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2020 Collegiate Wind Competition
Siting and Project Development Report

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1. **Site Description**

The site that our team decided to construct our wind farm rests in the north-eastern plains of Colorado, just outside the small rural town of Haxtun. The terrain consists of flat farmland that exhibits little variation in elevation. The average wind speed in this area is 7.66 m/s, with the majority of the wind blowing in from 305 degrees plus or minus 45 degrees in either direction, in relation to True North at 0 degrees. The power that our farm generates will connect to a substation in Haxtun where it can then be transported to the grid over 115kV lines. The site will have a minimal environmental impact with the only major concerns being the bald and gold eagle. The planned site spans 5190 acres and consists of 24 Vestas 4.2MW turbines with 150m rotor diameters and is supported by 100m towers. The turbines will be in an offset grid layout comprising of 4 of 5 turbines and 1 row of 4 turbines. On-site, there will also be an operation and management building to ensure the farm is kept in optimum working condition throughout its lifespan. A potential risk for the site is not being approved by the Federal Aviation Administration due to a nearby rural airstrip, however, this will likely not be a hindrance since it runs parallel to our farm.

2. **Site Design Changes**

Before arriving at our final site outside of Haxtun, Colorado, our team analyzed two other potential sites and determined them to be financially unviable. The first potential site was located 2.5 miles north of Kim, Colorado. This location initially seemed promising due to its high wind resource and low environmental impacts. Our team ruled this site financially un-viable after discovering the nearest high voltage transmission lines were 50 miles away in Villas, Colorado. The second potential site our team considered was located 3.5 miles south of Limon, Colorado, next to the Limon Correctional Facility. This site seemed promising because it was located next to Tri-State’s 230kV transmission lines, eliminating the transmission line distance problem we encountered at the other potential site outside of Kim. The limiting factor of this site was its inconsistent wind speeds and space constraints which were determined in the initial feasibility analysis.

3. **Financial Analysis**

3.1. **Initial Capital Cost:**

The initial capital cost was calculated using National Renewable Energy Laboratory's (NREL) Wind Turbine Design Cost and Scaling Model. (Fingerish) The initial capital cost consists of the sum of the turbine system costs and balance of station (BOS) costs. Our BOS costs were estimated utilizing a confidential model supplied by wind farm developer, Chris Purvis. We have estimated our initial capital cost to be $155,126,000 (1,549$/kW). (Purvis)

Before the construction of the site can begin, several permits must be submitted and approved. A list of these is provided below in table 1. We estimated this step to cost $600,000 (6$/kW). (Purvis)

Table 1

2020 Haxtun Wind Farm Permits	
Philips County	
	Conditional Use Permit
	Building Permit
State	
	Environmental
Federal	
	Federal Avaiation Administration
	USFWS Incidental Take Permit
	Interconnection Study

Since there is a possibility of and impact to bird populations at this wind farm site as is common of most windfarm sites. The project development team used a plug number of $1,000,000 (10$/kW) for bird mitigation and tracking. This includes the use of automated tracking and shut down system known as Robin, this will be used instead of relying on human tracking that can be impacted by fluctuating site conditions. (Robbin) This allotment also includes a bird deterrent system from Bird-X or comparable manufacturer. This system will include sonic devices, and potentially scent aversion liquids if deemed necessary. The final step in our 3-pronged bird mitigation system for this wind farm project is tracking avian deaths utilizing trained scent dogs. (Stanhope) We believe that the 3-pronged approach will result in the least amount of avian/turbine collisions over the life of the wind farm.

After all the required permits have been submitted, we will start securing the land that will be needed. The farm will encompass 5190 acres and will consist of a mixture of non-irrigated farmland and pastureland. Chico State decided on a mixture of the two due to the large price tag of irrigated land in Phillips county (Beiermann) and the permitting requirements for Phillips County. We have estimated the land lease rate to be $207,600/year (2.06$/kW).

The cost of the turbines is the largest contributor to the initial capital cost. The turbines are $3,750,000 each, totaling to $86,789,000 (861$/kW) for the 24 turbines. (Purvis) Shipping the turbines from the manufacturer to the site is a large logistics and construction project that will take approximately a year of advanced planning. Fortunately for this project, the wind farm site is not very far from the turbine manufacturers plant this will reduce the cost of shipping the turbines to the site. An estimate from the wind turbine shipping company, ATS, estimated this haul to cost $960,000 (9.52$/kW). (Lenke)

Before beginning the turbine tower construction, the roads between the Vesta's turbine manufacturing plant in Brighton, CO, and our windfarm site will need to be retrofitted to handle the weight and length of the freight loads. This step is estimated to cost $3,151,000 (31$/kW). (Kiewit)

While the access roads are being constructed, an operation and management building will be constructed. This building will be the primary control center of the wind farm and will also be used to store spare parts needed for routine turbine maintenance. This is building is estimated to cost approximately $1,250,000 (12$/kW). (Purvis) After the site's service roads have been constructed the next step will be to begin construction on the turbines' foundations. Instead of a traditional cast in place concrete foundation, we will utilize the RUTE foundation system. RUTE foundations are precast/prestressed concrete foundation system that is designed in modular segments that can be delivered nationally. The major benefit to the RUTE system is its time savings, that are delivered through eliminating curing time and rebar installation. They are advertised as being easy to dismantle and having an increased life expectancy over traditional turbine foundations. They also require less concrete than traditional foundations, enabling the RUTE foundation system to produce 50% less carbon dioxide emissions than traditional foundations. If our farm used traditional foundations their cost would be $6,129,000 (61$/kW) but the RUTE foundations will cost about $5,882,000 (58$/kW). This is a 5% savings and it is created through the reduced construction schedule that allows an owner to bring a wind farm online up to 2 months faster than utilizing traditional methods. (RUTE, McFeeters-Krone & Fernandes)

During the installation of the turbines, we can also begin working on the interconnection elements. The site will have one central collector substation which will cost $$4,576,000 (45$/kW). (Kiewit) Connecting the turbines to the collector substation will be the collection system which is estimated to cost $9,500,000 (94$/kW). (Kiewit) To transfer our power to the grid, flow and stability analysis studies must first be conducted, costing approximately $150,000 (1.5$/kW). These studies will test how the grid will be impacted if the wind farm or a series of power generators suddenly become disconnected from the grid. The results of the studies will also determine the costs for the required utility upgrades to the local grid. This cost can vary dramatically depending on the results from the IC study, however, $7,056,000 (70$/kW) is a reasonable reference. (Purvis) This cost also includes the cost of a switchyard with protection and metering at the point of interconnection. Assuming a conservative estimate of 1 mile of 115kV gen-tie transmission line from the site's collection substation to the point of interconnection, the estimated cost is $600,000 (5.95$/kW). The total of the interconnection costs amounts to $12,557,000 (125$/kW).

3.2. **Annual Operating Expenses:**

In addition to the initial capital cost, an annual operating expense (AOE) will ensure that the farm is properly tied into the grid and that the site is kept in optimal operating conditions at all times. We have estimated the total AOE for this project to be $3,496,016 (34.68$/kW-year). Outside of the land lease, community fund, and decommissioning bond, the AOE can be broken into two primary categories, operations, and maintenance as well as general and administrative expenses.

Operations and maintenance costs pertain to costs that keep the farm in optimal operating conditions. The service and maintenance cost includes employing specialty wind turbine technicians and quality assurance specialists, as well as the cost associated with any materials or tools these employees will need to perform their maintenance tasks. Maintenance at the site also includes general landscaping as well as fence and building repairs. Site O&M cost includes a supervisor for on-site security, site maintenance, and turbine service maintenance. It is unlikely that the spare parts fund will be utilized every year, especially in the initial years after startup. Turbine parts inevitably need to be replaced and it is beneficial to have a lump sum amount already budgeted due to their high costs. To keep the farm from potentially damaging itself or the grid, it is necessary to have 24x7 proactive monitoring and energy scheduling. Traditionally this was accomplished by a single person on-site; however, we opted to go with a more cost-effective method and plan on contracting an independent service operator (ISO). We have estimated the total annual cost of operations and maintenance to be $1,428,896 (14.18$/kW-year). (Brittle; Old; Pervis)

General and administrative expenses cover the expense that cannot be directly associated with producing revenue. They include administrative and management overhead for asset management; accounting, tax, and audit services; legal representation; owners' representatives; and owners' engineers. Included in the G&A expenses are also the cost of the letter of credit and the on-site water and electrical power. On-site power is necessary to keep turbines primed and ready to minimize startup times. Annual property tax was calculated utilizing Colorado's Department of Local Affairs: Division of Property Taxation's 2020 Renewable Template for Estimating Property Taxes. With a property assessment rate of 29% and a Mill Levy rate of 7.5%, the average annual property tax payment was calculated to be $18,500. We've estimated the total annual cost of general and administrative expenses to be $1,714,000 (17.00$/kW-year). (Brittle; Old; Pervis)

The remaining costs associated with the AOE include the land lease, community fund/PILOT payments, and the decommissioning bond. To comply with Phillips County regulations' our turbines should be located on non-irrigated farmland or pastureland. Fortunately for our farm, this drives the costs of land down to $40/acre, multiplied by 5112 acres gives a total land lease rate of $204,480 (2.03$/kW-year). We've allotted an annual payment of $60,000 (0.59$/kW-year) to a local Haxton non-profit organization the Community Foundation of Northern Colorado. This annual donation will be used to help support the local community and foster goodwill for the life of the wind farm. The decommissioning bond covers the demolitions, dismantling, and recycling expenses at the end of the wind farm's 20-year lifespan and will cost $80,000 per year (0.79$/kW-year). We anticipate utilizing blade recycling technology. This technology is currently in infancy however we expect it to be fully developed by our farms' decommissioning in 2042. (Paben)

The annual operating expense of all wind farms become increasingly expensive throughout the life of the turbines. We have accounted for this by budgeting for expenses such as replacement parts and the decommissioning bond since the initial inception of the project. With a capacity factor of 49.5%, the net annual energy production for our wind farm in the first year is 437,088,960 kWh.

4. **Financing:**

The net capital cost associated with the wind farm is $164,659,888. Financing for the project is modeled after the partnership flip structure and consists of two primary sources of capital, project term debt, and equity. We have decided to go with the partnership flip structure to take advantage of the economic benefits that stem from distributable cash and tax deductions from accelerated depreciation. The fees associated with financing were calculated through NREL's System Advisory Model (SAM). The cost to acquire financing is $1,000,000 and is included in the initial capital cost. The net salvage value of the site is 13%, which will amount to an additional profit of $19,000,800 at the end of the project's life. (Schwabe & Feldman)

Project term debt accounts for 60% ($95,002,504) of the net capital cost and has an annual interest rate of 4%. The debt closing cost is $1,675,000 with an additional closing cost of 2.75% ($2,612,568) of the total project term debt.

Equity accounts for 40% ($69,657,384) of the net capital cost and consists of 95% tax equity and 5% developer equity. The internal rate of return (IRR) for the tax equity investors is 12.38% at the end of the 20-year project and amounts to an investor net present value of $11,556,278. The net present value for developer equity is $4,001,653.The federal income tax rate for our project is 21% while Colorado's income tax rate is 4.63%. Depreciation is calculated through SAM using a 5-year Modified Accelerated Cost Recovery System (MACRS) schedule. The tax deduction schedule is listed below in Table 2.

Table 2

5 year MACRS w/50% bonus		
Year	% Decduction	Federal Depreciation
1	20.00%	$ 31,285,400
2	32.00%	$ 50,056,600
3	19.20%	$ 30,034,000
4	11.52%	$ 18,020,400
5	11.52%	$ 18,020,400
6	5.76%	$ 9,010,190
Total	100%	$ 156,426,990

5. **Market Conditions:**

The real levelized cost of energy for our wind farm is 3.17 ₵ /kWh, which is 6.8% lower than the Interior's 2018 average of 3.40 ₵ /kWh. (WTMR) The future of the US Wind Energy Market is difficult to accurately predict due to the ongoing COVID-19 crisis. Other factors impacting the market conditions are the current political climate of both the legislative and executive branches of the United States government. Future tax incentives may likely become available to encourage economic growth in the post-pandemic US economy. If the credits are similar to what was available before 2019 we predict the real levlelized cost of our wind farm to be 2.94 ₵ /kWh, this is a 7.3% decrease. This calculation utilized a production tax credit of 0.9 ₵ /kWh which was available before 2019. (Schwabe; Norton Rose Fulbright)

6. <u>Appendix</u>

6.1. *Appendix A - Initial Capital Costs (Kiewit, Purvis)*

CSU Haxtun Wind 100.8MW CapEx					100.8
		$K	$K	$K	$/kW
Wind Turbines		$ 86,789			$ 861
BOP (Engineer, IC, Commission)		$ 42,353			$ 420
BOP & Construction			$ 26,726		$ 265
BOP contractor -Turbine				$ 13,000	$ 129
BOP Collection Sysytem				$ 9,500	$ 94
O&M Building				$ 700	$ 7
Public Road Improvments				$ 1,250	$ 12
Misc Support Services				$ 375	$ 4
On Site Roads -miles x $/ft	20 mi x $18/ft			$ 1,901	$ 19
Interconnection Costs			$ 12,557		$ 125
IC Study Fee (ISO or TO)				$ 150	$ 1.5
IC Facilities and Network Upgrades				$ 7,056	$ 70
Gen-Tie (miles approx)	1			$ 600	$ 6
Consultants				$ 175	$ 2
Collection Substation				$ 4,576	$ 45
Constr Mngmt & Owner's Engr			$ 2,695		$ 27
Wind Consultants				$ 100	$ 1
Project Mngmt				$ 550	$ 5
Constr Mngmt				$ 450	$ 4
Site Admin Svcs				$ 120	$ 1
Site Inspection				$ 180	$ 2
Site Expenses				$ 160	$ 2
Construction Inspection				$ 160	$ 2
Site Security				$ 200	$ 2
Owner's Engineering				$ 500	$ 5
Misc Consultants				$ 275	$ 3
Commisioning			$ 375		$ 4
Project Insurance During Construction		$ 3,600			$ 36
Land (5112 acres)	$40/acre	$ 204			$ 2
Legal Costs		$ 880			$ 9
Permitting & Environmental		$ 1,600			$ 16
Financing		$ 1,000			$ 10
Development Costs		$ 2,500			$ 25
Project Develeopment Fees		$ 4,000			$ 40
G&A		$ 750			$ 7
Contingency		$ 2,476			$ 25
Project Cost (ex-Pre COD Int and Loan Fees)		$ 146,152			$ 1,450
Construction Financing Costs		$K	$K	$K	$/kW
Return on Construction Equity Drawn, if any Interest During Construction (Loan Int)		$ 8,115			$ 81
Loan Fees		$ 1,675			$ 17
Grand Total		$ 155,942			$ 1,547

6.2. *Appendix B - Annual Operating Expenses (Purvis)*

CSU Haxtun Wind 100.8MW OpEx			power in kW	100,800	
			# of WT's	Cost	$/kW-year
Operating Expenses					
Service and Maintenance	$/WT	$ 30,500	24	$ 732,000	$ 7.26
O&M (Including Site)	$/WT	$ 10,000	24	$ 240,000	$ 2.38
Maintenance at Site	$/WT	$ 500	24	$ 12,000	$ 0.12
On-site Security	$/WT	$ 3,954	24	$ 94,896	$ 0.94
Spare Parts		$ 250,000		$ 250,000	$ 2.48
24x7 Proactive Monitoring and Scheduling Coordinator		$ 100,000		$ 100,000	$ 0.99
Total O&M				$ 1,428,896	$ 14.18
General & Administrative Expenses					
Insurance	$/WT	$ 10,000	24	$ 240,000	$ 2.38
Property Tax (Foundations, BOP Collection System, O&M Building, Site Roads, Gen-Ties, Collector Substation)	$/WT	$ 13,550	24	$ 325,200	$ 3.23
G&A and Mgmt O/H for Asset Mgmt	$/WT	$ 3,000	24	$ 72,000	$ 0.71
On-Site Electric Power	$/WT	$ 2,200	24	$ 52,800	$ 0.52
Accounting, Tax, Audit Services	$/WT	$ 500	24	$ 12,000	$ 0.12
Cost of Letter of Credit	$/WT	$ 18,000	24	$ 432,000	$ 4.29
Owners' Representatives		$ 100,000		$ 280,000	$ 2.78
Independent Engineer		$ 100,000		$ 300,000	$ 2.98
Total G&A				$ 1,714,000	$ 17.00
Land Lease	Acres				
Acres @ $40/Acre	5112	$ 204,480		$ 204,480	$ 2.03
Land Easment (30/acre/year)	288	$ 8,640.00		$ 8,640	$ 0.09
Community Fund/PILOT payments		$ 60,000		$ 60,000	$ 0.60
Decommisioning Bond		$ 80,000		$ 80,000	$ 0.79
Total Annual Operating Expense				$ 3,496,016	$ 34.68

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