Siting and Project Development Report

Examination of Wind Development Potential on the Cow Knob Ridgeline

James Madison University

Team Member	**Sub-Team Affiliation**	**Individual Role**	**Contact Information**
Samantha Frey	Communications & Engagement	CWC Specialist	freysg@dukes.jmu.edu
Dylan Granados	Financial Analysis	Researcher	granadda@dukes.jmu.edu
Tess Jacobson	Siting Analysis	Team Lead	jacobstk@dukes.jmu.edu
Zach Lasek	Financial Analysis	Team Lead	lasekmz@dukes.jmu.edu
Jonny Lizama	Communications & Engagement	Team Lead	lizamajk@dukes.jmu.edu
Jamie Mears	Financial Analysis	CWC Specialist	mearsjm@dukes.jmu.edu
Brian Miles	Siting Analysis	Researcher	milesbj@dukes.jmu.edu
Brianna Smith	Siting Analysis	CWC Specialist	smith4bl@dukes.jmu.edu
Aaron Sortore	Communications & Engagement	Web Designer	sortorak@dukes.jmu.edu

Faculty Advisor: Dr. Jonathan Miles
External Advisor: EAPC

Additional Acknowledgements: Philip Sturm, Remy Pangle, Dustyn Vallies

Table of Contents

Site Description

The chosen site, from the 2018 siting competition, was on the Cow Knob ridgeline. Cow Knob is located 40 miles northwest of James Madison University, way within the competitions 100-mile limit, and within the Rockingham County border of Virginia.

There are multiple opportunities that Cow Knob presents as a good wind farm site. From a previous investigation of the site around 10 years ago, headed by Solaya Energy and Dominion Energy, EAPC was contracted to erect meteorological (MET) towers to gather wind data. Working with EAPC, the wind data from the prior investigation was acquired and used for this project. The data showed that the wind speeds are plentiful and steady along this ridgeline at speeds of 7-9 m/s, optimal for our chosen turbine. These MET towers are dated, so if there was interest in developing this site, new sensors would need to be installed to replace the old ones to gather data that is current and of acceptable precision. Another major economic and environmental opportunity with the Cow Knob site is that it possesses vast open lands. Open lands give way for less need to clear trees, lowering costs and impact on the local ecosystem.

Along with the opportunities the Cow Knob site presents, there are a number of challenges that were identified in relation to the site. Our biggest concern is the proximity to the George Washington National Forest. So far, there has not been a wind farm built on federal forest lands managed by the US Forest Service. However, the US Forest Services does not definitively state that wind farms cannot be built on federal forest lands. There is also the possibility that access roads would have to be built on federal lands, but the good news is that those lands allow access roads for industry use, such as for lumber. Additionally, the land on Cow Knob has never been formally surveyed so there is a lack of clarity as to where one property starts and where the next begins. Another challenge is making sure all 13 landowners are on board with the development and that they feel they are receiving sufficient compensation for the use of their land. From talking with the landowners throughout the course of this project, a decent amount of them are in support of a wind development on the Cow Knob ridgeline. Another challenge is that the roads leading up to the ridgeline are winding dirt roads and would need to be improved and widened to be able to accommodate the large vehicles and machinery that would need to make their way up the mountain. The last challenge we have identified at this site is that while there is already a transmission line running through the ridgeline, it is at such a high voltage that a large, expensive substation would need to be built to connect the wind farm to the transmission lines.

After identifying the opportunities and challenges, it is important to understand the permitting and policy side of developing a wind farm. The American Wind Energy Association (AWEA) Siting Handbook was used to understand the process for acquiring federal permits. Next, the Virginia Permit by Rule for wind energy projects was researched and used for the siting analysis. Lastly, the Rockingham County Wind ordinance was summarized to understand the policies and regulations to follow regarding the community aspects of a potential wind farm. A major takeaway from researching all of the policies associated with Cow Knob's development was that an environmental analysis would have to be conducted to determine the scope of environmental impacts. A list of endangered and threatened wildlife and plants were made, and the potential environmental impacts were thoroughly investigated.

Design Changes

For the most part, our site remained unchanged. However, the Alstom/GE ECO 100 3 MW turbine analyzed in our previous model and in the site analysis presented at the 2018 competition is no longer manufactured. For the 2019 competition, we decided to include a turbine currently available on the market in order to create the most accurate financial analysis possible. The new turbine chosen was the Vestas V126-3.45 MW.

Table 1. *Comparison of turbine specifications*

	Alstom/GE ECO 100 3 MW	Vestas V126-3.45 MW
Rated Power (kW)	3,000	3,450
Cut-in-Speed (m/s)	3	3
Cut-out-Speed (m/s)	25	22.5
Rotor Diameter (m)	100	126
Swept Area (m2)	7,980	12,649
Hub Height (m)	75	87

These turbines have a larger rotor diameter and swept area, therefore generating more electricity. Furthermore, changing our site design to include these new turbines resulted in slightly different turbine placement along the ridgeline and a higher rating of 117.3 MW compared to the configuration analyzed at the 2018 competition.

Table 2. *Comparison of turbine layout (34 turbines) simulation results*

	Alstom/GE ECO 100 3 MW	Vestas V126-3.45 MW
Theoretical Max. Energy (GWh)	894	1,029
Net Energy (GWh)	302.9	360.4
Capacity Factor (%)	33.9	35.0

This site remained primarily unchanged for the following reasons: First, this site is one of the only sites in Virginia with a reasonable wind resource within 100 miles of JMU. Virginia is drastically lagging behind other states in wind development, and this site serves as a place to show that utility-scale wind development in Virginia is economically viable. The Cow Knob site would be an appropriate starting place to demonstrate Virginia's wind development capabilities since it consists of primarily open, plentiful flat land, has an adequate wind resource, and there are already existing transmission lines that go through the site.

Second, a good relationship with the land owners of the site has been established and based off of feedback from our public information meeting last Spring, there is a high rate of public support for the actual development of a wind farm at Cow Knob. It is hopeful that public interest in this site will not only continue but increase as more citizens become aware of the benefits of wind energy.

Financial Analysis

Key Assumptions

After implementing the design changes, a financial analysis of the site was conducted using System Advisor Model (SAM) to determine the economic viability of the project. When working on a project like this, it is difficult to find values that accurately represent what the industry currently receives. In order to generate economic indicators, a lot of assumptions need to be made. Table 3 below contains the assumptions used for the financial analysis.

Table 3. *Assumptions made for Financial Analysis.*

Assumption	Value	Source
IRR Target	7%	EAPC, 2019
Project Term Debt	60% of total capital costs	EAPC, 2019
Installation Costs	40% per every million dollars spent	EAPC, 2019
Operations & Management Costs	$48 per kW-year	IHS Markit, 2017
Time Period	20 years	CWC Rules & Reqs, 2019
PPA Price Escalation	1% per year	System Advisor Model, 2014
Federal Income Tax Rate	21%	System Advisor Model, 2014
VA State Income Tax Rate	7%	System Advisor Model, 2014
Annual Interest Rate	7%	System Advisor Model, 2014
Debt Closing Cost	$450,000	System Advisor Model, 2014
Upfront Fee	2.75% of total debt	System Advisor Model, 2014
Land Lease Cost	2.5% of total gross revenue	EAPC, 2019
Current Sale of Wholesale Power	$23 per MWh	PJM, 2019
Current Inflation Rate	1.90%	U.S. BLS, 2019
Federal Reserve Discount Rate	3%	Amadeo, 2019
VA Sales Tax	4.30%	VA Dept of Taxation, 2018
Production Tax Credit	Expire in 2020	DSIRE, 2018
Investment Tax Credit	Expire in 2020	DSIRE, 2018

Some values were simply found online and were used as a rough estimate, for example, the current inflation rate or discount rate. For some values, we had conversations with EAPC to gain a better understanding of what each metric means and an estimate for what it would be for this project. They offered a range of 7%-9% for a target IRR of the project and gave us their insight into what a land lease would look like and how much it would cost. We assumed a 2% loss of generation due to curtailment for the protection of bird and bat species as per their guidance. Although many of the values associated with project debt were default values in SAM, they explained the complexity of debt and how many factors impact what kind of loan is used from the credibility of the borrow to the credit of the turbine providers. Being able to find values for every process associated with Installation and O&M was very difficult. Therefore, for Installation we assumed that the costs would be 40% of every million dollars spent on the turbines and the O&M costs were $48 per kW-year, the average cost of O&M for wind farms across the United States. The different costs associated with each are listed below in Table 4.

Table 4. *Costs associated with Installation and Operation & Maintenance.*

Installation	Operation & Maintenance
Engineering	Preventive Maintenance
Road Construction	Corrective Maintenance
Civil Work	Repair
Trenching	Replacement
Transportation	Service & Spare Parts
Site Preparation	Administration
Shipping	Monitoring
Legal Counsel	Land Lease
	Insurance

For the construction aspect of the project, we assumed all costs would be placed on one loan for a matter of simplicity in calculating payoff. In order to connect to the grid, a substation is needed for a 500-kV line; through some calculation based on a guide from WECC, we estimated a value of around $55 million for a 500-kV substation. Lastly, this economic analysis was completed without the Production Tax Credit and the Investment Tax Credit because of their expiration in 2020 and the assumptions that they will not be renewed by the federal government and that project construction will begin after 2020.

Financial Results

After using all of the assumptions above and the wind farm layout created with OpenWind, the following economic indicators were generated.

Table 5. *Financial indicators at the Cow Knob proposed wind site*.

Indicator	Value
Annual Energy Production	360,416,288 kWh
Capacity Factor	35%
Levelized PPA	6.98 ¢ /kWh
Levelized COE	6.73 ¢ /kWh
Net Present Value	$12,915,590
Internal Rate of Return (IRR)	7.00%
Net Capital Cost	$229,035,600
Equity	$91,651,040
Size of Debt	$137,384,560

When determining the financial indicators in the chart above, the annual energy production and capacity factor were provided by OpenWind. The 35% capacity factor falls within the wind industry average of

30%-40%. The IRR was set at 7.00%, given to us by EAPC as a general value for most wind projects in the industry today. From there, using all of the assumptions and values given above, SAM assisted us in generating these values.

The levelized Power Purchase Agreement (PPA) cost is 6.98 ¢ /kWh and the feasibility of that value depends on the offtake model which will be discussed later. The LCOE of the project is 6.73 ¢ /kWh. Based on the 2018 Virginia Energy Plan, the LCOE of wind in Virginia is expected to be between 3.5 ¢ /kWh and 6 ¢ /kWh. While the value produced from this modeling falls outside of that range, there are many other alternative ways of looking at the potential of this site with our team only observing one. Because of the great wind resource and other opportunities of the site, EAPC is currently examining the site in further detail and with better resources. The net present value calculated by SAM for the project is approximately $13 million, but we were unable to find another value from a previous similar project to compare it too, nor did we have an estimate for comparison. The total net capital cost of the project is around $230 million, which includes the cost of the 34 Vestas turbines at $3.25 million each, the associated installation costs mentioned above in Table 3—totaling 40% per million spent on turbines—and the cost of building a substation to connect with the 500-kV line at an estimated cost of $55 million. The size of the equity and debt were provided by EAPC as a rough estimate of 60% debt.

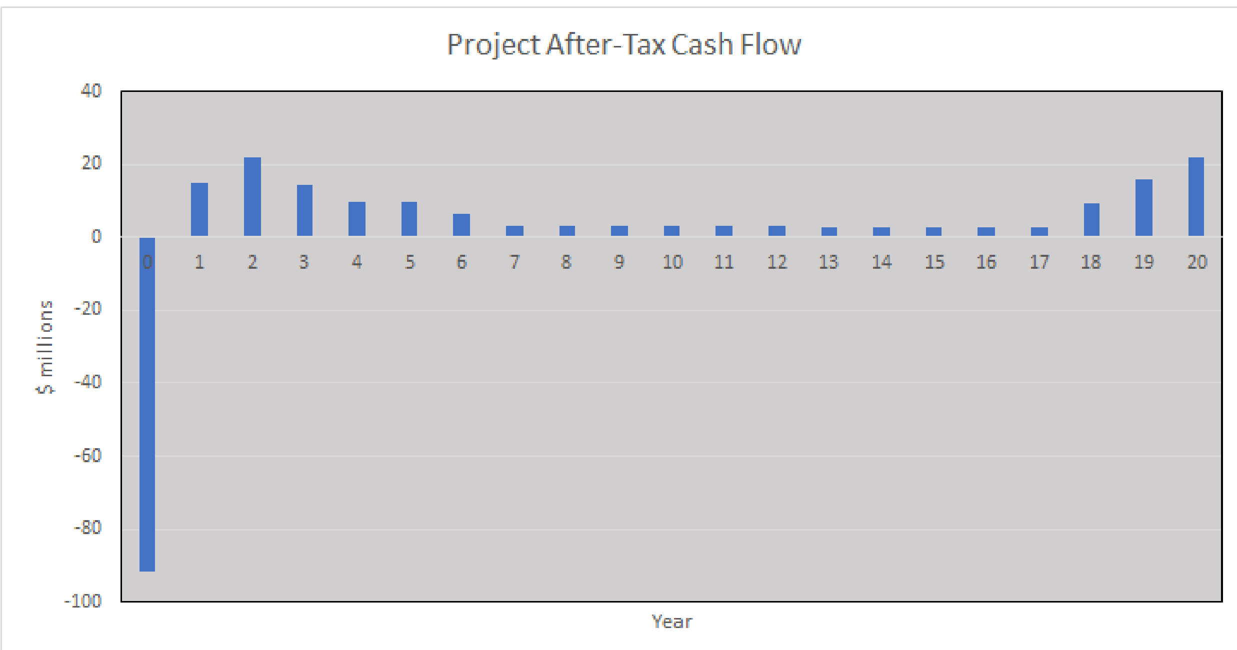

Figure 1. *20-year Project After-Tax Cash Flow*

Figure 1 above models the 20-year cash flow of the project after tax. Year zero represents the cost of equity paid to investors, with a 60% project term debt from the net capital cost. The resulting down payment in year zero is approximately $91,651,040. The sudden decline in revenue at year 5 is a product of the MACRS depreciation expiring. The debt is paid off at year 17 and generates higher profit for the remaining 3 years modeled, as indicated by the upward trend.

After discussing attractiveness of the project with EAPC, we started to draft up what an offtake model would look like for a project like this. While a typical PPA is the first model looked at, the PPA price is expected to be higher than the average PPA of a wind farm, so buyers must be willing to pay extra. However, EAPC had a novel idea: have interested local colleges sign the PPA, buying the power. In return the colleges would be able to claim the green energy for their energy portfolio and utilize the ridgeline as an off-site research center. This would allow schools to test new technologies, as well as analyze local ecosystem and environmental impacts and how various ecosystems recover from commercial-scale wind energy developments. As mentioned above, Virginia has yet to construct any large-scale wind yet, however, many universities have research related to wind energy that is currently being worked on. For example, both James Madison University and Virginia Tech have competed in the Collegiate Wind Competition. We have heard from other schools, such as West Virginia University, Old Dominion University, and William and Mary that have also invested in wind energy research over the past decade. Knowing that schools will be getting more out of the project than the just the electricity or renewable energy portfolio additions, they would be more willing to pay a higher cost for electricity. It would also potentially help calm those who are nervous about the impact on the endangered and threatened species of the ridgeline, knowing that there are colleges conducting research and monitoring these organisms.

Risk Assessment

Preliminary arrangements had to be made before undertaking the project in order to reduce or avoid risks associated with it. For the purposes of the siting portion, we defined the geographic scope of the analysis, which centers along the Cow Knob ridgeline and rests along the border of Virginia and West Virginia. To reduce the risk of policy conflicts due to cross-state boundaries, we kept the project site within the boundary of Virginia. With such a large team, analysis goals and projections were defined early on, to ensure that all proceeding work done was valuable and beneficial to the project. To avoid redundancies in research and to conduct such research more efficiently, the team was divided into into our sub-team affiliations. Furthermore, scheduled debriefings of sub-team findings allowed for collective comprehension of research to avoid disproportional understanding of the project.

For a project that involves implementation near populated areas, therein lies a risk of opposition from individuals, collective groups, or entire communities. This made it imperative to reach out to entities outside those that are in joint collaboration of the project in order to inform them of our research and intentions, with the hope of gaining support for our ventures. However, more specific risks arise when considering communities for a project such as this. Varying groups each have their own concerns about the project, whether that be environmental or wildlife effects, or concern for the day-to-day operations of living in the surrounding areas. The risk here entails an inability to address all of the relevant concerns, thus losing community interest and support. To address this, we have conducted several meetings with people concerned about the project, where we took note of their concerns and re-evaluated our efforts to ensure that we addressed their concerns as best as possible.

The collection and analysis of reliable wind data for the site prior to construction is crucial for risk management as the wind data informs the prospective turbines to be selected and placed. For example, a misinterpretation of the wind resource could result in an excess of installations or misinformed expectations of the power production potential of the site. As part of our siting analysis, we recognized that the current wind data from the MET towers on the ridgeline is outdated and the MET towers will need to be re-instrumented to recollect wind data in order to complete an up-to-date analysis of the wind resource on Cow Knob. Similarly, a thorough environmental assessment is needed to understand the potential impacts on existing wildlife, which will subsequently inform mitigation strategies to minimize impact on said species. Wildlife found on the site with a high potential for impact include, but are not limited to, bat, bird, and salamander species.

Identifying and acquiring permits related to siting a wind farm at the local, state, and federal levels is another element necessary for managing risk. The permits require certain criteria to be met, ensuring a limit to the overall impacts made by the development, construction, and operation of a wind farm. Acquiring permits themselves is also a risk associated with a wind project. Difficulty in obtaining permits can impact the length of the development process, increasing cost and influencing the Commercial Operation Date (COD) of the wind farm. Difficulty in getting permitted can also lead to a wind project not getting established at all, thus nullifying the time, money, and effort already made during the development process.

For the Cow Knob site, we have two choices for how to get the power to the grid—each with their own risks. The first, but potentially more expensive choice, is to build a substation to step the power up to 500-kV. This would involve essentially no new power lines but would involve a 500-kV transformer that would cost around $55 million. The second option is to connect to another, lower voltage (~130-kV) power line. This option would have substantially less substation costs but would have additional costs associated with building new transmission lines. We would need to calculate how much new line we would need to build, the cost/unit distance of said line, and the cost for a necessary transformer. Because of the great distance to the closest connectable low voltage line, the 500-kV line that runs through the sites seems like the most viable option, even though there is more risk involved.

Market Opportunity & Constraints

Although there is not widespread wind development in Virginia, this site has the potential to pioneer future wind development opportunities and show that wind development in Virginia can be both marketable and profitable. Currently, one major wind development opportunity that Dominion Energy is pursuing is offshore wind off the southeast coast of Virginia in partnerships with Ørsted. Given that Cow Knob is one of the few onshore sites that has a viable wind resource, in addition to other benefits such as sufficient open space and access to existing transmission lines, there is a definite market opportunity.

Unfortunately, there are also certain market constraints that must be considered which impact the economic viability of this project. On the state level, there is no tax abatement available in Virginia. Additionally, on the federal level, both the Production Tax Credit (PTC) and Investment Tax Credit (ITC) are set to expire in 2020. Although these tax credits may be renewed in the future, it is important to understand that, unless renewed, this site is not likely to be constructed while these credits are available. The 50% bonus depreciation for the Modified Accelerated Cost Recovery System (MACRS) after six years of operation also expires in 2020. The combination of these diminishing tax credits could consequently decrease the economic viability and investors' interest in developing the project.

Finally, other market constraints include who will be the power purchaser. Our primary power purchaser would be local universities with the end goal being these universities not only buy electricity generated by renewable sources, but also have the ability to use the Cow Knob wind farm site as a research center. Given that this sort of Power Purchase Agreement has never been done before, there is risk associated with expecting universities to show interest in this agreement. In the case that our primary target market is not interested in purchasing the power, we would need to evaluate other alternatives.

Evaluation of Alternatives

There are several alternatives that can be evaluated to possibly improve the feasibility of the site. If local industry such as Merck or MillerCoors is willing to offtake the power generated by the farm, then in return they will receive renewable energy credits. Alternatively, the scope of the wind farm itself may be subject to increase in order to produce greater energy output. For example, the current turbine placement model does not include development in National Forest or West Virginia land. However, if we could expand the available area onto these lands where wind resources are equivalent greater, the viability will improve. Another option would be to examine the potential for offshore wind alongside the coast of Virginia. Interest in offshore wind has increased due to the higher wind speeds, larger turbine size, greater efficiency, and accessibility to the grid.

Looking beyond the analysis in this document, Cow Knob does truly provide one of the greatest opportunities for onshore wind development in Virginia. Currently EAPC is working on re-instrumentation of the MET towers and further modeling of the site in order to understand Cow Knob's true potential. Over the course of this two-year analysis of Cow Knob, it is our hope that one day we will see wind turbines on the Cow Knob Ridgeline.

References

"Aging US Wind Energy Fleet Driving Surge in Operating and Maintenance Spending, IHS Markit Says." News.ihsmarkit.com. November 6, 2017. Accessed April 19, 2019. https://news.ihsmarkit.com/press-release/energy/aging-us-wind-energy-fleet-driving-surge-operating-and-maintenance-spending-ihs.

Amadeo, Kimberly. "Federal Reserve Discount Rate." The Balance. April 16, 2019. Accessed April 21, 2019. https://www.thebalance.com/federal-reserve-discount-rate-3305922.

"Business Energy Investment Tax Credit (ITC)." Energy.Gov. Accessed April 19, 2019. https://www.energy.gov/savings/business-energy-investment-tax-credit-itc.

Capital Costs for Transmission and Substations. PDF. Western Electricity Coordinating Council, October 2012. https://www.wecc.org/_layouts/15/WopiFrame.aspx?sourcedoc=/Reliability/1210_BV_WECC_TransCostReport_Final.pdf&action=default&DefaultItemOpen=1.

"Coastal Virginia Offshore Wind." Coastal Virginia Offshore Wind. Accessed April 19, 2019. https://www.dominionenergy.com/company/making-energy/renewable-generation/wind/coastal-virginia-offshore-wind.

"Modified Accelerated Cost-Recovery System (MACRS)." DSIRE. August 21, 2018. Accessed April 19, 2019. http://programs.dsireusa.org/system/program/detail/676.

"Renewable Electricity Production Tax Credit (PTC)." Energy.Gov. Accessed April 19, 2019. https://www.energy.gov/savings/renewable-electricity-production-tax-credit-ptc.

"United States Inflation Rate." United States Inflation Rate. Accessed April 21, 2019. https://tradingeconomics.com/united-states/inflation-cpi.

United States. Department of Mines, Minerals and Energy. Office of the Secretary of Commerce and Trade. *Virginia Energy Plan*. 2018. https://www.governor.virginia.gov/media/governorvirginiagov/secretary-of-commerce-and-trade/2018-Virginia-Energy-Plan.pdf.

Wind O&M. PDF. U.S. Department of Energy, September 3, 2015. https://www.energy.gov/sites/prod/files/2015/09/f26/Wind%20Plant%20O%26M.pdf.

Wind Permit By Rule (PBR) Guidance. PDF. Department of Environmental Quality, July 1, 2017. http://townhall.virginia.gov/L/GetFile.cfm?File=C:%5CTownHall%5Cdocroot%5CGuidanceDocs%5C440%5CGDoc_DEQ_4495_v11.pdf.