University of Wyoming Site Development Team

UNIVERSITY OF WYOMING

U.S. Department of Energy Collegiate Wind Competition 2021

Project Development Competition Report

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1. Preliminary Design

1.1 Turbine Info

To maximize the output of the potential wind farm, turbines from Vestas, GM, and Siemens were considered. After gathering the specifications of many different turbines and comparing those to the wind profiles of the initial site, it was determined that Vestas V117-4.2MW would be the ideal choice to maximize output while minimizing costs. The Vestas 4.2 MW platform was chosen because its nameplate capacity is higher than most of the other onshore offerings from the other major companies. With a nameplate capacity of either 4.0 MW or 4.2 MW, only 25 turbines would be required for the team to generate a total of 100 MW, therefore minimizing the total land and construction costs (Vestas, 2020a). Furthermore, the wind profile of Lawrence county, SD necessitated finding a turbine that was suitable for high wind conditions which led to the selection of the 117 m option. Longer blades are unable to safely handle the wind speeds that are common within the boundaries of Lawrence county. From here, further research was done to estimate the costs associated with the construction and purchase of these turbines. It was determined that the average sale price for turbines from Vestas was $887,000 per nameplate MW (Vestas, 2020b). From this figure, we rounded up the value to account for any unknowns that might be encountered and to ensure that our financial analysis was conservative.

Every wind turbine needs to be set on a foundation to ensure that it is structurally sound. Turbines do not have off the shelf foundations; each foundation needs to be designed based on several factors including soil composition, drainage, and frost depth. There are several different styles of foundation that are currently in use: shallow/slab, piled foundation, and rammed aggregate piers. Because the design team could not test the soil and geology of the site to gather site specific information, a general design was chosen. Research on turbine foundation costs concluded that most industrial wind farm projects spend about $25,000 - $45,000 per MW on foundations (Daniels, 2007). The upper value of this range was selected to ensure the project did not underestimate the associated costs. To further confirm that this assumption was correct, financial reports form the Chokecherry & Sierra Madre wind energy project were used as a comparison. While the Chokecherry farm is larger than this project, on a per MW basis the foundation costs came out to be about $44,000/MW which is right in the range used to complete the financial analysis (Power Company of Wyoming, LLC, 2014).

1.2 Project Boundary

Figure 1.1: The project boundary is denoted by the yellow line and is constructed using a 1000-foot buffer around the turbine locations, which are show as black and white targets. shows the total area of the project that we are building in. It encompasses 2,658.26 acres in the northeastern corner of Lawrence County, South Dakota, and has a perimeter of 8.86 miles after the inclusion of a 1000-foot buffer around each turbine. However, the entirety of this land within the boundary will be leased. Payments to the landowner will be made per turbine per year. The project boundary was drawn approximately to identify any habitats or other environmental factors the farm would affect.

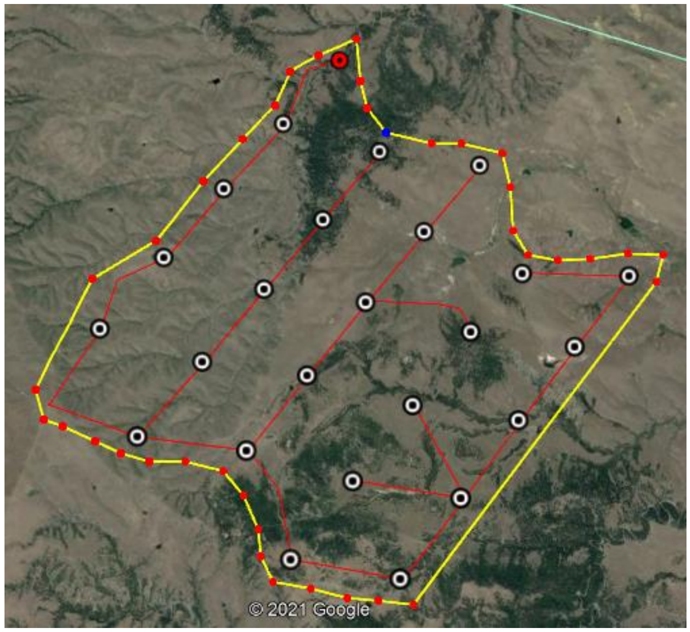


Figure 1.1: The project boundary is denoted by the yellow line and is constructed using a 1000-foot buffer around the turbine locations, which are show as black and white targets.

1.3 Site Characteristic

When selecting the county to site our wind farm in, the geography, wind class, access to transmission lines, and presence of endangered species were the factors considered. The highest wind speeds in the state occur in the mountainous regions of the Black Hills National Forest. However, we decided against attempting to develop a wind farm in this region because the Bureau of Land Management does not often sell or lease public land due to a congressional mandate passed in 1976. Additionally, the roads in this area are very tight and winding so it would be difficult to construct access roads and deliver turbines to the site. From Wind Prospector, we found that there was a whooping crane migration corridor in central South Dakota. Based on the aforementioned parameters we determined that Lawrence, Pennington, and Custer would be the best counties for development. Lawrence county was chosen because it is outside of the whooping crane migration corridor and its northeast corner has less vertical relief than the other two options, meaning inflow angles at the site would be lower. Additionally, Lawrence county has a lower tax rate then Custer county.

1.4 Permitting Information

National permits will need to be acquired to develop a wind farm of this magnitude. Nationwide Permit 51 is required to be obtained from the US Army Corps of Engineers, as the strong overturning moment of the wind turbines is secured using large foundational bases of concrete that require extensive excavation. This permit is issued once it is assured the material removed from the excavations will not negatively impact the environments, specifically with respect to watershed damages. There is also an Incidental Intake permit from the Fish and Wildlife service that requires an environmental study determining if there are any endangered species on the property occupied by the wind farm. If endangered species are present, a habitat conservation plan is developed to minimize the impact of the project on these species and their habitat.

There are also three permits that need to be filed with the South Dakota Public Utilities Commission concerning the transmission of the power the project produces to the grid: a Certificate of Public

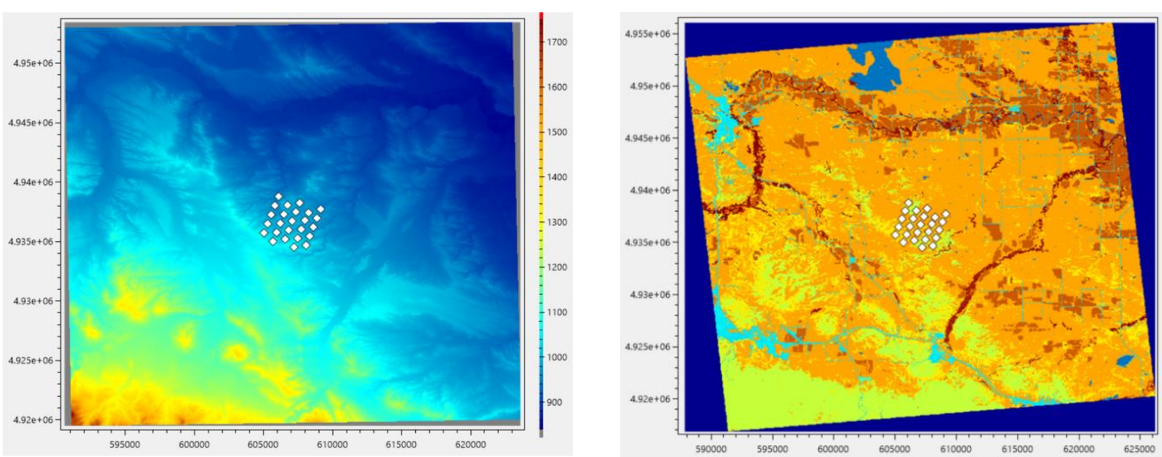
Convenience and Necessity, a Certificate of Corridor Compatibility, and a Route Permit. The Certificate of Public Convenience and Necessity is granted once it is proven that a transmission line is beneficial to the public. The Certificate of Corridor Compatibility concerns the general route of the lines, and the Route Permit concerns the exact route. The latter two should be easily attainable because we are building along a pre-existing transmission line corridor.

The Lawrence County Zoning Ordinance show that the site is in a General Agricultural [A-1] District. In an A-1 district we not expressly allowed to build a wind farm of this size (Lawrence County Zoning). However, Large Wind Energy Systems (LWES) can apply for a LWES Conditional Use Permit as outlined in Chapter 10, Article 1 of the Lawrence County Zoning Ordinance. Additional fees are assessed in the LWES Condition Use Permit on a per turbine basis, and these fees have been included in the initial cost per turbine of the finical model. Chapter 10, Article 1, Section 1.5, outlines the general requirements for all LWES being considered, which are mainly federal standards. Section 1.7 outlines the addition requirements for a LWES, most notably the 1000-foot setback requirement, which has been accounted for in the land lease plan and can be seen in *Figure 1.1*: The project boundary is denoted by the yellow line and is constructed using a 1000-foot buffer around the turbine locations, which are show as black and white targets.. In addition, the Conditional Use Permit is granted once a full site plan is presented and any additional mitigation strategies that we not outlined in in Section 1.5 have been addressed.

2. Detailed Design

2.1 Wind Resource

Wind resource data for western South Dakota was obtained from the National Renewable Energy Laboratory's Wind Toolkit. This data set consists of modeled land-based wind speeds at 100 meters. Digital elevation data was collected from the United States Geological Survey (USGS). The elevation product "3DEP" with a resolution of 1-arc second was used, as it is compatible with the selected modeling software. Land cover and roughness data for the area was also obtained through the USGS. Using the inputs listed above, topography and land cover maps were developed.



(a) (b)

Figure 2.1: (a) Digital elevation map of site described in Universal Transverse Mercator Coordinates and meters of elevation . (b) Digital land cover map of site described in Universal Transverse Mercator Coordinates and interpreted using the US National Land Cover Database.

From *Figure 2.1a)* above, the topography of the site is mild, easily lending itself to a project of this size. The site sites at an average elevation of 995 meters and is perched at a higher elevation than the valleys and river bottoms surrounding it. From *Figure 2.1b)*, the site primarily consists of rolling grasslands (orange) with scattered evergreens (yellow) throughout. Note that the site avoids woody wetlands (red) that are associated with river bottoms in the area. Once the wind flow model was finalized, it was found that the average wind speed across the site was 7.63 $\pm$ 0.03 m/s.

2.2 Turbine Locations

Due to minor changes in terrain across northeast Lawrence County, the wind flow model found little deviation in the wind speeds associated with the area. To further assess the quality of a site, proximity to structures, high voltage power lines, and substations was considered. Through contact with Basin Electric Power Cooperative, a map of high voltage powerlines and substations was acquired (See *Figure 2.2*). Using Google Earth, all structures in the area were accounted for and two regions of adequate area were identified. To further narrow the site selection zoning and permitting were considered. After close examination, the site in *Figure* was chosen due to its more favorable zoning and permitting regulations, proximity to a 230kV transmission line, and its wide-open spaces (Brekke, personal communication, 2021).

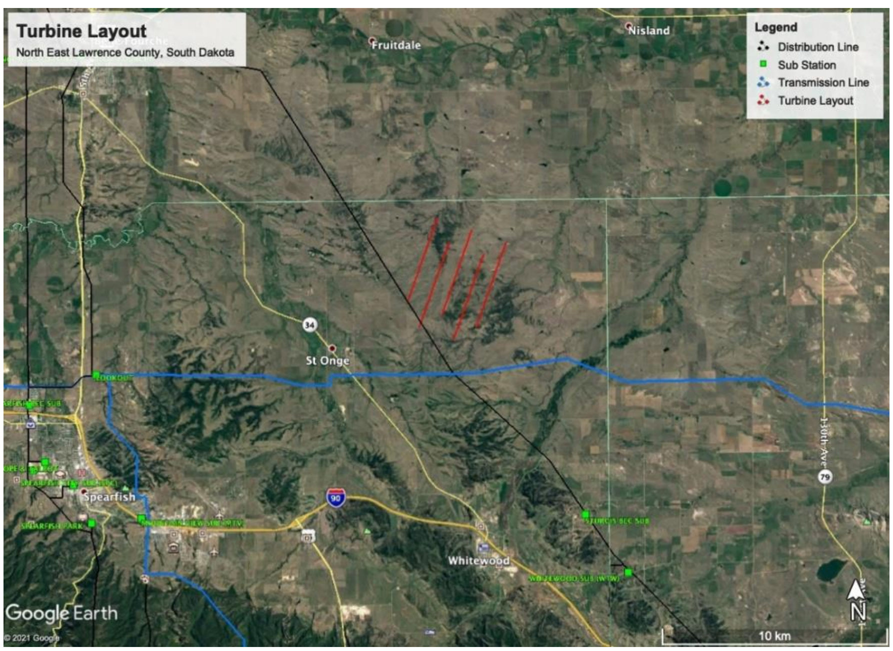
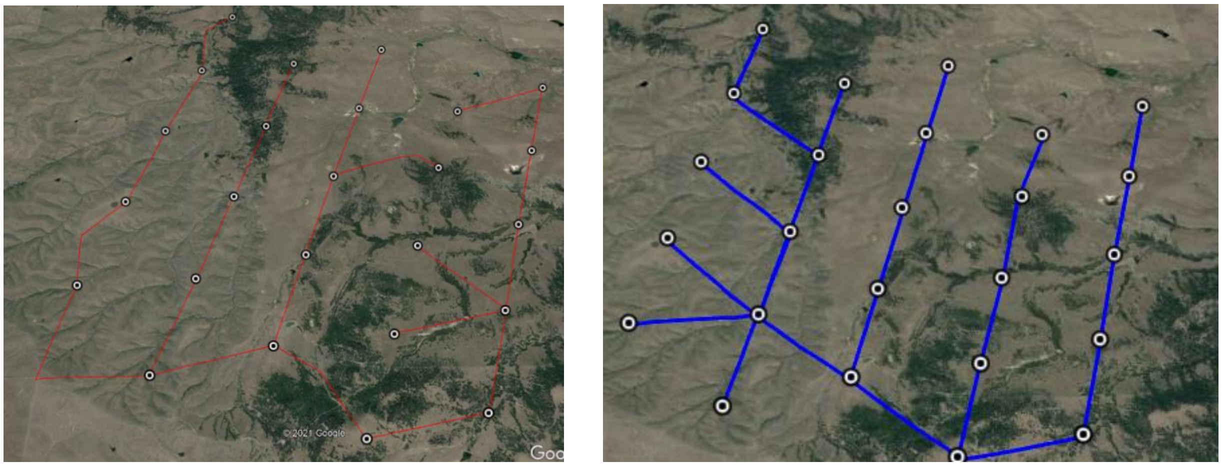


Figure 2.2: Google Earth image of initial turbine layout in northeast Lawrence County, South Dakota. Transmission line and substation data provided by Basin Electric.

To achieve a 100 MW capacity, a total of 25 turbines were used. A distance of 8 rotor diameters were maintained between any two turbines to minimize any wake loss associated with the layout.

2.3 Access Roads and Transmission

The site was designed to minimize the total length of roads and power collection lines required while still complying with grading requirements when dealing with elevation changes. In total, 9.78 miles of gravel access roads and 13.3 miles of underground power collection cabling must be built for construction and operation of the wind farm. A map of this infrastructure is included in *Figure* .



(a) (b)

Figure 2.3: (a) Site access roads for the wind farm, drawn as red lines. (b) *The power collection system employed by the farm.*

The construction of a substation is required to raise the voltage high enough for long distance distribution. After transformation, 1.39 miles of high voltage line, routed next to an existing low-voltage distribution line, are required to transfer the power to the grid (see *Figure*).

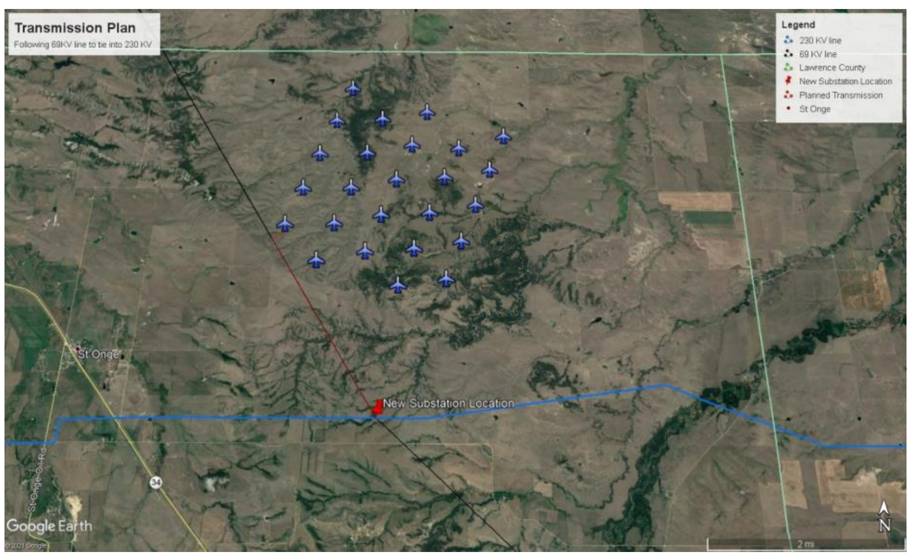


Figure 2.4: A map of the high voltage transmission line, shown in red, that must be constructed parallel to the 69kV distribution line to transmit power to the existing 230 kV transmission line, shown in blue.

From the turbine coordinates provided, we were able to determine land ownership and value, of which a breakdown is included in *Figure* . The 3520 acres of land have a total value of $621,968 (Landgrid, n.d.). This amounts to monthly land lease payments of $2,592 over a 20-year period if we were to pay back the full value of the land. However, for wind turbine land leases, it is customary that there be royalty payment of approximately $4000 per turbine per year (Windustry, n.d.). With 25 turbines, this would require a monthly payment of $8333.33.

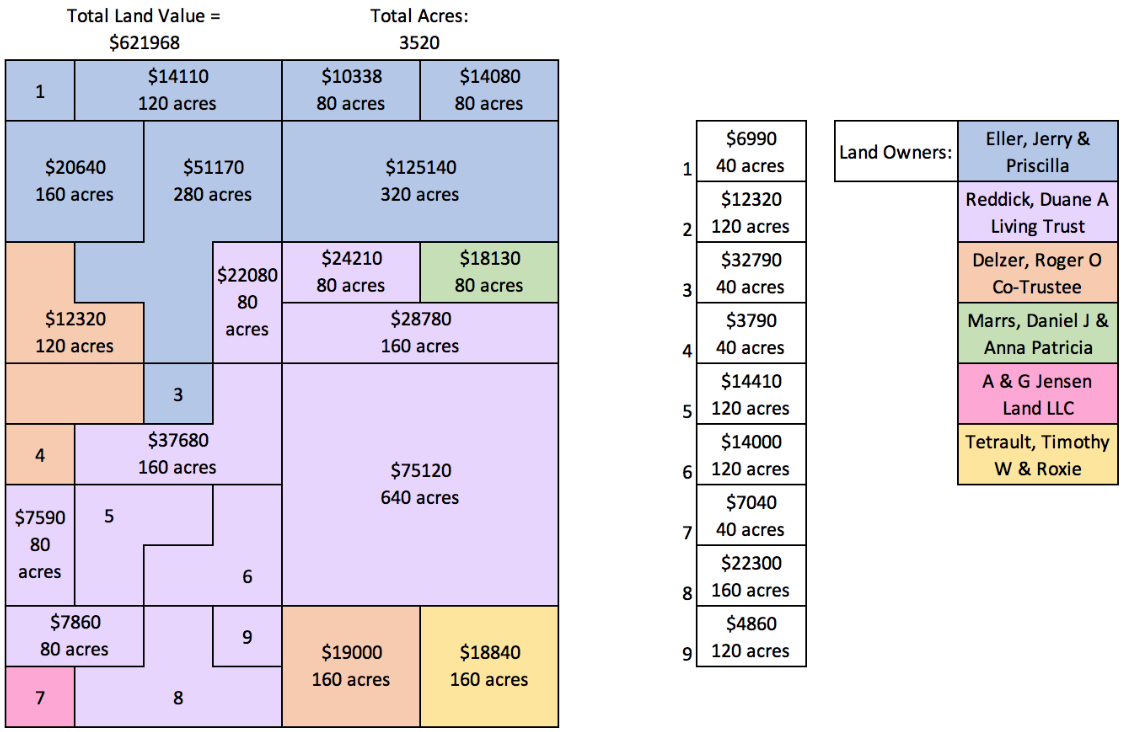


Figure 2.5: A map of land ownership of the location chosen for our project. The value of each parcel of land is also included.

3. Financial Analysis

3.1 Initial Capital Cost

After extensive research into the litany of factors involved in the construction of a commercial wind farm, such as the fabrication of foundations and the assembly of turbines, cost of creating access roads and building transmission lines, and insurance, legal, consulting, and permitting costs, a System Advisor Model (SAM) model was created reflecting the research. This simulation predicted an initial capital cost of $143,331,840 USD for a wind farm consisting of 25 Vestas V112-4.2MW turbines in their 4.0MW configuration. The turbine costs amounted to $4.2 Million per turbine (Vestas, 2020b), and the remaining balance of system costs were found using the NREL LandBOSSE model, assuming a 3-meter foundation depth, an interconnect voltage of 230kV (Basin Electric Power Cooperative, personal communication, February 11, 2021), and a transmission distance of 1.39 miles.

In South Dakota we are responsible for a 4.5% sales tax on everything we purchase for the Wind Farm including but not limited to, turbines, equipment, and any raw materials. However, state income tax will not be assessed. In addition, the property tax is replaced by a Nameplate Capacity tax and a Production tax. These taxes are quite helpful because they lower the overall tax and are much simpler to calculate than traditional tax credits. Federal taxes will include associated import, sales, production, and income taxes that would be expected for a corporation.

3.2 Operating Expenses

There are a variety of expenses associated with operation and maintenance (O&M) that are expressed on a per year basis. In a survey to benchmark the operating costs of wind power, it was found that average operational expenses are decreasing and were approximately $40/kW-yr, or $4 million per year

(Wiser et al, 2019). This will cover the salaries of permanent staff, as well as any repair costs or miscellaneous expenses.

3.3 Financial Model

An initial set of iterations made it clear that of the financial models included in SAM, a Power Purchase Agreement (PPA) partnership flip with debt would be most profitable. This model involves bringing a third-party investor on board to help cover a portion of the initial capital costs and paying them back over the course of the project. Initially, the investor receives 98% of the income and the developer 2%, until those values flip to the developer retaining 90% of income and the investor receiving the remaining 10%. Based off background research and iterations of the financial model, an Investor Rate of Return (IRR) of 10% flipping in year six of the project was found to be most economically viable. Initially the investor rate of return was selected as 10% to be competitive with other investing opportunities like stocks and real estate. However, further research showed that between a 7% and 10% IRR is competitive for a wind energy project of this size. A further breakdown of key financial assumptions is included in *Table 3.1*.

Table 3.1: Summary of key assumptions used in the financial model, as well as the outputs of the final model.

Inputs		**Results**	
IRR Target	10%	**IRR**	11.67%
Flip Year	6	**Levelized COE**	5.96 ¢/kWh
Federal Income Tax	21%	**Levelized PPA**	5.99 ¢/kWh
Sales Tax	5%	**Annual Energy Production**	292,629.8 MWh
Net Annual Expenses	$4,000,000 (Wiser et al, 2019)	**Capacity Factor**	33.4 %
Salvage Value	$6,667,852 (Pardo, 2018)	**Investor Net Present Value**	$2,714,721
PPA Escalation	2%	**Developer Net Present Value**	$1,326,449
Inflation Rate	2%	**Debt**	$100,188,088
		Equity	$43,143,756

Both debt and equity financing are employed. Additionally, both parties involved in construction turn a profit on the endeavor, though the Net Present Value (NPV) is relatively low considering the magnitude of the undertaking. The PPA escalation of 2% was chosen to offset inflation. The results included in *Table 3.1* were used to construct a cash flow analysis of the farm, which is included in *Figure* .

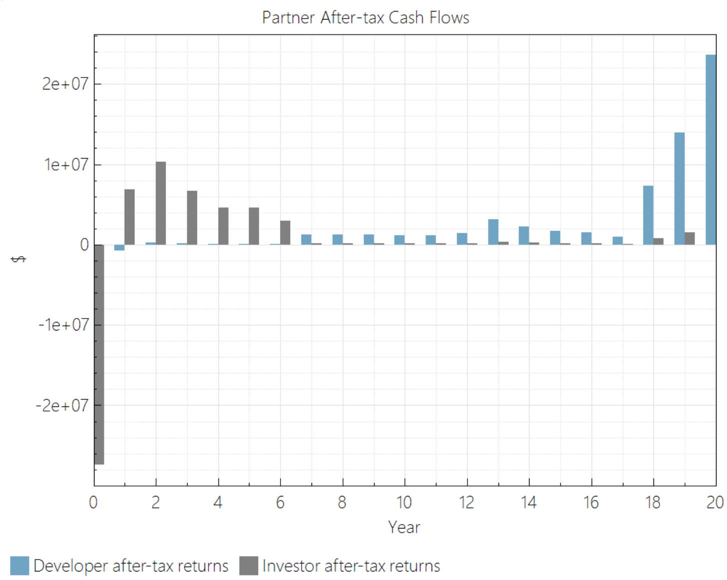


Figure 3.1: 20-year cash flow for the project, broken down by recipient of the income.

Above is a breakdown of the project's cash flow each year of its existence, broken down between investor and developer. The gray bars are money spent or gained by the investor, and blue indicates money received by the developer. Initial cash flow is high because of debt being accrued, and this period of high income is used to compensate the investor for their initial payments. The cash flow decreases each year up to year 6, the flip year, when the investor is paid back. After this, revenue stays low as debt is repaid, before increasing quickly in the last three years of the project. The spike in income in year 20 is largely due to the salvage value of the turbines.

A series of iterations were conducted which experimented with different flip years, IRR targets, and combinations of both. However, the initial figures included above proved to be the most financially viable option, as they produced profits for both parties while keeping the Levelized Cost of Energy (LCOE) and PPA price low. *Table* includes the financial metrics for a sample of the iterations conducted.

Table 3.2: *Collection of key financial model outputs for iterations of different flip years and IRR targets.*

Target IRR	**7%**	**10%**	**15%**	**7%**	**10%**	**15%**
Flip year	**6**	**6**	**6**	**10**	**10**	**10**
LCOE	5.95 ¢/kWh	5.96 ¢/kWh	5.98 ¢/kWh	5.94 ¢/kWh	5.95¢/kWh	5.97 ¢/kWh
PPA	6.85 ¢/kWh	5.99 ¢/kWh	6.17 ¢/kWh	5.72 ¢/kWh	5.86 ¢/kWh	6.07 ¢/kWh
Investor NPV	$625,250	$2,714,721	$5,754,342	$77,102	$2,690,946	$6,435,761
Developer NPV	-$213,702	$1,326,449	$3,566,955	-$4,723,163	-$2,514,898	$4,142

As exhibited above, the chosen IRR target and flip year are most financially advantageous. It is the only configuration where no parties have a net loss on the project and the LCOE and PPA prices are competitive.

3.4 Cost per Kilowatt Hour

After SAM was updated to provide an effectively identical capacity factor and annual energy production as the Continuum model, the projected LCOE is 5.96 cents per kWh, and the equivalent PPA price is 5.99 cents per kWh. Both are adjusted for inflation over the 20-year life of the farm.
While these values exceed the cost of energy for the coal-based operations currently being used to power South Dakota, they prove competitive when compared to larger markets with clean energy requirements.

3.5 Market Research

The target market was identified as states with 100% clean energy goals that did not have the appropriate terrain, climate, or space to house clean energy projects. The targeted states were refined to California and Michigan because of the abundance of high transmission lines to and from each of these states. If the project were funded by a private investor, California would be a more suitable option because the market could handle the premium price required to satisfy the private investor. The target investor for Southern California is a traditional investor who is expecting to profit from their speculation. For this case, the IRR target would remain at 10% but the TOD factors would be updated to fit the market. It is expected that the TOD factors for Southern California would be high at times when the project is producing the most energy, which would increase the price of power. The target investors include but are not limited to large investing firms and private investors.

However, the most viable option would be to sell to the market in Detroit, Michigan. Many companies located in Detroit do not have the infrastructure to support the in-house development of projects of this scale. In addition, a few large corporations have set their own net-carbon neutral goals and have begun the implementation of such projects. The specific targets are the Ford Motor Company and/or the General Motors Company (GM). In 2019 Ford set a goal to power all their manufacturing facilities with renewable energy by 2035, and GM set a similar goal in 2020. These commitments provide an opportunity to present this project as an investment opportunity for these corporations to help power their facilities in Detroit or use the project as a carbon offset program. Partnering with one of these large corporations would allow for the IRR to be decreased because the investor would not be expecting a profit, which in turn would lower the PPA price. Additionally, Michigan has set a goal to be economy-wide carbon neutral by 2050, so additional options for investors are likely to emerge (Whitmer, 2021).

3.6 Risk management

Through consulting the U.S. Fish and Wildlife Service's (USFWS) Information for Planning and Consultation (IPaC) website, the two main biological concerns to the project seem to be whooping crane habitat and the migration corridors of bald and golden eagles (IPaC, 2021). However, other sources examined by the team, including both Wind Prospector identify the planned project's location as outide the area inhabited by whooping cranes. As a result, and in accordance with the Tier two of "U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines", multiple site visits by a wildlife biologist will be required to determine the affect the wind farm would have on the aforementioned species.

There are several high critical risks that put the project's viability in danger. First, the uncertainty of securing an investor willing to provide enough money to assist with the capital cost of the project could immediately stop the development of the project. On top of this, if any of the six landowners do not accept the lease and royalty payments offered to them the arrangement of the turbines, as well as power transmission plan, may have to be altered to the point the project is no longer financially viable.

Finally, the potential inability to establish a PPA into a nearby market could also undermine the project. This area of the country has an especially low average retail electricity price due to an abundance of fossil fuels, however with the possibility of multiple coal-fired power plants, such as Glenrock, WY's Dave Johnston Plant (Stimson, 2019), shutting down over the next twenty years companies may see an advantage in a PPA that could protect them from future rises in electricity cost.

3.7 Discussion of Optimization

The optimization of this project was a product of the team's hands-on style of gaining familiarity with the software, and optimization of both the physical and financial models occurred simultaneously due to time and manpower constraints.

To generate a wind flow model using Continuum Wind Energy, the following process was implemented. The initial inputs to the software were gathered based on their accessibility, compatibility, and accuracy. The initial inputs spanned much of western South Dakota, which required the model to extrapolate the data over large areas of land. This resulted in an elevated level of uncertainty, as well as large computation times. As potential sites were eliminated, the geographic bounds for the Continuum inputs were updated. Once the final site was selected, the final geographic inputs were updated with a 12 km buffer around the site, as required by Continuum. These finalized inputs produced an uncertainty of 0.39% in the final wind flow model, which is highly accurate. With the wind flow model finalized, and exceedance model was generated using baseline parameters provided by Continuum. These associated losses were then compared to the loss model generated by the financial model, and appropriate adjustments were made. The net energy production and wake loss models were then calculated for 4 MW and 3 MW variations of the selected turbine. These results were then used in the financial model to determine the suitability of the site.

The process employed for the financial model included the following steps: 1. Conduct extensive research into wind farm finances and costs of all components. 2. Update the initial figures with information specific to the chosen location and turbine. 3. Include optimized values from the Continuum model. 4. Iterate models with various financial parameters. 5. Continue research, updating results as information is gained from outside sources and/or the Continuum model, and creating a baseline model as reference. When significant numbers of parameters were updated at once, a new model was created so that the previous iteration could be preserved for later reference. Finally, when financial models and parameters were being optimized, single variables were changed, so the results of each change could be accurately observed and documented. The end goal was to make the PPA price as competitive as possible, while still creating a profit for both parties involved in financing the construction of the farm.

Citations

Black Hills Energy. (2019) *Schedule of Rates, Rules, and Regulations for Electrical Service*, https://www.blackhillsenergy.com/sites/blackhillsenergy.com/files/bhe-coe-rates-tariff_0.pdf

Dakota Range III, LLC. (2018, October 26). *Application to the South Dakota Public Utilities Commission for a Facility Permit*. South Dakota Public Utilities Commission. https://puc.sd.gov/commission/dockets/electric/2018/el18-046/application.pdf

Daniels, L. (2007, December 5). *Chapter 8: Costs*. Windustry. https://www.windustry.org/community_wind_toolbox_8_costs#:~:text=For%20a%20single%20turbine%20project,cost%20per%20foundation%20will%20decrease

IPaC. (n.d.). *Endangered Species.* U.S. Fish and Wildlife Service. https://ecos.fws.gov/ipac/location/6XVKECVTA5BADI6RLMGDE655YM/resources

Johnson, T. (2009). *How much does a wind turbine earn? When will it pay for itself? Let's calculate profit and break-even points*. Windpower Engineering and Development https://www.windpowerengineering.com/windpower-profitability-and-break-even-point-calculations/

Landgrid. (n.d.). *St. Onge.* landgrid.com/us/sd/lawrence/st-onge#b=none

National Renewable Energy Laboratory. (2012). *NREL Wind Prospector.* The Wind Prospector. https://maps.nrel.gov/wind-prospector/?aL=MlB4Hk%255Bv%255D%3Dt%26VMGtY3%255Bv%255D%3Dt%26VMGtY3%255Bd%255D%3D1&bL=clight&cE=0&lR=0&mC=40.21244%2C-91.625976&zL=4

Pardo, D. (2018, September 12). *Dakota Range III Wind Project Decommissioning Cost Analysis.* South Dakota Public Utilities Commission. https://puc.sd.gov/commission/dockets/electric/2018/el18-046/appendixm.pdf

Power Company of Wyoming. (2014, April). *Chokecherry and Sierra Madre Wind Energy Project: Project construction Cost Estimate.* http://deq.wyoming.gov/media/attachments/Industrial%20Siting/Application%20and%20Permits/Chokecherry%20and%20Sierra%20Madre%20Wind%20Energy%20Facility/2014-0515_ISD_Application-Appendix-F-Chokecherry-Sierra-Madre-Project-Construction-Cost-Estimate.pdf

Schaefer, V. Ashlock, J. (2011). *Foundations for Wind Turbines.* http://home.eng.iastate.edu/~jdm/engr340-2011/ENGR%20340%20-%20Foundations%203%20-%20Ashlock%20-%20Schaefer.pdf https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1029&context=cengin_gradprojects

Stimson, C. (2019). *Troubling future of coal hits Dave Johnston Plant*. Gillette News Record. https://www.gillettenewsrecord.com/news/wyoming/article_6622e29c-60a2-5f77-a8ad-e5dcdaa58996.html.

The Nature Conservancy. (2020, November 16). *Site Wind Right*. https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/site-wind-right/?vu=sitewindright

United State Geological Survey. (2016). *MRLC Viewer.* Multi-Resolution Land Characteristics Consortium. https://www.mrlc.gov/viewer/

United State Geological Survey. (2019, October 12). *TNM Download (V2.0).* The National Map. https://www.mrlc.gov/viewer/

Vestas. (2020a). *4 MW Platform*. https://www.vestas.com/en/products/4-mw-platform/v117-4_2_mw#!technical-specifications

Vestas. (2020b). *Interim Financial Report Third Quarter 2020*. https://www.vestas.com/~/media/vestas/investor/investor%20pdf/financial%20reports/2020/q3/201104_36_company_announcement.pdf

Whitmer, G. (2020, September 23). *Executive Directive 2020-10: Building a Carbon-Neutral Michigan.* https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-540278--,00.html

Whitmer, G. (2021). *Executive Order 2020-182: Council on Climate Solutions*. https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-540277--,00.html

Windustry. (n.d.). *How Much Do Farmers Get Paid to Host Wind Turbines?* www.windustry.org/how_much_do_farmers_get_paid_to_host_wind_turbines.

Wiser, R. Bolinger, M. Lantz, E. (2019, January). Benchmarking Wind Power Operating Costs in the United State: Results from a Survey of Wind Industry Experts. https://escholarship.org/content/qt8qp887gg/qt8qp887gg_noSplash_656ba2a10f89dc62b2b73f3df721d4ea.pdf?t=psirmt

General Motors https://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2021/jan/0128-carbon.html