Lafayette County Energy Center

WiscWind

University of Wisconsin-Madison

U.S. Department of Energy Collegiate Wind Competition 2019

Siting and Project Development Challenge

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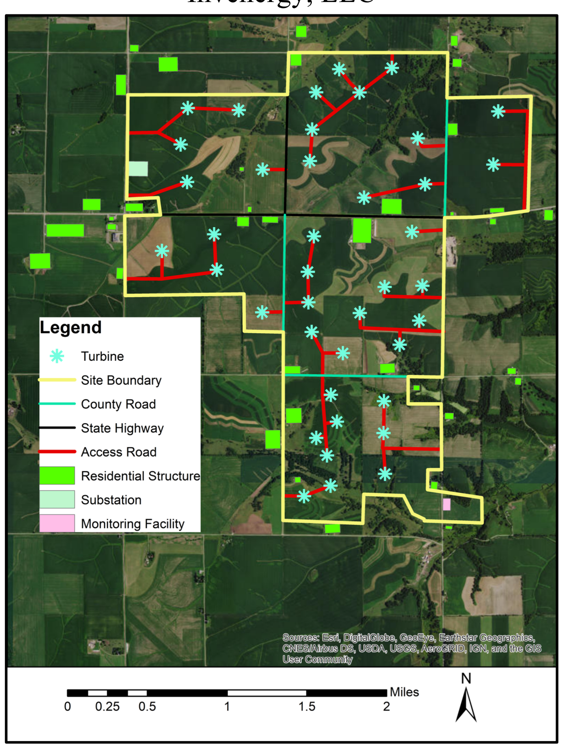

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Introduction

This report will provide a brief description of our 2018 Collegiate Wind Competition site and the changes made to the original design, followed by a detailed financial analysis of the proposed Lafayette County Energy Center in Gratiot, Wisconsin. The report will recognize project financial risks and determine the economic feasibility of the proposed wind farm.

Site Description

The Lafayette County Energy Center is located in the southwestern Wisconsin town of Gratiot. The 2900-acre agricultural site involves lease agreements with eight different property owners. One of the deciding factors for the selection of this location is the strong wind resource. At a height of 94m, the average annual wind speed on site is anticipated to be 7.0 m/s, one of the windiest locations in Wisconsin.

In the 2018 design, 39 GE 2.5-116 turbines were chosen amounting to a total nameplate capacity of 97.5 MW. These turbines have a rotor diameter of 116m and a hub height of 94m. The choice to operate below 100 MW was made to avoid state regulations in Wisconsin that would add additional regulatory filings to the development process. Upon consideration of redesign for this year's competition, our analysis determined the energy production could be increased with a new turbine. The GE 2.5-127 with a rotor diameter of 127m and hub height of 89m is estimated to increase the net annual energy production of the facility from 276 GWh to 299 GWh. This decision was justified because it sustains the goal to use American-made and locally manufactured GE wind turbines, and will not require a layout change because the setback distances will be altered minimally by a maximum tip height increase of 2.5 meters.

Annual Energy Production

With the on-site wind resource, the 39 GE 2.5-127 wind turbines are expected to produce on average 1056 kW each, amounting to a gross annual energy output of 360.8 GWh. However, it is expected that the wind farm will experience energy losses from the gross energy production at the turbines. These losses arise from the factors listed below:

- **Wake Effects** 5.0% (reduced wind resource for a turbine in the wake of another turbine)
- **Availability** 5.5% (availability of the grid, wind turbines, and balance of plant)
- **Electrical Efficiency** 2.5% (energy transmission losses in collection lines, transformers, etc.)
- **Turbine Performance** 3.5% (wind turbine underperformance, nonstandard wind conditions)
- **Environmental** 0.4% (icing, blade and equipment degradation, environmental shutdown)
- **Curtailments** 0.1% (grid limitations, environmental or permitting requirements)

These losses are estimated based on data from similar wind farms in the Midwestern U.S. and site specific elements. With a total anticipated energy loss of 17%, the wind turbines are projected to perform at a net capacity factor of 42.24% and produce 299.4 GWh annually.

Initial Capital Cost

Taking into consideration all design changes, an initial capital investment of about $164,400,000 will be required to construct the wind farm. This initial capital investment includes the purchasing of all turbine components and equipment needed for the balance of plant (BOP) features, as well as the cost of construction and installation. A breakdown of these costs by project component is displayed in Table 2 in the Appendix. These estimates are based on of the findings in the 2017 report, “Cost and Wind Energy Review”, by the U.S. National Renewable Energy Laboratory [1].

A majority of the capital expenses are from the purchase of the 39 wind turbines. The assembly of each turbine requires the purchase of multiple components, including: the rotor module (blades, pitch control, hub), nacelle module (generator, gear drivetrain, yaw control, etc.), and the tower sections. The estimated cost for each GE 2.5-127 wind turbine is about $2,800,000. With a design consisting of 39 turbines, the total turbine cost is estimated to be about $109,500,000.

The remainder of the initial capital expense is comprised of civil BOP, electrical BOP, and other costs associated with construction. The electrical BOP sector is expected to be the most expensive of the remaining group with an estimated cost of $18,300,000. Electrical BOP consists of all equipment and materials needed for features in the electrical infrastructure of the wind farm including the following: a below ground collection system connected to each turbine, interconnection to the substation, substation installation, and high voltage transmission line tie-in. The civil BOP includes the materials and equipment needed to construct the civil infrastructure on-site. This consists of: below-grade gravity based foundations for all 39 wind turbines, site access roads for transportation to the wind turbines, crane pads, crane walks, assembly areas, staging areas for turbine equipment deliveries, and any necessary improvements to existing roads and intersections. The total projected civil BOP cost is about $11,300,000. Lastly, all activities associated with the construction crews include: crew labor and equipment costs (i.e. cranes, etc.) for assembling and installing the wind turbines, labor costs involved in constructing the various BOP features, development costs (bidding, mobilization, overhead, engineering), and engineering management (project managers, inspection, etc.). With each of these components taken into consideration, the total for all labor and contracting is estimated at $8,600,000.

Annual Operating Expenses

The total annual expense of operating the Lafayette County Energy Center is estimated to be about $3,800,000 per year. The majority of this expense is incurred through fixed and variable operations and maintenance (O&M) costs, with an additional expense associated with land lease payments. These expenses are estimated from the 2017 report, “Cost and Wind Energy Review”, by the U.S. National Renewable Energy Laboratory [1]. O&M expenses are expected to fluctuate over the life of the wind farm with the variability of O&M issues, but are modeled as equal annual costs.

The fixed O&M expenses include administration, insurance, and scheduled maintenance. Four wind turbine technicians will be employed on-site with an annual salary of $55,000 each, as well as the wind farm manager who will earn an estimated salary of $80,000. Insurance is typically offered on a wind farm to cover builder’s risk, property and operations [2]. Generally, insurance can account for roughly 10% of the total annual operating expense. Scheduled maintenance covers the costs of general turbine repair: turbine spare parts, repair tools, lubrication, oil changes, bolt tightening, blade and gearbox inspections, as well as the balance of plant maintenance associated with the O&M building, snow removal on roads, vegetation control around each turbine base, and transmission line maintenance. Variable operation and maintenance costs arise with unscheduled maintenance and replacement parts. As the wind farm ages, the amount of maintenance and need for replacements could possibly increase due to component wear and tear. However, the annual variable O&M expense is modeled as an equal annual amount because the exact values for each year are unpredictable.

The total annual lease payment is estimated to be about $250,000 per year; a split payment to the eight landowners with whom lease agreements were established. Each landowner will be paid $3,500 per installed turbine on their land and a royalty of 1% of the total revenue ($11,000,000) from gross energy production will be divided among all landowners. Other property expenses are associated with the upkeep and utility payments for the on-site maintenance building. A small annual expense will be allocated for environmental assessments as they are needed. For example, the city council of a southern Wisconsin town, Beloit, requested that studies be completed to assess the impact of a new wind farm on the bird population.

Financing

Wind energy financing is typically comprised of three main capital sources: tax equity, sponsor equity, and debt. The wind farm in Lafayette County, WI will be financed through a construction loan, as well as sponsor equity. The construction loan will have generally lower risk and lower return than the other sources of equity. A debt capital provider will benefit from financing protections such as contractually-fixed payment schedules, access to collateral, and rights to assume control of a defaulting company if necessary [6]. Construction debt is primarily used to fund the design, engineering, equipment procurement, and construction of a wind farm [6]. The sponsor equity will come from our development firm, and we will manage the long-run functioning of the project, including providing O&M services. Sponsor equity is typically the ultimate "financial backstop" in a project and is the last entity to receive payment from project income [6]. This wind farm will be a single-owner project with the development, finance, and operations completed by our firm. This eliminates the requirement for third-party tax equity, which is having a diminishing role in wind farm financing due to the PTC and ITC phase-out, and allows smaller transaction costs for setting up the financial structure of the project than doing so with an outside entity [6]. It is the simplest financial structure, and keeps the project and its assets within our control.

The construction loan for this project was sized using the annual cash flow available for debt service (CFADs) which includes the earnings before interest, taxes, depreciation and amortization (EBITDA) reduced by the debt service coverage ratio (DSCR). This ratio is calculated by dividing the project net income by the total debt service. The construction loan was calculated to be $72.5 million, with the remaining project cost being covered by the development firm's available equity. All elements of the project pro forma were calculated using a reasonable discount rate of 8%.

Using a feasible power purchase agreement (PPA) price for the Wisconsin area of $37/MWh and an annual energy production (AEP) of 299.4 GWh, the wind farm is expected to earn over $11,000,000 per year. In addition to energy generation revenue, the wind farm will also receive tax incentives from the production tax credit (PTC) and depreciation tax offsets through the Modified Accelerated Cost Recovery System (MACRS). The PTC is a tax credit administered by the U.S. Internal Revenue Service (IRS) to eligible renewable energy producers. The duration of the tax credit is 10 years. As part of the PTC phase out, the credit steps down by 20% every year, so producers can qualify for 80% in 2017, 60% in 2018, and 40% in 2019 [4]. In order to calculate the credit for any given year, the IRS releases an inflation adjustment factor for each year that is multiplied to the original 1993 credit. The credit value for energy production with construction beginning in 2019 is $0.01/kWh, so the wind farm is expected to earn around $3,000,000 in tax credits annually, increasing slightly with inflation over 10 years. Using the 5-year MACRS schedule, the wind farm will have large tax benefits in the beginning years of the project which boost the financial attractiveness.

The annual revenue from wind energy production will be taxed by the state and federal government at an effective tax rate of 27.24% (7.9% state, 21% federal). The taxable income includes the wind farm revenue less the annual operating expenses, depreciation, and interest on the construction loan. From these tax deductions, there are anticipated tax benefits in the first 5 years of operation, with the subsequent 15 years being tax liabilities. Furthermore, property tax payments must be made to participating landowners in the project, and can often be the largest long-term financial contribution from a wind generation project to the local community [7]. This value is project specific and can vary greatly between sites, so an exact value for this property tax contribution has not been determined.

Wind farms must also be covered by "cradle-to-grave" insurance that includes physical damage and time delay exposures [8]. Transit physical damage coverage is in effect when the turbine components are shipped to the site, and construction risk coverage coincides with commencement of the work on site [8]. The operating risk policy begins on the commercial operation date (COD). Time delay exposure protection insures against lost power production due to transit delays and construction delays, as well as operational revenue losses from any PTC or renewable energy incentive payments [8].

Based on the project size, the anticipated financial costs include construction financing costs as well as contingency funds for unforeseen problems with the wind farm, and will be about $15,700,000 estimated from the NREL 2017 Cost of Wind Energy Review. The overall project net present value (NPV) is -$27,000,000, at an internal rate of return (IRR) of -2.8%, so it is anticipated that the project will lose money in the long run. Figure 1 in the Appendix shows an overview of the project cash flow for the Lafayette County Energy Center.

An economic measure that can be used to gain an understanding of a power plant's cost competitiveness is the Levelized Cost of Electricity (LCOE). In simple terms, the LCOE is the total estimated cost of building and operating the power plant divided by the plant's total estimated electricity generation over the project's lifetime. This measure is typically reported in units of $/kWh or $/MWh. To estimate the economic competitiveness of the Lafayette County Energy Center, the project's LCOE was calculated using NREL's simplified LCOE formula. This is calculated by summing all of the project's costs over its lifetime while discounting those values to account for the time-value of money, and dividing it by the total estimated electricity production of the wind farm, also discounted over time. This calculation results in a LCOE of $68.66/MWh (or ¢6.87/kWh). This result falls within Open EI's range of average LCOE values for onshore wind farms in the United States, between $40/MWh and $80/MWh, and resides closely to the median value of $70/MWh [10]. These results were presumed as the site's wind resource in Wisconsin is average when compared to the rest of the United States.

Project Risk and Mitigation

Utility scale wind projects are expensive, complex infrastructure assets. The decision to invest in a wind energy project is influenced by future expectations for the project that can have some uncertainty. Financial ratings agencies, industry analysts, and investors recognize a few major areas of risk [6]. They are detailed below.

Table 1. This table explains the anticipated project financing risks for a wind farm [6].

Risk	**Description**
Pre-Construction Energy Estimate Risk	This is associated with the accuracy of the forecasted annual energy production. Production is a key factor in determining investment sizing, viability, and profitability of a wind farm.
Project Development Risk	This reflects the uncertainty of a project reaching commercial operations and energy generation. Lack of transmission access, wind resource uncertainty, and unfavorable market dynamics are common issues.
Regulatory Risk	This arises from the inability to predict if regulatory schemes supporting wind energy development will still be available for the project. Tax incentives, for example, provide a project revenue source but are only valuable if considered secure by the project investor.
Construction Risk	This is a low complexity risk based on the industry's history of successful construction of land-based projects. Construction is typically completed with a fixed-price contract that has built-in protection for the investors.
Market or Selling Price Risk	This encompasses the extent to which the source of revenue for the project is subject to an unknown selling price. A project with a guaranteed price over the entire lifetime has less uncertainty and perceived risk compared to a project with market price exposure.
Technology and Energy Production Risk	This refers to reduced energy production and therefore diminished electricity sales. Factors influencing this include project availability, curtailment, technology reliability, weather anomalies, and unexpected O&M events.

Many of these risks can be mitigated through the use of state-of-the-art technology to ensure the most accurate analyses, proper maintenance to improve project equipment quality, as well as through strong relationships with all companies involved to reduce uncertainty and thereby limit risk associated with the project.

Project Feasibility - Economic and Technology Development

As the negative NPV and IRR of the project indicate, the wind farm is projected to lose money long term. These estimates use reasonable PPA price for the area of $37/MWh. There are a few developments that could make the project financially viable long term, including incentives, technology progression, electricity market changes, and repowering of the wind farm past the expected life.

Wind Energy Financial Incentives

The project financial model uses the qualifying PTC price of $0.01/kWh. The anticipated start of construction is in 2019, so this value corresponds with the federal government's PTC phase out. With this PTC scenario, the wind farm would need to receive an agreement for a PPA price of $46.44/MWh to achieve a Net Present Value (NPV) of zero and become a breakeven project in 20 years. However, if the federal government were to restore the PTC to its original value of $0.023/kWh from before the phase-out began, the PPA price needed to achieve a NPV of zero falls to a much more reasonable value of $37.39/MWh. This portrays the positive financial impact federal incentives can have on a wind farm project, especially when located in an area with an average wind resource, such as Wisconsin.

Cost-Effective Electricity Storage

One of the main constraints on the electricity market today is the time dependent rate of use. Because electricity can not currently be stored economically on large scales, electricity must be consumed as soon as it is produced. If there is excess generation and no end users consume it, that excess electricity is essentially lost to the grid. The emergence of cost-effective large scale electricity storage could provide significant benefits to wind energy in the future, both technologically and financially. If a wind farm is equipped with a large scale battery storage system, it can more efficiently manage the on-peak/off-peak loads and intermittency of generation from the wind turbines. For example, when the wind is blowing strong on site during off-peak electricity pricing hours, the wind farm could allocate some of its current generation towards charging the batteries. Instead of being lost to the grid as part of over-generation or sold at a lower price, the electricity can be "saved" for a later time where the wind may not be blowing as strong or the grid is experiencing peak demand with higher prices per kWh. By managing a storage system in this manner, a wind farm can benefit from the opportunity to supply electricity to the grid at a more constant rate and experience higher price margins for the utility by taking advantage of peak pricing. This technology would help increase a wind farms revenue by influencing higher PPA prices and help to curb the negative effects of the intermittent nature of wind energy.

Reduce Government Funding for Fossil Fuels

Tax incentives and subsidies for the U.S. coal, oil, and gas industries have been around for years with some dating back over a century. According to researchers at Oil Change International (OCI), the U.S. government provides $20.5 billion annually in corporate welfare to the fossil fuel industry [9]. That mark is nearly seven times higher than the government assistance awarded to renewables. At current operating costs and electricity rates, 72% of operating coal plants would go under without funding assistance [9]. Reducing these subsidies would cause the marginal cost of fossil fuel electricity sources to increase, raising sale prices to maintain profitability and pushing a natural market shift towards financially viable renewables.

Post Life Opportunity

At the end of the 20-year operating period, there are two main options for the future of the wind farm: repowering of the turbines, and repurposing of the land. This decision depends on land lease agreements, PPAs, and the economic feasibility of each pathway [6]. Depending on the advancement of technology by 2039, retrofitting the turbines with new generators or blades could be a possibility. This would help maintain the flow of income for the project, and could make the project more financially attractive. The newer generators will most likely produce more power based on the wind energy industry trend, but could have different sizes or weights. Studies will need to be conducted to determine whether the existing electric cables could handle the new power, and if the steel tower and concrete foundation could withstand the decades of additional forces. The substation would also need to be re-evaluated and possibly redesigned if the amount of energy produced will increase.

The second alternative could be to repurpose the site and return it to the original agricultural land. This would require extensive recycling and repurposing of materials, including the steel towers, composite blades, electric cabling, and other components. There is potential for innovative solutions to seemingly unrecyclable materials like the wind turbine blades. Currently, Germany maintains the world's only industrial-scale factory for reprocessing wind turbine blades. The facility chops old blades up into chunks but then shreds and hammers them into fragments which are mixed in with other wet waste material and used as fuel at a cement-making factory [5]. Blades could also be repurposed and sold for use on other wind farms. There is no perfect solution to this issue, but eliminating landfill waste is a step in the right direction.

Financial Conclusion

Overall, the Lafayette County Wind Farm is not anticipated to be an economically viable project with the current state of the industry, but could prove successful if changes to incentives, technology, or the market make the project more attractive. As the PTC is phasing out, the implementation of new policies to benefit the industry could continue to drive the wind energy industry forward, and bring more renewable energy production to Wisconsin and the entire United States.

Appendix

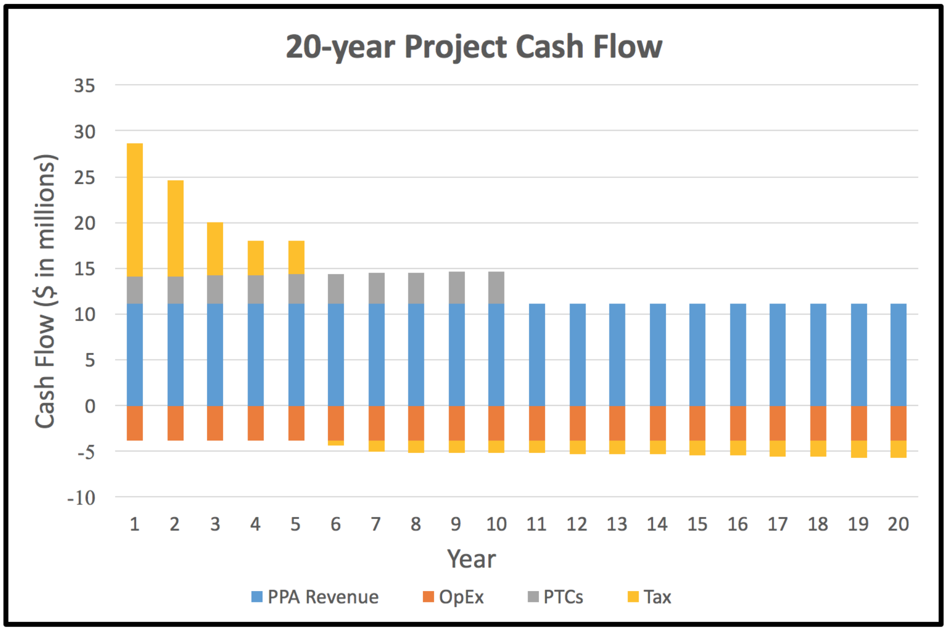

Figure 1. This graph shows the 20-year project cash flow for the Lafayette County Energy Center, including PPA revenue, operational expenses, production tax credits, and taxes.

Table 2. This table breaks down the initial capital costs for the Lafayette County Energy Center.

Project Component	Estimated Cost
Rotor Module	**$ 31,700,000**
Blades	$ 20,300,000
Pitch Assembly	$ 6,600,000
Hub Assembly	$ 4,800,000
Nacelle Module	**$ 54,000,000**
Nacelle Structural Assembly	$ 10,800,000
Drivetrain Assembly	$ 21,100,000
Nacelle Electrical Assembly	$ 18,400,000
Yaw Assembly	$ 3,500,000
Tower Module	**$ 23,700,000**
TURBINE CAPITAL COST	**$ 109,500,000**
Civil BOP	**$ 11,300,000**
Foundation	$ 6,500,000
Site Access and Staging	$ 4,800,000
Electrical BOP	**$ 18,300,000**
Substation	$ 2,000,000
Electrical Collection Infrastructure	$ 16,300,000
Construction Costs	**$ 8,600,000**
Development Costs	$ 1,700,000
Engineering Management	$ 2,000,000
Assembly and Installation	$ 4,900,000
Monitoring Facility (Materials and Labor)	**$ 1,000,000**
BALANCE OF SYSTEM	**$ 39,200,000**
Construction Financing Cost	$ 6,000,000
Contingency Fund	$ 9,700,000
FINANCIAL COSTS	**$ 15,700,000**
Total Capital Expenditure	**$ 164,400,000**

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