University of Maryland Wind Terpines
2021 Collegiate Wind Competition

Project Development Report

Advisors:
Dr. James Baeder (Aerospace Engineering)
Dr. VT Nagaraj (Aerospace Engineering)

With additional support from:
Dr. Peter Sandborn (Mechanical Engineering)

Project Development Team Lead:
Aleks Theobald (Aerospace Engineering)

Team Members:
Lauren Thomas (Environmental Science & Policy)
Jennifer Lees (Environmental Science & Technology and General Biology)
Logan Daytner (Geographical Sciences)

Table of Contents

Executive Summary

Using an in-depth and holistic siting process that considered the local impacts and economic evaluations on our proposed wind farm installation, Testudo (the University of Maryland's terrapin mascot) Wind Farm, the University of Maryland Wind Terpines Team selected a final wind farm location in Meade County, located in the western part of South Dakota to be installed by the end of 2021. This report explains the siting process and considerations for the construction of a 99 MW wind farm in Meade County and provides a financial analysis of capital, operational, and maintenance costs. Wind farms were considered in both Bennett County and Tripp county which had high wind speeds, but were on tribal land. They were especially interesting because of the high wind speed available in addition to the potential economic justice and collaboration for and with the Native American Community. However, due to the time of construction needed, the lack of developed roads and transmission lines, potential delays from the Bureau of Indian Affairs, and no federal PTC these two sites were not chosen. Various ecological impacts were considered early on in the siting process, as South Dakota has a significant presence of migratory bird paths and threatened or endangered species extents. The chosen location in Meade also intends to minimize the impact of the wind turbines on these species, while maintaining compliance with local permitting processes and community impacts.

The turbine model used for this project is the Senvion 3 MW 122 meter diameter turbine. Turbines with higher individual outputs were considered, but it was determined that the use of 33 individual 3 MW turbines enabled the team to get as close as possible to the 100 MW goal through the maximization of net farm capacity at 99 MW, which resulted in better annual wind farm production. The 33 turbines will have a separation of no less than 8 rotor diameters of distance between them.

Annual energy produced during the first year of operation was found to be 396,647,232 kWh. Testudo Wind Farm had capital expenditures amounting to $143,888,119 with a resulting Levelized PPA at 4.49 cents/kWh and a Levelized Cost of Energy of 4.11 cents/kWh. After 20 years, the farm had a net present value of $13,067,247 with an Internal Rate of Return of 13.35%.

Site Description

Initial Site Choices

We initially used NREL Wind Prospector to determine locations of favorable land cover along with high areas of wind speed for the Testudo Wind Farm. We determined that the 100 meter hub height range had higher values of wind speed in the western region of South Dakota. We noted six counties of interest with specific latitude and longitude coordinates, Bennett County, Harding County, Meade County, Perkins County, Todd County, and Tripp County. Each had several areas of suitable land cover and wind speed, and we chose the best locations in each county that had a close proximity to both roads and transmissions lines as reported from the

Energy Information Administration's (EIA) energy mapping system. The EIA energy mapping system revealed the roads and nearest transmission lines for each location we entered into the system. We used this to further develop the best locations which we used for comparison to find the top three county coordinates.

Comparison of Counties

With the best sites chosen for each county determined, we used a combination of an Analytical Hierarchy Process (AHP) and Pugh Matrix to determine the top three counties. The AHP helped determine the weights of each of the criteria we used to differentiate the different counties' sites. The six criteria we used were wind Speed, transmission line and road availability, nearby wildlife, community factors, and terrain. The AHP (Figure 1) compares the relative importance of each criteria against each other. For example, the left column is the base that we used to reference against the horizontal criteria in the first row. For the criteria of wind speed, we determined it to be slightly more important than transmission line availability and denoted it as 3 to represent that. The weight of 1 means that the two criteria are equally important, 3 relates to slightly more important, 5 relates to more important, 7 much more important, and 9 being the utmost priority, while the inverse of this scale represents less important, i.e. ⅓ being slightly less important. This comparison continues throughout the columns, then the next criteria is compared. The shaded cells signify that the weight is comparing against itself, and the diagonal created separates the relative comparisons on the right side of the diagonal and the inverses of those relative comparisons on the left.

The sums of each column are the unnormalized relative weights of each criteria, and are used to create the normalized weights such that the sum of each column is equal to one. The center diagonal of the bottom matrix consists of the normalized weights, which are then scaled to ten to allow easy understanding of the weights. The AHP had a Consistency Ratio (CR) of 0.0898, which is below the threshold value of 0.1. The CR represents the consistency of the relative rankings we divined for each criteria, and that there are no erroneous rankings. The final weights bottom of Figure 1 show that wind speed is the most important criteria, while community factors are the least important.

Figure 1: AHP for Site Selection Weights

	Wind Speed	TLA	Road availability	wildlife	Community factors	Terrain	Total
Wind Speed	1.00	3.00	3.00	5.00	7.00	5.00	24.00
TLA	0.33	1.00	1.00	3.00	5.00	3.00	13.33
Road availability	0.33	1.00	1.00	3.00	5.00	3.00	13.33
wildlife	0.20	0.33	0.33	1.00	3.00	0.33	5.20
Community factors	0.14	0.20	0.20	0.33	1.00	0.14	2.02
Terrain	0.20	0.33	0.33	3.00	7.00	1.00	11.87
Total	2.21	5.87	5.87	15.33	28.00	12.48	

	Wind Speed	TLA	Road availability	wildlife	Community factors	Terrain	Total
Wind Speed	0.452586207	0.511364	0.511363636	0.326087	0.25	0.400763359	2.452164
TLA	0.150862069	0.170455	0.170454545	0.195652	0.178571429	0.240458015	1.106453
Road availability	0.150862069	0.170455	0.170454545	0.195652	0.178571429	0.240458015	1.106453
wildlife	0.090517241	0.056818	0.056818182	0.065217	0.107142857	0.026717557	0.403231
Community factors	0.064655172	0.034091	0.034090909	0.021739	0.035714286	0.011450382	0.201741
Terrain	0.090517241	0.056818	0.056818182	0.195652	0.25	0.080152672	0.729958
Total	1	1	1	1	1	1	

Wind Speed	TLA	Road availability	wildlife	Community factors	Terrain
10.00	3.77	3.77	1.44	0.79	1.77

These weights were then used in a Pugh Matrix (Figure 2) that compares each county. We used Todd County as the baseline that each county will compare against. The relative weights used ranged from -2 to +2, with positive values being better than the baseline. Each relative weight is then multiplied by the weights determined through the AHP, and are then summed to determine the value that shows how much better or worse each county is compared to the baseline. A positive value shows it is better than the baseline, while a negative value represents worse than the baseline. As Figure 2 shows, we then determined that the top three counties to be further developed and researched are Bennett County, Meade County, and Tripp County.

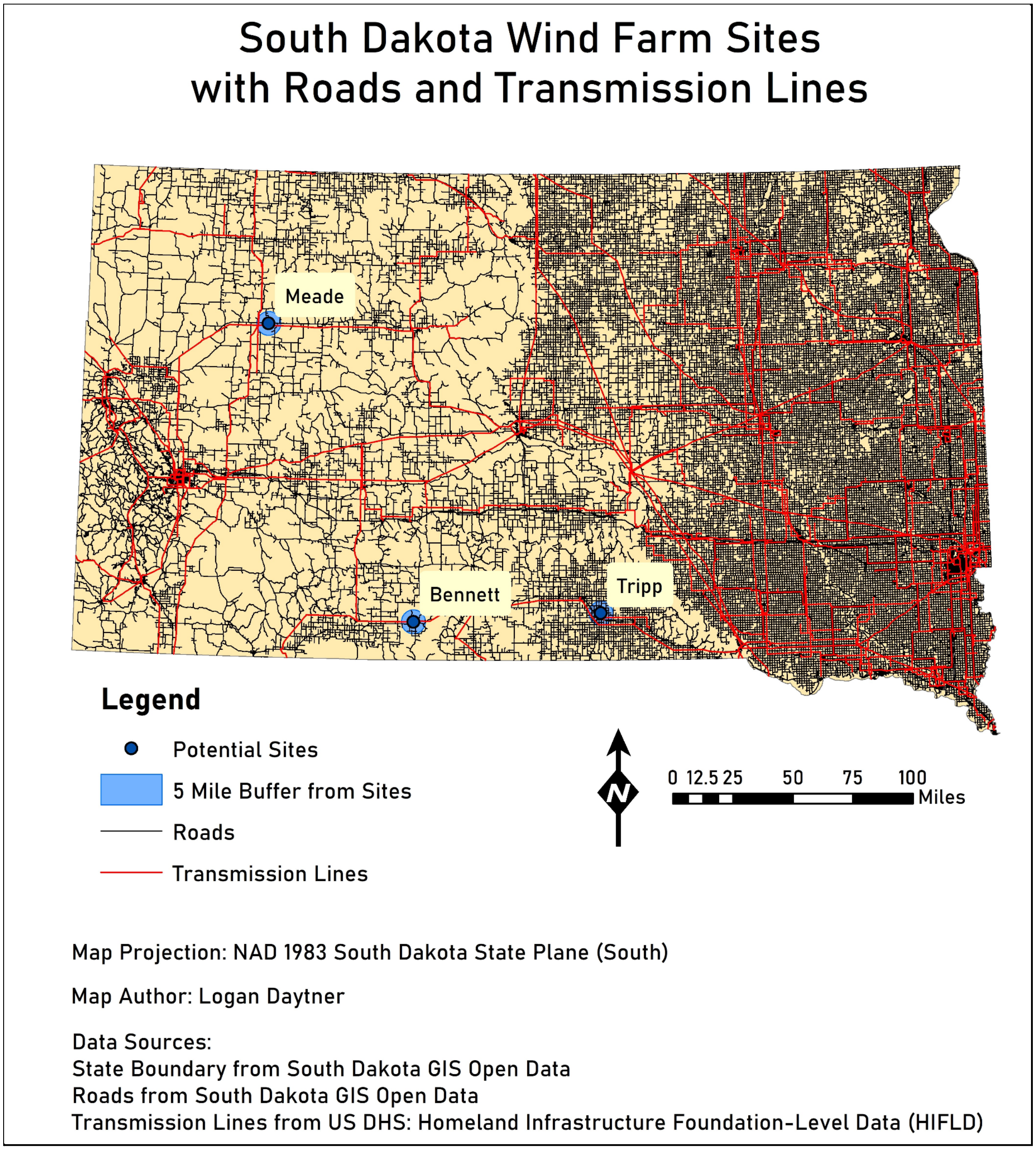
Figure 2: Pugh Matrix for Site Selection

Criteria	Weights	Todd	Meade	Harding	Bennett	Perkins	Tripp
Wind Speed	10.00	0	-1	-1	0	-2	0
Transmission Line Proximity	3.77	0	2	0	2	1	1
Road availability	3.77	0	2	1	0	1	2
wildlife	1.44	0	1	1	1	0	0
Community factors	0.79	0	-1	0	-1	1	0
Terrain	1.77	0	0	1	1	0	-1

Wind Speed	0	-10	-10	0	-20	0
Transmission Line Proximity	0	7.54	0	7.54	3.77	3.77
Road availability	0	7.54	3.77	0	3.77	7.54
wildlife	0	1.44	1.44	1.44	0	0
Community factors	0	-0.79	0	-0.79	0.79	0
Terrain	0	0	1.77	1.77	0	-1.77
Rating	0	5.73	-3.02	9.96	-11.67	9.54

Each of the final three locations are visualized in Figure 3, with nearby roads and transmission lines. For reference, the latitude and longitude coordinates for Bennett, Meade, and Tripp are 43.2287°,-101.2443°, 45.02036°, -102.5032°, and 43.2826°,-99.6960°.

Figure 3: South Dakota Wind Farm Sites with Roads and Transmission Lines



Analysis of Wind Resource using Continuum

To get a better understanding of the wind resource of each of the top three counties, we used the open-source software Continuum. There, we input both the elevation and land cover data for each set of coordinates, which were then used to determine the long term wind resource using MERRA2 data sets. Using the MERRA2 data sets, we were able to determine the average monthly wind speeds from 2008 to 2018 (Figure 4) for each site and their corresponding wind rose (Figure 5) at 50 meters. The monthly wind speeds are greatest for Bennett, with Meade and Tripp having similar values. Note that the highest wind speeds are in the colder winter months of South Dakota where the amount of electricity usage will be high, the higher amount of potential energy production in winter months is optimal for the needs of our wind farm.

Figure 4: Meade Monthly Wind Speed

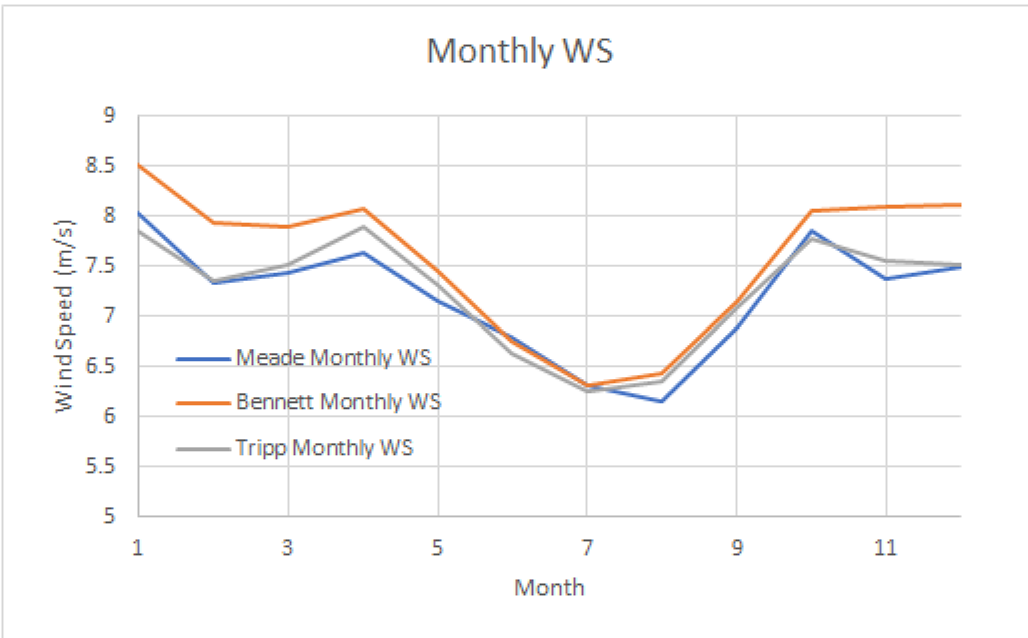
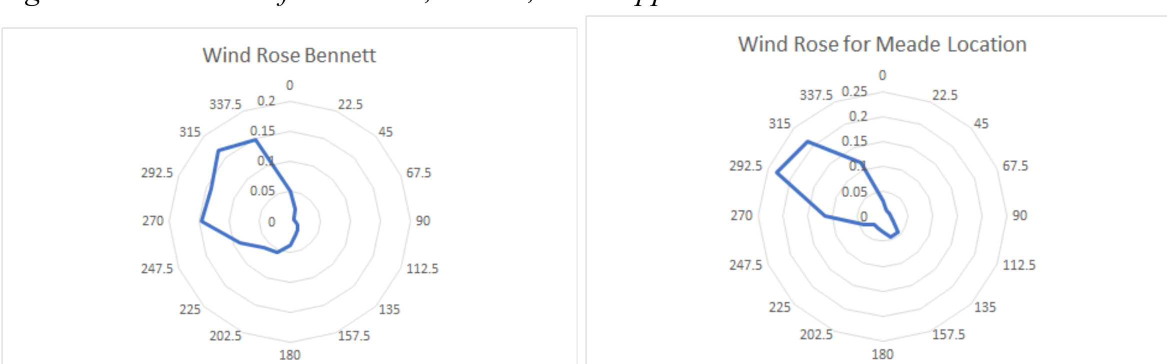
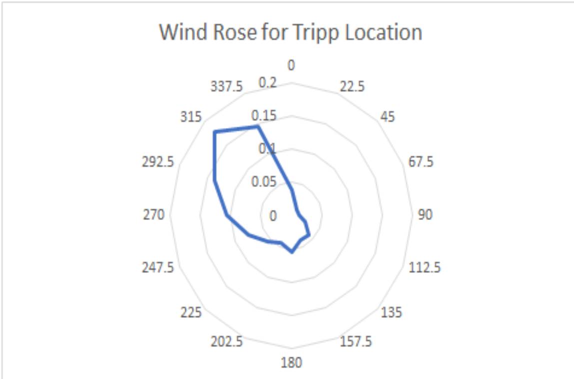


Figure 5: Wind Roses for Bennett, Meade, and Tripp





Environmental & Community Impacts

Wind farm siting decisions had to consider a variety of factors including proximity to Native American reservations and environmental impacts for threatened and endangered species. Due to the prevalence of Native American land throughout South Dakota, wind energy development projects provide a great opportunity to work with local residents if proposing wind farm construction on tribal lands, although the execution of these plans seems like a more drawn out process due to the need to work with and receive approval from the Federal Bureau of Indian Affairs. Considerations of local impact were especially relevant for our proposed locations in Bennett County and Tripp County due to the locations of Pine Ridge Reservation and Rosebud Reservation. Pine Ridge Indian Reservation encompassess all of Bennett County and the desired wind farm location in Tripp County is East of Rosebud Indian Reservation.

Environmental impacts were initially evaluated using the NREL Wind Prospector tool. The main wildlife concerns that were considered were bald eagle extent, whooping crane flight paths, and prairie chicken extent. The US Fish and Wildlife Service states that bald and golden eagles are particularly susceptible to vulnerabilities caused by wind turbines, and in the western part of the U.S., significant deaths of golden eagles have been caused by wind turbines (U.S. Fish & Wildlife Service). The Bald and Golden Eagle Protection Act prohibits impacts to these species unless allowed by a permit, and in order to comply with the Act, wind facilities can obtain a permit from the FWS that allows for the accidental take of eagles that may result from wind farm operation (U.S. Fish & Wildlife Service). Each location has minimal bald eagle presence with the nearest populations being further than 5 miles away. Whooping crane flight paths are present throughout the majority of South Dakota, especially in more centrally-located counties like Bennett and Tripp. The proposed site in Meade County did not fall under the whooping crane flight path. This impact was important to consider, as whooping Cranes are still currently categorized as endangered, although species population numbers have improved since they reached an all time low in the mid-1900s. In accordance with Section 9 of the Endangered Species Act (ESA), wind farms are expected to avoid any take of whooping cranes, so reducing wind farm construction in these flight paths is a preferred method of preventing impact on this species ("Wind Farms"). Lastly, while they are not categorized as endangered, prairie chicken extent is continually threatened by habitat loss and fragmentation due to a variety of causes, including conversion of native grasslands for uses in agriculture and energy development. The proposed location in Tripp County had notable prairie chicken extent, and this was considered in pugh decision matrix scores.

Policy Considerations

The feasibility of permitting and policy was considered for the sites at Meade, Bennett, and Tripp. Since all three sites are located in South Dakota, the federal and state-level regulations are the same.

There was limited information on permitting for wind farms in Tripp County. A previous wind turbine project in Tripp County required permits for zoning, conditional use authorization, building, road approach, and accessibility (Department of Energy). It also required a soil erosion and sediment control plan (Department of Energy). Since the proposed location for the wind farm is located east of the Rosebud Indian Reservation (RIR), there would likely be requirements that are additional to the general county-level requirements. Working with the federal Bureau of Indian Affairs would result in a lengthier and more complicated approval process.

There was also relatively limited information available on wind farm permitting in Bennett County. Development in Bennett County, like in Tripp County, would require working with the Bureau of Indian Affairs because the Pine Ridge Indian Reservation encompasses all of Bennett County. The Bureau of Indian Affairs has the legal authority to approve or deny any type of land development project located on a reservation (Clarke). Additionally, the federal Production Tax Credit (PTC) for wind energy does not apply to tribal-owned development (OpenEI).

Of the three sites, the greatest quantity of permitting information was available for Meade County. First, the nearest reservation to the location in Meade County is the Cheyenne River Indian Reservation, but it is far enough away that the approval process would likely not require approval from the Bureau of Indian Affairs. Meade County ordinances that regulate wind farms are also available online. Wind farms fall under the category of conditional uses for the A-1 Agricultural District, and proposals for new projects require a conditional use permit (Rapid City Journal, 2011). Wind farms must also meet various requirements for factors like location and size, which are explicitly described in Ordinance No. 32 (County of Meade). Additionally, the site in Meade County is located in the Unorganized Territory of North Meade, so there should not be any more local regulation.

A separate AHP and Pugh Matrix, as seen in Figure 6, were used to evaluate the various policy and regulatory obstacles to development at each of the three sites. The five policy-related criteria were first weighted based on relative importance using the Analytical Hierarchy Process (AHP). The five criteria and their corresponding weights were Strictness of Build Limitations (10.00), Community Allowance (9.80), Wildlife Permitting (3.65), Total Fees (1.94), Availability of Information/Feedback (1.28), and Incentives (1.08). Then, to create a Pugh Matrix, each location received a rating for each of five policy-related criteria. The final results showed that Meade, with a final score of 0.00, would best from a policy standpoint. Both Tripp and Bennett received scores of -4.27, indicating that they each have significant policy-related challenges in comparison to Meade.

Figure 6: Pugh Matrix for Policy and Permits

Criteria	Weights	Meade	Bennett	Tripp
Strictness of Build Limitations	10.00	0.00	-1.00	-1.00
Community Allowance	9.80	0.00	1.00	1.00
Wildlife Permitting	3.65	0.00	-1.00	-1.00
Total Fees	1.94	0.00	1.00	1.00
Availability of Information/Feedback	1.28	0.00	-1.00	-1.00
Incentives	1.08	0.00	-1.00	-1.00

Strictness of Build Limitations	0.00	-10.00	-10.00
Community Allowance	0.00	9.80	9.80
Wildlife Permitting	0.00	-3.65	-3.65
Total Fees	0.00	1.94	1.94
Availability of Information/Feedback	0.00	-1.28	-1.28
Incentives	0.00	-1.08	-1.08
Rating	0.00	-4.27	-4.27

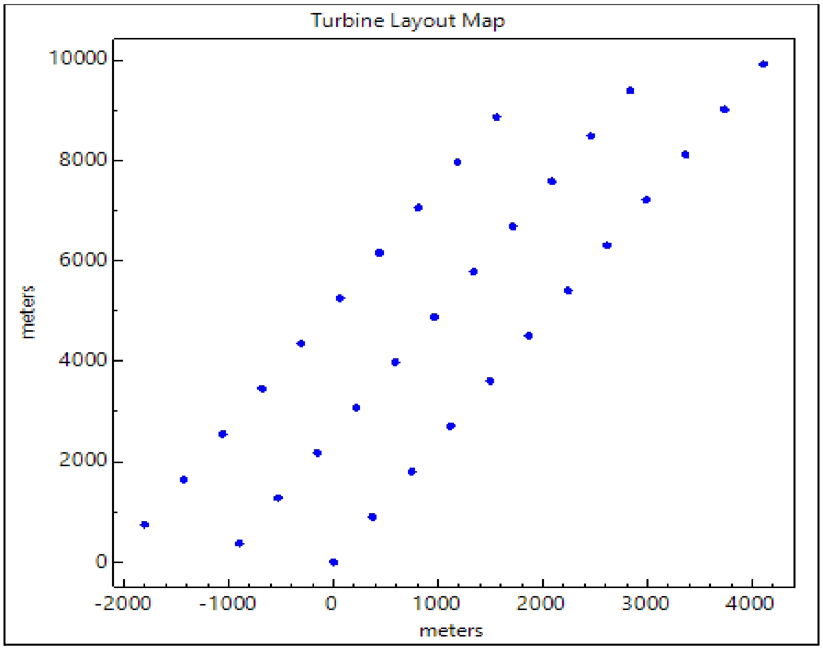
Final Site Selection

After reviewing the policy considerations, available wind resources, and environmental impacts, we selected Meade as the best site for the Testudo Wind Farm. Although Meade does not have the highest wind resource of the three, with Bennett having the highest wind speed, the other two factors made the Testudo Wind Farm more feasible. The easier route for the project would be with Meade, since the other two sites are on Native American land. The development and implementation of wind farms on Native American land is possible and has been spearheaded by groups like the Oceti Sakowin Power Authority. However, due to the time of construction needed, the lack of developed roads and transmission lines, potential delays from the Bureau of Indian Affairs, no federal PTC, and considerably more impact on wildlife led these two sites to not be chosen. Therefore, we chose the Meade site as our best option for further analysis, despite having lower wind speeds than the other two locations.

Wind Turbine Selection and Wind Farm Design

With the final site selected for the Testudo Wind Farm, we proceeded to flush out the design of the farm. Our finalized site consists of 33 Senvion 3 MW 122 meter diameter turbines with a hub height at 136 meters, netting us a farm capacity of 99 MW. We discussed using different turbines in the 3.6 MW range like the GE 3.6-137 or the Siemens 3.6-130, however, we found that using a 3 MW turbine could get us closer to the 100 MW goal without exceeding the limit. Although the output per turbine for the Senvion 3 MW is not as great as the 3.6 MW rating, we found better wind farm annual production with the 3 MW class. The 33 turbines will have a separation of no less than 8 rotor diameters of distance between them, and will be oriented in the prevalent direction of the wind resource. For Meade, the wind rose indicates that the most prevalent wind direction comes from an orientation of 292.5°, which places it in the west-northwest direction. We rotated the leading part of the farm by 67.5 degrees to orient the farm in the west-northwest direction. Figure 7 shows the farm design, which takes up an area of about 80 km^2. Using the System Advisory Model (SAM) and inputting this farm design, we produced an annual energy during the first year of 396,647,232 kWh.

Figure 7: Testudo Wind Farm Layout



The final site for our wind farm has close proximity to US-212, less than 500 meters away, and the nearest transmission line is about one mile away. The surrounding area is mainly flat land with vegetation and some sparse amounts of forests in the vicinity. Also, there are some surrounding farmlands, however, the site we have chosen is away from them.

Financial Analysis

Jobs and Economic Development Impacts (JEDI) Wind Model

With JEDI, we modeled the annual operations and maintenance costs in $/kW and the total installed project cost before and after sales tax. The inputs that were changed from the default options in JEDI were the project location being changed to South Dakota, the nameplate capacity changed to 99 MW, turbine size changed to 3 MW, and the sales tax costs to reflect the 4.5% sales tax of South Dakota. The final costs before and after taxes were $143,888,119 and $150,363,084, with a cost of $1,453.42/kW before taxes and $1,519/kW after taxes (Table 1). The assumed annual operations and maintenance costs were $38.0 /kW before taxes and 39.53 $/kW after taxes. Total annual operational costs would be $26,109,121.

Table 1: JEDI Results and Assumptions

Wind Farm - Project Data Summary based on User modifications to default values		
Project Location	SOUTH DAKOTA	
Year of Construction	2021	
Total Project Size - Nameplate Capacity (MW)	99	
Number of Projects (included in total)	1	
Turbine Size (kW)	3000	
Number of Turbines	33	
Installed Project Cost ($/kW)	$1,519	$1,453 without taxes
Annual Direct O&M Cost ($/kW)	$39.53	$38.00 without taxes
Money Value (Dollar Year)	2021	
Installed Project Cost	$150,363,084	
Local Spending	$32,837,327	
Total Annual Operational Expenses	$26,109,121	
Direct Operating and Maintenance Costs	$3,913,039	
Local Spending	$947,915	
Other Annual Costs	$22,196,082	
Local Spending	$448,039	
Debt and Equity Payments	$0	
Property Taxes	$0	
Land Lease	$297,000	

Parameters and Assumptions

After inputting the wind farm design into SAM, the default values for losses remained unchanged, i.e. wake losses, availability losses, electrical losses, etc. However, the annual depreciation value was changed to 0.6% to more accurately reflect the depreciation of annual energy during the lifespan of a wind farm. Staffell and Green have noted a 12% drop in energy over a 20 year period by observing 283 wind farms in the United Kingdom. The 0.6% was included to show this 12% drop in our wind farm. The energy production during the first year of operation for the Testudo Wind Farm was 396,647,232 kWh, while at year 20 the energy production was 353,790,144 kWh showing approximately an 11% decline, which is close enough to the findings of both Staffell and Green (Staffell et al).

The next considerations are the capital costs of our designed wind farm. Typically, the capital costs include the sales tax of all the purchased products. However, a South Dakota incentive for renewable energy, called the Renewable Energy Facility Sales and Use Tax Reimbursement, covers the sales tax for "project costs associated with a new or expanded facility [that] must exceed $20 million, and the costs associated with equipment upgrades must [also] exceed $2 million," ("Tax Incentives"). Based on this incentive, instead of inputting $150,363,084 for the capital costs, we saved $6,474,965 and the capital expenditure was $143,888,119. The assumed operation and maintenance costs, before sales tax, of $38.0/kW was used. We plan on receiving a loan 6 months before installation date for the initial capital costs, with a 4% interest rate to be paid off over the 20 years of operation.

Under financial parameters, we assumed a nominal discount rate of 9.06%/year. Property and sales tax were reflected in our financial analysis as well. The state income tax rate of South Dakota is 0% and was used as an input. However, the property tax rate for our wind farm required more calculation. South Dakota has another incentive for adjusting property tax under the legislation for Large Commercial Wind and Solar Alternative Taxes. It has rates for the capacity of the farm set at $3000/MW summed with an additional rate of $0.00045/kWh, which represents the total energy production of the farm. For our 99 MW farm with a first year energy output of 396,647,232 kWh, the yearly property tax under the alternate taxes legislation would be $475,491 for year one. To reflect this value in the cash flow breakdown, a property tax rate of 0.331% per year was used. One more assumption was made. Given that the annual energy production depreciates over time, this would be expected to affect the year to year property tax cost. So, an annual decline rate equal to the depreciation rate of annual energy (0.6%) was used to model this property tax rate change.

For our Power Purchase Agreement (PPA) a rate of 4.2 cents/kWh was used. We assumed that it was low enough to be competitive in the wind farm market, yet still high enough to gain profit. Finally, the last two inputs were for the ITC and PTC values. PTC rates after 2021 are now 1.5 cents/kWh after having a steady decline over the past 5 years ("Renewable Electricity"). Since our farm will be in development before December 31st, 2021 the ITC percentage for large farms of 18% is still valid based on the Business Energy Investment Tax Credit legislation, and it will be a considerable boost after our first year in service.

Results

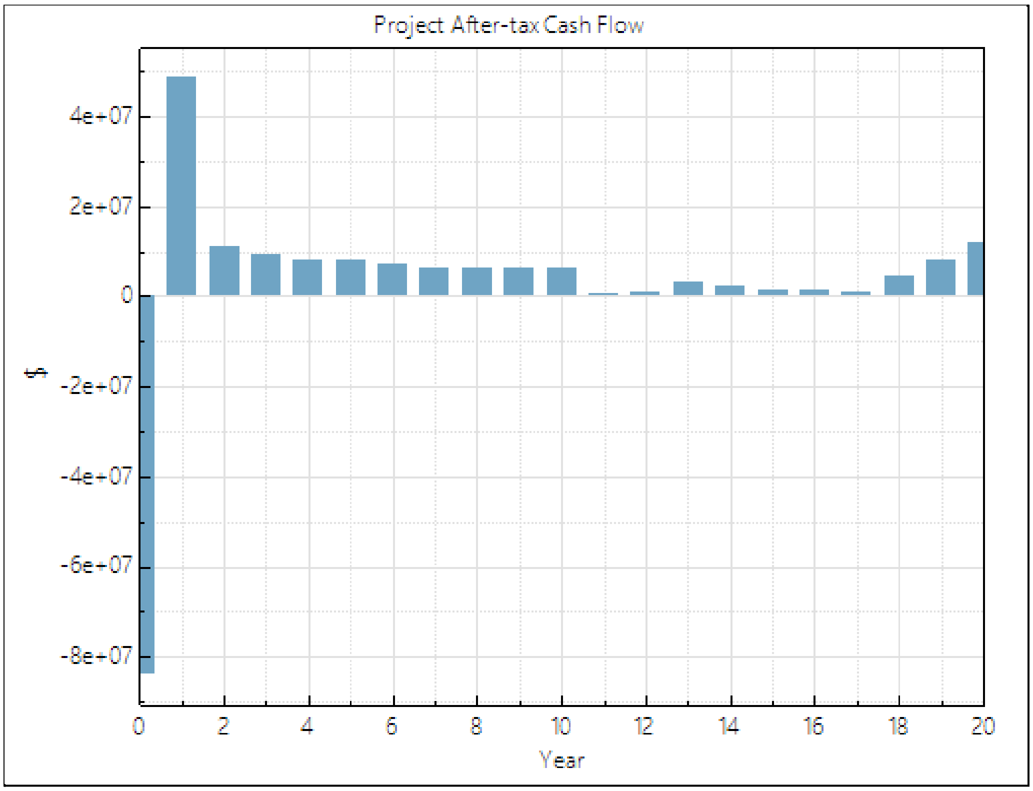
Over the 20 year period of operation, our wind farm results in a net present value (NPV) of $13,067,247 with all the assumptions we have made. The wind farm we have designed has a competitive capacity factor of 45.7%. We gain positive after-tax cash flow starting at year 6. Additional SAM Simulation Outputs (Table 2) show that we also have an expected Internal Rate of Return (IRR) of 13.35% after 20 years of operation, with a Levelized PPA at 4.49 cents/kWh and a LCOE of 4.11 cents/kWh.

Table 2: SAM Simulation Outputs

Metric	Value
Annual energy (year 1)	396,647,232 kWh
Capacity	99,000 kW
Capacity factor (year 1)	45.7%
PPA price (year 1)	4.20 ¢/kWh
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	4.49 ¢/kWh
Levelized PPA price (real)	3.69 ¢/kWh
Levelized COE (nominal)	4.11 ¢/kWh
Levelized COE (real)	3.38 ¢/kWh
Net present value	$13,067,247
Internal rate of return (IRR)	13.35 %
Year IRR is achieved	20
IRR at end of project	13.35 %
Net capital cost	$155,108,512
Equity	$84,052,128
Size of debt	$71,056,376

Large expenses, or negative cash flow as shown in Figure 8, are seen in year 0 due to costs of construction and initial start up of Testudo Wind Farm. This is followed by a large positive cash flow in year 1 due to the available federal tax credits. Based on the progression of after-tax cumulative NPV, the wind farm would be expected to break even during years 8 and 9 before achieving a NPV of over $13 million by year 20.

Figure 8: After-tax cash flow



Risk Management

One of the massive potential risks associated with the Testudo Wind farm currently laid out, is the removal of the sales tax incentive that is currently in effect in South Dakota. That incentive has been in place for more than 8 years, and has a chance to be restructured or completely removed in the 20 year life span of our farm. The removal of the sales tax incentive would add an additional money to any new operating costs that would have been covered by the sales tax. Another big risk is assuming the discount rate to be the value it is. Over those 20 years, there could be a massive recession, as seen recently, which could heavily impact the profit we could gain especially since the net present value and the depreciation rate are inversely proportional.

Discussion of Optimization Process

For each of the Pugh Matrices, we would have each member create their own individual matrix. We would then compare and contrast the differences of what each member came up with to create a final Pugh Matrix that would have the best few sites. When it came to financial modeling, there were many iterations of our inputs into SAM. We first started with a base model farm at a northward facing orientation, and developed some key approximations into what our initial expenditures for the capital and operating costs would be. The initial model would have a negative net present value with the levelized cost of energy (LCOE) being greater than the levelized PPA. We then introduced different parameters like incentives and taking into account South Dakota income tax to find a more feasible wind farm. We would result in having a positive net present value and having the levelized PPA being greater than the LCOE, however, to model a more realistic depreciation of annual energy we increased the rate of depreciation and netted a lower annual energy per year than before. This lowered our results, but made them hopefully more realistic.

Additional iteration occurred with the use of different turbines. We first assumed that we should use wind turbines that have the highest MW ratings, and used 3.6 MW rating as a baseline. We had a relatively low nameplate capacity, so we shifted to 3 MW to achieve a higher nameplate capacity without going over the 100 MW limit. That is where we decided to use the Senvion 3MW 122 at a hub height of 136 meters, where we discovered our best financial analysis.

Conclusion

The design of Testudo Wind Farm was formulated after many iterations and site elimination, where we finalized on 33 Senvion 3MW turbines in Meade County at 136 meter hub heights that had each turbine spaced 8 rotor diameters away with the entire farm oriented in the west-northwest direction. Our Testudo Wind Farm is capable of achieving 396,647,232 kWh at a LCOE of 3.69 cents/kWh for the first year, and finished with a net present value of $13,067,247 after 20 years. We believe this farm is worth the investment of a potential liener's capital.

Works Cited

Clarke, Chris. "What's Keeping Tribes From Harnessing Their Wind Energy?" KCET, 2 May 2017, kcet.org/shows/earth-focus/whats-keeping-tribes-from-harnessing-their-wind-energy.

County of Meade. "WECS (Wind Energy Conversion System) Ordinance 32." Meade County, 2019, static1.squarespace.com/static/55f1f6a6e4b0fdc2e7a036d1/t/5d27b21e4c5d280001b35803/1562882591582/Meade+County+WECS+ORDINANCE+32+REVISED_FINAL_04242019.pdf.

Department of Energy. *Draft Environmental Impact Statement for the South Dakota PrairieWinds Project DOE/EIS #0418*. Energy.gov, Jan. 2010, energy.gov/sites/prod/files/2015/08/f25/EIS-0418-DEIS-2010.pdf

DSIRE. "Business Energy Investment Tax Credit (ITC)." NC Clean Energy Technology Center, 24 Feb. 2021, programs.dsireusa.org/system/program/detail/658.

DSIRE. "Renewable Electricity Production Tax Credit (PTC)." NC Clean Energy Technology Center, 27 Jan. 2021, programs.dsireusa.org/system/program/detail/734/renewable-electricity-production-tax-credit-ptc.

OpenEI. "Wind Projects on Native American Lands." OpenEI, 21 Jun. 2018, openei.org/wiki/Wind_Projects_on_Native_American_Lands

Rapid City Journal. *Special Zoning Ordinance No 36 - Meade County*. Rapid City Journal, 15 Jun. 2011, rapidcityjournal.com/meadecountytimes/public_notices/special-zoning-ordinance-no-36---meade-county/article_d9d28b0a-96d6-11e0-a1d4-001cc4c03286.html.

Staffell, Iain, and Richard Green. "How Does Wind Farm Performance Decline with Age?" Renewable Energy, vol. 66, 2014, pp. 775–786., doi:10.1016/j.renene.2013.10.041

"Tax Incentives." South Dakota Governor's Office of Economic Development, 5 Mar. 2021, sdgoed.com/financing-incentives/tax-incentives/.

U.S. Fish & Wildlife Service. "Wildlife Concerns Associated with Wind Energy Development." U.S. Fish and Wildlife Service in the Midwest, 2 Jan. 2020, fws.gov/midwest/wind/wildlifeimpacts/index.html

"Wind Farms and Whooping Cranes." Whooping Crane Conservation Association, 21 Jul. 2011, whoopingcrane.com/wind-farms-and-whooping-cranes/