Wind Turbine Team at Virginia Tech

Siting & Project Development Written Report

2019 U.S. Department of Energy Collegiate Wind Competition

Virginia Polytechnic Institute and State University

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COLLEGIATE WIND COMPETITION
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Section I: Introduction

Abstract

This report examines the financial potential for the wind farm designed for Wills Ridge in Floyd County, VA. Extensive cost and financing research was completed and input into the NREL System Advisory Model (SAM) software. Simulating the model in the software revealed that the project is not expected to be financially viable because the required PPA price was calculated to be higher than the market would typically support. This is mostly due to poor wind resource in the region preventing maximum energy generation, but the initial cost to build the wind farm is also higher than average due to difficult terrain conditions and use of large turbines. There are several options available to increase the viability of the proposed wind farm, such as utilizing the full PTC, decreasing turbine costs through research and development, and selling RECs to outside companies.

Site Description

The site analyzed in this report is located on Wills Ridge in Floyd County, VA along the southern side of Route 730. The site contains 21 GE 4.8-158 wind turbines. This turbine is very new to the market, but it was chosen due to its ability to produce power in low wind speeds, which fits the site conditions. A layout of the site can be seen in **Figure 1**, below.

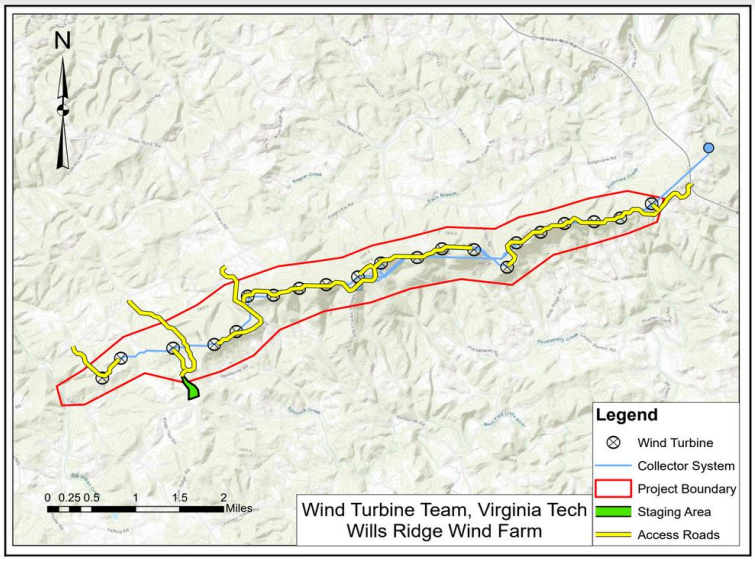


Figure 1. Conceptual Site Plan

The land surrounding the site is primarily used for agricultural purposes (farming/ranching) and is lightly populated. The site is situated along a ridgeline which poses many challenges related to construction and operation. Located just outside the project boundary is a substation, denoted as the blue circle on the conceptual site plan. This was a significant reason for choosing the site because using an existing substation will reduce cost.

The site has a rated capacity of 100.8 MW, just over the 100 MW requirement. OpenWind indicates that the net annual energy production can be expected to be 279.67 GWh per year. The net capacity factor for this site is 31.7%.

Design Changes

Several design changes were made to the layout from the 2018 plan. Access roads were straightened from the suggested layout generated by OpenWind for constructability. Additionally, upon visiting the site,

the team determined that the proposed road improvements to Route 730 were unnecessary because it is comparable in width to roads used to transport turbines to Beech Ridge Wind Farm in West Virginia, which the team also visited. The team also determined that Route 730 is a low-volume roadway [1], so closing the road at night to deliver turbine parts to the staging area would likely cause minimal impact to the community. It is also important to note that despite low wind speed conditions, the site location remains the same as there are no feasible sites within the required 100-mile radius from Virginia Tech that offer better wind resource while also being within reasonable proximity to roads for turbine transportation and a convenient connection point to the electrical grid, among other factors.

Section II: Project Costs

Costs Summary

The costs for the Wills Ridge wind farm project are outlined in Table 1, below.

***Table 1**. Accumulated Costs*

Initial Capital Costs	
Hard Costs	**Cost**
Wind Turbines	$175,141,500
Access Roads	$1,407,200
Turbine Foundations	$3,990,900
Electrical Infrastructure	$4,306,500
Resource Assessment	$130,800
Control and Electrical Hardware	$500,000
Staging Area	$12,000
Soft Costs	**Cost**
Engineering and Surveying	$110,000
Land Development Permits	$23,500
Total	**$185,622,400**
Annual Operating Expenses	
Land Leases	$168,000
Maintenance	$2,290,400
Daily Operations	$354,800
Administrative and Legal	$126,000
Total (annual)	**$2,939,200**

Initial Capital Costs

Engineering and Surveying

Engineering costs include the design of the wind farm, such as the location of turbines, met masts, grading, access roads, staging areas, and stormwater management. The team contacted Draper Aden Associates and Gay and Neel, Inc., to estimate engineering and design fees for the Wills Ridge Site; these companies are local land developments firms that work in this area of Virginia. This means their estimates are comparable to costs that the Wills Ridge site would encounter. Both firms estimate engineering and design fees to total approximately $75,000 [2,3]. Additionally, surveying costs for the site are estimated by Gay and Neel, Inc. to be approximately $35,000 for a total of $110,000 [3].

Roads

The Windustry cost to construct access roads is $35,000 per ¼ mile [4]. The steep slopes and dense foliage on the project site will likely lead to a higher cost, so an additional cost for clearing and grubbing areas with dense foliage of $2,250 per mile was added [5]. After adjusting for inflation, this cost was calculated at $1,400,000 for all access road construction.

Rather than expanding the offsite roads for turbine transportation, such as Route 730, workers will be hired to direct traffic and block off lanes as needed. This is justified as the roads utilized have a low average daily traffic [1], and there are houses along many of these roads, which would preclude road widening. The cost of hiring traffic flaggers was determined to be $7,200 assuming two flaggers are needed per road for a 10 day period and are each paid $15/hour [6].

Land Development Permits

The project will require federal, state, and local permits before construction can begin. At the federal level, an Incidental Take Permit will cost $100.00 [7]. Nationwide Permit 51 "Land based Renewable Energy Generation Facilities" is required through the US Army Corps of Engineers [8]. At the state level, Virginia's Permit by Rule process covers all necessary state regulated permitting and analyses for wind projects, costing $16,000 [9]. At the local level, Floyd County requires building and electrical permits for each wind turbine constructed at a cost of $50 each. The county also requires a soil erosion and sediment control fee as well as a floodplain fee, which cost $100 and $150, respectively. There is also a 2% state surcharge on the building, electrical, and floodplain fees [10], and all new street and road signs require a fee of $200 per intersection [11] Considering all of the above-mentioned factors, the total land development permitting costs will be $23,500.

Foundations

Foundation volume for each turbine, based on tower height, was estimated to be approximately 253.86 m^3 [12]. The foundation cost for each turbine was calculated by scaling the average cost of foundation per cubic meter for a 2 MW turbine to a 4.8 MW turbine. The resulting total cost for all 21 turbine foundations was estimated at $3,990,900 [13].

Turbine Costs

Due to the fact that the GE 4.8-158 turbine is not in commercial use and no cost data is currently available, NREL's Turbine Design Cost and Scaling Model equations were used to determine the approximate cost based on its size. The use of this model to approximate cost is justified because it uses turbine size as the main factor in calculations and because it was designed to acknowledge the trend for turbines to become increasingly larger as technology improves. To calculate total nominal cost for each turbine, individual component costs were estimated using parameters such as rotor diameter, hub height, machine rating, and a single stage drive with medium-speed generator configuration [14]. Based on these calculations, the total real cost for all turbines was estimated at $175,141,500. This estimate of approximately $1.75M per MW is on-cost with other typical estimates that project on-shore turbines to cost between $1.3M and $2.2M per MW of capacity [15].

Turbine Component Transportation

Turbine components will be shipped to the site from GE manufacturing facilities in Pensacola, FL and Little Rock, AR. First, parts will be transported by train to Roanoke, VA and then by truck to the site. Based on NREL's transportation cost calculator, the estimated transportation nominal cost for each turbine is $1,147,019.52 in 2002 USD [14]. After adjusting for inflation, the real cost is $33,698,286.48 for all turbines [16].

Electrical Infrastructure

Through OpenWind, it was determined that 15 miles of medium voltage distribution lines are required for the site's collector system [17,18]. To estimate costs associated with the system, the team analyzed a preliminary electrical design plan for the proposed Black Nubble Wind Farm to be located Maine in similar terrain to the Wills Ridge site. The 34.5 kV collector system costs $89,000 per mile for cable and installation, plus an additional $193,000 for connectors, riser poles, design and procurement of the system, and miscellaneous expenses [19]. When applied to the Wills Ridge site, the cost of the collector system will be $1,530,000.

Additionally, 5000 ft of high voltage transmission lines are needed to connect to the substation mentioned in the site description section. The Western Electricity Coordinating Council created a report detailing the costs of high voltage transmission lines containing baseline costs as well as multipliers for terrain, conductors, structure type, length, and right of way [20]. Given the terrain and length of the proposed wind farm, the cost of 5000 ft of 138 kV high voltage lines will be $2,776,500.

The combined total cost of the collector system and high voltage transmission lines is estimated at $4,306,500. Cost for a substation has not been incorporated into this analysis because there is an existing substation approximately one mile from the project boundary which will be utilized in the collector system design.

Resource Assessment

Wind Power Monthly estimated that buying and installing a 100 meter met mast in the United States would range from $80,000 to $130,000 excluding permitting and land leasing fees [21]. Given the difficult terrain and soil conditions on Wills Ridge, a $130,000 cost was conservatively assumed. The journal estimated that for a 40 meter met mast, land leasing was negotiable but usually ranged between $300-$500 a year in 1997 [22]. Assuming a $500 cost and accounting for inflation, the total leasing price is estimated to be $800 for one year, the standard time period for a wind resource assessment [23]. Thus, the total cost of resource assessment will be $130,800.

Control and Electrical Hardware

A supervisory control system is required to be designed and purchased separately apart from the individual turbine control systems. The team consulted with an industrial automation firm which estimated the total cost of the system to be approximately $500,000 for the site [24].

Staging Area

A temporary staging area, designated in green in Figure 1, will be positioned in the vicinity of proposed access roads on the southern side of the site. A total of 4.5 acres, consisting of two parcels, have been allotted for the purpose of construction activities and short-term material storage. Both parcels of leased land currently have no permanent residents and are privately owned [25]. The total estimate for the one-year lease is $12,000 [26]. This was found using an online calculator and inputting the 6% interest rate given in Virginia Code § 6.2-302 [27], the total asset value of $51,000, according to Floyd County GIS [25], and an assumed residual value of $51,000 since land does not depreciate.

Annual Operating Expenses

Land Expenses

Leasing land was determined to be a more cost-effective approach than purchasing. The standard annual land lease rate is $4,000-$8,000 per turbine [28]. Given the size of the turbines and the history of community pushback in Virginia associated with wind farm development, the team chose to use the $8,000 leasing price. Therefore, the total annual cost is $168,000.

Maintenance

Maintenance is a variable expenditure that depends on the amount of electricity generated by the turbines. Costs include planned and unplanned turbine maintenance as well as unplanned plant maintenance [29]. To obtain a more accurate representation of the maintenance costs for the proposed wind farm, the NREL 2016 Cost of Wind Energy Review was examined. This study of 2.16 MW turbines from the year 2000 and onward estimated the cost of maintenance to be $7.9/MWh. Based on this value and the wind farm's net annual energy production of 279.67 GWh, the annual maintenance expense is estimated at $2,209,400 [30].

Daily Operations

The team estimated that five full time employees will manage day-to-day operations of the wind farm based on discussions with the Operations Manager at Beech Ridge Wind Farm. Based on the average income rate for a wind farm employee of $50,000 per year [31] and the average multiplier for the cost of an employee [32], each employee will cost approximately $70,000 per year to employ. An available office space in Floyd, near the project site, was selected, costing approximately $4,800 annually [33].

Administrative and Legal Fees

According to Windustry, annual administrative and legal fees concerning taxes, contracts, billing, and insurance settlements total approximately $6,000 per turbine per year. This results in a total administrative and legal cost of $126,000 [4].

Decommissioning Costs and Salvage Value

Following the 20-year expected life of the wind farm, the disposal and salvage process begins. Energy Ventures Analysis estimates decommissioning costs for Beech Ridge Wind Farm to be $97,000 per turbine [34]. After adjusting for inflation, turbine size, and the total number of turbines, decommissioning for the Will Ridge site will cost $6,200,000. Windustry estimates that the salvage value of a wind turbine is, on average, 7.5% of the original cost of the turbine [4] for a total salvage value of $13,200,000 for all 21 turbines.

Section III: Financing

Model Selection

The NREL System Advisory Model (SAM) was selected to be used for this financial analysis based on the recommendation of industry professionals. This model takes into consideration all of the cost information as well as incentives, PPA structure, and various other inputs, as described below.

Incentives

There are two main federal incentives available to wind farm developers in the United States, the Investment Tax Credit (ITC) and the Production Tax Credit (PTC), which are both monetary subsidies in the form of tax deductions. According to Scott Davis, a Financial Analyst at Apex Clean Energy, it is no longer common practice to apply the ITC to wind farms because the PTC provides a higher value tax deduction with the most recent policies [35]. Although the PTC has been critical to financing in the wind industry for the past decade, it is currently being phased out and is expected to end by 2020. Therefore, to qualify for the PTC, construction must begin by December 31, 2019 and be completed within four years. Specifically, the federal government is offering 40% of the PTC at 9¢/kWh [36], which will be applied to the Wills Ridge wind farm.

In addition to the PTC, the Modified Accelerated Cost Recovery System (MACRS) is an accelerated federal depreciation tax offset that allows businesses to recover investments in certain property through depreciation deductions. This incentivizes investment in wind energy from financial institutions

with large tax exposure who benefit from the tax offsets. The Wills Ridge project qualifies for five-year MACRS which allows for 100% of qualifying costs to be depreciated in the first six years of commercial operation [37].

In contrast to federal incentives, state-level incentives are generally not monetary. Instead, most states have a Renewable Portfolio Standard (RPS) encouraging major utility companies to source a certain amount or percentage of their energy from renewable sources. While these incentives stimulate the renewable energy industry as a whole, they do not directly aid in the financing of individual wind projects. Thus, any RPS policies in the state of Virginia were ignored for the purpose of this study.

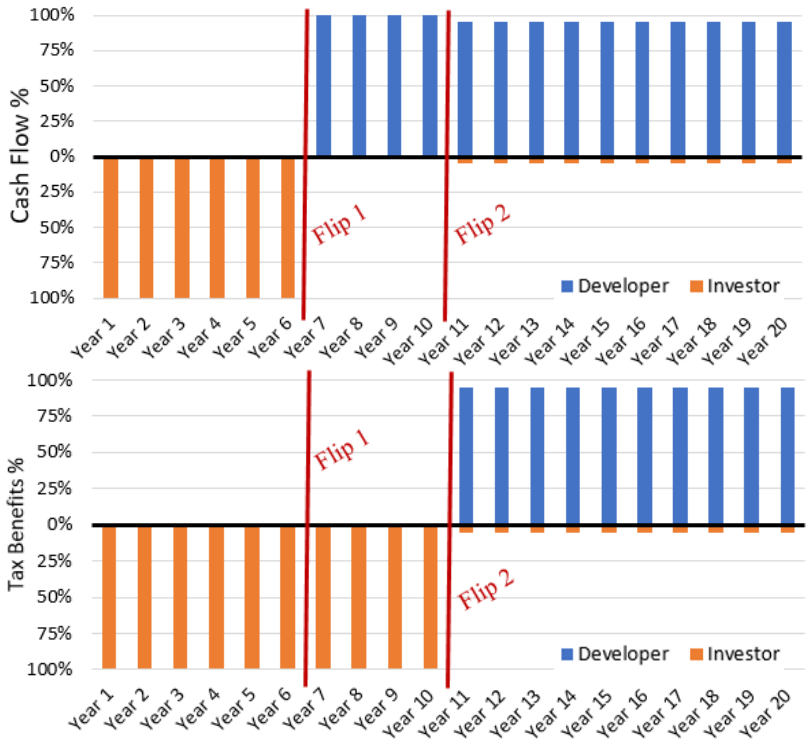
Power Purchase Agreement

A Power Purchase Agreement (PPA) is a contract that defines the terms in which energy will be bought by a utility company. The agreement for the Wills Ridge wind farm was constructed as a Partnership-Flip with debt. This PPA structure includes equity investment from a tax investor and construction and term debt. Terms of the PPA for the proposed Wills Ridge wind farm would be negotiated between the developer, a tax investor and the regional utility provider - Appalachian Power Company.

The terms and conditions for PPAs in the wind energy sector do not vary significantly across projects, as PPA structures are generally uniform and cost of energy must remain in a range that keeps it cost competitive. Using the NREL System Advisor Model (SAM), industry standards for financial parameters in the model were found.

Terms of Power Purchase Agreement

The equity investment portion of the PPA was structured as a pre-tax, after-tax partnership structure as that is typical for the industry. This equity deal assumes the investor will contribute 40% of the total capital costs and includes two flip points at Year 6 and Year 10. Error! Reference source not found. and **Figures 2-** below show the flip points and percentage of cash flow and tax benefits for the developer and investor.



Figures 2-3. Percentage of Cash Flow to Developer and Investor (top), Percentage of Tax Benefits to Developer and Investor (bottom)

The team chose a target internal rate of return (IRR) of 8% in Year 10. This falls within the typical goal of 7% to 12% for a wind farm [38]. 8% was chosen because it allows for a positive net present value (NPV) for both the developer and the investor while maintaining the lowest PPA price possible at 11.14¢/kWh. A nominal discount rate of 8.52% was calculated by the model using an annual inflation rate of 1.9% [39] and a real discount rate for onshore wind of 6.5% [40].

Associated Loans

To generate the remaining capital required for construction and operation, the developer will receive commercial loans on 60% of all capital costs. Construction loans have higher interest rates due to risk and are usually structured in a staggered funding system where lenders only give the money needed after certain planned milestones are met. The second loan type are term loans, which are a refinancing of the construction loans to obtain a lower interest rate. These loans take place once the wind farm is officially operational, and usually last 12-15 years [41]. The average interest rate on loans for renewable developers in 2017 was 6.1% [40]. Debt closing costs on commercial loans is typically a rate of approximately 2% [42].

Additional Model Inputs

Site Information

Wind resource data based on the latitude and longitude of the site was downloaded and used for the analysis. Since the GE 4.8-158 turbine selected for the site is not included in the system, the Gamesa G128 4.5MW was used as a comparable model. The number and layout of the turbines was also included.

Tax and Insurance Rates

The federal tax income rate of 21% [43] and the state income tax rate of 6% [44] were used. Virginia sales tax is 5% [45], Floyd County sales tax is 5.3% [46], and the expected insurance rate is 3% of annual costs [4,47]. Several counties in Virginia have introduced 100% property tax abatements for renewable energy sites. Given that the government of Floyd County has also shown a significant commitment to renewable energy [48], property tax for the Wills Ridge site was assumed to be 0%.

Reserve Accounts

Reserve accounts of 6-12 months for working capital and debt service are typically held by developers [49]. Nine months of working capital and debt service will be held for this project at an interest rate for required reserves of 2.4% [50].

Model Outputs

Analysis of the model illustrates that over the 20-year lifespan of the wind farm, the project can be profitable for the developer and the investor, using the high PPA price of 11.14¢/kWh. An anticipated cash flow diagram can be found in **Figure 4** below.

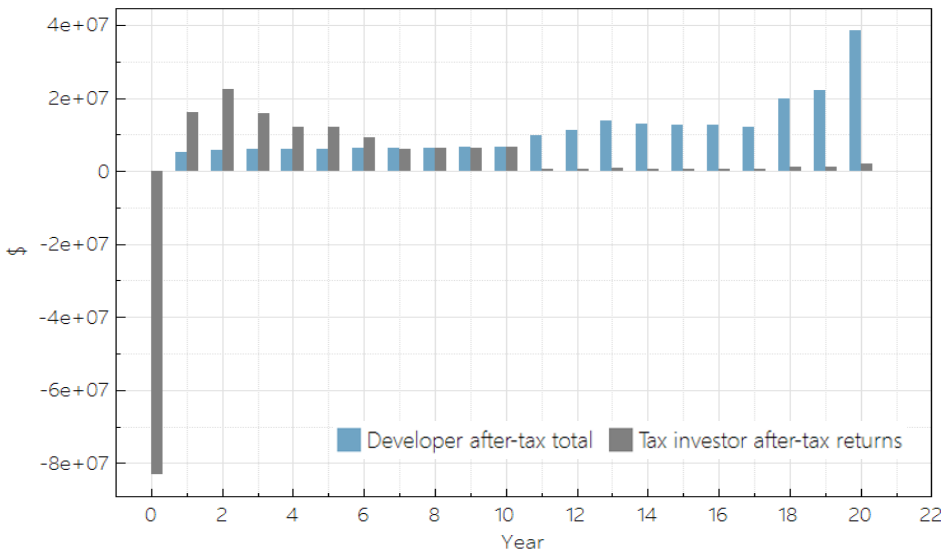


Figure 4. Cash flow diagram

Outputs from the model include a real levelized cost of energy (LCOE) of 8.40¢/kWh, an investor net present value (NPV) of about $819,000, and a developer NPV of about $84,500,000. However, the average PPA price for wind power in PJM territory, which encompasses the site, is 3.05¢/kWh [51]. Due to the low wind resource in the area, the PPA price was set at 11.14¢/kWh, which is atypical of the market and would not be competitive. This means that, although this model displays profitability for the developer and investor, the project is not ultimately economically viable.

Section IV: Evaluation of Alternatives

PTC Renewal

Full implementation of the PTC would greatly impact the cost of the project as a whole. With the 60% reduction enforced by current policies, the Wills Ridge wind farm is much less profitable than it would have been if it could take advantage of the full PTC. This would require a renewal of the current policy. Unfortunately, this renewal seems unlikely to come in the future as the wind industry continues to grow and become more independent of government subsidies in general [35].

Technological Advancement

U.S. Department of Energy records show that wind turbine costs per kW peaked in 2009 and have continuously decreased as technology has improved in this field [52]. As large turbines capable of operating at low wind speeds become more common, prices will decrease thereby reducing initial capital costs. Turbine costs account for approximately 87% of total capital costs for this project. Therefore, reducing the amount spent on turbines would improve profitability for both the developer and the investor. Based on these factors, the team anticipates that the Wills Ridge wind farm project may be more economically feasible if built in the future.

Renewable Energy Certificates (RECs)

Renewable Energy Certificates (RECs) are proof that a certain amount of energy has been generated from renewable resources and fed into the grid [53]. RECs can be traded and sold to corporations in order to offset their carbon footprint by showing that they are investing in the renewable energy industry. Selling RECs from the Wills Ridge site would increase the income to developers, thereby increasing the profitability of the project.

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