

Project Development Report

Bartlett Towers

By Prosim Power

Virginia Tech

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Background/Opportunity

The Virginia Tech CWC Project Development Team has set out to develop a 100 MW wind farm in western South Dakota, operating under the company name “Prosim Power.” The location of this wind farm will be determined through an analysis of siting considerations and will result in a full-scale wind project design. This design process will be followed by an economic analysis and risk management plan to identify possible financial, social, and environmental hazards and ways to proactively mitigate them. Prosim Power’s goal is to develop a wind farm that exceeds current standards for environmental stewardship and host community relationships.

The events of 2020 and 2021 reinforced the need to improve the energy infrastructure of the United States to compensate for challenges that arise in strained supply chains, inefficient energy transmission, and climate variability. This year marks thirteen years since the Department of Energy published a report, *20% Wind Energy by 2030*, outlining suggested market changes to achieve the necessary capacity of wind energy to meet a 20% and 35% U.S. wind energy diversification by 2030 and 2050, respectively. Today, the wind industry has evolved towards larger turbines that capture more energy. Additionally, the extension of the production tax credit (PTC) and other economic incentives have enabled developers to pursue higher nameplate capacities to provide wind energy to consumers at rates competitive with traditional fossil fuel plants [1]. South Dakota is one of the windiest states in the United States, and has the potential to generate 882,000 MW of electricity state-wide. In 2020, only 2,305 MW of the potential wind energy capacity had been installed [2]. As wind energy becomes more affordable, South Dakota offers a competitive market for new wind farm development led by Prosim Power.

Site Selection

The first step Prosim Power took in project planning was a preliminary site selection for the new wind farm. To determine the project site, influential factors regarding the farm’s energy output and cost of energy were identified. These factors, from most influential to least influential, are as follows: high wind resource, access to transmission, existing transportation infrastructure, community acceptance of wind projects, ability to gain land ownership, low presence of endangered wildlife and protected environmental areas, and ease of acquiring permits. Meade, Todd, Dewey, and Tripp counties were selected as potential locations due to high wind resource availability. The counties were then evaluated further and scored using a decision matrix shown in Table 1.

County	Transmission	Weight	Wind Resource	Weight	Environmental Factors	Weight	Permitting	Weight	Transportation	Weight	Community	Weight	Land Ownership	Weight	Final Score
Meade	10	0.8	8	1	4	0.3	3	0.1	6	0.6	6	0.5	10	0.4	28.1
Tripp	5	0.8	10	1	3	0.3	7	0.1	9	0.6	7	0.5	10	0.4	28.5
Dewey	5	0.8	9	1	4	0.3	7	0.1	6	0.6	5	0.5	10	0.4	25
Todd	5	0.8	10	1	4	0.3	6.5	0.1	8	0.6	5	0.5	10	0.4	27.15

Table 1: Siting Decision Matrix

Dewey County

Dewey County was found to have suitable average wind speeds of 7.0 - 8.5 m/s with increased velocities as high as 9.5 m/s in the center of the county [3]. Dewey County land ownership consists of federally owned Tribal Trust lands which are held communally by the Great Sioux Tribe, as well as federally-owned allotted trust lands. The Cheyenne River Reservation encompasses the greater part of the county. Research revealed that a proposed 450 MW wind development is to be implemented in Dewey county with support by the Sioux tribes through the Oceti Sakowin Power Project [4]. Environmental factors considered include the presence of the endangered Whooping Crane and Least Tern as well as the

threatened Northern Long-eared Bat and Piping Plover. Furthermore, several brownfield sites were identified around the county [5]. The challenges of land ownership in Dewey County, the presence of a large wind project, and the presence of brownfield sites were ultimately why the project was not placed in Dewey County.

Meade County

The majority of Meade County consists of wind speeds of 7.0 - 8.0 m/s - notably lower than other counties. However, some areas of Meade County have wind speeds reaching up to 9.0 m/s [6]. Meade County has two high-voltage transmission lines carrying more than 230 kV, and a single low-voltage transmission line carrying less than 230 kV. The availability of these transmission lines was the largest advantage for choosing this county. The highest paying industries in Meade County are mining, quarrying, and natural gas extraction, which indicate challenges for community acceptance of a wind project [7]. Finally, Meade County is home to several endangered and threatened species, including Whooping Cranes and Northern Long-eared Bats [8]. Meade County was not chosen for the final site location due to community and environmental considerations.

Todd County

Wind resource in Todd County is one of this location's biggest appeals, with most of the county having wind speeds of 8.0 - 8.5 m/s and some areas of increased velocities up to 9.0 m/s [9]. Unfortunately, Todd County has low voltage transmission lines, and an existing 30 MW wind farm in the county was required to upgrade existing infrastructure in order to transmit higher voltages [10]. Prosim Power anticipates expenses in further upgrading the existing infrastructure, and saw this as a drawback in siting Todd County. Additionally, all of the land in Todd County lies in the Rosebud Indian Reservation. After discovering Apex Clean Energy's partnership with Native tribes of the Oceti Sakowin Power Authority regarding construction of the Ta'Teh Topah wind farm, Prosim Power sought opportunity for a similar project in partnership with the Rosebud Indian Reservation in Todd County. However, Todd County is the 20th poorest county in the United States per capita, and it was therefore determined that the construction of a large-scale wind project may not be economically feasible in Todd County at present [11]. While Todd County has a smaller list of endangered and threatened species potentially impacted by a wind project and high wind resource, the lack of transmission and economic conditions of the county resulted in Todd County not being considered for the final wind farm location.

Final Site Selection

The final project site chosen is Tripp County, shown in red in Figure 1. The new wind farm's name is "Bartlett Towers" after the County's namesake, Bartlett Tripp.

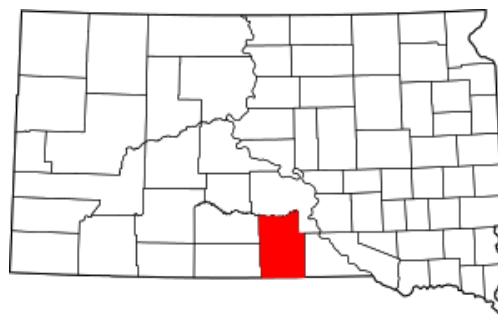


Figure 1: Tripp County, South Dakota

Wind Resource

The average wind speed at a height of 80 meters in Tripp County is approximately 8.0 - 8.5 m/s with increased speeds of 9.0 m/s present towards the central region of the county [9]. The proposed wind farm, Bartlett Towers, will be located in a concentrated region of higher average wind speeds.

Existing Wind Farms

There are no existing wind farms in Tripp County, the nearest being Rosebud Sioux Tribe wind farm - roughly 65 miles away. This is beneficial for the proposition of Bartlett Towers since the county remains relatively undeveloped.

Terrain

Tripp County covers an area of approximately 1600 square miles on the southern border of South Dakota [12]. Generally, the county terrain slopes to the southeast as it follows the Keya Paha River with rolling hills at an elevation range of 1300-2500 feet [13]. The majority of property in Tripp County has been transformed into agricultural cattle farms with little to no local forestry. Undeveloped land remains in the form of open prairies [14]. The relatively low roughness of the terrain allows for comparatively higher, more consistent wind speeds.

Access to Transmission

Tripp County has one existing low-voltage transmission line that carries less than 230 kV. The transmission line runs laterally through the middle of the county. There are two existing substations in Tripp County - one near the City of Winner and one near the City of Colome [15].

Access to Transportation

The ability to transport turbine parts to the site is a critical factor in siting a wind farm. The chosen site in Tripp County is bounded by state-numbered Highway 44 running east/west, state-numbered Highway 49 running north/south, and US-numbered Highway 18 running diagonally. These three routes will allow for ease in the mobilization of turbine components [16].

Environmental Factors

With over five million acres of public and private hunting areas throughout South Dakota, there are several protected game production areas in Tripp County [17]. An emphasis on wetland protection, game production, and community access is apparent through conservation efforts in the county [18]. Protected species include the endangered Whooping Crane, threatened Northern Long-eared Bat, Rufa Red Knot, Black-footed Ferret, and the American Burying Beetle [19].

Tripp County lies in the Whooping Crane migration corridor where the avian population flies from Canada to Texas for the winter. Throughout this migration corridor, Whooping Crane flocks may stop for rest near bodies of water. Prosim Power consulted with the Whooping Crane Conservation Association (WCCA) to discuss the impacts of Bartlett Towers on migrating flocks. In general, Whooping Cranes avoid wind turbines but are likely to be killed by striking power lines near wetlands. WCCA recommended that Prosim Power hire biologists to monitor Whooping Cranes near the wind farm and record any avian fatalities. If Whooping Cranes are in close proximity to turbines, shut down procedures take effect [20]. Throughout the project lifetime, Bartlett Towers will implement these mitigation strategies.

Community Factors

Community factors considered include population size, demographics, average income, and residents' outlook on wind energy - factors that play a role in a wind farm's success. Tripp county has a population of 5,441 people and population density of 3.5 persons per square mile. Current demographics reveal that 15.8% of the county population is Native American. Of the total population, 19.9% live under the poverty line with an average per capita yearly income of \$26,242 [1].

Understanding the concerns and needs of the community is a priority of Prosim Power. Two phone interviews were conducted with Tripp County officials Dan Forgey and Joyce Kartak to gauge public opinion on wind farms. Dan Forgey, District II Unified Economic Development Commissioner, expressed excitement for the proposed wind farm as he believes it would boost economic and infrastructure growth for the rural community. He claimed that the development of the wind farm would stimulate the economy and promote further development. Joyce Kartak, Planning and Development District III Commissioner, expressed concern over the proposed wind farm due to economic and social factors. With respect to real estate values and disruptions to game hunting activities in proximity to the wind farm, Ms. Kartak voiced valid implications about the negative impact of the erection of turbines locally. The Texas power grid failure of February 2021 was also an area of concern due to the association with wind turbines; additionally, the deicing technology of the selected Vestas wind turbine had no influence on her fear of potential failure in inclement weather [22]. To help address common misconceptions about wind energy and the Texas grid failure, Prosim Power will hold several town forums in Winner and Colome to address public concerns.

Land Ownership

After review of Tripp County's GIS data, it was determined that the majority of land in Tripp County is privately owned, with the exception of 325 parcels of Native American owned territory. These parcels are not in close proximity to the chosen site, and will not impact the project. Due to the vast majority of land in the county being developed cattle farms, estimated property values are relatively low [23]. This makes Tripp County ideal for a wind farm, as turbines will not cause a great disturbance to the surrounding land in regards to usage.

Permitting

Permitting on a federal level may involve the Federal Aviation Administration, the United States Fish and Wildlife Services, and the Environmental Protection Agency. The closest airport to the wind turbine site in Colome, SD is the Winner Regional Airport. FAA forms 7460-1 and 7460-2 must be filed to determine and ensure that turbine erection and/or construction will comply with FAA lighting requirements and regulations. An Incidental Take Permit must be purchased from the USFWS if wind farm operations are "reasonably certain" to harm threatened and endangered species - as in the case of Bartlett Towers. Finally, a National Pollutant Discharge Elimination System (NPDES) permit will be obtained before construction, which involves a stormwater pollution prevention plan [24].

State permitting is regulated by the South Dakota Public Utilities Commission (PUC). Wind farms 100 MW and larger must obtain permits through the PUC. Prosim Power's permit proposal will be required to: comply with state and local laws and regulations; have minimal to no threat to environmental, social, or economic conditions of the area; not impair the health, safety, and welfare of the inhabitants; and not interfere with regional development. Stakeholders can be involved by reviewing an electronic docket, attending public input meetings, submitting informal comments, becoming an intervenor, and by communicating with a commissioner on record [25]. The PUC has the authority to grant, deny, or modify the permit proposal, and decisions of the PUC can be appealed, if necessary.

Tripp County does not have any required county permits nor ordinances for wind development at this time. While this is beneficial for the siting of Bartlett Towers, Prosim Power is willing to work with local officials and address their concerns [27].

Detailed Project Design

Turbine Selection

The Vestas V90-2MW turbine was selected for Bartlett Towers. The specified turbine was selected based on present market trends in South Dakota, local wind resource maps, and feature-packages offered to help maximize efficiency and reduce ecological impacts. Lighter material composition of the selected turbine will also aid in reducing transportation and foundation costs [28].

The wind resource map of Tripp County pairs well with the turbine's cut-in speed of 4m/s and the IEC class II rating of 8.5 m/s annual average wind speeds. The rotor diameter and hub height are 90 m and 80 m, respectively. The specifications of this turbine match the average market trends in South Dakota as the hub height, rotor diameter, and power capacity have average values of 80 m, 95 m, and 2.1 MW. [28].

The Vestas V90-2MW turbine has a multitude of package features which make this turbine the optimal choice for the given environment. A cold-weather operation package enables reliable operation to a minimum threshold of -30 degrees Celsius. This feature should assist the team in mitigating public concerns following the icing of wind turbines in Texas during February of 2021 that has led to skepticism of the industry. Fear of avian disturbances may be quelled with the addition of a Bat Protection System that is able to reduce bat fatalities by 78% while maximizing operational times through prediction of bat flight patterns using adaptive software parameters [28].

While larger turbines were considered, the Vestas V90-2MW is the best suited for the wind conditions in South Dakota due to its versatility and durability. The reduction of materials and expenses related to foundation construction will also improve the economic feasibility of Bartlett Towers. Additionally, a Vestas manufacturing facility located in Colorado ensures reduction of transportation distances and associated costs. With package features of the V90-2MW that are able to address community and environmental concerns, Prosim Power feels confident in the success of the selected technology.

Openwind Model

The site layout for Bartlett Towers was constructed using Openwind software. Prosim Power considered shapefiles of local roads, transmission lines, substations, water bodies, and land cover in the site design. Using rasters of elevation and vegetation height from Openwind, along with a Wind Resource Grid (WRG) from AWS Trupower, wind speeds were modeled in the software to produce a wind map.

Prosim Power explored two different project areas for Bartlett Towers, shown in Figures 2 and 3. Project Area A was chosen to allow turbines to be spread out enough for optimal energy production with Project Area B chosen to minimize the parcels of land impacted by the wind farm. For both project areas, a layout of 50 Vestas V90 2MW turbines was optimized for energy production.

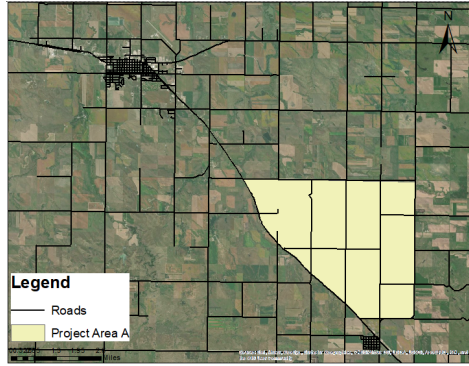


Figure 2: Project Area A

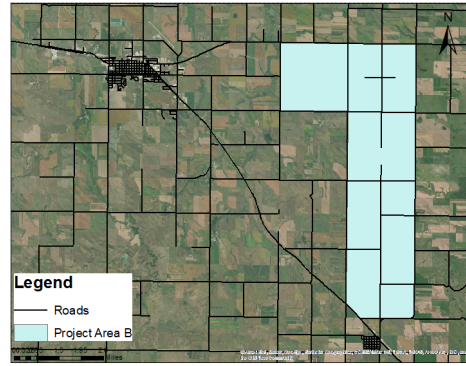


Figure 3: Project Area B

While energy production is critical to wind farm profitability, the placement and cost of roads and transmission lines for the project are also important. Since Tripp County has no ordinances for wind turbines, setbacks from Clark County, SD were used as guidelines. Clark County requires a setback of at least 300 m from buildings. To exceed this requirement and further reduce turbine noise, Prosim used a setback of 400 m. Clark County’s setback of 150 m from roads was used for Bartlett Towers [29]. However, since Clark County did not define setbacks from water bodies, a value of 30 m from the Openwind training was used. Clark County defined a noise limit of 50 dB, while Openwind tutorials defined a noise limit of 45 dB - the 45 dB noise limit was used for Bartlett Towers as it was more conservative [30]. The site layout was optimized for cost of energy using the prescribed setbacks and noise limit. Next, shadow flicker, horizontal/panoramic angle, and vertical subtended angle were modeled to assess visual impacts of the farm. For both project areas, attempts were made to reduce the turbine visibility by manually relocating turbines. To reduce shadow flicker, curtailment schedules were implemented. For Project Area B, these efforts did not significantly reduce shadow flicker time or panoramic view of towers, and most of the turbines were visible up to 328 degrees of a 360 degree circle from the buildings on site.

Project Area A was chosen as the final site for two main reasons. First, a curtailment schedule for shadow flicker reduced unmitigated time from 5,480 minutes per year to less than 59 minutes per year, per building. Second, by manually relocating two wind turbines that were located near clusters of buildings, the panoramic visibility of the turbines from those buildings was reduced. While the panoramic angle still reached a value of 328 degrees, it can be seen that the area of maximum angles decreased in the center of the project site. The horizontal angle before and after moving the turbines is available in Figures 4 and 5, respectively.

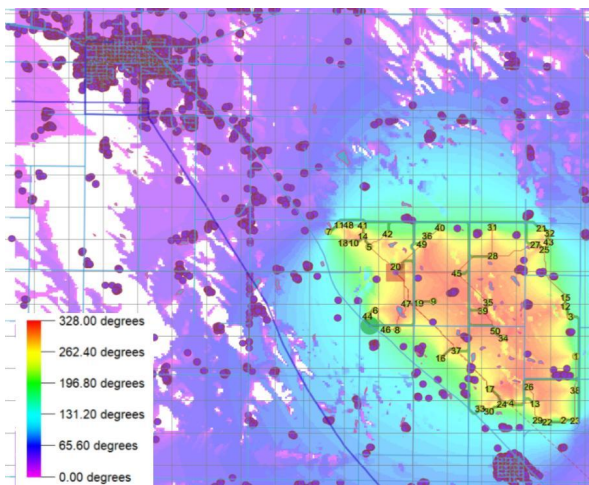


Figure 4: Original Horizontal Angle

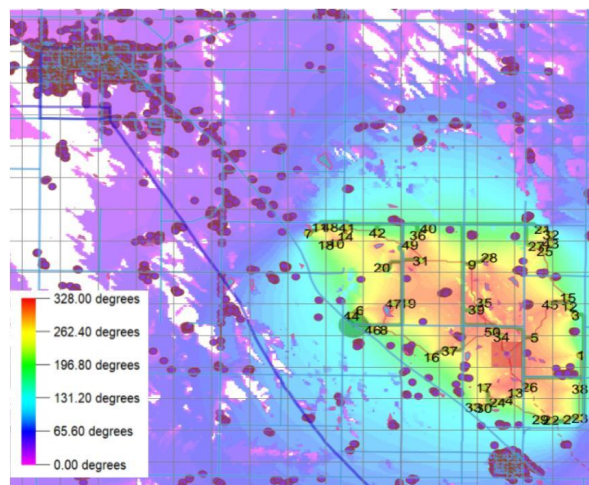


Figure 5: Horizontal Angle After Relocation

The final design of Bartlett Towers, shown in Figure 5, will produce a net annual energy of 426 GW with a capacity of 48%.

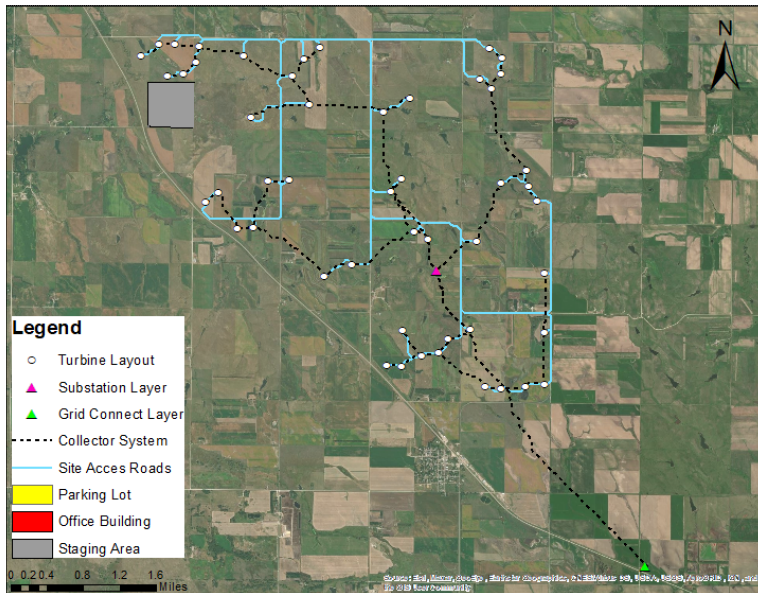


Figure 6: Bartlett Towers Openwind Design

Initial Capital Costs	Cost
Site Surveying and Preparation	\$14,426,722.00
Resource Assessment	\$85,000.00
Roads	\$443,401.00
Staging Area	\$6,707,072.00
Operations Facility	\$32,991.00
Land Development Permits	\$100,025.00
Turbine Foundations	\$3,016,171.00
Turbines	\$123,900,000.00
Turbine Transportation	\$6,774,750.00
Electrical Infrastructure	\$7,750,372.00
Total	\$163,236,504.00
Annual Operating Expenses	Cost/year
Land Leases	\$5,210,000.00
Operations	\$875,755.00
Maintenance	\$2,168,250.00
Total	\$8,254,005.00

Figure 7: Costs Summary

Costs Summary

The total initial capital costs and annual operating expenses for Bartlett Towers are shown in Figure 7. The total initial capital cost for the project is \$148,813,132 and the total operating expenses are \$8,253,909. A further breakdown of these costs is reported below.

Initial Capital Costs

Site Surveying and Preparation

Bartlett Towers will occupy approximately 13.7 square miles of land and will require topographic and boundary surveys to identify local gradient and parcel boundaries. Prosim Power will be commissioning Sayre Associates Inc of Sioux Falls, SD for surveying. The cost of a topographic survey, site and road grading, and a geotechnical survey consisting of two test pits is \$3,350 [31]. To estimate labor costs during construction, the NREL's JEDI model was used. The total cost of site labor for turbine erection, foundations, electrical installation, management/supervision, and other miscellaneous tasks is \$2,560,050. Materials for site preparation include construction materials, electrical cables and wires, and HV line extensions. The cost for these materials is an estimated \$11,683,332 according to the JEDI model [32]. The total cost for site surveying and preparation is \$14,426,772.

Resource Assessment

Resource assessment is performed to measure local meteorology patterns, determine an efficient wind farm layout, and to estimate total energy production of the final project. Understanding these variables allows for a suitable design under given environmental conditions [33]. Information recorded from met masts for the purpose of wind resource assessment will be most accurate if calculated at the

same height and general location as the turbines themselves are intended [30]; therefore one 80 meter meteorological tower will be installed for a duration of two years prior to project construction at an expense of approximately \$85,000 [34]. Following the two-year data collection period, met masts will be removed from site. Expenses for construction and deconstruction of the mast are estimated to be \$15,000.

Roads

Bartlett Towers will require 10.91 miles of gravel access roads to be constructed. The average price of a 12 ft wide gravel road is \$40,550 per mile, resulting in a total cost of \$443,401 [35].

Staging Area

A 160 acre parcel of land in the northwest corner of Bartlett Towers has been chosen as a temporary gravel staging area during construction. The cost of purchasing this land is \$162,522. The expense of removing the topsoil, installing 2-3 layers of gravel, and compacting the layers will cost \$6,544,550 bringing the total expenses of the staging area to \$6,707,072 [36].

Operations Facility

A 3,000 square-foot steel warehouse will be constructed on the parcel of land purchased for the staging area. Half of this building will be used for Bartlett Towers offices, and the other half will be used as a maintenance bay. The cost of the steel warehouse and insulation will be \$31,871 [37],[38]. In addition to the operations facility, a 2400 square-foot gravel parking lot will be built for a price of \$1,120 to accommodate twelve vehicles on site [39]. This will allow adequate spaces for Bartlett Towers employees and visiting clientele. The total cost of the operations facility is \$32,991.

Land Development Permits

The federally required Incidental Take Permit has an associated fee of \$25 [40]. NPDES and FAA permits are obtained at no additional cost [41].

Permitting totals to cover PUC expenses depend on whether a proposal is contested or litigated. When a permit proposal is contested or litigated, an attorney and several analysts must be hired to assess adverse effects of the project. According to the past ten wind dockets submitted to the Public Utilities Commission - from wind farms ranging from 100MW to 300MW - the average permitting cost is \$100,000 [42],[43].

Foundations

According to the life cycle assessment of an onshore wind farm based on V90 2MW turbines, each turbine foundation requires 5.96 tons of unalloyed iron, 32.2 tons of alloyed steel, and 750.88 tons of concrete. Since there will be fifty turbines on the wind farm, the total material required for construction of the foundations is 298 tons of iron, 1610 tons of steel, and 37,544 tons of concrete [44]. The unit prices per ton for iron, steel, and concrete are \$121, \$541 and \$56. With these prices, the total foundation cost will be approximately \$3,016,172.

Turbine Costs

According to the datasheet provided by Vestas, an 80m tubular tower for the Vestas V90 2MW is made from IEC IIA steel. The unit price received from Vestas for a set of one IEC IIA tower and one turbine is \$2.478M [45]. The cost of 50 turbines for Bartlett Towers is approximately \$123,900,000.

Turbine Transportation

Prosim Power will be using the services of BNSF Railways to transport turbines from the Vestas manufacturing facility in Colorado to Bartlett Towers. This will require transportation of the turbines by rail from Colorado to a distribution center in Laurel, NE. The price per rail platforms, or flat rail decks, varies based on the turbine component being transported. To transport 150 turbine blades (50 turbines, three blades per turbine) will require 225 platforms total, at a price of \$5,250 per platform. Transporting 50 turbine towers will require dividing the components into 250 sections, with each section taking up one platform for a cost of \$7,000 per platform. Finally, 50 nacelles and 50 hubs can be loaded as a set into one train car each, at a price of \$8,500 per car. The total rail cost is \$3,356,250. The trains carrying the wind turbine components will move as a unit all the way to the distribution center, with no additional cars or interchanges along the way [46]

The distribution center will serve as an unloading and loading point to transfer the shipped components from train to truck. The distribution center in Laurel is a loop track location where components are unloaded from the west end of the loop and placed in storage until they are loaded onto trucks. Loading “last-in, first-out” works best for the distribution center. The turbine components are preloaded in the afternoon or evening and will depart the following morning. Depending on the cycle times of truck delivery, the trucks are reloaded mid-day for a second run if one set of trucks are used to make two deliveries per day. If not, trucks are reloaded in the afternoon for next day deliveries. With thorough planning, the rail and truck schedules can be timed such that delivery of parts will incur minimal surcharges. The total cost of trucking is \$3,418,500, bringing the combined trucking and rail cost to \$6,744,750 [46].

Electrical Infrastructure

Voltage generated from the wind turbines will be collected using a 25.3-mile-long system of interconnection lines. Using the MISO Transmission Cost Estimation Guide, the cost of the interconnection lines - including poles, conductors, pole tops, guy lines, labor, and transportation - is \$7720.73 per mile, or \$195,335 total [47].

Bartlett Towers will utilize two substations for transmitting power. The first is located on the wind farm property and will receive power from the collector system to increase the voltage to 115 kV with a transformer. Since the capacity of Bartlett Towers is 100 MW, two 50 MVA transformers are needed to feed the power flow. The substation will also require a bus support system. Using MISO’s Transmission Cost Estimation Guide, the cost of the substation foundations, materials, and the circuit breaker was calculated to be \$1,756,450 [44]. Voltage will be transmitted from the substation on site to a substation that lies south-east of Bartlett Towers via a 4.16-mile-long, 115 kV transmission line. The cost of constructing this transmission line will be \$5,603,022.86 [47]. Upgrading an existing off-site substation is the most economical method to connect to the grid. The substation will need to be upgraded with three circuit breakers for a three-phase transmission line, a new control room, a new control enclosure, a relay panel, and disconnect for a total cost of \$195,565 [47]. The cost of electrical infrastructure totals \$7,750,372.

Annual Operating Expenses

Land Expenses

The cost of land in South Dakota differs based on the region; Tripp County is located in the South Central region of the state. The average cash rental for non-irrigated cropland in this region is \$73 monthly per acre or \$876 per acre annually [48]. The average land use for a wind farm with a cluster configuration is 40 acres per MW [49]. Since this wind project is 100 MW (50 2MW turbines), the total

average land usage is estimated at 3,900 acres - solely land developed as part of the farm, not total acreage. At \$876 a year, the total annual cost is \$5,210,000.

Operations

Operations costs include the recurring expenses of running the wind farm (including utilities, employees, insurance, and taxes). After consulting with local real estate agent Dan Clark, the average utility bill for the 3,000 square-foot operations facility was determined to be \$468.86 annually [50]. Using NREL's JEDI model, Bartlett Towers is estimated to have eight full time employees including field technicians, administrative, and management personnel. The combined cost of compensation for all employees is \$555,286 per year [32]. According to the South Dakota Wind Energy Association in Pierre, the cost of wind farm insurance and administrative fees is \$310,000 per year [51].

One additional operating expense is the Bartlett Towers Scholarship Fund. Bartlett Towers is committed to setting a new precedent for wind farm engagement with communities. As mentioned in "Community Factors," Tripp County is home to Native Americans, primarily the Rosebud Sioux Tribe, and 19.9% of the population is in poverty. Bartlett Towers has created the Bartlett Towers Scholarship Fund for Native Americans in Tripp County who are pursuing careers as a wind turbine technician. Over the twenty-year project life, every four years, two individuals will receive scholarships of \$40,000 total or \$10,000 per year at a four-year institution. This will result in ten individuals receiving the Bartlett Towers Scholarship Fund over the life of the project. With this scholarship, Bartlett Towers hopes to fund the careers of minorities who may not otherwise have had the opportunity to invest in the future of the wind industry. The total operating cost will be \$875,755 annually.

Maintenance

Maintenance costs can be difficult to precisely quantify due to the lack of standardization in the wind industry. Current operations and maintenance costs typically vary between 1.5 - 2% of the initial investment in the turbine technology and are incurred on an annual basis [52]. For Bartlett Towers, this cost would range between \$1,858,500.00 - \$2,478,000.00 annually with an average value of \$2,168,250. Additional maintenance expenses can be managed through reserve accounts if necessary.

Decommissioning Costs and Salvage Value

Information on decommissioning costs of a V90-2MW wind farm in South Dakota is limited due to the scarcity of long-term projects in the region. Using data from a V136-4.2MW wind turbine farm that was decommissioned in 2019, the following information was inferred based on similarities in hub height and blade length of the aforementioned models. The estimated cost of disassembly of one V90-2MW wind turbine is \$87,000 with a removal cost of \$57,800. For fifty turbines, the total onsite cost of all turbines is \$7,240,000. The onsite cost of all association facilities is as follows: the onsite cost of the substation is \$753.33 per MW; the total onsite meteorological mast tower cost is \$63,000; \$169,143 per mile for 345kV transmission line at an expense of \$164,358 per mile for the interconnection lines; and the onsite cost for access road of \$77,959 [53]. These calculations bring total decommissioning costs of Bartlett Towers to \$8,151,333.

According to the life cycle assessment of the specified turbine, 98% of metal components can be recycled while 95% of cable and transmission lines can be recycled. For a 100MW wind farm, 12,278 tons of steel and cast iron, 332 tons of copper, and 2,556 tons of polymer materials will be used. According to the market price of raw materials, the salvage cost for scrap metal will total \$8,448,020.67. Fifty percent of the polymer material will be incinerated and the remnants will be disposed of via landfill - incurring no [54]. This brings the total salvage value after the farm's 20-year life span to \$8,448,020.67.

One alternative to a full decommissioning of Bartlett Towers is a “repowering” of the wind farm. The wind farm repowering market is currently rising, and expected annual investments are projected to reach \$25 billion by 2030 [55]. A partial repowering of Bartlett Towers in which the turbine drive trains and rotors are replaced with newer equipment and technology could increase the capacity factor, project reliability, and grid service capabilities as well as lower the cost of energy. Otherwise, full repowering is an option in which completely new, larger turbines are installed. Larger turbines would reduce the number of turbines needed to produce a 100 MW capacity. Furthermore, turbine technologies twenty years from now could provide even more efficient means of energy production [56]. Because it is difficult to estimate costs for these new technologies and estimate how wind farm efficiency will be impacted by repowering, these options were not modeled in the financial analysis. However, they are still important options to be aware of and consider at the end of Bartlett Towers’s 20-year life.

Financial Parameters

Project Tax and Insurance Rates

For this project, a federal income tax rate of 21% per year and a state income tax rate of 4.5% per year are used [57]. Wind farms in South Dakota must pay a nameplate capacity tax of \$3 per kW and a production tax of .000045 per kW [58]. In Tripp County, the property tax rate is 1.3% of the property’s assessed market value [59]. To calculate the assessed market value, the total installed cost of the project, \$148,674,552 is first divided by the combined nameplate capacity tax and production tax to find the assessed tax percentage. The resulting percentage is 0.40% of the installed cost. Multiplying the assessed tax percentage by the installed cost results in an assessed market value of \$737,729 that is subject to the Tripp County property tax rate. This would amount to property taxes of approximately \$959,047 per year. The annual insurance rate in South Dakota is 2.5% [60].

Incentives

The federal renewable energy tax credit (PTC) is a tax credit for electricity generated by qualifying energy resources and sold during the taxable year. As a result of the COVID-19 pandemic, the PTC was extended for another year in December 2020. The PTC can be applied to wind projects that start construction before December 31, 2021 and is valued at 0.015 cents per kWh for the first ten years of the project life. This PTC will be used for Bartlett Towers with an escalation rate of 2.0% [61].

Project Term Debt

Initial capital costs make up the majority of the expenses for wind projects. To address this, initial construction loans can be refinanced into term loans which stretch over a longer time frame [62]. The term debt tenor - the number of years over which the loan is repaid - chosen for Bartlett Towers was 16 years. Since this debt is spread out over a long time-period, the interest rate on term debt is low compared to an interest rate on construction debt [63]. The interest rates fluctuate based on decisions made by the Federal Reserve, but have averaged around 4% for the past 15 years [63]. Most banks charge an upfront fee for their services which can range from 1% to 3% of the principal of the loan. [63]. Since this is a wide range, for debt closing costs, the SAM default value of \$450,000 was used.

The Debt Service Coverage Ratio (DSCR) is the ratio of annual cash available to pay off loans to the sum of the annual principal payment of the loan and the interest rate. Loans will not be issued by lending institutions if the DSCR is below 1 because the project is not projected to make enough profit to pay off the loan. A DSCR debt structure is a more realistic method of financing a wind farm, as wind resource, and therefore cash flow, can vary annually. To ensure that Bartlett Towers is able to pay off its

loan, a DSCR of 1.40 was chosen, meaning the farm's net income is expected to be 1.40 times the debt payment each year [63].

Construction Period Debt

Construction debt is used to fund the engineering, design, equipment procurement, and construction of a wind project. A national average construction loan interest rate of 5.75% will be used for the construction of Bartlett Towers [64]. Typically, lenders will not fund more than 75% of the project construction [65]. Therefore, the loan used for this project will be 75% of the construction cost. Prosim Power will carry the construction period and project term debt with bank loan financing.

Reserve Accounts

Reserve accounts are essentially saving accounts for large industry projects in the event of unforeseen expenses. The essence of a reserve account is to ensure the financial stability of the project through episodes of invariable power production or mechanical failure. Developing methods vary in predicting necessary reserve funds and are primarily focused on the prediction of unmitigated factors (i.e. COVID-19). Current methods include demand curve analysis and/or deterministic values such as a fixed percentage of the load [66]. The SAM model for a single owner PPA offers a default value of \$12 million for "Major Equipment Replacement Reserve Accounts" which accounts for approximately 600% of expected annual maintenance costs. Without the ability to measure demand and cost curves, this value was deemed appropriate for Prosim Power's financial model.

Power Purchase Agreement

As a result of the heightened responsibility of higher education institutions to invest in sustainable energy solutions, Prosim Power has chosen to enter into a Power Purchase Agreement (PPA) with Virginia Tech in order to fund Bartlett Towers. Following Virginia Tech's approval of the Climate Action Commitment (CAC), the university has set a goal to transition to 100% renewable energy by 2030 [67]. Other universities have reached this goal by purchasing Renewable Energy Certificates (RECs) - a way to fund renewable energy and effectively offset any of the negative impacts of using fossil fuel [68]. This is a trend that is becoming more common as institutions discover ways to implement sustainability without local renewables to invest in. Through RECs, both parties of the purchase agreement will benefit regardless of where the electricity is veritably being generated or used. A power purchase agreement with Prosim Power will give Virginia Tech the opportunity to encourage long term sustainability on a local and national level.

Time of Delivery Factors

A specific Time of Delivery (TOD) schedule could not be implemented for Bartlett Towers due to a lack of data for Colome, SD. As a result, the General Summer Peak schedule was chosen in SAM, as this option most realistically models TOD in South Dakota. This produced a capacity factor of 33.3%, which is more realistic than the Openwind capacity of 48%.

Cash Flow Model

After simulating the Bartlett Towers financial model in SAM, the real Levelized COE was 7.44 cents per kWh. and the real Levelized PPA Price was 7.71cents per kWh. Since the target energy buyer is Virginia Tech, these prices were compared to the cost of electricity in Virginia. The cost of residential and commercial electricity in Virginia is 11.39¢ per kWh and 7.51¢ per kWh, respectively. Prosim Power is

confident that Bartlett Tower’s PPA price is competitive with the energy market in Virginia since it is significantly lower than the residential cost of electricity, and only slightly higher than the commercial cost of electricity. The net present value is \$8,248,889 - a number that was optimized by choosing a tenor for project term debt that would produce a high net present value while maintaining a competitive PPA price. The net capital cost from the model was \$170,269,600 with a total equity of \$55,852,148 and debt of \$114,417,456. The annual energy output for Bartlett Towers is expected to reach 292,134,720 kWh with a capacity of 33.3%. The Project After-tax Cash Flow is available in Figure 8.

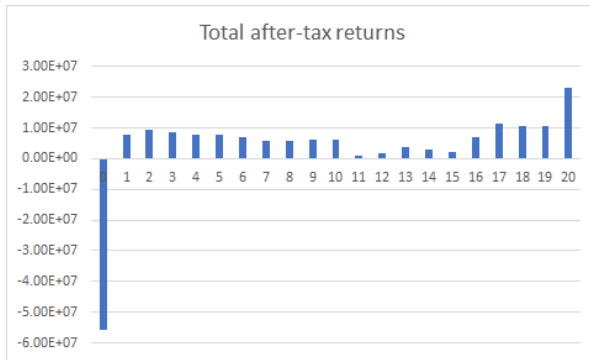


Figure 8: Overhead Transmission Cash Flow



Figure 9: Underground Transmission Cash Flow

Model Iterations

A second iteration of the financial model was performed to assess how increased wildlife protection measures at Bartlett Towers would impact project profitability. After communications with Tripp County officials regarding community attitudes towards wind energy projects, Prosim Power became aware of concerns of Whooping Crane fatalities. Consulting with the WCCA, as reported in “Environmental Factors,” revealed that transmission lines are the cause of most Whooping Crane fatalities near wind farms. As a result, Prosim Power has investigated the cost of building the 4.16-mile-long, 115 kV transmission line underground. The cost of building the underground transmission line would be 5.26 times more expensive than the overhead lines, at a cost of \$29,471,900 [69]. Increasing the project debt tenor from 16 to 17 years, and keeping all other parameters the same, the resultant real LCOE and PPA price are 8.29¢ per kWh and 8.56¢ per kWh, respectively. The PPA price is still lower than the residential COE in Virginia and 1.05¢ per kWh more expensive than the commercial COE. The project’s net present value is \$8,354,975, net capital cost is \$196,303,856, equity is \$58,776,036, and size of debt is \$137,527,824. The After Project Tax Flow is available in Figure 9. Prosim Power is proud to offer this alternative financing plan that exchanges a slightly higher COE, for true environmental protection and stewardship. With the implementation of an underground transmission line, Bartlett Towers shows respect for the community's concern and exceeds minimal permitting expectations.

Risk Management

Involving, informing, and openly communicating with stakeholders in the early stages of project planning is critical in mitigating community backlash and preventing contestation and litigation. Since South Dakota has no state environmental regulations associated with the siting of wind turbines, each permit proposal is considered on a case-by-case basis. Community backlash can not only delay the permit approval provided by the South Dakota PUC, but could also result in increased permitting costs due to the

additional involvement of experts to assess adverse effects on stakeholders. By identifying potential problems and negative impacts early, and by facilitating stakeholder involvement, the risk of permit approval delays and inflated permit costs are minimized.

Bird and bat collision mortality has been a controversial matter for previous permit applicants; therefore, Prosim Power plans to involve wildlife agencies and universities to perform a biological resource survey in order to deter resistance. Avoiding sensitive habitats, such as prairies and wetlands, and avoiding road construction on steep slopes can prevent soil erosion and deterioration of local water quality. Building environmentally friendly temporary access roads where feasible, in lieu of permanent roads, can also help reduce long-term impacts. Preventing Whooping Crane fatalities by using underground transmission lines, as discussed in “Model Iterations,” will also be an important risk-management tool to avoid public backlash.

The impact on residents can be taken into account by creating a platform that allows cooperation and communication between stakeholders. Transparency is critical in encouraging trust and open dialogue within a community. The community can be socioeconomically benefitted by using local contractors and suppliers. The preservation of the community’s heritage will be taken into consideration by understanding the local cultural, archeological, and paleontological resources through consultations with the South Dakota State Historical Society. By facilitating stakeholder communication in the early stages of project planning, such as contacting county officials, as exhibited in the “Community Factors” section of this report, stakeholder’s concerns can be addressed. Reducing environmental and community impacts of Bartlett Towers are an important part of the project’s triple bottom line. Periodic assessments of Bartlett Towers’s triple bottom line during the 20-year life can help identify areas in which changes must be made to reduce impact on wildlife or improve relationships with the community.

The construction phase of any project has inherent risks involving overall cost and scheduling. Financial losses may be incurred by misuse of materials or a late project finish. Falling behind schedule can result from unskilled workers and/or inconsistent workmanship necessitating corrective work resulting in additional project time. The risks in the construction phase may be mitigated by developing a strong project plan as well as choosing an appropriate project delivery method such as the design-bid-build (DBB) method. A well thought-out project can help to eliminate risk with construction phase timelines and over- or under-purchase of materials by providing a holistic overview of the project such that all essential material and temporal knowledge is available prior to the first task performed on the project site. A project delivery method is used to organize the communication between the project owner, architects, engineers, and contractors such that the project cost and scheduling are balanced in the most efficient manner for the owner. The design-bid-build project delivery method was chosen because it is a universal approach to project management with a competitive bid submission that would provide the highest financial relief to the owner.

Substations are necessary components of a wind farm to transmit energy to the end user; however, risks associated with their operation, such as fires, may cause infrastructure damage and bad publicity. A substation fire may result from thermal stress which induces an energy overload, igniting the dielectric fluid within the substation transformer. A substation fire can last hours, but may be prevented through proper heat management. If a substation fire does occur, it is imperative that it is put out immediately to prevent loss of power, property damage, or loss of human life. Passive substation sprinkler systems such as the HI-FOG Water Mist Fire Protection by Marioff may be implemented to quickly suppress the intensity of the fire prior to extinguishment [70].

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