Lewis Canyons Wind Farm

U.S. Department of Energy-Collegiate Wind Competition 2020

Project Development Report

WiscWind

University of Wisconsin-Madison

Team Members:

Samuel Ast (ast@wisc.edu)

Anson Liow (eliow@wisc.edu)

Joe Wade (jewade2@wisc.edu)

Special Thanks To:

Dean Baumgardner- Industry Professional

Dr. James Tinjum- Faculty Advisor

Professor David Drake- Faculty Advisor

Joe Brunner- Invenergy LLC

Scott Williams- Faculty Advisor/Coordinator

Mohamed Nofal- Industry Professional

Table of Contents

Introduction

This report will investigate the site assessment and financial feasibility for a 100MW wind farm in Lewis Canyons of Logan County, located at the northern end of Eastern Colorado. After selecting the appropriate site and turbine model, the wind farm was designed to optimize the annual energy output while minimizing cost. The environmental and social impacts were analyzed, and necessary mitigation efforts were proposed. Finally, a financial analysis was conducted to determine the financial feasibility of the project via various economic metrics and parameters.

Site Description and Energy Estimation

Site Selection Process

In order to choose sites for comparison and analysis, there were many factors needed to be considered and synthesized. The most important factor in choosing a site is wind resource, as this parameter is primarily related to the energy production and therefore the financial viability of the project. Therefore, sites with the highest wind speeds were prioritized. The next most important factor in siting the wind farm was the transmission capabilities. Transmission lines and grid interconnection are very costly, so sites near an existing grid line large enough to handle the electrical load from the wind farm were prioritized. Other factors considered for the initial site investigation included:

- Site Terrain
  - Although the best wind resource is often located atop ridgelines, steep rocky terrain can greatly increase construction costs and can even make it impossible to construct turbines.
  - Flatter sites were prioritized over sloping sites.
- Site Access
  - Nearby roads and highways play an important role in transportation and construction costs, which are very significant in the overall financial metrics of the wind farms.
  - Larger and straighter roads were prioritized.
- Roughness
  - The height of objects on the ground in and around the wind farm affect the wind speeds at hub height. The more numerous and taller ground objects there are, the slower the wind speeds at hub height.
  - Sites with smoother ground surfaces were prioritized.
- Land Ownership
  - Fewer landowners lead to less permitting, land leases, community due diligence costs.
  - Sites that would include fewer landowners were prioritized.

Using ArcGIS, a map of Colorado was created that included the wind resource, transmission lines, substations, roads and highways, existing wind farms, counties, cities, and waterways [1]. Using this GIS map, these factors were used for consideration for potential sites within the project boundaries. As a rule of thumb, about 50-80 acres per MW (26 km_2 in total) was used for sizing each potential site. After investigation by the team, four potential sites were identified Weld County, Peetz, Granada, and Andrix. **Table 1** below shows a weighted decision matrix if the potential sites.

Category (Weight)	Weld County	Peetz	Granada	Andrix
Wind Resource (.5)	4	4	2	3
Transmission (.3)	3	4	4	1
Site Terrain (.05)	1	3	4	4
Site Access (.05)	3	3	3	4
Roughness (.05)	4	4	3	4
Land Ownership (.05)	2	4	1	2
Total (1)	3.4	3.9	2.75	2.5

Table 1. The weighted decision matrix for choosing the site on which to develop a 100MW wind farm.

Site Specifications

Chosen Site Location

From the results of **Table 1**, the site chosen to develop a 100MW wind farm is located approximately 8 km southwest of Peetz, CO as seen in **Figure 1**. The site is in the in the northeast corner of the state, within Logan County. The area is primarily scrubland and shortgrass prairie with some agricultural and pastural land uses. The site has an area of 30.9 km^2 and is made up of 7 different land parcels owned by 6 different parties.

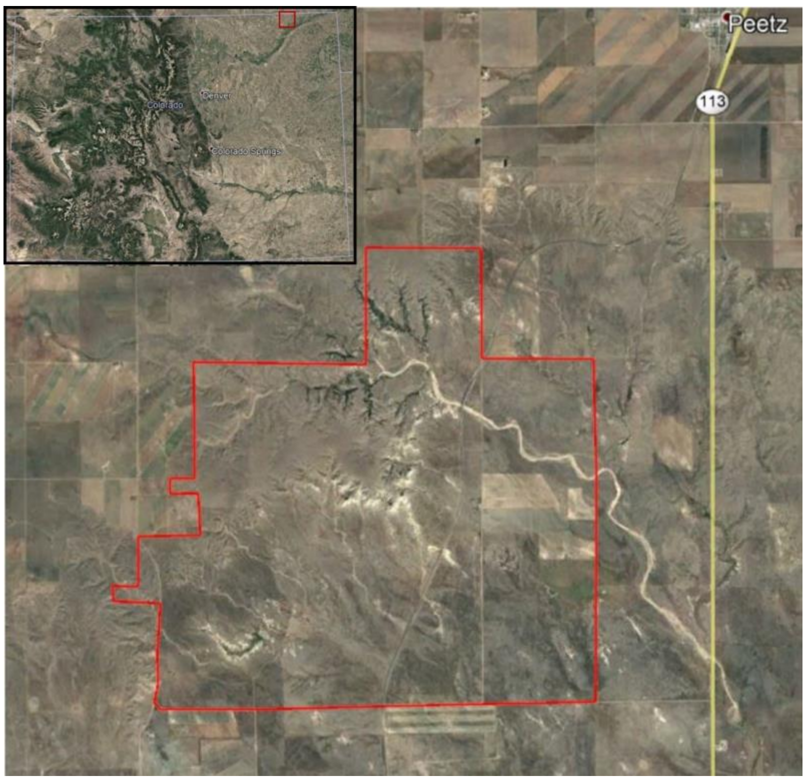

Figure 1. Overhead satellite image of the Lewis Canyons Wind Farm site.

Wind Resource

The prominent feature of the site is a large plateau on which the largest amount of wind energy can be obtained. To initially estimate the wind resource at our site, a map of 50m average wind speeds from the National Renewable Energy Laboratory (NREL) was overlaid with a map of the site. **Figure 2** shows this distribution of average wind speeds. Furthermore, data from a meteorological (MET) tower located 6 km north of the site was obtained. A wind rose was created from this data and is shown in **Figure 3**.

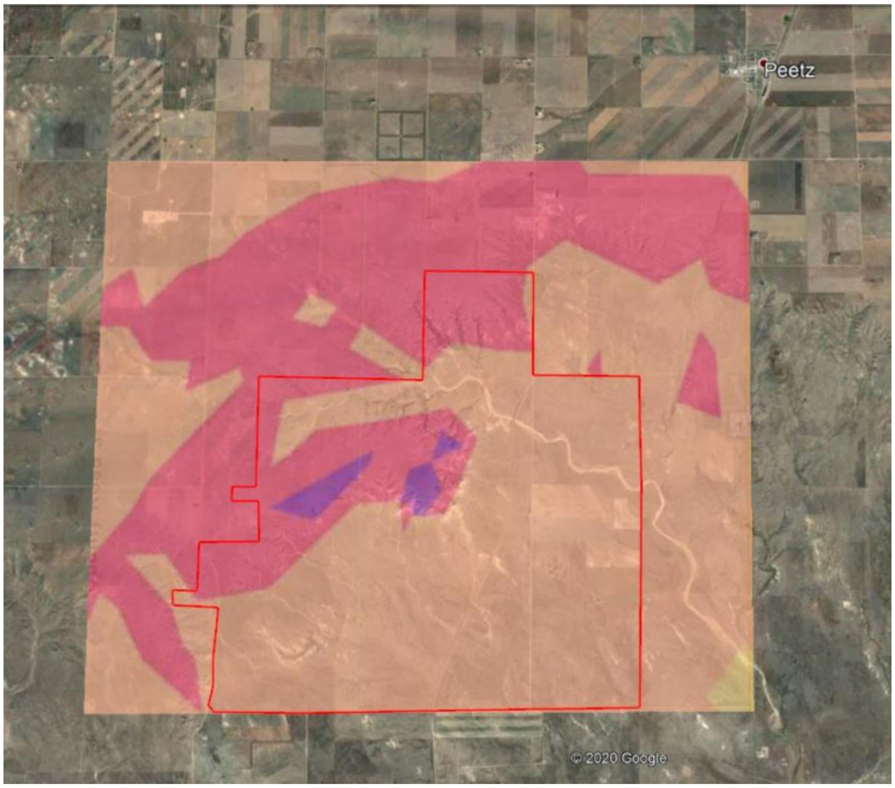

Figure 2. Map of the 50m average wind speeds referenced to the Lewis Canyons Wind Farm site. The yellow, orange, red and purple coloring represents average wind speeds of 6.4 - 7.0 m/s, 7.0 - 7.5 m/s, 7.5 - 8.0 m/s, and 8.0 - 8.8 m/s respectively.

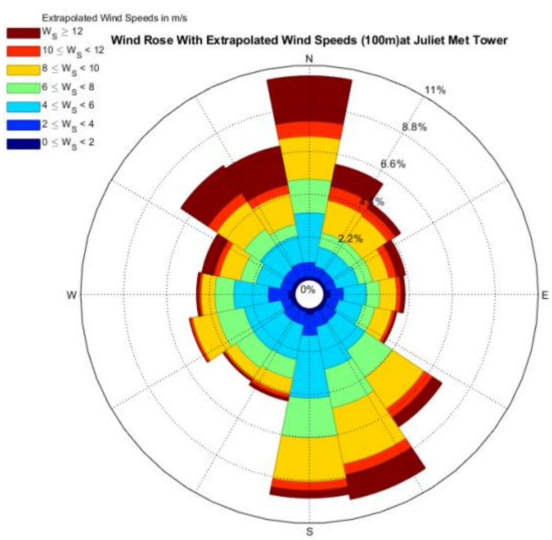

Figure 3. Wind Rose from data (2017-2019) measured at the Juliet MET tower showing predominant wind directions of north, northwest, south, and south-southeast.

Turbine Selection

In order to select the turbine for which to use on the site, models from three of the top turbine manufacturers were considered. The turbines chosen for comparison were the Vestas V136-4.2MW, Siemens Gamesa (SG) 4.5-145, and General Electric (GE) 5.3-158. These three models were chosen as they have the highest rated capacities for onshore turbines. A high rated capacity means that fewer turbines are needed to reach our 100 MW goal of the project, which can significantly reduce our balance-of-plant (BOP) costs and other recurring operation and maintenance costs in the future. Three key factors were taken into consideration when deciding between the three selected turbine models: Turbine Cost, Transportation of the Turbine Components to the Site, and Turbine Installations and Construction of Site Infrastructure.

Turbine Cost

To estimate the costs of the turbine models, normalized pricing from professionals within the industry was received. The cost per kW for each of the models was $725, $765, and $745 for Vestas, GE, and SG respectively. Additionally, a $100,000 hub height adder was required for the Vestas model above the Vestas standard 82m height. The total cost of each turbine model is expressed as “Unit Cost”.

Transportation

Transportation cost of turbine component deliveries is dependent on the distance of the vendor/manufacturer to the wind farm site. While this cost is included in the turbine supply agreements, manufacturers that are farther away will have proportionally higher costs to make up for the added distance to deliver the turbine. To account for this factor, the “Transportation Cost Adder (TCA)” is used to estimate the added percentage of cost relative to the closest manufacturing facility between the chosen models. It is assumed that the ratio of the distance between the wind farm site from the turbine manufacture for each turbine model compared to the closest turbine model manufacturer is the percentage increase in cost of the turbine supply agreement. The distance of the LCWF site to each turbine blade and towers manufacturing facilities is 407, 1120, and 2391 miles for the Vestas, SG, and GE models respectively.

Installation of Turbines and Construction of Site Infrastructure

The number of turbines needed to meet the 100MW demand is related to the cost of turbine installation and construction of site infrastructure. The more turbines used in the wind farm, the higher the electrical infrastructure, earthwork, and maintenance costs. To account for this factor, the “Construction Cost Adder (CCA)” is used to estimate the added percentage of cost relative to the model with the lowest required number of turbines. It is assumed that the ratio of the required number of turbines for each model compared to the lowest required number of turbines out of all the models is the percentage increase in costs for installation and construction. To satisfy the 100MW demand, 24, 22, and 19 turbines are needed for the Vestas, SG, and GE models respectively.

Turbine Selection

Table 2 shows the comparison of the three turbine models and the resulting cost per power produced. Since the Vestas V136-4.2MW turbine had the lowest cost per installed power, this was the model chosen to use at the Lewis Canyons Wind Farm site.

Turbine Model (Hub Height)	**# of Turbines Needed**	**Unit Cost**	**TCA**	**CCA**	**Total Cost**	**$/kW (installed)**
Vestas V136-4.2 (105m)	24	$3,145,000	0.0%	1.26%	$76,433,432	$758
SG 4.5-145 (107.5m)	22	$3,442,500	2.75%	1.16%	$78,696,040	$795
GE 5.3-158 (101m)	19	$3,948,500	5.88%	0.0%	$79,428,783	$789

Table 2. Comparison of the estimated costs and power production of the three turbine models.

Site Layout

Turbine Locations

In order to maximize the production, efficiency and investment of the wind farm, the 24 V136 4.2MW turbines were located in areas with the highest average wind speeds occurring in **Figure 3**. Due to the predominant wind directions being largely parallel to each other, a turbine spacing of 2.6 and 5 rotor diameters was used for the secondary (East-West) and prevailing (North-South) directions respectively. Additionally, a 1.1 times structure height (tower height plus blade radius) setback was used in regard to property lines and roads. The resulting turbine layout of the wind farm can be seen in **Figure 4** below. In total, 14 turbines were located on the plateau and the other 10 turbines were located around the agricultural fields. The area within the turbine arrays takes up roughly 10% of the space on the site.

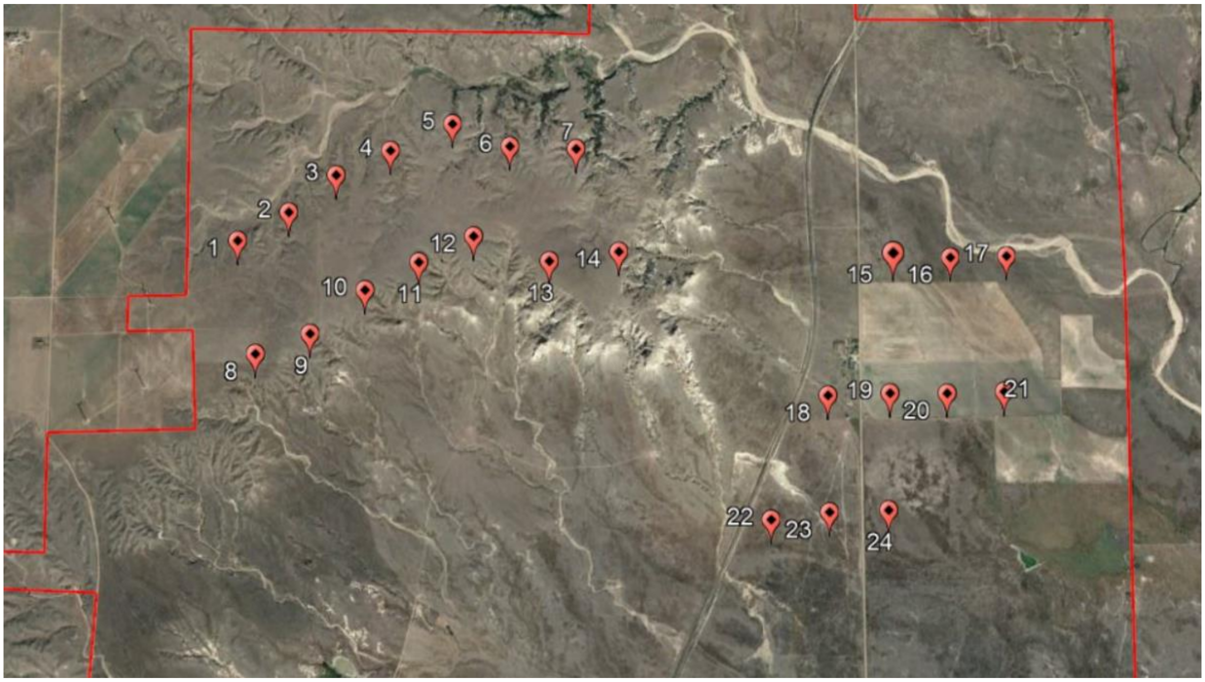

Figure 4. Proposed turbine locations for the Lewis Canyons Wind Farm.

Collection System

The collection system for the wind farm was designed to address the need of transmitting the electricity generated at the turbines to the grid. Due to the location of the plateau relative to the existing transmission line, two separate arrays of turbines were created. The plateau array of turbines consists of three separate circuits that all converge at the southwest corner of the plateau. Here, the underground line transitions into a double circuit overhead line and connects to the substation. An overhead line is used in this case because the slope of the ground around the plateau is too steep for the trenching machines. The turbines in the field array are connected in two separate circuits. Both circuits converge near turbine 21 and from there are routed to the substation. The trench spacing between circuits is to be determined by a soils resistivity test but is assumed to be 8’ to allow for heat dispersion. A map of the proposed collector system with its accompanying one-line diagram is shown below in **Figure 5** and **Figure 6** respectively. Additionally, the cable lengths and sizing are shown in **Table 3**.

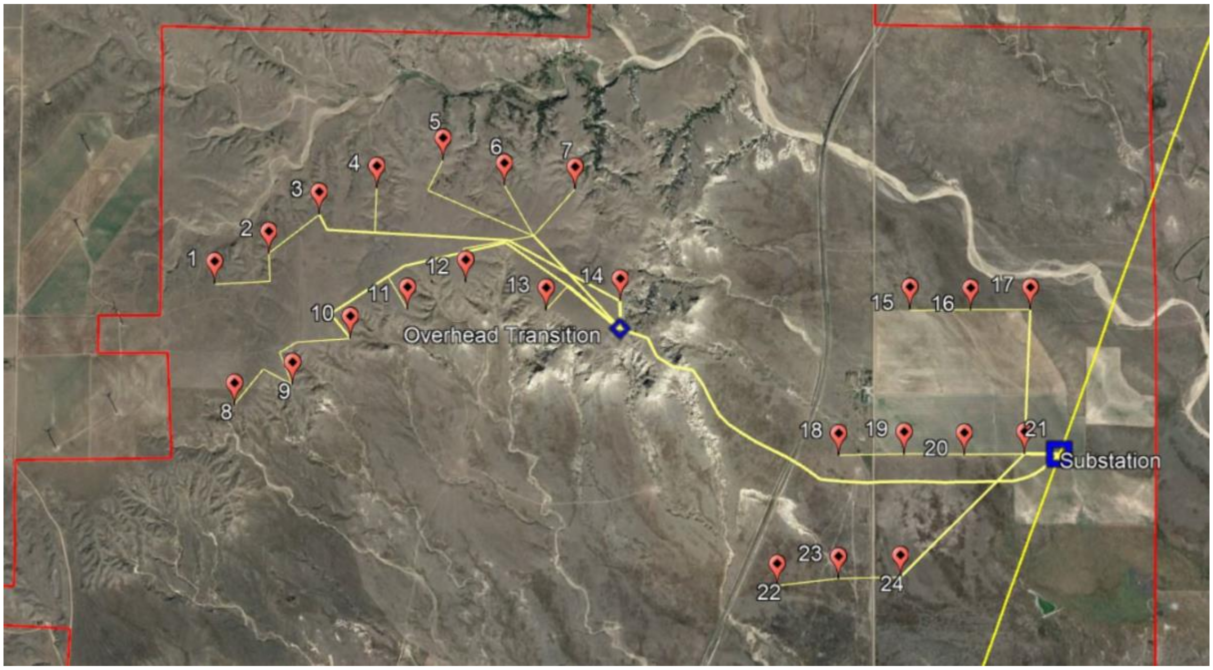

Figure 5. Map of the proposed collector system at the Lewis Canyons Wind Farm site.

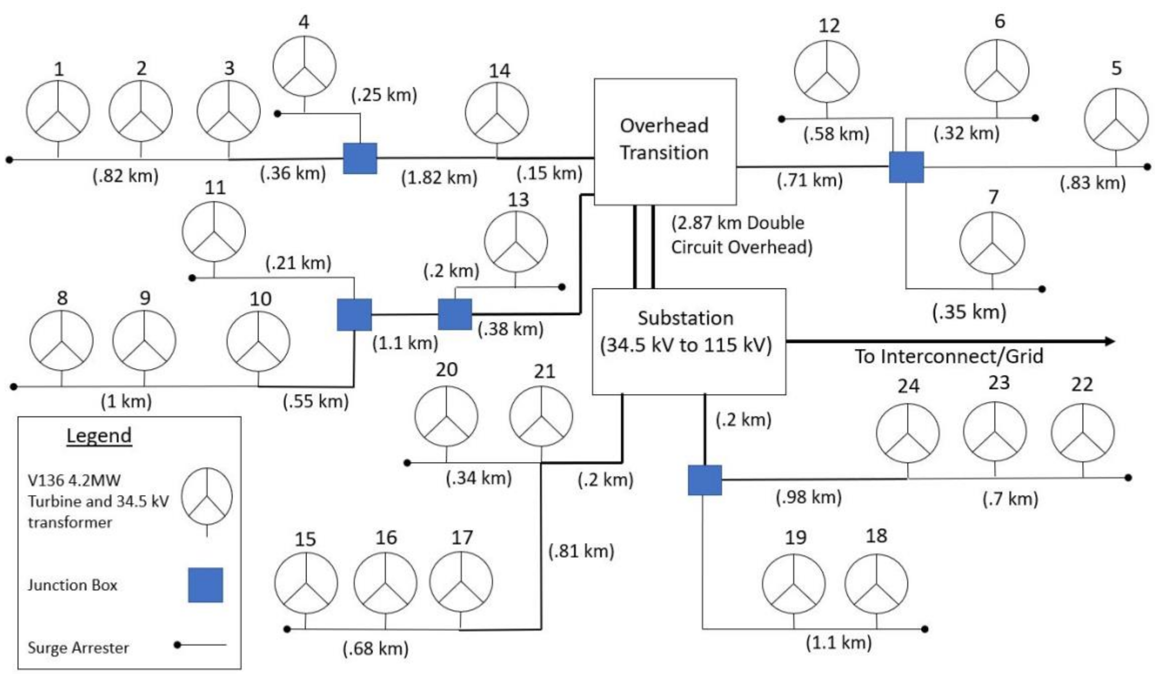

Figure 6. The one-line diagram for the proposed collector system at the Lewis Canyons Wind Farm site.

Cable Size	Plateau Array	Field Array	Total
Small	4.36 km	2.82 km	7.18 km
Medium	4.18 km	1.79 km	5.97 km
Large	0.53 km	0.40 km	0.93 km
Overhead	2.87 km		2.87 km

Table 3. Cable size and length used for the proposed collector system at the Lewis Canyons Wind Farm site.

Access Roads

The access roads for the Lewis Canyons Wind Farm are designed for the delivery and maintenance of the turbines at the site. A map of the proposed access roads system is shown in **Figure 7**. Turbines in the plateau array can be accessed via County Road 36 (offsite) and are arranged with the individual turbine roads branching out from a central road. The turbines in the field array can be accessed via County Road 45 (onsite) and are arranged in a straight-line pattern. The roads servicing the plateau and field arrays have a total length of 8.35 km and 2.83 km respectively for an overall total of 11.18 km. Roads characteristics will be constructed according to turbine specifications.

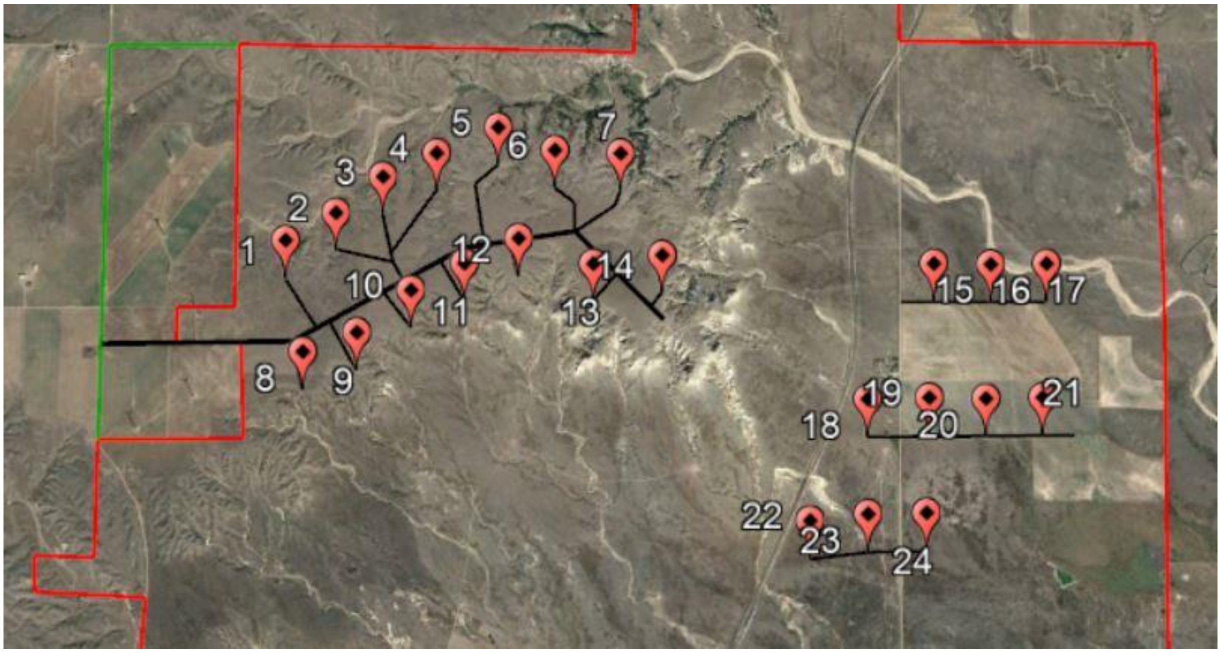

Figure 7. Proposed access roads for the turbine locations at the Lewis Canyons Wind Farm site.

Generation Estimate

In order estimate the electrical generation of the Lewis Canyons Wind Farm, two different methods were used. The first method comes from using the MET tower data represented in **Figure 3**. In this method, the data was horizontally and vertically extrapolated to hub height (105m) and fit with a Weibull distribution. When combined with the V136 4.2MW's power curve, this method yielded an Annual Energy Production (AEP) estimate of 375,024 MWh/year for the wind farm. The second method of estimating the electrical generation of the wind farm is by using the wind speed map overlaid with the proposed turbine locations. This map overlay is shown in **Figure 8**. In this way an approximation of the average wind speed, vertically extrapolated to hub height, at each turbine can be combined with its power curve to yield the AEP. This map-based method of estimation yields an AEP value of 526,384 MWh/year. Energy losses due to electrical, environmental, wake loss, turbine performance, operational strategies/curtailment and other factors is estimated to be 15% for a net yield of 447,426 MWh/year and a net capacity factor of 50.7%.

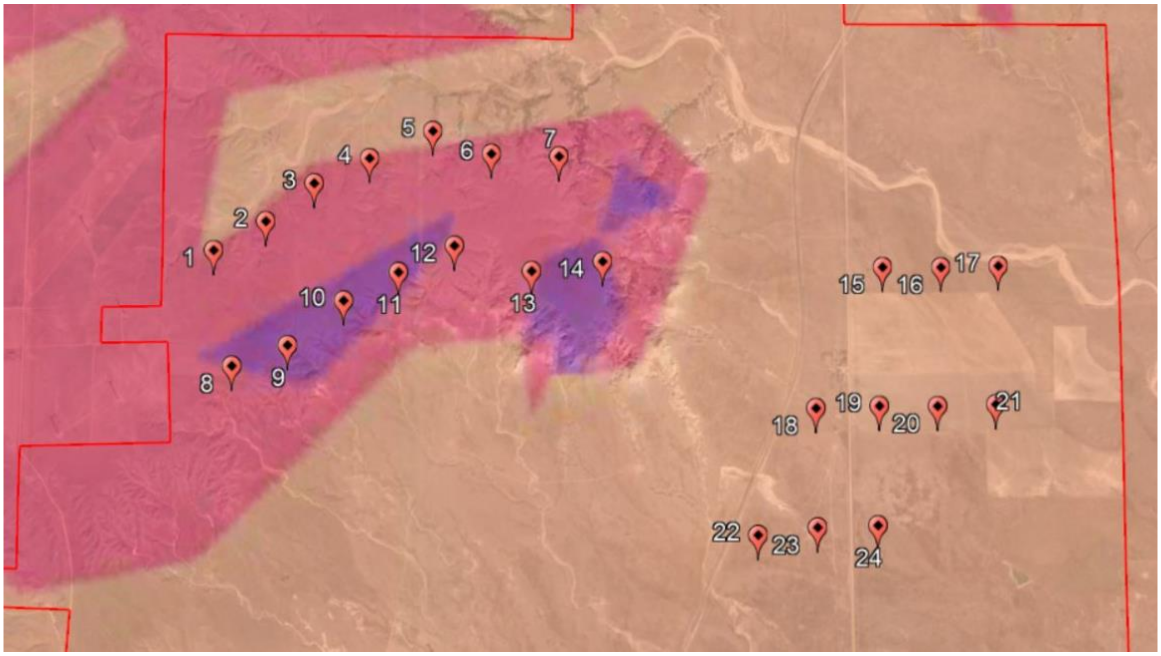

Figure 8. Proposed turbine locations overlaid with the 50m wind speed profile at the Lewis Canyons Wind Farm site. Turbines 1-7 are considered in the red zone, turbines 8-14 are considered in the purple zone, and turbines 15-24 are considered in the orange zone.

Community and Environmental Considerations

As part of its development, the Lewis Canyons Wind Farm needs to take into consideration any potential community and environmental impacts. These impacts are important to consider as proper management/mitigation can increases the wind farm's overall sustainability by protecting and conserving the surrounding ecosystems and its inhabitants.

Wildlife Impacts

One of the primary ways in which species are affected by wind turbines is through direct mortality. Birds and bats are at high risk of being killed by wind turbines due to the spinning blades and obstruction of airspace [2]. Direct collision with the blades and towers is the primary source of mortality for bird [3] and bat [4] species at wind farms. In bat species, however, an additional way in which wind turbines can induce fatality or life-threatening injuries is through barotrauma.

Another way in which the construction and operation of the wind farm affect wildlife is through habitat displacement. Construction of the turbines and site infrastructure can fragment and destroy existing species' habitats causing a decline in their population. Additionally, roosting and hunting locations can be displaced, causing additional stress on the species and can be costly for the health of the species.

Wildlife Impact Monitoring and Mitigation

In order to fully understand what, if any, population impacts would have been caused by the development of the wind farm, it was recommended by industry professionals that a Before-After-Control-Impact (BACI) evaluation be conducted with respect to birds and bats. This evaluation compares the abundance of species found before and after the site is developed. To make this study more accurate, searcher efficiency is calculated to account for missed observations. Additionally, scavenger removal must be estimated to determine if any individuals are being removed before the searchers can find them. Several species have been specifically identified for their high vulnerability to potential impacts through the United States Fish and Wildlife Service's (USFWS) Environmental Conservation Online System (ECOS) [5] and Information for Planning and Consultation (IPaC) [6] tool:

- Endangered Species
  - Least Tern, Piping Plover, Whooping Crane, American Peregrine Falcon, Little Brown Bat, Bald Eagles
- Migratory Birds
  - Golden Eagles, Burrowing Owl, Chestnut-collared Longspur, Lark Bunting, Mccown's Longspur

Upon conclusive evidence from the BACI study, if any significant impact to the populations of species' is deemed to have occurred at any of the wind turbines, the following measures have been identified and should be used in any combination to try and reduce those impacts: increase the wind, turbine's cut-in speed, slow or stop the turbine's blade movement, reduce operational hours of the wind turbines, curtailment during times of migration or breeding, and habitat reparations at nearby location(s). Ideally to further reduce species impacts, when choosing the turbine layout, areas of orographic lift and flight corridors would be avoided by implementing setbacks from these regions. To properly account for these factors, an analysis of the site's species' movements would be needed.

Community Impacts and Mitigation

Noise and shadow flicker are the two primary community impacts of wind turbines as they can both be bothersome to nearby residents. However, there is only one occupied building at which these effects potentially apply. To mitigate these impacts, a 1000 ft setback was used to reduce noise levels to less than 50db at the receptor. To mitigate any shadow flicker, vegetation barriers can be constructed to block the building from the shadows of the turbine blades. Another potential community problem is that turbines may interfere with microwave tower signals. However, no turbines are believed to conflict with microwave tower Fresnel zones and if they were, slight tower relocation for offending turbines would be able to solve this problem.

Risk, Mitigation and Fatal Flaws

Risk and Mitigation

As an infrastructure asset, commercial- and utility-scales wind projects are complex and high in initial capital cost. Risks have to be identified and mitigated so that a wind project is financially viable and the investors and lenders are aware and are comfortable accepting the risks associated with the project. The risks associated with a land-based wind project can be divided into six areas [7]:

1) **Preconstruction Energy Estimate-** Associated with the projected annual energy production (AEP) based on available data such site wind condition, layout, turbine selection, loss estimation and more.

2) **Construction-** Low-complexity risks of land-based on industry's history of successful land-based projects. Damage to assets like turbine blades during construction can have significant impact on the overall costs and scheduling of wind projects.

3) **Project Development-** The uncertainties of a project reaching commercial operation and energy generation such as site control difficulties, lack of transmission access, and unfavorable market dynamics.

4) **Regulatory-** Failure to predict with complete certainty whether regulatory policies supporting wind energy development will be available for the term of project. This is especially true for our site since the Production Tax Credit (PTC) is phasing out and it may or may not be renewed in 2021.

5) **Market/Selling Price-** Uncertainties in sources of revenue due to unknown selling price. While a fixed-price PPA agreement can reduce the negative exposure of market variability, it prevents investors benefitting from potential upsides of increasing market price. However, the ability to finance a project is generally dependent on securing a long-term PPA.

6) **Technology/Energy Production-** Associated with the reduced energy production and the diminished electricity sales volume and thus revenue. Some of these factors including curtailment, technology reliability, unexpected operations and maintenance (O&M) events, and extreme weather events are already factored into the loss calculation applied to gross energy production.

Fatal Flaws

The first potential fatal flaw of the proposed wind farm is that the existing 115 kV line may not have enough capacity to accommodate the addition of this extra 100 MW. As the current capacity is unknown, it is assumed that there is the capacity to add in the 100MW from the Lewis Canyons Wind Farm. A transmission grid study will be necessary to determine capacity of this line. If the existing line does not have the capacity for the addition of the wind farm, upgrades on the Xcel Energy system may be necessary. A second, but less significant, fatal flaw is that another substation is connected to the 115 kV line 6 km north of the proposed interconnection point. Xcel Energy may require the Lewis Canyons Wind Farm to interconnect at the northern substation rather than having the wind farm connect onsite. This would require an estimated cost of $150,000/km of additional transmission lines to route the electricity and an upgrade to the northern substation. The cost of this upgrade would be offset by eliminating the need for a new interconnection switchyard onsite. A third potential fatal flaw is that in order to access the plateau and additional 1.86 km_2 of land is needed. This area is shown within the green boundaries in **Figure 7**. Furthermore, this land already has turbines from an adjacent wind farm on it and therefore obtaining access to this required land may be restricted.

Site Restoration

The leases with landowners will require site restoration when the wind plant ends operations. Given the country's need for renewable energy, it is likely that leases will be extended in the future for continued operations and the wind farm may even be repowered with more advanced technology. However, when operations cease, turbines will be removed for salvage and foundations will be removed to three feet below ground level. Owners will be permitted to retain the access roads, if desired, but otherwise the road materials will be removed, regraded, deep-plowed and replanted with native vegetation.

Optimization Process

Site Layout

The optimization of the site layout for the Lewis Canyons Wind Farm occurred through three different aspects: Turbine Locations, Collection System, and Access Roads. The process roughly occurred in that order although minor changes to each of the three areas of the site design were made in no particular order as feedback from various resources was obtained. The design of each of these three components of the wind farm sought to improve energy production and/or reduce balance of plant costs.

Turbine Locations

The first step in the optimization of the turbine locations was to situate more of them in the region with the fastest wind speeds, the plateau. Starting out, only one row of turbines was initially in the plateau array due to an initial 7 rotor diameter spacing in the primary wind direction. After discussion with several sources, it became clear that it was worth to accrue slightly higher wake loss effects to include an additional row of turbines in the plateau array, thus boosting the energy output of the wind farm. Next, changes were also made to turbines in the field array to locate them in positions of the highest elevation. A secondary goal of turbine location optimization was to minimize the agricultural space taken up by the turbines. In this way, the landowners of the fields are kept satisfied as they still have almost all of their fields to grow crops.

Collection System

After the locations of the turbines were finalized, the optimization of the collection system began. The first step in this process was to determine the locations of the substation and overhead transition of the plateau array. The substation was located as close as possible to the existing 115 kV transmission line and the overhead transition was located as close to the substation as possible. Next, the location and size of each cable connecting the turbines to the substation was planned given that each cable size could hold the current of two additional turbines. To minimize the length and sizing of cable needed, junction boxes were used to connect individual turbines to the rest of the circuit as the cable size increase. The final step in optimizing the collection system was to check the slope of each of the cable paths. This was done because the trenching machines have a threshold slope after which they cannot be operated safely. This threshold slope was estimated to be around 15% after discussion with various sources.

Access Roads

After the collection system was finalized, the access roads were optimized. First, in order to reduce costs, the least amount of road was desired. To accomplish this a branching network of roads was used for the plateau array whereas the field array simply had straight access roads connecting the turbines to the existing roads. Second, much like the collection system, the roads were each checked for their slopes. A threshold of 10% was used to ensure safe turbine delivery to each of their locations.

Financial Analysis

Capital, Operations, and Maintenance Costs

The capital costs for the Lewis Canyons Wind Farm were estimated using the values for the 2.4 MW onshore turbine in the NREL's Cost of Wind Energy 2018 report [8]. However, the cost values for the turbine section in that report were replaced with the estimates received for the V136 4.2MW model by industry professionals. Keeping everything else the same, the total capital cost of the Lewis Canyons Wind Farm is estimated to be $122,700,631.

The Cost of Wind Energy 2018 report [8] was also used to estimate the annual operations and maintenance costs for the Lewis Canyons Wind Farm and comes out to be $4,435,200/year for the 100.8 MW system. In order to accurately depict an increasing operation and maintenance cost, a 2% annual escalation factor was included in the financial analysis.

Net Annual Energy Production

The estimated AEP value of 526,384 MWh/year from the map-based method of analysis of **Figure 8** was used for this financial analysis. Factoring in the estimated 15% losses, the projected Net Annual Energy Production for the Lewis Canyons Wind Farm is 447,426 MWh.

Market Conditions

The electricity generated at Lewis Canyons Wind Farm will be sold to a wholesale electricity buyer such as Xcel Energy at the rate of $18.1/MWh [9]. At this rate, the Internal Rate of Return (IRR) for the project is projected at 2.76%. For the wind farm to be more economically feasible, a PPA escalation factor was considered. **Table 4** shows the corresponding total PPA revenue and IRR based on different escalation factors. A 4% escalation factor was used in the financial analysis in order for the project to be more financially attractive for investors and it was assumed that this is the maximum allowable rate that can be successfully negotiated with the utility.

	Escalation Factor (Per Year)				
	0%	**1%**	**2%**	**3%**	**4%**
PPA Revenue ($ Millions)	$161.9	$178.3	$196.8	$217.6	$241.1
IRR	2.76%	4.19%	5.62%	7.07%	8.52%

Table 4. Total PPA Revenue and IRR based on varying PPA escalation factors.

Financial Incentives

One of the main financial incentives for any wind project in the United States is the Production Tax Credit (PTC). Assuming the anticipated start of construction is before 31 December 2020, the Lewis Canyons Wind Farm is eligible for a $0.015/kWh tax credit if the construction is completed in 4 years [10]. Assuming this PTC rate, the total value was $57,046,870 over the first 10 years of wind farm operation. In addition, investors will have the opportunity to opt for the Business Energy Investment Tax Credit (ITC) instead of PTC for a wind project like the Lewis Canyons Wind Farm. The ITC is structured as a one-time credit that is valued at 18% of the eligible expenditures such as system costs if the construction begins by 31 December, 2020 [10].

Financing

The project will be financed through debt from a bank and investors equity with the ratio of 70% debt and 30% equity. The interest rate for the debt is assumed to be 5.5% and will lead to a total cost of $85,890,442 and $36,810,189 in debt and investor equity respectively.

Sale of Wind Farm

Due to the quality and longevity of the V136 turbine, it was estimated that the wind farm will be operational for approximately 30 years. Because of this, it is estimated that the wind farm can be sold for the same value as the original capital cost ($122,700,631) and thus help boost the financial feasibility of the Lewis Canyons Wind Farm.

Taxes

The income taxes were determined using the combined federal and state tax rate of 24.7% for the state of Colorado [11]. The total income tax payment over 20 years is calculated to be $49,006,099 based on the gross revenue generated from the PPA, selling the wind farm and the costs of operation and maintenance and interest debt. Property taxes were excluded since the land will be leased and available for original use.

Financial Metrics (NPV, LCOE)

Using a discount rate of 8%, the project Net Present Value (NPV) was calculated to be $20,359,683. This value suggests that the project is worth pursuing as it is projected to bring profit to the developers and investors. The Levelized Cost of Energy (LCOE) is an economic measure to compare the price competitiveness between various sources of energy generation and calculated by dividing the lifetime costs of the project by its energy production. The LCOE of Lewis Canyons Wind Farm was estimated to be $0.0582/kWh before application of tax incentives like the PTC.

Cash Flow Diagram

Figure 10 represents the projected cash flow diagram broken down into individual component annual gains and losses of the Lewis Canyons Wind Farm over a 20-year timespan.

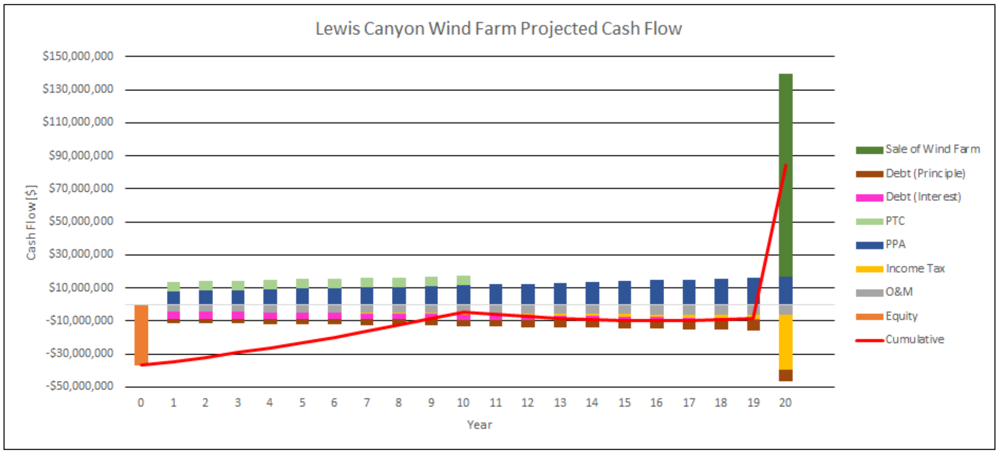

Figure 10. The 20-year projected cash flow for the Lewis Canyons Wind Farm.

Conclusion

The goal of this report was to develop a site plan for a 100 MW wind farm in Eastern Colorado that would be attractive to investors and include a robust financial analysis. To accomplish this, site investigations were conducted, turbine models and annual energy productions were compared, and a site layout was designed. Using AEP and cost estimates from various sources, a financial analysis was then conducted. The Lewis Canyons Wind Farm was found to be not financially feasible with the current baseline assumptions. However, this could prove successful with greater PPA escalation factors shown in **Table 4** or better market conditions, corresponding to a higher IRR that is more attractive to investors.

References

[1] *arcgis.com.* [Online]. Available: https://www.arcgis.com/home/webmap/viewer.html?webmap=946243a229a946a6bf15ce1fbd4bd279. [Accessed: Jan. 18, 2020].

[2] K.S. Smallwood. "Comparing bird and bat fatality-rate estimates among North American wind-energy projects," *Wind Energy and Wildlife Conservation*, vol. 37, no. 1, pp. 19-33, 2013. [Online]. Available: https://wildlife.onlinelibrary.wiley.com/doi/abs/10.1002/wsb.260. [Accessed: Mar. 17, 2020].

[3] A.M. Manville. "Towers, Turbines, Power Lines, and Buildings – Steps Being Taken by the U.S. Fish and Wildlife Service to Avoid or Minimize Take of Migratory Birds at these Structures," *Proceedings of the Fourth International Partners in Flight Conference: Tundra to Tropics*, pp. 262-272, 2009. [Online]. Available: https://www.fws.gov/migratorybirds/pdf/management/manville2009.pdf. [Accessed: Mar. 11, 2020].

[4] NREL National Wind Technology Center, "Reducing Bat Fatalities From Interactions with Operating Wind Turbines," 2013. Available: https://www.nrel.gov/docs/fy14osti/60427.pdf. [Accessed: Mar. 8, 2020].

[5] U.S. Fish and Wildlife Service, "Species by County Report," [Online]. Available: https://ecos.fws.gov/ecp0/reports/species-by-current-range-county?fips=08075. [Accessed: Apr. 19, 2020].

[6] IPaC: Information for Planning and Consultation, "IPaC Explore Location: Endangered Species," [Online]. Available: https://ecos.fws.gov/ipac/location/SJNJEYY6NNANPEVAS3NUAB2KQQ/resources [Accessed: Apr. 20, 2020].

[7] P. Schwabe, D. Feldman, J. Fields, and E. Settle. "Wind Energy Finance in the United States: Current Practice and Opportunities," *National Renewable Energy Laboratory*, NREL/TP-6A20-68227, 2017. [Online]. Available: https://www.nrel.gov/docs/fy17osti/68227.pdf. [Accessed: Mar. 8, 2020].

[8] T. Stehly and P. Beiter. "2018 Cost of Wind Energy Review," *National Renewable Energy Laboratory*, NREL/TP-5000-74598, 2019. [Online]. Available: https://www.nrel.gov/docs/fy20osti/74598.pdf. [Accessed: Mar. 10, 2020].

[9] D. Schlissel. "IEEFA update: The American wind-energy horse is out of the barn: Power purchase agreement prices fall," *IEEFA.org*. https://ieefa.org/ieefa-update-the-american-wind-energy-horse-is-out-of-the-barn/ [Accessed: Apr. 19, 2020].

[10] Office of Energy Efficiency and Renewable Energy, "Advancing the Growth of the U.S. Wind Industry: Federal Incentives, Funding, and Partnership Opportunities," Feb., 2020. [Online]. Available: https://www.energy.gov/sites/prod/files/2020/02/f71/weto-funding-factsheet-2020.pdf. [Accessed: Apr. 15, 2020].

[11] K. Pomerleau. "The United States' Corporate Income Tax Rate is Now More in Line with Those Levied by Other Major Nations," *taxfoundation.org*, February 2019. [Online]. Available: https://taxfoundation.org/us-corporate-income-tax-more-competitive/. [Accessed: April 10, 2020].