THE PENNSYLVANIA STATE UNIVERSITY
WIND ENERGY CLUB

PROJECT DEVELOPMENT TEAM REPORT

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EXECUTIVE SUMMARY

Last year our company, Nittany Lion Consulting (N.L.C), determined that Knob Mountain was a suitable location for a 100 MW wind farm in Spring Run, PA. Our client requested a comprehensive cash flow analysis for the expected life of the project, the Levelized Cost of Energy (LCOE) and Power Purchase Agreement (PPA) price. This included initial capital expenditures, operating expenses, all available incentives and their maximum possible net annual energy production.

We have accomplished this by consulting with industry professionals from NextEra, reading published reports from NREL and the DOE Office of Energy Efficiency and Renewable Energy, implementing IEC certification evaluation procedures and by using two modeling software tools. The Openwind[1] software provided the net annual energy production for three different turbine types. The Alstom ECO 110 Class IIA was chosen as a suitable representative turbine from this analysis, producing a net annual energy output of 316,214,080 kWh, which was used in the financial analysis. The System Advisor Model[2] software (SAM) assisted with the financial analysis of the project. The SAM simulation yielded a PPA price (year 1) of 4.81 ¢ /kWh, an LCOE of 3.90 ¢ /kWh, and an investor NPV over the life of the project of $952,238. These numbers are competitive with the typical prices in the state of Pennsylvania[3] and the project should have no problem attracting a PPA offtaker.

Additionally, since the Three Mile Island nuclear plant will be closing in 2019 and Bruce Mansfield coal plant will be closing in 2021[4,5], there will be available grid capacity in the PJM system. Thus a 100MW wind farm would be able to fulfill some of the lost energy generation from the closing power plant, while providing clean, carbon-free electricity.

SITE DESCRIPTION

The site for which the financial analysis herein is conducted is one finalized after a thorough review of various sites within a 100 mile radius of Pennsylvania State University. The site runs along the ridge of Knob Mountain (shown in Figures 1 and 2) until the edge of Fannett Township in Franklin County and steers clear of all undesirable siting attributes by having:

- ✓ A wind resource of 7±1 m/s
- ✓ An Elevation Greater than 2,000 ft
- ✓ A Length of 10.5 miles, which can support 100 MW of capacity
- ✓ A Continuous Strip of Land
- ✓ Established Road Access
- ✓ Access to 115 kV transmission lines cutting over the ridge, closer than the required 2 miles
- ✓ Minimal Townships Crossed (one)
- ✓ Non-Restrictive Ordinances
- ✓ No Environmentally Sensitive areas
- ✓ No State Game Land

FIGURE 1: THE KNOB MOUNTAIN RIDGE IS CLEAR OF ENVIRONMENTAL (BLUE & PURPLE) AND STATE GAME (ORANGE) LAND AS PER THIS ENVIRONMENTAL REVIEW USING THE PENNSYLVANIA NATURAL DIVERSITY INVENTORY (PNDI)

DESIGN CHANGES

An obstacle of the site chosen in 2018 is that half of the land is owned by the state. Specifically, the land is owned by the Department of Conservation and Natural Resources (DCNR) as a part of Tuscarora State Park. Unlike State Game Land, there are no specific restrictions for developing wind projects on the land, yet no wind projects have been approved on state land to date. However, oil and natural gas projects have likewise been developed on state land in Pennsylvania and the thoroughness of the site evaluation carried out in 2018 make the compelling case for this site. After careful consideration, the siting team chose to continue to pursue the site location at Knob Mountain. The risks of pursuing the project on state land are addressed in the Risk Assessment section.

A new PNDI search was conducted to make sure that there were no new potential impacts to threatened or endangered species at the site since last year. Updates to the database were made in early 2019 to include additional protection for three cave bat species as reported by the Pennsylvania Game Commission[6]. The site remains to be clear of environmental concerns as shown by the updated PNDI review in Figure 1.

SITE LAYOUT

Developed by UL, Openwind[1] is a software tool that has the capability to optimize the layout of wind turbines based on local wind speeds, wind direction, power density, elevation, wake losses, as well as a multitude of other engineering factors. The task optimized the placement of turbines for a 100 MW wind farm that will maximize the amount of annual net energy and achieve a minimum LCOE and PPA for the project.

Three turbine types were tested given wind data at 100 m hub height. In order to meet the criteria of 100 MW, a 3.0 MW turbine would require 34 total turbines and a 2.7 MW turbine would require 37 turbines. These different turbine models were simulated in Openwind to determine the net annual energy and capacity factor produced. Table 1 describes the differentiating characteristics of these three turbine models.

TABLE 1: CHARACTERISTICS OF VETTED OPENWIND BUILT-IN TURBINE MODELS

Turbines Chosen for Layout Optimization	IEC Wind Class	Swept Dia-meter	Rated Capacity	Hub Height	Cut-In Wind Speed	Cut-Out Wind Speed	Total No. Of Rotors
Name of Model	*I, II, III*	*m*	*kW*	*m*	*m/s*	*m/s*	*Turbines*
Alstom ECO 100, 3.0	IA	100	3000	100	3	25	34
Alstom ECO 110, 3.0	IIA	110	3000	100	3	25	34
Alstom ECO 122, 2.7	IIIA	122	2700	100	3	25	37

The team considered adding more models to Openwind to analyze additional turbines; however, Openwind requires detailed performance characteristics of a turbine which we were not able to obtain. We felt the options available were a good representation of the range which would give us an idea of what IEC class would be best for the site and what capacity factor could be expected incorporating wake effects and other standard losses.

Wind resource data from the Spring Run, PA area was obtained from UL at an elevation of 100 m. In order to simplify the wind project permitting approval process, all turbines were kept within the Fannett Township boundary. In order to reduce the wake effect and optimize the capacity factor, annual net energy output, and the annual gross energy output, an elliptical turbine separation distance of eight rotor diameters was selected in the downwind orientation and three rotor diameters for those turbines lined up with the dominant wind direction of 290°. The terrain gradient was also restricted such that turbines would not be placed on slopes greater than 10°. Table 2 displays the Openwind simulation results for the three separate turbines.

TABLE 2: PERFORMANCE OF THREE TURBINE OPTIONS IN OPENWIND

Optimized Turbines	Total No. of Rotors	Total Rated Power	Capacity Factor	Annual Net Energy Output	Annual Gross Energy Output
Rated Power, Class	Turbines	MW	%	GWh	GWh
3MW, Class IA	34	102	33.23	297.21	306.44
3MW, Class IIA	34	102	35.48	317.26	328.24
2.7MW, Class IIIA	37	99.9	42	367.81	379.07

When choosing an optimal turbine, several characteristics need to be analyzed. One of the more significant factors is the annual mean wind speed (AMWS) at the turbine location. If the AMWS experienced at the site is higher than that of the certified standard, the turbine may not be an acceptable option. Another significant factor is the reference wind speed (V_{ref}) and characteristic turbulence intensity (I_{15}) at 15 m/s. The V_{ref} from Openwind needs to be below the value in the IEC standard in order for the turbine to be in compliance with the regulations. Flow inclination angle was taken into account as well as the annual average air density at the site. Displayed in Table 3 is an analysis of meeting IEC certification standards.

TABLE 3: AVOIDING FATIGUE BY CHOOSING OPTIMAL TURBINE CLASS FOR SITE

Fatigue-Related Characteristics	I A Standard	I A Layout Site Specs.	I IA Standard	II A Layout Site Specs.	III A Standard	III A Layout Site Specs.
Flow Inclination Angle [°]	**Below** 8	0-5.28	**Below** 8	0-5.50	**Below** 8	0-6.26
Annual Average Air Density [kg/m³]	**Below** 1.225	1.150	**Below** 1.225	1.152	**Below** 1.225	1.153
Weibull Shape Factor	**Above** 2	2.4	**Above** 2	2.4	**Above** 2	2.4
I_{15} [%]	**Below** 16	10.82	**Below** 16	10.72	**Below** 16	10.58
V_{ref} [m/s]	**Below** 50	30.7	**Below** 42.5	37	**Below** 37	30
AMWS, V_{ave} [m/s]	**Below** 10	6.08-7.93	**Below** 8.5	5.65-7.93	**Below** 7.5	5.86-7.91

The team chose the Alstom ECO 110 3.0 Class II A turbine. Although the Alstom ECO 122 turbine had the highest capacity factor, annual net energy output, and annual gross energy output, it did not pass all of the characteristic tests. In addition, the number of turbines would increase and the longer blade length would pose as a challenge for construction in the mountainous terrain. The Alstom ECO 100 3.0 Class IA and the Alstom ECO 110 3.0 Class IIA all successfully meet the characterization requirements. Comparing their energy outputs, the class IIA turbine yielded a higher energy output and therefore this turbine would be most optimal for the project. Depicted in Figure 2, the Openwind optimized layout of the Alstom ECO 110 turbine is presented along with a wind rose representative of this area.

FIGURE 2: OPENWIND OPTIMIZED LAYOUT OF THE ALSTOM ECO 110 IEC IIA TURBINE

FINANCIAL ANALYSIS

This section was informed by input from industry professionals at NextEra, the System Advisor Model from NREL and published studies by both NREL and the DOE.

MODELLING TOOL ALIGNMENT

Although the Alstom ECO 110 3.0 Class IIA was selected as an optimal wind turbine, this model is no longer available since GE purchased Alstom in 2015. Furthermore, a financial analysis was conducted on the Senvion 3.0 MW 122 turbine to emulate the Alstom model in SAM. In the SAM, a financial analysis was simulated using the same parameters used in Openwind. This included replicating the capacity factor of 35.4%, a 34 turbine layout at an evaluated 100 m hub height, turbine spacing of 3 rotor diameters, and a 290° orientation facing the incoming wind.

PROJECT COSTS

The ballpark turbine costs were estimated based on average costs derived from the 2017 Wind Technologies Market Report (WTMR)[3]. The WTMR reported average total installed costs of $1,600/kW for a 100 MW project in 2017 and in this was also consistent with average installed costs in the Great Lakes region[3]. The range of prices for the turbine itself (rotor, nacelle, tower and delivery) are given by the WTMR in the range of $750/kW - $950/kW [3]. With a trend in declining prices, and additional research by the team, a turbine cost of $775/kW was determined to be a reasonable estimate.

Subtracting $775/kW from $1,600/kW, leaves a balance of system (BOS) cost of $825/kW. Multiplying the turbine cost and BOS cost by 102,000 kW, the total turbine cost and BOS equated to $79.05M and $84.150M, respectively. Summing both these costs together, the total installed cost comes to $163.2m. The capital expenditure in year 0 for the entire project is $175,823,312. The remaining difference between the total installed cost and the cap ex is accounted for by the various financing costs, as described in Figure 3.

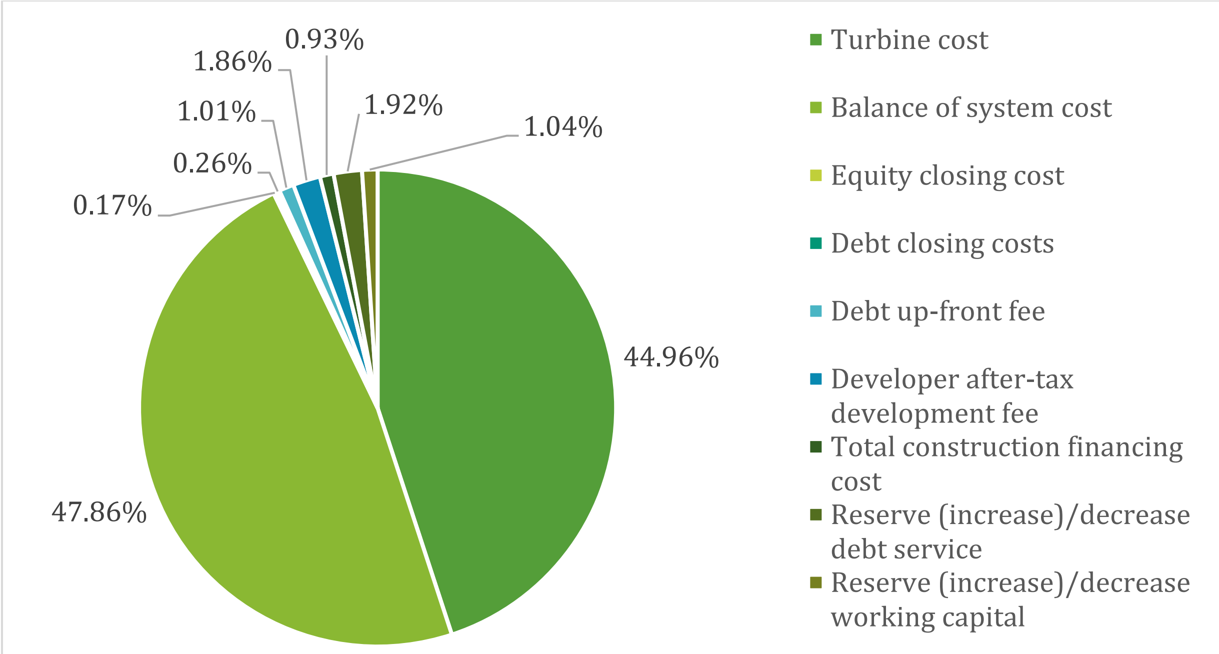

FIGURE 3: BREAKDOWN OF NET CAPITAL EXPENDITURES TOTALING $175,823,308

Figure 4 includes a further breakdown of the balance of system costs.

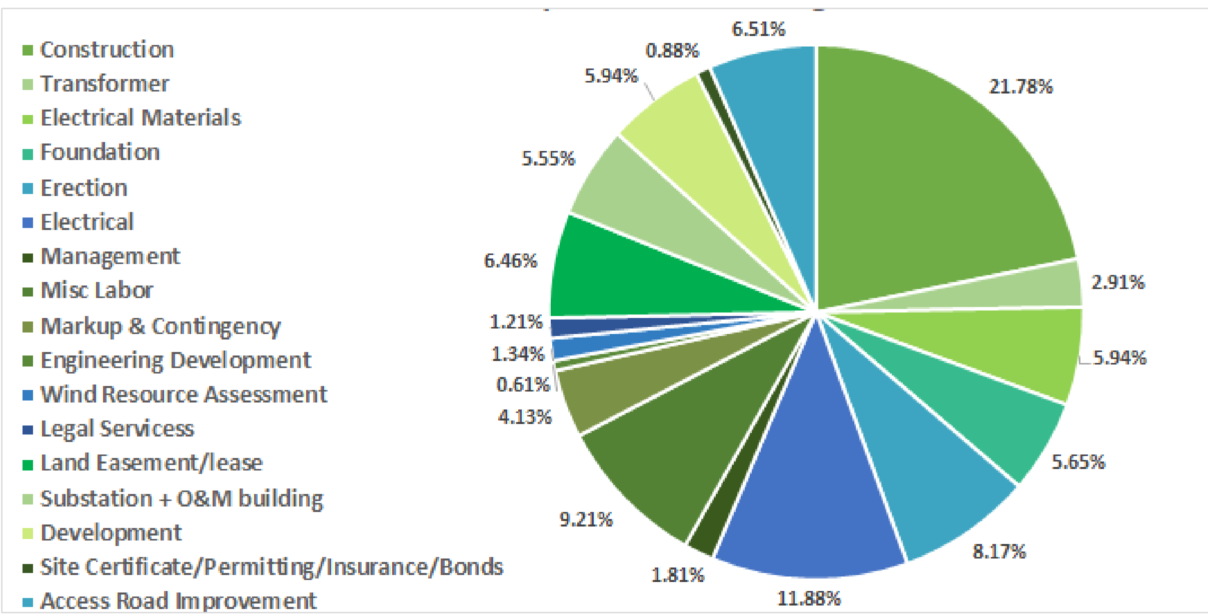

FIGURE 4: BREAKDOWN OF BALANCE OF SYSTEM COSTS TOTALING $84,150,000

Several sources informed the BOS costs, including the textbook by Jain[7], the BOS calculator in System Advisor Model[2], the road construction calculations in Openwind, and NREL's Cost of Wind Energy Review[8]. The outdated costs were compared to current values from the WTMR and the were then adjusted to model the observed decrease in cost over the past few years. The costs simulated directly through SAM were a low estimate of the actual BOS costs, so the team modified them to accurately depict typical costs in the region.

Costs estimated from Jain[7] include:

Material Costs (per turbine)

- Construction $546,000
- Transformer $72,000
- Electrical $147,059

Legal Services $30,000/turbine

Contingency &Markup $102,275/turbine

Labor Costs (per turbine)

- Foundation $139,936
- Erection $202,196
- Electrical $294,118
- Management $44,896
- Miscellaneous $228,000

Costs estimated from the BOS calculator in System Advisor Model include:

- Wind Resource Assessment $1,130,400
- Substation and O&M Building $4,667,300
- Development Costs $5,000.000
- Site Certification/Permits/Insurance/Bonds $738,463
- Project Management costs $$1,526,480
- Engineering Cost $494,084

Land Easement/Lease costs were estimated at $8,000/turbine/yr[9].

INCENTIVES

The project is planning to use turbines purchased in 2016 by the project developer to achieve 5% of the total installed cost of the project, thus constituting safe harbor for the purposes of being eligible for the PTC in 2016 at a full rate of $0.024/kWh for a term of 10 years escalated at 2.50%/year. This project must be built by the end of 2020 in order to use the safe harbored turbines on this project.

The project will also be taking advantage of the ability to use 100% bonus depreciation in the first year of the project. Pennsylvania has an Alternative Energy Portfolio Standard (AEPS) which on average could provide another $10.15/MWh incentive for the project based on average rates from 2017[10]. This was not included in the financial simulation as the value of the Renewable Energy Credits are highly volatile and the developers are waiting to lock in at a good rate for purchase of these RECs. This will be discussed more in the Market Opportunities and Constraints Section.

OWNERSHIP STRUCTURE

The project will be financed as a partnership flip with a third-party equity partner with debt. The equity partner allows the project to take advantage of the 100% bonus deprecation incentive and thus they can get their investment back relatively quickly. Borrowing part of the project via debt, allows the project to keep the overall financing costs down as debt is generally much cheaper to borrow than the return which equity investors expect. That said, a high ratio of debt borrowed on a project is not realistic, as the banks will have a minimum Debt Service Coverage Ratio requirement.

The intent is to define a PPA price to sell the resulting electricity to a utility or a large corporation or University. As equity partners and loan rates were sought, the team conducted a parametric analysis on IRR rates as well as debt service coverage ratios (DSCR) to help potential investors and banks make decisions about the project.

Table 4 shows how the real LCOE, first year PPA and Investor NPV vary with changing the IRR from 9 to 12% with a target of year 9 for this return. A DSCR of 1.3 was chosen for this analysis. This project was fortunate to find an equity partner willing to invest for an IRR of 9%.

TABLE 4: IRR PARAMETRIC ANALYSIS

IRR Value		9%	10%	11%	12%
PPA Price (Year 1)	₵/kWh	4.81	4.91	5	5.09
Levelized COE (Real)	₵/kWh	3.90	3.90	3.90	3.89
Investor NPV over Project Life	$	952,238	3,385,802	6,822,747	9,171,701

Table 5 shows the real LCOE, first year PPA and Investor NPV for a range DSCRs from 1.2 - 1.5 to account for different bank requirements. Ultimately, this project was able to secure a loan at a rate of 5% with a DSCR of 1.3.

TABLE 5: DSCR PARAMETRIC ANALYSIS

DSCR Value		1.2	1.3	1.4	1.5
PPA Price (Year 1)	₵/kWh	4.69	4.81	4.94	5.05
Levelized COE (Real)	₵/kWh	3.84	3.90	3.96	4.01
Investor NPV over Project Life	$	772,198	952,238	1,119,382	1,274,999

The financial parameters section of the analysis incorporates the target IRR of 9% and the various tax and insurance rates. The project is to be analyzed over a 20 year period with an inflation rate of 2.5%/year with a real discount rate of 6.4%/year. We incorporated a 21%/year federal income tax rate and state sales tax of 6%.

FINANCIAL RESULTS CONCLUSION

TABLE 6: SUMMARY OF FINANCIAL RESULTS

Metric	Value
Annual Energy (Year 1)	316,214,080 kWh
Capacity Factor(Year 1)	35.40%
PPA Price (Year 1)	4.81
Levelized COE (Real)	3.90
Investor IRR(Year 9)	9%
Investor NPV Over Project Life	$952,238
Developer NPV Over Project Life	$12,624,769
Net Capital Cost	$175,823,312
Equity	49.67%
Debt	50.33%

There are a few key takeaways in the results of the SAM simulation analysis. These are summarized in Table 6. The PPA price, LCOE and investor NPV were the three most important results of the simulation. In order for our project to be considered competitive in the industry, and therefore viable, these three numbers had to fall within certain ranges. The NPV for the Investor and the Developer also needed to be positive. The DSCR of 1.3 determined the relative split of Debt and Equity, which was fairly close to 50/50. The resulting After-Tax Cash Flow for the project, the Equity Investor, as well as the Developer can be seen in Figure 5.

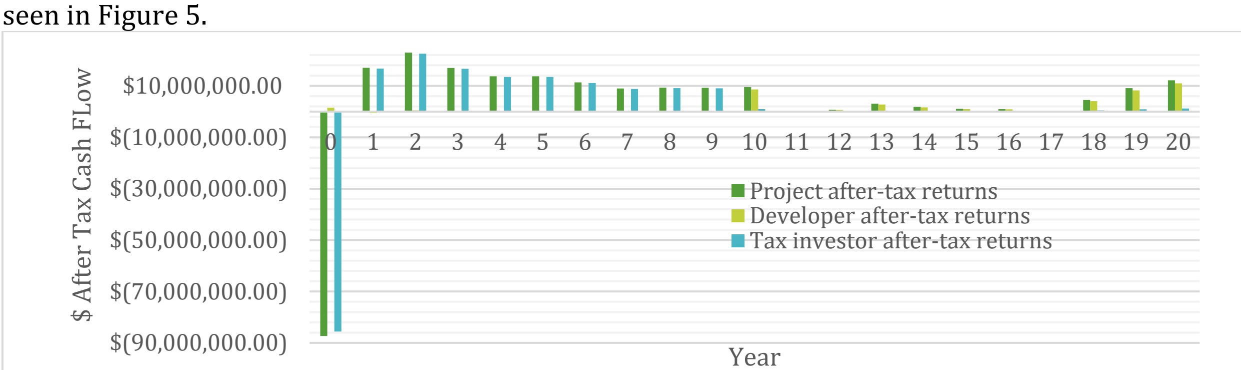

FIGURE 5: PROJECT AFTER-TAX CASH FLOW

MARKET OPPORTUNITIES & CONSTRAINTS

The team primarily wanted to focus on the PPA prices to determine whether or not the project financial analysis fell within the averages of typical developments within the Northeast/Great Lakes region.

According to the 2017 Wind Technologies Market Report [3 fig.52] looking at the average PPA price for the Great Lakes region, which is a better fit for price comparison based on recent history for this scale of project and still in the same PJM market as our project, the average is around $35/MWh. It is much higher for the Northeast at $70/MWh, however generally smaller projects have been developed in this region over the last few years. The industry wholesale electricity prices in 2017 were ranging from $16/MWh to $38/MWh (10th percentile to 90th percentile) [3 fig 51].

The Pennsylvania Alternative Portfolio Standards (AEPS) provides an additional revenue stream for this project. Values for RECs have varied quite a bit over the last couple of years, but they averaged $10.15/MWh in 2017[10]. This would bring an additional $0.0115/kWh value to the project.

There are many large companies and Universities in the market for Renewable Energy in Pennsylvania and the PJM region, such as Penn State, which just announced a 70 MW collaboration with BP on an offsite solar project in the same county (Franklin) as this proposed wind project[11]. The project could also be of interest through a virtual PPA to the many data centers in Northern Virginia.

Overall, the team feels the $0.0481/kWh PPA price, with potential to have value at $0.03795/kWh or lower with the sale of RECs, is a competitive venture in the PJM market as many companies look toward a more carbon neutral future.

RISK ASSESSMENT

ROAD ACCESS

The current road to reach the top of Knob Mountain through the Tuscarora State Forest raised some concerns because there are several tight turns and bends in the road. This would make travel for construction vehicles impossible so we had to come up with a solution. We planned on building on the existing road to increase the width however this was cost prohibitive.

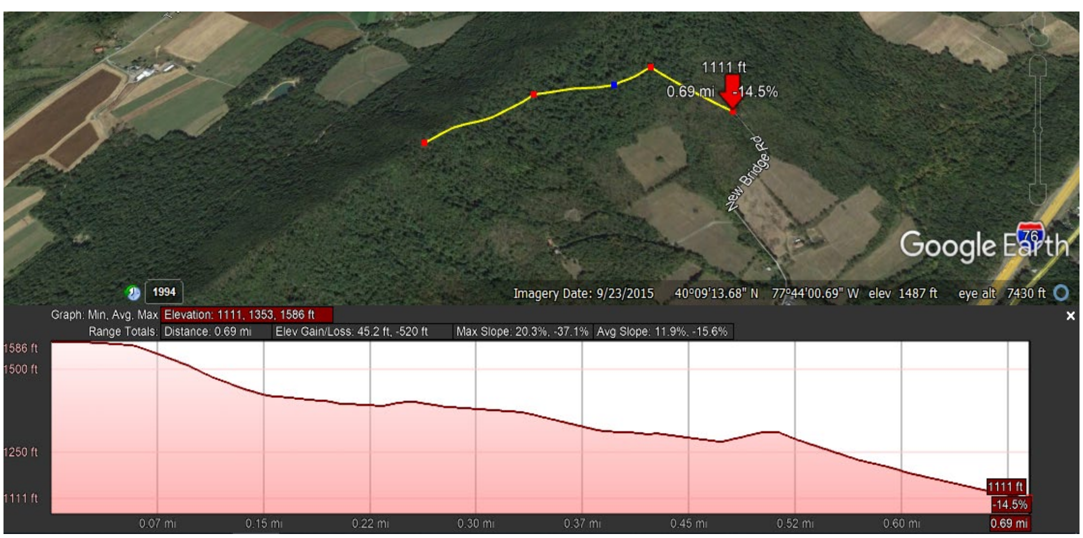

FIGURE 6: OPTIMAL ROAD OPTION

Our team decided we would have to create our own road that was under a 30° slope to get to the top of the mountain. With Google Earth Pro[12] we were able to create road options which helped inform us about the maximum attainable slope. In Figure 6 you can see the option chosen to reach the top of the mountain. This was an ideal situation as it built off a partially existing road and also switchbacks were not required in this region to stay below the max slope requirement, thus reducing the overall length of the new road required.

TRANSMISSION

The capacity of the transmission line the project has direct access to on the mountain is 115 kV. A higher voltage would be more desirable for a 100 MW project, however, upcoming nuclear and coal-fired closures in the area will free up capacity on these lines, thus making them suitable for the project.

The nuclear power plant, Three Mile Island, located in Harrisburg PA, will be closing as of 2019. According to the owner Exelon Corp, the power plant has not been competitively profitable over the past 5 years[13]. Unit 1 in Three Mile Island generates 837 MW of zero-emissions energy, enough carbon-free energy to provide electricity to 800,000 homes[4]. Not only is Three Mile Island closing but the Bruce Mansfield power plant in Beaver County Pennsylvania will also be closing as of June 2021[5]. The coal-fired plant provides 983 MW of electricity annually, thus at least a total of 1820 MW will need to be produced in order to meet market demand[5]. As a result, the added availability within the PJM transmission lines will allow this project's electricity output to use the added capacity on this line.

STATE PARKS

On Knob Mountain, half of the proposed land is on a state park (DCNR land). As stated before, while there are no laws against building a wind farm on this land, no wind farm has been approved doing so yet. Although this is a risk, we believe there are many points that can be made in favor of getting the project approved. In the DCNR mission statement[14] it states that their mission "is to maintain, improve and preserve state parks; to manage state forest lands, to assure their long-term health, sustainability and economic use." From this we believe that a case can be made to move forward with the project because it would both (1) help assure sustainability and (2) assist with economic growth. We also believe that constructing this project on state park land is likely because the DCNR is part of the U.S Green Building Council[15], and as such advocates for an increase in renewables. Their commitment to renewables and sustainability decreases the risk of unprecedented development.

CONCLUSION

This wind energy project in Spring Run, PA built in 2019 generated an IRR at the end of the project of 9.37%. The annual capacity factor found from Openwind was 316,214,080 kWh with an investor footing expecting a 9% return. LCOE of 3.90₵/kWh with a PPA price for year 1 of 4.81₵/kWh. Each one of these figures has been determined both competitive and viable in the Northeast/Great Lakes regions.

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