



HOPKINS STUDENT WIND ENERGY TEAM

Project Development Report

Johns Hopkins University
Collegiate Wind Competition 2021

Siting Team

Dong-Woo Seo (Siting Lead), Kyra Rothwell,
Ethan Underweiser

Finance Team

Jonathan Spangler-Sakata (Co-Finance Lead),
Sam Choi (Co-Finance Lead), Ebuka Ezekwesili, Lance Kotler,
Nathan Felmus, Shardul Rakshit

Table of Contents

Executive Summary	2
1.0 Siting Analysis	2
1.1 Wind Farm Design	3
1.2 Permitting	4
1.3 Environmental and Community Impact	5
1.4 Net Annual Energy Production	6
2.0 Capital Expenditures	6
2.1 Financing Plan	7
2.2 Power Purchase Agreement	8
2.3 Market Conditions	9
2.4 Incentives	9
2.5 Operating Costs	10
2.6 Risk and Mitigation Strategies	10
2.7 End of Life	13
3.0 Optimization Procedures	13

Executive Summary

The [Johns] Hopkins Student Wind Energy Team (hereafter, referred to as “HSWET,” the “developer,” or the “sponsor”) has developed a report for a 98.4 MW wind farm in western South Dakota. After extensive research into the siting characteristics and financials for the region, HSWET has created a rough development plan for a 100-MW wind farm in Union Center, which is in Meade County, SD. Siting aspects of the project were visualized using Wind Prospector while the financial analysis for the project was done using the System Advisory Model (hereafter, referred to as “SAM”). The project offers attractive economics to both the developer and tax equity investor with 11.87% and 7.07% returns respectively along with a high-capacity factor of 46.3% and competitive LCOE of 0.022 \$/kWh.¹

The wind farm is attractive to investors for various reasons, including HSWET’s unique combination of strategies using larger wind turbines, back-leveraged loans with refinancing options, an as generated bus bar PPA with an investment-grade local utilities company, safe harbored equipment, and Renewable Energy Credits.

Figure 1: Project Summary	
Capacity	98.4 MW
Capital Expenditures	\$129 M
Cost/kilowatt-hour	\$1,290.90
PPA price (year 1)	20.9 \$/mWh
Levelized PPA price (nominal)	22.9 \$/mWh
Levelized Cost of Energy (nominal)	22.3 \$/mWh
Tax Equity Investor Return	7.07%
Developer Return	11.87%

1.0 Siting Analysis

HSWET utilized Wind Prospector for preliminary site selection and to produce maps showing average wind speeds, land ownership, terrain, endangered species, and nearby infrastructure.² HSWET then overlaid these results with a map of the transmission grid from the U.S. Energy Information Administration.³ With a preference for high wind potential and a short distance to existing transmission infrastructure, HSWET chose three areas for further investigation: South Dewey, West Todd, and Meade County. HSWET ultimately decided Meade County was most viable for a potential wind farm due to public land ownership and minimal exposure to endangered species. South Dewey and West Todd had higher wind potential but were both on Indian Reservations and in the Whooping Crane migratory path. Within Meade County, Union Center was the area of particular interest as most of the land is not developed and the site is easily accessible by an existing road.⁴

Figure 2 - Location of HSWET's Proposed Wind Farm

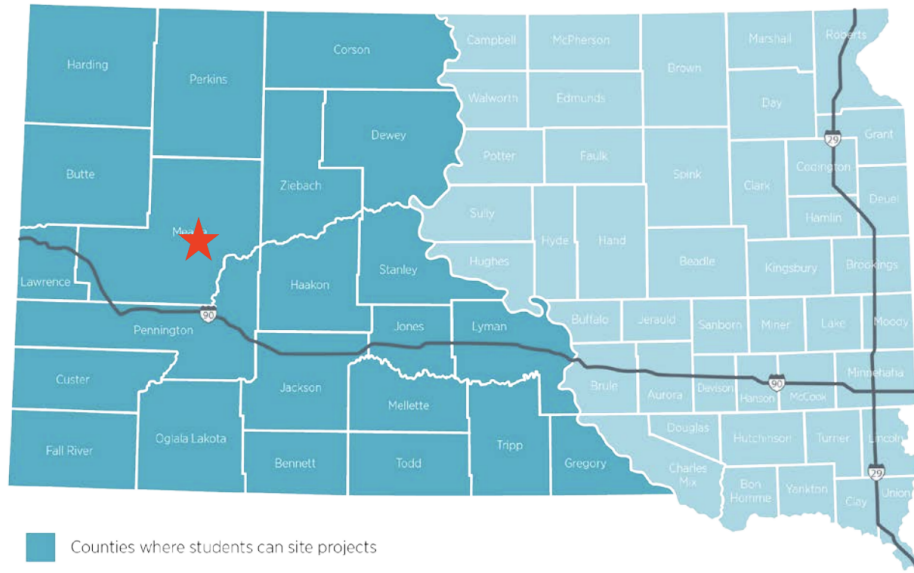


Figure 3 - Satellite View of Proposed Location



Site Characteristics

The site is in Meade County with the coordinates (44.664055, -102.660985). The area primarily consists of grasslands, with nearby pasture lands, wetlands, and barren land. Residing in the Missouri River Basin, the elevation of the site is 928m above sea level.⁵ Meteorological data from the Wind Integration National Dataset Toolkit sampled at 30-minute increments from 2007 to 2012 showed an average wind speed of 8.4 m/s and an average temperature of 8.9°C.⁶

Figure 4: Site Characteristics				
	Minimum	Maximum	Median	Average
Wind Speed	0.02 m/s	29.30 m/s	8.08 m/s	8.39 m/s
Temperature	-28.43°C	38.05°C	9.31°C	8.90°C

1.1 Wind Farm Design

Upon consultation of historical meteorological data and industry mentors, HSWET chose to use 22 Vestas 150-4.2MW and 3 Vestas 136-3.45MW turbines for the project. The Vestas manufacturing plants located in Colorado are roughly 400 miles from the project site, which is favorable compared to the

locations of other turbine manufacturing sites throughout the country. The V150-4.2MW turbine has a rated power of 4,000/4,200 kW while the V136-3.45 turbine has a rated power of 3,450kW.⁷ We incorporated 3 of the older V136-3.45MW turbines as HSWET expects the tradeoff will improve the financial return of the project, which is described in further detail in the financial analysis safe harbor section.

Turbine	Rated Power	Rotor Diameter	Hub Height	Cut-In Value	Cut-Out Value	Shear Coeff.
V150-4.2MW	4,000/ 4,200kW	150m	140m	3m/s	22.5m/s	0.14
V136-3.45MW	3,450kW	136m	142m	3m/s	22.5m/s	0.14

In designing a wind farm, turbine spacing must be given careful consideration. Wind turbines that are too close together can result in increased wake losses and higher noise pollution. However, increased distance between turbines results in higher costs due to the additional transmission infrastructure necessary and greater land coverage. In the SAM model, HSWET assumed turbines are placed in a rectangular grid where each turbine is 7 rotor diameters apart, which should be sufficient to allow each turbine to receive a reasonable amount of turbulent air flow.⁸

1.2 Permitting

In the process of evaluating prospective site locations, HSWET compared the advantages and disadvantages of private and public land. While public land offered more advantageous economic incentives, it also required a much more rigorous permitting approval process and involved the engagement of the NEPA, the Bureau of Land Management, and possibly the Bureau of Indian Affairs if located on Tribal Land.⁹ Such a project would most likely demand an extensive environmental assessment or possibly even an Environmental Impact Statement which is a time intensive and expensive process.

With these factors in mind, HSWET chose to site the wind farm on private land where the permitting process would be much simpler. In compliance with Meade County Local Ordinance 32 on the development of Wind Energy Conversion Systems, the wind facility will be placed on agricultural property of at least 73 acres of continuous land. HSWET's method of obtaining this land will be through acquiring compensatory contracts from private landowners. This approach will consist of a more personal and direct exchange with community actors. HSWET anticipates that community impacts will be more prevalent in wind farms being constructed and established in residents' backyards. This further emphasizes the need to be sensitive to the effects of the wind farm on the community as well as ensure all development sufficiently follows all local ordinances.

Throughout the permitting application process, HSWET will make sure that all residences with compensatory contracts as well as residents with properties within a 2,500-foot radius of the wind facility are notified of the project's hearing at least 2 weeks prior. To encourage transparency between the wind facility and the residents, they will also be provided with contact information, a map of the expected project, and the link to a website where residents can anonymously comment or ask questions about the project development and design.

The design and installation of the wind farm will follow the design safety guidelines established by the American National Standards Institute, the International Building Code, and the National Electric Code. The project will also comply with the local ordinance's visual appearance requirements such as the color of the turbines being non-obtrusive and containing no artificial light or advertising. The transmission and power lines can also be placed underground to reduce visual disturbance. Additionally, the shadow flicker of the wind farm will be restricted to just 36 hours per year to fulfill local ordinance guidelines.¹⁰

With regards to the setbacks, the wind facility will be installed at a distance of at least two times the height of the turbine from the property line of residents participating in compensatory contracts. As for non-participating landowners, the wind facility will be installed at a distance of at least five times the height of the turbine from said residents' property lines. As for public roads, the facility will be set back a distance of at least two times the height of the turbine from the public road boundary. All the measurements listed above meet the local regulations explained in local ordinance 32 of Meade County.

1.3 Environmental and Community Impact

An ecological survey of a nearby region with similar terrain (Butte County, South Dakota) indicates low species diversity in Meade County. This survey documented 8 reptilian species, 118 avian species, and a variety of mammals including big game species.¹¹ Endangered and threatened species and species with special status in this area include the Sprague's pipit, the Red Knot Bird, the Least Tern, the Whooping Crane, and the Northern-long Eared Bat, the last two of which are of the greatest concern. The Whooping Crane migration corridor centers along the middle of South Dakota, following the Missouri River. Union Center is on the western edge of this pathway, seeing a low density of migrating birds.¹² Northern-long Eared Bats and other bat species tend to be found in trees and caves but can have a wide hunting range.¹³

Other environmental factors that were considered as part of the siting analysis include the acoustic and visual resources of the region. The chosen site is not near any populated areas; Meade County has a population density of less than eight people per square mile, and the chosen site is not near any towns. National parks and recreation areas are also not impacted by this site.¹⁴ The closest state and national parks—Bear Butte State Park and Badlands National Park—are more than 50 miles away. This indicates a low impact on visual and audio resources in this area.¹⁵

Paleontological resources are moderate throughout western South Dakota. While there is risk in damaging these during site construction, this risk is no higher than any other area in South Dakota.¹⁶ The impacts to paleontological resources can be mitigated by collaborating with a paleontological consultant during site construction.¹⁷

Environmental justice concerns for this site are low. General average income data indicates that Meade County is comparable to other counties in western South Dakota.¹⁸ The site is not located on Native American lands and is in a sparsely populated area suggesting a low overall impact on humans.¹⁹

Mitigation Strategies

To minimize the environmental impact of this project, HSWET considered a variety of mitigation techniques that help to encompass the entire project process from construction to end of life. These strategies consider the use of land, ecological resources, and other environmental resources.

Prior to construction, an evaluation on the site will be conducted to ensure that turbines are not being placed in Whooping Crane stopover locations. To protect Whooping Cranes and other avian species as well as minimize the damage to habitats, all parts of the process will seek to avoid wetlands.²⁰ During construction, vehicles will be cleaned outside of agricultural areas to prevent the spread of weeds. Local, state, and federal laws will be followed to minimize dust particle and chemical spread to natural habitats and streams. Limits will be set on idling diesel equipment, and interference with farming and livestock operations nearby will be minimized. Noisy construction activities will be scheduled at the same time to avoid frequent noise disturbances, and the installation of equipment will also be planned to avoid nesting times, migration periods, and other sensitive times for wildlife. Additionally, turbines will be painted appropriately before installation to avoid excessive light scattering. Following construction, any drainage or soil compaction problems will be corrected, and disturbed areas will be reclaimed and restored.²¹

Turbines themselves will operate using ultrasonic noise deterrence to avoid collisions and harm to bats. Anti-perching devices will also be installed to reduce collisions with birds. The project will feature buried electrical lines and use the minimum amount of pilot warning and obstruction avoidance lighting

as required by the Federal Aviation Administration (FAA).²² To further reduce impacts to wildlife, turbine cut-in speeds can be increased, and the turbine blades can be feathered.²³

Throughout the project, wildlife will be monitored to ensure minimal impact. Moreover, a plan will be set to avoid transporting noxious or invasive plants into this region. At the end of the project's life the terrain and vegetation will be restored to match the surrounding environment.

1.4 Net Annual Energy Production

The SAM model indicates that the Year 1 Annual Energy Production is **405,497,344 kWh** at a **46.3% capacity factor**. This means that the wind farm will essentially be operating at **46.3%** of its total MW potential for every hour of the year. The high capacity factor is due in most part to a larger modern turbine design (the Vestas V150) and great wind resources.²⁴

2.0 Capital Expenditures

Developing an initial capital cost is a complicated procedure involving numerous components such as the cost of turbines, transportation, construction, and land. Thus, most of the SAM model's inputs are derived from data provided by industry mentors working on projects in the region and research performed from online sources ranging from South Dakota government reports and energy assessments to NREL and DOE documents. The remaining figures came from industry benchmarks and default model values. Ultimately, HSWET calculated that the project's net capital cost is **\$129,090,328**.²⁵

HSWET found that the main components affecting the net capital cost are the turbine cost, balance of system cost, and financing cost.²⁶ Elements affecting the turbine cost include distance from manufacturer to location, cost of labor, and cost of resources, among other factors.²⁷ One major element worth accounting for is the size of the turbine. When faced with the option of having more "smaller" turbines or fewer "larger" turbines, HSWET elected to go with the latter. The logic is that with each turbine comes a new foundation, nacelle, hub, crane pic, and transmission line, not to mention the additional cranes and workers needed for construction. As a result, while HSWET will pay more money per turbine, total construction and long run maintenance for the wind farm will be less than it would be with smaller turbines.²⁸

While the SAM model has its own estimation-of-turbine-costs calculation, an industry mentor mentioned that the model's estimated cost per turbine was higher than he expected and he subsequently suggested that HSWET should use **\$3.4MM** per V150 turbine. With this assumption the project costs around what the industry would expect (**\$1.30-\$1.50/watt**).²⁹

Figure 6: Use of Funds

Cost Type	Amount	Percentage
Turbine Cost	\$ 85,000,000	65.85%
Balance of System Cost	\$ 28,849,816	22.35%
Financing Cost	\$ 15,240,512	11.81%
Net Capital Cost	\$ 129,090,328	100.00%

Another element that heavily affects the net capital cost are balance of system costs. The BOS cost considers all direct construction costs such as site development, management, site preparation, foundation construction, turbine erection, collection system construction, grid connection, and substation connection. It excludes the cost of the turbines.³⁰ HSWET used NREL's LandBOSSE modeling software to model balance of system costs.³¹ Listed on the table below is a breakdown of the project's balance of system costs.

Figure 7: Balance of System Costs	
Expense Type	Amount
Turbine Foundation	\$ 3,378,575
Labor	\$ 1,964,659
Equipment Rental	\$ 96,413
Material	\$ 1,156,449
Mobilization	\$ 161,054
Site Preparation	\$ 2,272,666
Labor	\$ 960,355
Equipment Rental	\$ 96,413
Material	\$ 1,156,449
Mobilization	\$ 59,449
Collection System	\$ 4,017,444
Labor	\$ 1,661,886
Equipment Rental	\$ 381,666
Material	\$ 1,782,454
Mobilization	\$ 191,438
Transmission and Distribution	\$ 4,821,131
Tower Erection	\$ 1,929,949
Labor	\$ 1,200,220
Equipment Rental	\$ 192,699
Mobilization	\$ 530,514
Fuel	\$ 6,516
Substation	\$ 5,432,424
Management	\$ 6,847,627
Bond	\$ 209,165
Construction Permitting	\$ 267,643
Engineering	\$ 1,426,188
Insurance	\$ 121,354
Markup Contingency	\$ 2,438,547
Project Management	\$ 1,543,295
Site Facility	\$ 841,435
Development	\$ 150,000
Total:	\$ 28,849,816

Finally, the financing cost accounts for costs such as bank and legal fees and legal fees involved in contract negotiations. This accounts for the smallest amount of the capital cost.³²

2.1 Financing Plan

As the developer, HSWET needs to identify the site, secure land leases, select vendors, and most importantly negotiate contracts with debt and equity investors. Thus, it is HSWET's job to spread risk to the parties best prepared to handle said risk. A combination of sponsor equity, tax equity, and term debt will fund the **\$129MM** capital cost.³³

HSWET will enter into a back levered deal as front levered projects have gone by the wayside due to tax equity not wanting to be subordinated by project companies defaulting on loans. As part of the back levered deal, the developer (HSWET) will directly receive the debt in the project rather than have the debt go straight into the project company. However, even though HSWET directly takes on the project debt, the developer maintains its non-recourse status as do all parties in project finance other than the project company itself.³⁴

For the **\$129MM** project, **\$92.4MM** will come from equity and **\$36.6MM** will come from debt financing.³⁵ This is typical of a back levered project of this size, especially given the high capacity factor of over **46%**. The high capacity factor means that the project will be throwing off lots of PTCs which in turn provides a higher percentage of investment from tax equity than would be available with a lower

capacity factor. Further, the sponsor is responsible for putting up **10-15%** of the total capital cost to show that they have “skin in the game.”³⁶

The investor’s IRR in the flip year will be **7%** which is standard for the industry (typically 6-8%).³⁷ Over the lifetime of the project the tax equity investor will have a **7.07%** return with an assumed discount rate of **6.08%**.³⁸

Further, HSWET has also acquired one large lender (again for simplicity reasons HSWET is assuming that it would not spread its debt across multiple lenders). HSWET has signed a contract with the same lender that ensures HSWET will receive a mini perm upon COD. After eight years HSWET will face a bullet payment, although the loan goes through year 12.³⁹ This scenario will force HSWET to seek a lower-risk permanent loan to refinance the initial mini perm in year eight. This provides HSWET the opportunity to receive more favorable interest rates as the project will have seven and a half years of proven cash flow and data by the time the team looks for the project’s permanent loan.⁴⁰

HSWET will hire an EPC contractor that will design, construct, and commission the 100MW farm. The construction period will be eight months (with a three month pause for winter) with five tranches of loans. Upon COD the project will get turned over to the O&M contractor who will ensure the project runs smoothly in day-to-day operations.⁴¹

Listed below is a source of funds table that details how the project is being funded.

Source	Amount	Percentage
Developer	\$ 18,479,630	14.32%
Tax Equity	\$ 73,918,520	57.26%
Project Debt	\$ 36,692,178	28.42%
Total:	\$ 129,090,328	100.00%

2.2 Power Purchase Agreement

After doing extensive research into the independent system operator (ISO) within which Union Center, SD, is located, HSWET concluded that the proposed wind farm would be producing power in the Western Electricity Coordinating Council (WECC) Wyoming region of the Federal Energy Regulatory Commission.⁴² Further research suggests that operation in a merchant power market would be infeasible as no robust merchant market currently exists in WECC. As a result, a PPA would certainly be required for a wind farm to be economically viable.

Therefore, HSWET will be signing an as-generated, bus bar PPA with an investment-grade local utilities company, Black Hills Energy Corporation. They are headquartered in Rapid City, SD, and have a market cap of \$4.15 billion⁴³ with 1.2 million customers across an 8-state region.⁴⁴ Fitch rated Black Hills a BBB+, or solidly investment-grade,⁴⁵ with a stock price of \$66.17 as of May 21, 2021 on the New York Stock Exchange.⁴⁶ Black Hills Energy Corporation’s low-risk, regulated utility operations, predictable cash flows and revenue increases, and constructive regulatory environment drive their strong credit reliability.⁴⁷ The PPA contract will specify a price of **\$20.9/MWh for 15 years** under the agreement with an optional 5-year contract extension at a renegotiated PPA price that could be exercised if no merchant power market is developed in WECC by the time the original contract ends. These figures for the PPA are based on power curves for WECC Wyoming, the grid region covering Union Center, SD, over the next 20 years, and with confirmation from industry mentors working on financing projects in the region.⁴⁸ The agreement also includes the sale of the Renewable Energy Credit (REC) of \$12 per MW of energy produced to Black Hills Corp. The sale of the credit was able to bring the PPA price down from about \$33/MWh to an even more attractive \$21/MWh.

With the bus bar agreement, Black Hills is buying the power at the same location HSWET puts it on the grid. This will eliminate basis risk because Black Hills will purchase power at the same node as the generated power joins the grid, meaning there will be no difference in prices based on distance. This is a

viable PPA with Black Hills since they are headquartered in Rapid City, less than an hour down the road, and cover the area around it, including Union Center.

2.3 Market Conditions

Renewable energy accounts for 70% of South Dakota's electricity generation. Wind energy's share of state electricity production currently stands at 30% and continues to grow rapidly.⁴⁹ South Dakota has the highest capacity factor for wind energy in the country, at over 44% (46.3% at the location, according to SAM), and new transmission capacity is expanding wind's attractiveness.⁵⁰ With South Dakota's population growing at a rate of about 9% and hydroelectric energy somewhat capped along the Missouri River and facing more opposition,⁵¹ there is space for a faster-growing wind energy to fill the utilities companies' portfolios. Specifically, Black Hills Energy Corporation is looking to increase their renewable energy holdings by 200 MW by 2023.⁵²

A cost of **\$20.9/MWh** is superior to that of hydroelectric, coal, solar, or other sources of electricity in South Dakota, and a very attractive price for regional utilities to purchase. Residential, commercial, and industrial electricity sells for an average of \$123.10/MWh, \$115.90/MWh, and \$91/MWh, respectively,⁵³ meaning significant profit opportunity arises from utility sale to consumers.

Long-length PPAs are also becoming rare, though they still exist, due to the rate of technological innovation. The LCOE of the most cutting-edge turbine produced in 2021 may be far higher than the LCOE of a turbine produced five or 10 years later. Thus, if a utility locks itself into a 10+ year PPA, they could end up overpaying for their power as over time power gets cheaper to produce. Once again, for simplicity reasons and due to the inability for a wind farm to operate in a merchant market in WECC, HSWET is assuming that it will sign the 15-year PPA with the optional extension. Traditional "as generated" contracts with local offtakers are becoming rarer, though they also still exist. One reason as generated contracts are harder to find is because offtakers are opposed to onboarding the risk of committing to pay a predetermined price for all the power the wind farm produces. Offtakers could be hurt if the market price of power is lower than the predetermined PPA price/MWh since the offtaker would still be forced to pay the power producer the agreed upon PPA price even though they could get cheaper power from the market. This risk is typically mitigated by a "fixed contract" where the offtaker is only obligated to pay the PPA price for a fixed amount of power that the contract specifies. However, for simplicity reasons HSWET is assuming that it will use an as generated contract.

2.4 Incentives

A major incentive that significantly increases the profitability of the wind farm is revenue from renewable energy certificates (RECs). REC prices in the WECC ISO region currently stand at around **\$12** per MW.⁵⁴ After conferring with industry experts, HSWET has projected that REC prices in the WECC region will decline by 50% in the next 20 years as the supply of RECs continues to increase in the area.⁵⁵ Annualizing this 20-year decline suggests that REC prices will decline by 3.5% annually. The existence of RECs allows this wind project to maintain profitability at the chosen PPA price as HSWET has factored in the REC price to the PPA (through the use of a Production Based Incentive in the SAM) as the offtaker of the power will also be purchasing all of the wind farm's RECs.⁵⁶

Anticipating that HSWET's project's commercial operations date (COD) is in 2022, HSWET will be partnering with Steelhead Vestas under a joint development agreement as part of a safe harboring strategy.⁵⁷ Steelhead Vestas will be providing the project with three Vestas 136-3.45MW wind turbines, which equates to about **7%** of capital costs for the project, making the project eligible for the 2017 PTC rate of **80%**.⁵⁸ In exchange for Steelhead's safe harbored wind turbines and developer expertise, Steelhead will receive **\$10.2** million of the development fee upon COD, which is earmarked under turbine costs in the SAM model.⁵⁹ The SAM model suggests that the increase in the PTC tax credit rate from 60% to 80% due to safe harboring allows the project to net an additional **\$16.8** million in tax equity funding

(from \$57.1 M to \$73.9 M) which is quite significant. Executing this safe harbor strategy allows the project to fund an additional **13%** of net capital costs through tax equity financing.⁶⁰

There are a few regional incentives for wind farms in the state of South Dakota. One incentive that the wind farm will use is the Renewable Energy Sales and Use Tax Reimbursement which allows commercial contractors to receive reinvestment payment for up to 100% of sales and use taxes paid for a project.⁶¹ This decreases the sales tax for direct costs from 4.5% to 0%. Another incentive that can be utilized is the Large Commercial Wind Exemption and Alternative Tax which enables large (>5MW) wind farms to pay a production tax and nameplate capacity tax in place of property taxes. The production tax is the product of \$0.00045/kWh and the net annual energy production. It applies to wind farms generating power on or after April 1, 2015.⁶² The nameplate capacity tax is the product of \$3.00/kW and the nameplate capacity⁶³. The result of these incentives is a total tax of \$474,916.

2.5 Operating Costs

As the developer, HSWET will hire an O&M contractor to provide labor, day-to-day operations, and ensure that the wind farm delivers to its listed capacity. HSWET will have a fixed-price contract with a clause that requires the O&M contractor to pay HSWET a fee for every day that the plant is unable to deliver up to its capacity. These factors are important to ensure that the operating costs are predictable and do not drastically fluctuate from year to year, which can affect profitability.⁶⁴

Specifically, the total annual operating cost calculated by the SAM model is **\$5,063,468 for year 1** and increases to **\$7,190,106 by year 20**. The primary input that affects this value is the fixed cost by capacity. The fixed cost by capacity is the flat cost required to maintain one kilowatt of energy per year, thus as the nameplate capacity of the system increases, the cost increases. This is calculated using the insurance annual premium, which is what the sponsor pays every year to cover the project, and the inflation rate. The fixed cost of capacity is **39\$/kW-yr** based on Lazard's 2020 Levelized Cost of Energy Analysis.⁶⁵ What HSWET found after using **39\$/kW-yr** in the SAM model matched closely with Lazard's findings.

2.6 Risk and Mitigation Strategies

HSWET has identified eight different categories of risks posed to the project. Of the eight, HSWET selected and ranked four that pose the largest threat to the project based on impact on returns.

Figure 9: Wind Farm Risk Assessment	
Risk Type	Description
1. Political / policy / regulatory risks	Risks arising from changes in government policy support schemes for wind farms (changes to PTC, subsidy expiration), complications arising from long approval process
2. Market / sales risk	Risk due to uncertain cash flows resulting from inaccurate wind resource prediction, future energy prices, limitations in grid management/infrastructure
3. Strategic / business risks	Risks arising from scarcity of capital & insufficiency expertise, inadequate depth of the tax equity market
4. Cost Overrun risk	Risks arising from unexpected cost overruns
Technology / innovation risk	Risks arising from potential inaccuracies in early planning/assessment (ex: inaccurate wind resource assessment, inadequate land mapping)
Operation / maintenance risk	Risks arising from damages to physical assets due to weather, defective
Liability / legal risk	Risk arising from liabilities to third parties due to environment damages, legal disputes/contracting risks arising from revenue loss
Counterparty risk	Risk arising from poor credit quality of supplier, power purchaser

The first is political / policy / regulatory risk. This covers everything from PTC policy to the permit approval process. If the approval process were to be prolonged, dragging out the COD date of the project, it could pose a serious risk to the tax equity sponsor, as the project may potentially overshoot the 5-year construction window of the safe harbored equipment from 2017. Subsequently, HSWET would become ineligible for 80% PTC tax credit, instead defaulting to 60%. To construct the project, HSWET needs to receive approval from the South Dakota Public Utilities Commission (hereafter, PUC) who have several responsibilities pursuant to SD Codified Law § 49-41B.⁶⁶ HSWET must notify the PUC of HSWET's intent to apply for a permit six months before submitting the permit application, after which the PUC has a maximum of nine months to approve or deny the permit once submitted. Once the permit application is submitted, the PUC organizes a local review committee made up of South Dakota residents living near the proposed site. This committee holds a public hearing where residents can air formal and informal grievances about potential impacts of the project. After surveying these complaints as well as analyzing the project's impact on local public works and quality of life, the review committee submits a report to the PUC stating their concerns and proposed mitigation strategies. The political risks arising from this process are mainly due to the potential of strong public opposition to the project, manifesting as anything from a formal complaint to a lawsuit. These complaints and the subsequent report could force HSWET to change operation and construction times, move the site or adjust the turbine layout, or even abandon the project altogether. National trends indicate that public opposition to wind farms has grown significantly over the past several years due to invigorated local and national anti-wind lobbies, especially in states where construction has grown significantly.⁶⁷ In 2019, South Dakota experienced the largest percent increase in wind farm development of any state in the US, indicating an environment ripe for these problems.⁶⁸ To mitigate these political risks, there are several key strategies we can take. The first is to make sure that HSWET representatives are constantly interacting with the local population and working to spread positive, accurate information on the project to prevent the spread of pseudoscientific theories that have derailed projects in the past. Taking important procedural elements like public hearings seriously can demonstrate HSWET's commitment to the people of Union Center, building a trusting rather than a contentious relationship. Finally, HSWET must plan for potential construction delays. Due to these regulatory risks, it is very possible that permitting and construction could take upwards of two years, so the project must be financially viable if the construction window is missed. Fortunately, any political/regulatory delays are highly unlikely to delay construction beyond the 80% PTC qualification deadline, so financial viability is assured assuming the worst.

The second major risk is market / sales risk. Unfavorable market conditions could pose a major threat to the project's cash flows. Unexpected price fluctuations in the power market might force the project to accept a lower-than-expected PPA price, severely depressing returns. We currently plan on signing a 15-year PPA priced at \$20.9/MWh with an option for the power producer to extend the PPA an additional 10 years. An analysis of different PPA price scenarios and their effect on returns are listed below in Figure 10.

Figure 10: PPA Price Scenarios

PPA Price	price % change	Developer Return	Tax Investor Return
\$20.9/mWh	-	11.87%	7.07%
\$19.86/mWh	-5%	6.84%	6.93%
\$18.81/mWh	-10%	-1.28%	4.38%

The third major risk to the project is financing risk arising from expensive debt. Changing market conditions could force the project to accept loans at interest rates that adversely affect returns. The current financial plan entails an initial construction loan and two refinancing loans with an average interest rate of 3.8% on \$36.7 million in debt with a total tenor of 20 years. If the discount rate were to rise, developer cash flows would be affected as higher debt servicing costs bite into developer returns. An analysis of different interest rates and their effect on returns is provided below in Figure 11. It should be noted that

tax investor return remains untouched because cash flows allocated to tax investors are allocated before debt servicing costs and cash flow allocated to the developer.

Interest Rate	Developer Return	Tax Investor Return
3.80%	11.87%	7.07%
4.30%	8.80%	7.07%
4.80%	7.07%	7.07%
5.30%	5.27%	7.07%

A fourth major risk is weather variability and its effect on returns. A 20-year probability of exceedance analysis was conducted through the SAM model.⁶⁹ P50 is the base case scenario where there is a 50% chance that wind farm performance is greater than predicted. The poor case scenario is P75, where there is a 75% chance that wind farm performance is greater than the baseline, and the worst-case scenario, P90, where there is a 90% chance that wind farm performance is greater than expected. An analysis of P25, P50, and P90 probability scenarios of wind resource availability and their effect on investor returns are provided below in Figure 12.

Probability %	Production (mWh)	Tax Equity Return	Investor Return
P50 (standard)	405,497	7.07%	11.87%
P75 (poor)	384,750	6.33%	8.42%
P90 (worst)	376,234	5.85%	0.79%

Additionally, there is a chance that the project could be affected by cost overruns resulting from unforeseen circumstances such as unexpectedly high interconnection costs. We have run a scenario analysis of cost overruns and how they affect returns below in Figure 13.

Cost Overrun %	Net Capital Cost	Developer Return	Tax Investor Return
-	\$129 M	11.87%	7.07%
5%	\$135 M	10.77%	5.24%
10%	\$142 M	9.38%	3.92%

Finally, road and transmission line access need to be analyzed as sources of potential risk. Roads to the site are necessary for transporting parts during construction and must be accessible for large trucks carrying turbine blades and other pieces. The Union Center site is located at the intersection between County Highway MC-27, or Stoneville Road, and County Highway Mc-22a, allowing for easy access to the site. A large dirt road can be easily constructed across the site for installation of turbines as the topography is relatively flat and treeless, with gentle, rolling grass hills that are easily navigable for large trucks.

Transmission lines are important because they deliver the energy generated from the wind farm to residential and commercial properties. The two big risks are distance from existing electric grid and the grid interconnection limit. Distance is not a concern because the closest electric grid line is only one mile from the proposed wind farm and the costs to interconnect to the main grid should be minimal. The grid interconnection limit is the maximum AC power that can be supplied to the grid and any surplus power above the limit is curtailed. Curtailment is when the maximum amount of energy that's allowed to be supplied to the grid is reduced, which reduces the profits generated since less electricity is able to be produced. The voltage of the nearest transmission line is 230 kV.⁷⁰ Assuming overhead high-voltage transmission lines are used, the electric conductor lines, also known as Aluminum Conductor Steel

Reinforced (ACSR), are in the 220 kV 'Zebra' class which means that the maximum current carrying capacity is 200 MVA⁷¹. This can be used to calculate the grid interconnection limit which is roughly 61,000 kW⁷². This is larger than the power generated by the wind farm which is around 46,290 kW, so curtailment should not be an issue.

2.7 End of Life

There are two decisions to choose from when the end of the project life is getting close: decommissioning and repowering. Decommissioning involves breaking down the wind farm and selling the various turbine components to other parties or scraping them for raw materials. Repowering involves continuing the operation of the wind farm for an additional number of years. A lifetime extension assessment involving a theoretical calculation and physical inspection of the wind farm's turbines can be done to determine the most profitable way to maximize salvage value.⁷³

HSWET is planning to sign a repowering contract with another developer at the end of the project's life. This simplifies many factors such as what to do with the existing turbines, transmission lines, and foundations. Further, the fact that those pieces of infrastructure already exist make a repowering agreement attractive to a future developer.

3.0 Optimization Procedures

Since the 2020-2021 competition season was the first year for the JHU Student Wind Energy Team, the team focused heavily on the learning aspect of wind energy development and competition requirements. HSWET took a top-down approach to optimize the project proposal. First, the team identified the three most favorable regions in western South Dakota based on wind potential and distance to transmission lines. Then, HSWET conducted deeper due diligence on the permitting procedure and environmental conditions for each region and focused in on Meade County. The specific coordinates were chosen based on terrain, use of land, and distance to existing roads. Turbines were selected based on wind conditions and industry standards were assumed for the turbine layout.

Finally, HSWET optimized the proposal further through varying levels of equity ownership between tax equity and the developer, while identifying ideal partnerships to minimize the cost of capital. HSWET's process consisted of background research and learning (i.e. using CWC rules and regulations, past project reports, and industry mentor meetings), an outline of a general plan, individualized research and assignments on various parts of the development project, and compiling SAM inputs. Using each person's individual research via memos to the team, HSWET gathered preliminary figures for the SAM inputs, refined through meetings with industry mentors, and optimized via multiple iterations of the financial model to reach the most profitable and attractive financial plan with minimized costs and diversified risk across prepared parties.

References

- ¹ NREL. System Advisor Model (SAM). <https://sam.nrel.gov/>. Published 2021.
- ² NREL. Wind Prospector. <https://maps.nrel.gov/wind-prospector/>. Published 2021.
- ³ U.S. Energy Information Administration. South Dakota State Profile and Energy Estimates. <https://www.eia.gov/state/?sid=SD>. Published 2021.
- ⁴ Google Maps. (44.664055, -102.660985). Accessed May 1, 2021.
- ⁵ USGS National Map. (44.664055, -102.660985). Accessed May 1, 2021
- ⁶ Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015. "The Wind Integration National Dataset (WIND) Toolkit." *Applied Energy* 151: 355366.
- ⁷ Vestas. "V150-4.2 MW™." V150-4.2 MW™ - Vestas, Vestas, www.vestas.com/en/products/4-mw-platform/v150-4-2-mw#!related-products.
- ⁸ Gaughan, Richard. "How Much Land Is Needed for Wind Turbines?" *sciencing.com*, <https://sciencing.com/much-land-needed-wind-turbines-12304634.html>. 1 May 2021.
- ⁹ "Wind Projects on Public Lands." WINDEXchange, windexchange.energy.gov/projects/public-lands.
- ¹⁰ Meade County, South Dakota, Municipal Code §32
- ¹¹ Hanebury, Louis, Marsh, Mathew, et al. "Willow Creek Wind Energy Facility Final Environmental Assessment." *U.S. Department of Energy Western Area Power Administration*, November 2016
- ¹² Esch, J. 2012. "Grus americana" (On-line), *Animal Diversity Web*. Accessed May 1, 2021 at https://animaldiversity.org/accounts/Grus_american/
- ¹³ "South Dakota Bat Management Plan." *South Dakota Bat Working Group Wildlife Division Report*, July 13, 2004.
- ¹⁴ "QuickFacts Mead County, South Dakota." *United States Census Bureau*, 2019.
- ¹⁵ Google Maps. (44.664055, -102.660985). Accessed May 1, 2021.
- ¹⁶ USGS National Map. (44.664055, -102.660985). Accessed May 1, 2021
- ¹⁷ "CDOT Paleontology Analysis and Documentation Procedures" *Colorado Department of Transportation*
- ¹⁸ Google Maps. (44.664055, -102.660985). Accessed May 1, 2021.
- ¹⁹ Bureau of Land Management. 2013. Bureau of Land Management Socioeconomics Strategic Plan 2012–2022. Division of Decision Support, Planning, and NEPA, Washington, DC.
- ²⁰ Canadian Wildlife Service and U.S. Fish and Wildlife Service. 2005. International recovery plan for the whooping crane. Ottawa: Recovery of Nationally Endangered Wildlife (RENEW), and U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 162 pp.
- ²¹ "South Dakota Bat Management Plan." *South Dakota Bat Working Group Wildlife Division Report*, July 13, 2004.
- ²² Ibid.
- ²³ Allison, Taber. "Bats and Wind Energy: Impacts, Mitigation, and Tradeoffs." *American Wind Wildlife Institute*, 2018, p. 14
- ²⁴ Vestas. "V150-4.2 MW™." V150-4.2 MW™ - Vestas, Vestas, www.vestas.com/en/products/4-mw-platform/v150-4-2-mw#!related-products.
- ²⁵ NREL. System Advisor Model (SAM). <https://sam.nrel.gov/>. Published 2021.
- ²⁶ Ibid.
- ²⁷ "How Much Do Wind Turbines Cost?" Windustry, www.windustry.org/how_much_do_wind_turbines_cost#:~:text=The%20costs%20for%20a%20utility,%243%2D%244%20million%20installed.
- ²⁸ Spangler-Sakata, Jonathan, et al. "Meeting with Tim Rosenzweig." 25 Mar. 2021.
- ²⁹ Received by Jonathan Spangler-Sakata, Quick Question on Cost of the Vestas V150, 29 Mar. 2021.
- ³⁰ Eberle, Annika, et al. NREL, 2019, NREL's Balance-of-System Cost Model for Land-Based Wind, www.nrel.gov/docs/fy19osti/72201.pdf.
- ³¹ Ibid.
- ³² Spangler-Sakata, Jonathan. "Phone call with Joe Kraut." 18 May. 2021.
- ³³ "What Is Project Finance?" Renewable Energy Project Finance Modeling (Online), <https://courses.pivotal180.com/courses/take/renewable-energy-project-finance-modeling-online/lessons/10218002-1-1-what-is-project-finance>.
- ³⁴ Spangler-Sakata, Jonathan, et al. "Meeting with Joe Kraut." 8 April. 2021.
- ³⁵ System Advisor Model (SAM)
- ³⁶ "Meeting with Joe Kraut." 8 April. 2021.
- ³⁷ "Meeting with Tim Rosenzweig."
- ³⁸ System Advisor Model (SAM)
- ³⁹ "Meeting with Tim Rosenzweig."
- ⁴⁰ Ibid.

- ⁴¹ “Role of Parties and Contractual Cashflow.” Renewable Energy Project Finance Modeling (Online), <https://courses.pivotal180.com/courses/take/renewable-energy-project-finance-modeling-online/lessons/10218002-1-1-what-is-project-finance>.
- ⁴² Ela, Erik & Milligan, Michael & Kirby, Brendan. (2011). Operating Reserves and Variable Generation. 10.2172/1023095.
- ⁴³ Bureau of Land Management, “BKH Stock Price: Black Hills Corp. Stock Quote (U.S.: NYSE).” MarketWatch, 21 May 2021, www.marketwatch.com/investing/stock/bkh.nd Management. 2013. Bureau of Land Management Socioeconomics Strategic Plan 2012–2022. Division of Decision Support, Planning, and NEPA, Washington, DC.
- ⁴⁴ “Who Is Black Hills Corp?” Black Hills Corporation, 2 Mar. 2017, www.blackhillscorp.com/about-black-hills-corporation/corporate-headquarters/who-black-hills-corp.
- ⁴⁵ “BKH Stock Price.”
- ⁴⁶ “Fitch Affirms Black Hills Corp. and Black Hills Power at ‘BBB+’; Outlooks Stable.” Fitch Ratings: Credit Ratings & Analysis For Financial Markets, Fitch Ratings, Inc, 21 Aug. 2020, www.fitchratings.com/research/corporate-finance/fitch-affirms-black-hills-corp-black-hills-power-at-bbb-outlooks-stable-21-08-2020.
- ⁴⁷ Ibid.
- ⁴⁸ Choi, Sam. “Meeting with Guy Van Syckle.” 21 January. 2021.
- ⁴⁹ “U.S. Energy Information Administration - EIA - Independent Statistics and Analysis.” South Dakota - State Energy Profile Analysis - U.S. Energy Information Administration (EIA), US Energy Information Administration, 20 May 2021, www.eia.gov/state/analysis.php?sid=SD.
- ⁵⁰ “South Dakota - State Energy Profile Analysis.” EIA - Independent Statistics and Analysis, U.S. Energy Information Administration (EIA), 20 May 2021, www.eia.gov/state/analysis.php?sid=SD#:~:text=South%20Dakota's%20remaining%20electricity%20is,of%20the%20state's%20net%20generation.
- ⁵¹ Tarlock, Dan. “Hydro Law and the Future of Hydroelectric Power Generation in the United States.” Vanderbilt Law Review, vol. 65, no. 6, Nov. 2012, pp. 1737–1767., scholarship.law.vanderbilt.edu/cgi/viewcontent.cgi?article=1363&context=vlr.
- ⁵² “Fitch Affirms Black Hills.”
- ⁵³ “South Dakota State Energy Profile.” EIA, US Energy Information Administration, 20 May 2021, <http://www.eia.gov/state/print.php?sid=SD>.
- ⁵⁴ Choi, Sam. “Meeting with Guy Van Syckle.” 21 January. 2021.
- ⁵⁵ Ibid.
- ⁵⁶ System Advisor Model (SAM)
- ⁵⁷ Choi, Sam. “Phone call with Joe Kraut.” 4 April. 2021.
- ⁵⁸ Medina, Jorge. “IRS Extends Continuity Safe Harbor for Renewable Energy Projects.” Pillsbury Law, 28 May 2020, www.pillsburylaw.com/en/news-and-insights/irs-safe-harbor-renewable-energy.html.
- ⁵⁹ “Phone call with Joe Kraut.” 4 April. 2021
- ⁶⁰ System Advisor Model (SAM)
- ⁶¹ Governor's Office of Economic Development. “Tax Incentives.” South Dakota, 5 Mar. 2021, sdgoed.com/financing-incentives/tax-incentives/. [South Dakota Code § 1-16G-56 et seq.](#)
- ⁶² South Dakota Department of Revenue. “Large Commercial Wind and Solar Alternative Taxes.” DSIRE, 2021, programs.dsireusa.org/system/program/detail/2879/large-commercial-wind-and-solar-alternative-taxes. [SDCL § 10-35-16 et seq.](#)
- ⁶³ Ibid.
- ⁶⁴ “Allocation of Risk” Renewable Energy Project Finance Modeling (Online), <https://courses.pivotal180.com/courses/take/renewable-energy-project-finance-modeling-online/lessons/10218002-1-1-what-is-project-finance>.
- ⁶⁵ Singh, Davinder pal. “Lazard's Levelized Cost of Energy Analysis - Version 14.0.” Lazard.com, 2020, www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf.
- ⁶⁶ S.D. Codified Laws § 49-41B
- ⁶⁷ Bryce, Robert. “Warren Buffett's Iowa Wind Power Expansion Derailed By The Bridges Of Madison County.” Forbes, Forbes Magazine, 13 Jan. 2021, <http://www.forbes.com/sites/robertbryce/2021/01/13/iowa-wind-expansion-derailed-by-the-bridges-of-madison-county/?sh=6cdaaefda0ce>.
- ⁶⁸ “Wind Powers America Annual Report 2019.” American Wind Energy Association, American Wind Energy Association, 21 Apr. 2020, https://www.powermag.com/wp-content/uploads/2020/04/awea_wpa_executivesummary2019.pdf.
- ⁶⁹ “Estimating the Uncertainty of Revenues and Investment Decisions.” Exceedance Probabilities, Green Rhino Energy, www.greenrhinoenergy.com/finance/modelling/revenue_uncertainties.php.
- ⁷⁰ Hudson, Kiersten. “Electric Power Transmission Lines.” Homeland Infrastructure Foundation-Level Data, 13 Nov. 2020, hifld-geoplatform.opendata.arcgis.com/datasets/electric-power-transmission-lines?geometry=-104.891%2C44.051%2C-100.106%2C45.416.
- ⁷¹ “Welcome to Uttar Pradesh Power Transmission Corporation Limited, Government of Uttar Pradesh, India. / Current Carrying Capacity of Overhead Transmission Line ACSR Conductor.” Current Carrying Capacity of Overhead Transmission Line ACSR Conductor, 2020, upenergy.in/upptcl/en/article/current-carrying.

⁷² Ibid.

⁷³ Ingram, Elizabeth. "How to Extend the Lifetime of Wind Turbines." Renewable Energy World, 14 Jan. 2019, www.renewableenergyworld.com/om/how-to-extend-the-lifetime-of-wind-turbines/.