,339,652
State Taxable Income (USD)	-24,070,956	-38,684,416	-23,713,176	-14,805,292	-14,984,362	-8,381,310
State Income Tax Rate (fraction)	0.070	0.070	0.070	0.070	0.070	0.070
State Tax Benefit (liability) (USD)	1,684,967	2,707,909	1,659,922	1,036,370	1,048,905	586,692

**PROJECT STATE
INCOME TAXES FOR
SIEMENS GAMESA SG
3.4-132**

- Merchant Plan
- Site 7
- SG 3.4 - 132 had a lower LCOE
- Maximum Number of Turbines -28

Table 5: Project Federal Income Taxes

Project Federal Income Taxes	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Total Federal Tax Depreciation (USD)	23,922,222	38,388,456	23,255,394	14,170,046	14,154,892	7,339,652
Federal Taxable Income (USD)	-22,385,990	-35,976,508	-22,053,254	-13,768,921	-13,935,457	-7,794,618
Federal Income Tax Rate (fraction)	0.210	0.210	0.210	0.210	0.210	0.210
Federal Tax Benefit (liability) (USD)	4,701,058	7,555,066	4,631,184	2,891,474	2,926,446	1,636,870

**PROJECT STATE
INCOME TAXES FOR
SIEMENS GAMESA SG
3.4-132**

- Merchant Plan
- Site 7
- SG 3.4 - 132 had a lower LCOE
- Maximum Number of Turbines -28

SCHEDULE

CWC Project Development

Northern Arizona University

MSPL © 2017 by VertexIQ.com
<https://www.vertexiq.com/Excel/Temp/ScheduleProjectGanttChart.html>

Project Start:

Duration (Weeks):



THANK YOU