CWC Site Team Hardware Review

Introduction

The main focus of this memo is to explain the current state of the Collegiate Wind Competition Site Team's hardware. The memo will cover the site location, turbine selection, runs in Openwind, and upcoming tasks for this semester.

In the first semester, the team narrowed down on three possible counties in Colorado: Prowers, Yuma, and Kit Carson. These counties scored high on the decision matrix that was based on the amount of wind resource, available land for a 100 MW wind farm, accessibility to the wind farm site location, and local wildlife impact. As a result of this decision matrix, the team concluded that Prowers County would be the desired location for the wind farm.

Site Location

Prowers County was chosen for its high scores in accessibility via roadways and power lines, wind resources greater than 6.0 m/s, ability to power 100 MW wind farm, and the terrain the area was not harsh. In addition, the preferred site had a few characteristics that stood out such as the lowest max turbulence intensity percentage at 15 m/s and the high free wind speed was small range variance of 8.364 to 9.005 m/s.

To ensure the team has a contingency, Yuma County will be the next site location the team will conduct simulations for then Kit Carson county will follow after. Scores of the counties are shown in Appendix A, in addition other counties in eastern Colorado are listed as well. The decision of having backup locations will provide the team with a safe net, just in case Prowers county does not work out for logistical reasons such as land permitting, banning of certain components of a wind farm, or wildlife conservation through the county.

Turbine

The turbine selection was based on the engineering requirements listed by the customer and the conditions of the site in Prowers. The wind farm the team is designing must meet the requirement of producing 100 MW [1]. To generate this power last semester the team collected data from the Market Report [2] for the three top wind turbine companies: Vestas, General Electric, and Siemens Gamesa. Each of the companies provided various turbines for different wind conditions that were categorized through the International Electrotechnical Commission (IEC) that sets international standards for the wind speeds each wind class must withstand [3], shown below in Table 1. Prowers can then be categorized as the IEC wind class IB with its average free wind speed reaches to 8.684 m/s, with max turbulence intensity percentage at 15 m/s is 9.935 m/s.

Table 1: IEC Wind Class [3]

IEC Wind Classes				
	I (High Wind)	II (Medium Wind)	III (Low Wind)	IV (Very Low Wind)
Reference Wind Speed	50 m/s	42.5 m/s	37.5 m/s	30 m/s
Annual Average Wind Speed (Max)	10 m/s	8.5 m/s	7.5 m/s	6 m/s
50-year Return Gust	70 m/s	59.5 m/s	52.5 m/s	42 m/s
1-year Return Gust	52.5 m/s	44.6 m/s	39.4 m/s	31.5 m/s

With these data sets of the wind characteristics of the area, the team retrieve wind data from the National Renewable Energy Laboratory's Wind Prospector to gather data for 80m. The wind class and wind data height helped the team determine a turbine with a hub height of 80m that could withstand the IB classification. As a result, the team initially selected the Vestas V117, but after careful research the team discovered the turbine was no longer manufactured in the U.S. This led to further research to select the turbine Vestas V120-2.2, which was used in the Openwind software. This turbine is manufactured locally in the state of Colorado, potentially reducing the cost of transport. The Vestas turbine's characteristics and specifications were inputted into the software, then manually plotted for the micro-siting simulations.

<u>Openwind</u>

Within Openwind, the team conducted six different micro-siting simulations in the southwest corner of Prowers County. The six different micro-siting simulations helped the team understand their placement of turbines to account for production and wake losses. Each simulation produced an energy capture report that summarized the energy production, array efficiencies, and other comparable factors. The comparisons of the six turbine layouts underwent a decision matrix to select the best micro-siting for the hardware review. Table 2 displays the scoring of the simulations. The relative score is higher based on the most preferable outcome.

Table 2: Turbine Layout Decision Matrix

Turbine Layout Decision Matrix						
Run	**Net Energy**	**Array Efficiency**	**Inclined Loss**	**Capacity Factor**	**Site Area**	**Total**
1	2	3	2	2	3	12
2	1	1	1	1	2	6

3	2	2	2	2	3	11
4	3	3	2	3	2	13
5	2	3	3	2	2	12
6	3	3	2	3	1	12

From Table 2, the team selected simulation 4, shown in Figures 1, 2, and 3. Figure 1 demonstrates the turbine layout in contrast to Powers county. The areas in green illustrate the buildable areas in Prowers, which the team placed all the turbines within, shown in both Figure 1 and 2.

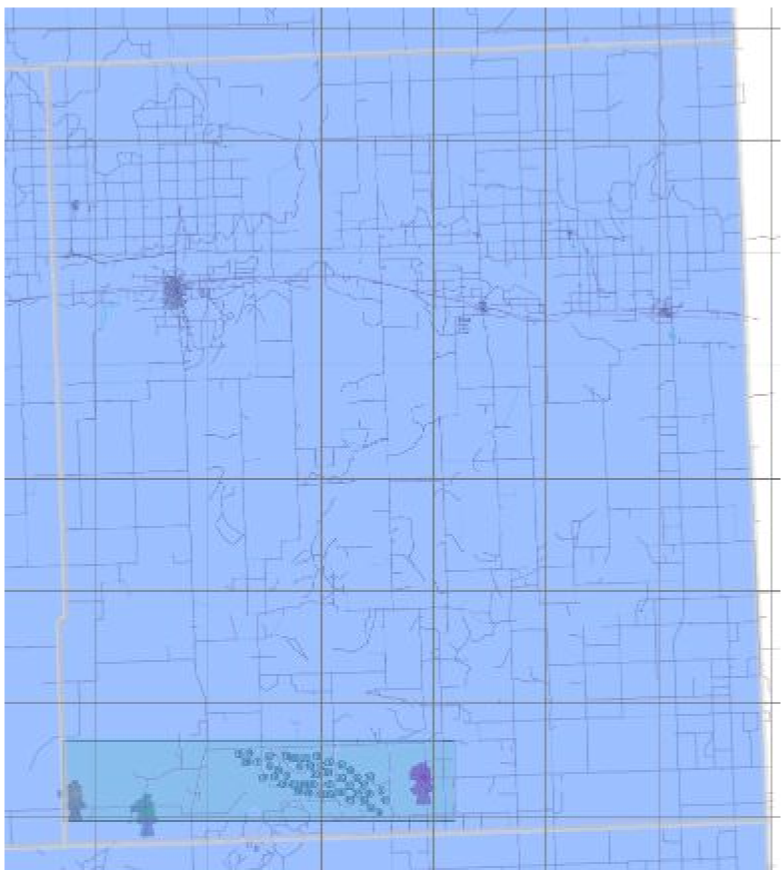

Figure 1: Site lay in relation to Prowers county

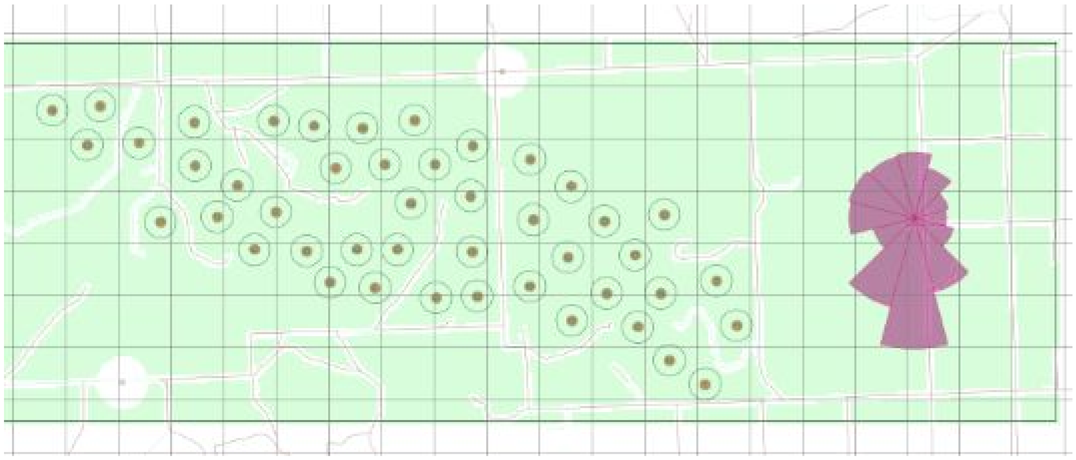

Figure 2: Site layout on Prowers County.

The team oriented the turbines in a diagonal line in relation to the wind resources coming from the southwest that is displayed within the meteorological mast, colored in pink, purple, and brown in the below in Figure 3. The turbines were placed individually in Openwind. In addition, the turbine specifications of the selected simulation were seven rotor diameters from the sides and back to account for effect of wake, that slows the speed of the wind as it passes through one turbine to the next. This loss would decrease the overall array efficiency.

Figure 3: Site layout with respect to meteorological masts.

The layout of simulation 4 produced the following results in Table 3. Of the six simulations, this run was able to produce to the standard 100 MW and good efficiency. With the results, the team believes there are various ways the site can be setup to improve the efficiency while maintaining a decent land coverage.

Table 3: Openwind Data Summary Results

Ideal Energy [GWh]	521.64
Theoretical Gross Energy [GWh]	530.31
Gross Energy [GWh]	530.31
Net Energy [GWh]	512.94
Capacity Factor [%]	59.11
Topographic Efficiency [%]	101.66
Array Efficiency [%]	96.74

Upcoming Work

With the data and results gathered so far, the team will consider conducting more simulations to better understand better turbine layouts to increase their product and efficiency the best way possible, in addition to meeting laws and regulations, permits, and wildlife considerations. Further research may also cause the site to change to a different location, so the team may change site location and turbine selection. These changes will also require the team to gather more meteorological mast data collection of different heights for turbine heights and classifications.

On the other hand, the team will look further into conditional use permits and regulations for wind farms in Prowers county, and process of constructing a fictitious wind farm in the county. These permits require sections of zoning, wildlife preservation, community acceptance, and height requirements of the FAA. So to help with this research, the team has contacted Tom Koronkiewics of Steven W. Carothers and Associates for a meeting to talk through wildlife practices especially with wind farms and their impacts on the environment. The team also hopes to contact Alana Benson, who works with AWS Truepower, to ask for guidance and questions about Openwind. The team's customer, professor Willy, also suggested to contact Karin Wadsack, previous person of contact for the collegiate wind competition, to ask for ways the team can improve their wind farm and prepare for the competition.

In general, the team hopes to research more into the turbines, come to a solid conclusion of an ideal site and turbine, then ensure their site follows permit requirements, community engagement, and wildlife regulations.

Work Cited:

[1] U.S. Department of Energy Collegiate Wind Competition. 2019. [pdf] National Renewable Energy Laboratory. Available: https://www.energy.gov/sites/prod/files/2019/01/f58/CWC%202019%20Rules%20and%20Requirements%20Manual_20190104_0.pdf [Accessed: 13-Sep-2019].

[2] R. Wiser and M. Bolinger, 2018 Wind Technologies Market Report: Summary, 2018.

[3] "LM Wind Power," LM, [Online]. Available: https://www.lmwindpower.com/en/stories-and-press/stories/learn-about-wind/what-is-a-wind-class. [Accessed 2 October 2019].

APPENDIX

Appendix A: Site Location Decision Matrix

Solutions	Accessibility	Wind Speed >6.0	Less than or equal to 100MW	Terrain	Wildlife Impact	Total
Weight Points	4	5	5	2	3	
Sedgwick	4	5	3	2	3	66
Yuma	5	5	4	4	2	79
Kit Carson 1	5	5	3	4	3	77
Kit Carson 2	5	5	3	4	3	77
Kiowa	4	5	3	3	4	74
Prowers	5	5	5	5	4	92
Cheyenne	2	5	2	5	3	62