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



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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.

$$T = \frac{1}{2}\rho A U^{2} [4a(1-a) \qquad C_{T} = \frac{T}{\frac{1}{2}\rho V_{0}A_{t}}$$

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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 i	n Wind Prospec	tor		Generate	d in Wind Prosp	ector	
File Name: 80 Meter Data	Long	-102.588501		File Name: brit1	Long	-102.615	
WS Units	Lat	45.07149124		WS Units	lat	45 06995	
Date & Time Stamp	Velocity (mps)	Wind Direction	Air Temperature C	Data & Time Stamp	Valacity (mps)	Wind Direction	Air Tomporaturo (
1/1/2012 0:00	11.89	305.43	1.52	Date & Time Stamp	velocity (mps)	wind Direction	Air Temperature C
1/1/2012 0:05	11.7	305.15	1.38	1/1/2012 0:00	11.05	304.37	-1.88
1/1/2012 0:10	11.69	304.76	1.26	1/1/2012 0:05	11.09	304.58	-1.9
1/1/2012 0:15	11.96	304.67	1.16	1/1/2012 0:10	11.11	304.93	-1.92
1/1/2012 0:20	12.53	305.5	1.09	1/1/2012 0:15	11.09	305.28	-1.94
1/1/2012 0:25	13.14	306.84	1.06	1/1/2012 0:20	11.05	305.47	-1.96
1/1/2012 0:30	13.52	307.43	1.02	1/1/2012 0:25	10.98	305 59	-1 98
1/1/2012 0:35	13.59	306.88	0.95	1/1/2012 0.20	10.04	305.55	1.50
1/1/2012 0:40	13.49	306.04	0.87	1/1/2012 0:30	10.94	305.69	-2
1/1/2012 0:45	13.45	305.35	0.81	1/1/2012 0:35	10.88	305.56	-2.03
1/1/2012 0:50	13.5	304.69	0.74	1/1/2012 0:40	10.79	305.3	-2.05
1/1/2012 0:55	13.64	304.23	0.67	1/1/2012 0:45	10.7	304.81	-2.07
1/1/2012 1:00	13.85	304.18	0.59	1/1/2012 0:50	10.57	304.21	-2.1
1/1/2012 1:05	14.1	304.43	0.5	1/1/2012 0:55	10.45	303.55	-2.12
1/1/2012 1:10	14.31	304.9	0.42	1/1/2012 1:00	10.32	302.04	-2.14
1/1/2012 1:15	14.35	305.43	0.35	1/1/2012 1.00	10.32	202.34	-2.14
1/1/2012 1:20	14.27	305.89	0.29	1/1/2012 1:05	10.19	302.39	-2.10
1/1/2012 1:25	14.18	306.17	0.23	1/1/2012 1:10	10.1	301.94	-2.19
1/1/2012 1:30	14.04	306.21	0.18	1/1/2012 1:15	10.03	301.54	-2.22
1/1/2012 1:35	13.81	305.94	0.14	1/1/2012 1:20	9.99	301.33	-2.25
1/1/2012 1:40	13.51	305.18	0.09	1/1/2012 1:25	9.96	301.45	-2.29
1/1/2012 1:45	13.16	303.98	0.03	1/1/2012 1:30	9.93	301.84	-2.32
1/1/2012 1:50	12.88	302.84	-0.04	1/1/2012 1:35	9.88	302.4	-2.35
1/1/2012 1:55	12.74	302.49	-0.13	1/1/2012 1:35	0.95	202.4	2.35
1/1/2012 2:00	12.81	303.39	-0.22	1/1/2012 1:40	9.65	303.12	-2.39
1/1/2012 2:05	12.95	304.9	-0.31	1/1/2012 1:45	9.8	303.83	-2.42
1/1/2012 2:10	13.14	300.11	-0.38	1/1/2012 1:50	9.74	304.37	-2.46
1/1/2012 2:15	13.21	300.02	-0.44	1/1/2012 1:55	9.67	304.88	-2.5
1/1/2012 2:20	13.14	206.38	-0.49	1/1/2012 2:00	9.61	305.24	-2.53
1/1/2012 2.23	12.03	206.65	-0.54	1/1/2012 2:05	9.55	305.68	-2.57
1/1/2012 2.30	12.02	207 19	-0.55	1/1/2012 2:10	9.46	306.08	-2.6
1/1/2012 2:55	15.05	307.15	-0.04	1/1/2012 2.10	2.10	500.00	2.0

Figure 5: 80 Meter Data

Figure 6: 100 Meter Data

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THRUST AND THRUST COEFFICIENT DATA FOR EACH WIND TURBINE

• The Thrust was calculated using the equation below with

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

- density = 1.25
- a=0.33
- The Thrust Coefficient was calculated using the equation below

$$C_T = \frac{T}{\frac{1}{2}\rho V_0 A_t}$$

	Thrust Coefficient (C_T)												
	80 M	eter Data			100 Me	ter Data							
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						
0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889						

	Thrust (Newtons)													
	80 me	ter <mark>data</mark>	10	100 meter data										
680078.34	773776.63	1074820.66	1481893.77	587380.86	668307.68	928318.17	1279905.54							
658516.95	749244.60	1040744.25	1434911.40	591641.09	673154.87	935051.19	1289188.59							
657391.76	747964.39	1038965.96	1432459.61	593776.97	675585.03	938426.83	1293842.70							
688109.56	782914.36	1087513.50	1499393.84	591641.09	673154.87	935051.19	1289188.59							
755261.55	859318.26	1193642.95	1645718.32	587380.86	668307.68	928318.17	1279905.54							
830588.60	945023.54	1312692.57	1809856.30	579962.50	659867.26	916593.93	1263740.90							
879323.37	1000472.79	1389714.79	1916049.59	575744.61	655068.24	909927.81	1254550.09							
888452.37	1010859.53	1404142.58	1935941.71	569446.63	647902.55	899974.26	1240826.77							
875425.38	996037.75	1383554.26	1907555.85	560064.60	637227.91	885146.56	1220383.29							
870241.53	990139.68	1375361.51	1896260.21	550760.51	626641.93	870442.03	1200109.62							
876723.75	997515.00	1385606.25	1910385.00	537458.84	611507.62	849419.59	1171125.23							
895001.94	1018311.48	1414493.76	1950213.25	525324.69	597701.68	830242.34	1144684.87							
922772.79	1049908.48	1458383.84	2010726.07	512335.71	582923.14	809714.08	1116381.82							
956386.55	1088153.40	1511508.25	2083970.60	499509.33	568329.59	789442.79	1088433.07							
985086.81	1120807.85	1556867.18	2146508.59	490724.77	558334.73	775559.36	1069291.49							
990601.63	1127082.48	1565583.01	2158525.41	483946.22	550622.26	764846.29	1054520.99							
979587.38	1114550.74	1548175.69	2134525.31	480093.93	546239.21	758757.98	1046126.83							
967269.95	1100536.27	1528708.77	2107685.58	477214.81	542963.42	754207.72	1039853.22							
948264.41	1078912.22	1498671.72	2066272.42	474344.35	539697.49	749671.14	1033598.47							
917450.39	1043852.79	1449972.13	1999128.54	469579.49	534276.15	742140.59	1023215.83							
878023.08	998993.35	1387659.76	1913216.25	466732.13	531036.48	737640.51	1017011.41							
833118.95	947902.52	1316691.63	1815369.94	462005.76	525658.93	730170.78	1006712.62							

Figure 8: Thrust data

	Perkins county Climate Monthly averages													
Month	January	February	March	April	Мау	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 1 <i>5</i> °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		

Table 1: Perkins county monthly averages



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]. Naveen Vidanage, CWC, 3/24/2021, Page 8





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Table 2: IEC wind turbine classes

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



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



V1	12	-3.	45
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Power output: 3.450kMW

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

Wind shear coefficient

Results

v1 = 9.175; %100m hub height data h2 = 100; v2 = 9.325;

%80m hub height data

A = (log(v2)-log(v1))/(log(h2)-log(h1))

A = 0.0727

h1 = 80;

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

Table 2: LCOE Calculator

LEVELIZED COST OF ENERGY (LCOE)

)	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

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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 STATEMerchant PlanINCOME TAXES FOR SIEMENS GAMESA SG 3.4-132Site 7S.4-132SG 3.4 - 132 had a lower LCOEMaximum 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 S INCOME TA SIEMENS G 3.4-132	TATE XES FOR AMESA SC	 Mercha Site 7 SG 3.4 Maximu 	unt Plan - 132 had a lowe um Number of Tur	er LCOE bines -28		

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Cite Colorities	Team	87%	3(38)33	2/38/25														
Site Location	Team	100%	3(28)(25	2(3)25														
Landsamer	ilener .	WIN	2/3/25	2(19)(23														
Size .	ilener (1000K	3/38/35	3/3/25														
Darsminster Line and Peace ildebisishation	ilener (WUK.	3(28)25	2/18/21														
lishage	ilener .	SHIPS	3/29/25	2(1)/21														
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Implement tasking	Team	NUK	2/18/21	3/13/31														
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Date Pennin.		HPK.	9/5/25	9(3/35														
Finlenal Permits.		BIX.	3/9/20	8/58/25														
Local Dulinamon.		IN.	9/36/20	9/29/25														
Lentinee		an a	3(34(35	9/35/25														
Finance	Texam	385	9/3/30	9/35/25														
Initial Capital Cents.	Madalia	HPK.	9/3/25	3/34/33														
demail Operating Expension	Madalia	UPK.	3/34/33	9/35/25														
Market Candillans.	ilenen.	in .	9/3/35	9/9/35	+++++++++++++++++++++++++++++++++++++++			++++++										
Financing Plan	kiatalia	386	9/3/35	9/35/25														
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Internet straffs			40400	8/3/20		+++++	++++++											
Rob Management Flat	Natalia	200	20007	8/3/20	++++++	++++++	++++++	+++++										
University, University and Delays		1.000	8/38/20	8/8/20	+++++	+++++	++++++	+++++	++++++									
Publishing of Concurrence		1.000		00000	++++++	++++++	+++++	+++++	+++++++									++++++
Company of Web		385	6000	0.0000	++++++	+++++	++++++	+++++	+++++++									++++++
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THANK YOU