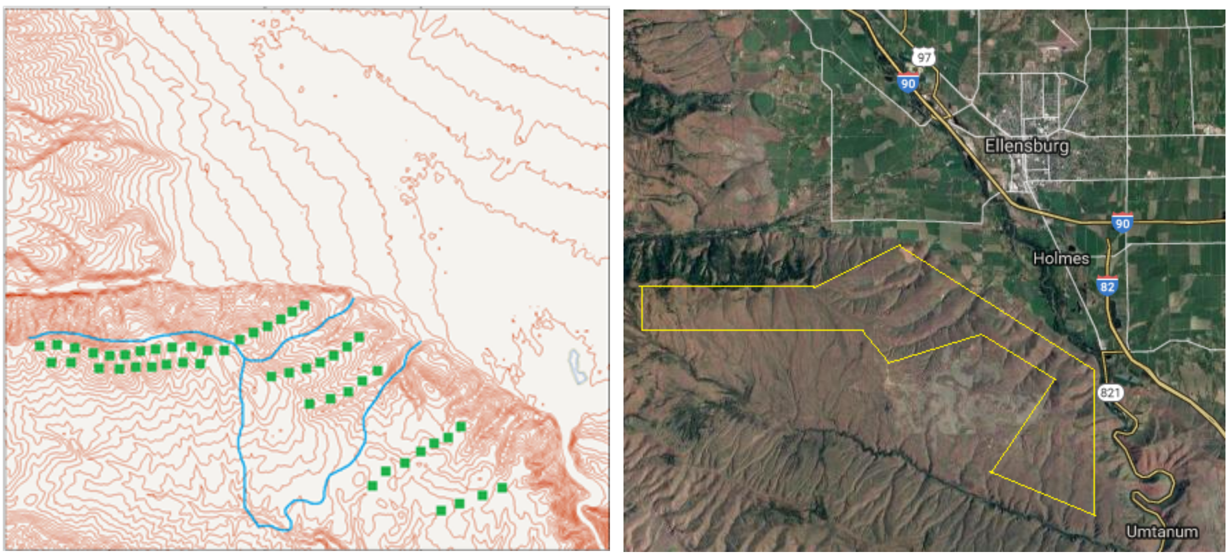
Collegiate Wind Competition 2019
Siting and Project Development Analysis



(Locations of the 50 turbines on the Ellensburg wind farm site)

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*Special thanks to Mr. Kevin Smith of DNV-GL for his guidance on this analysis

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1. Introduction

Based on the 2018 Collegiate Wind Competition rules, the 2018 Seattle University (SU) team conducted a thorough study to determine the best wind farm site within a 100-mile radius of SU. The site southwest of Ellensburg, located in Kittitas County, WA, was chosen for the following criteria: high wind speeds, decent terrain quality, accommodating access for construction, naturally clear mountain ridges, moderate land acquisition rates, and high accessibility to grid connection. In the constraint analysis from the 2018 SU team, Ellensburg was found to have low wind resource quality; medium risks for wildlife, vegetation, wetlands, and protected areas; and low risk for avian and bat species, land development constraints, threatened or endangered species or habitats, and archeological and historical resources.

The site design from the 2018 SU team included fifty V100-2.0 MW Gridstreamer turbines as shown on the cover page. After analyzing several different types of turbine, the 2018 SU team concluded that this specific turbine would be the best for the selected site because it allowed for the highest amount of annual energy production. This turbine also provided the least amount of wake loss compared to the others, which aided in the total amount of energy produced. It was concluded that with fifty of these turbines, the selected site could produce 132.06 gigawatt hours each year, which corresponds to a net annual average capacity factor of 15.08%.

This year, we continued to study the selected Ellensburg site for the 2019 competition as it was deemed the best wind farm location in the area and made no change in the wind farm design from last year. This report presents our analysis for the financial, environmental, and social aspects of the selected site without changes from the 2018 SU team's design. After undergoing more detailed site analysis for the current project, we discovered two major insights that demonstrate the Ellensburg location as an unsuitable site. First, after conversing with city planners from Kittitas County, we learned that the county already predetermined State Environmental Policy Act (SEPA) certified areas for wind farm resource overlay zones according to Chapter 17.61A of the Kittitas County Code [1], suggesting that placing a wind farm anywhere out of those the indicated zones will be unlikely. Second, after assessing the site based on financial feasibility, environmental impact, and social cost and benefit, we concluded that the Ellensburg site will be a challenging investment because of its low net capacity factor, high turbine costs, close proximity to the city limits, and less than optimal wind resource. We detail each aspect of our analysis in the following sections.

2. Financial Analysis

2.1 Required Capital/Cost of Development

Most wind farms allocate similar percentages of their total costs of development on specific categories of capital [2]. Using the projected cost of the turbines from the 2018 SU team, we were able to deduce the cost of the total development of this wind farm. Fig. 1 illustrates the breakdown of its cost of development [2]. We projected that it will cost around *$626 million* to build this wind farm.

There are three major sections contributing to the total cost - **Turbines, Balance of Systems, and Financial**. Each section is broken down into subcategories. The specific amount spent in each category can be found in Table 1. The largest portion of the cost of development is spent on the wind turbines, which will cost *$426 million*. The price of these turbines, determined by last year's team, is very high for industry standards, making the cost of development for this project unreasonable. A more realistic total cost for 100 MW wind turbines (50 of 2 MW turbines) would be around $150 million to $200 million [3].

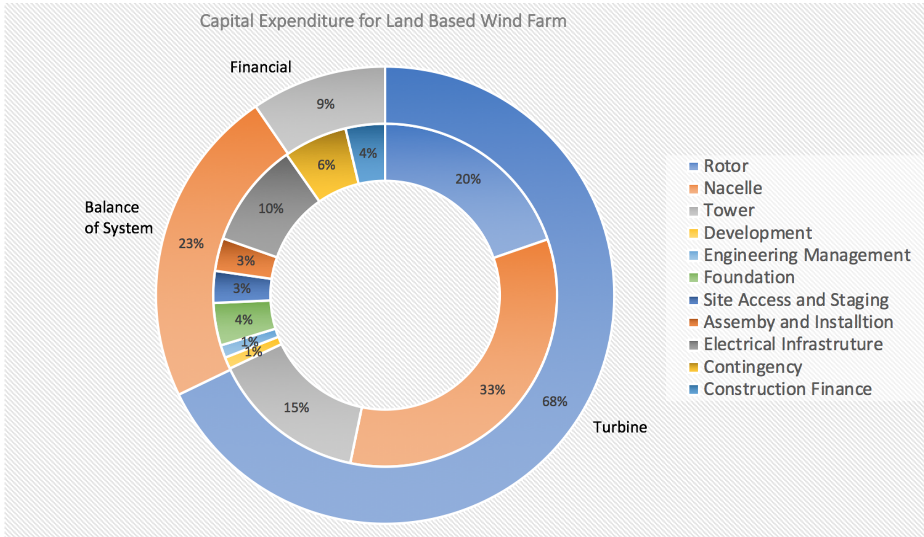

Figure 1: Breakdown of the cost of development for the Ellensburg wind farm

The balance of system components, which includes development, engineering management, foundation, site access and staging, electrical infrastructure, and assembly and installation will cost *$141 million*. The electrical infrastructure and the foundations are the most expensive pieces of the cost of development besides the turbines. The financial components of development, which includes contingency and construction finance, will cost *$59 million*. Given such a high cost development, financing this project would be very difficult.

Category	Cost
Turbines	$426,270,000
Rotor	$123,492,926.47
Nacelle	$210,000,661.76
Tower	$92,149,554.12
Balance of Systems	$141,045,220.59
Development	$6,895,544.12
Engineering Management	$7,522,411.76
Foundation	$25,074,705.88
Site Access and Staging	$18,806,029.59
Assembly and Installation	$19,4342,897.06
Electrical Infrastructure	$62,059,897.06
Financial	$59,552,426.47
Contingency	$37,612,058.82
Construction Finance	$23,194,102.94

Table 1: Cost of each category to develop the Ellensburg wind farm

2.2 Operating and Maintenance Expenses

Figure 2 illustrates the breakdown of the cost of operating and maintenance expenses spent on the wind farm each year. The wind farm is expected to incur $0.03/kWh of operating expenses each year [4]. It is expected to produce 132,060,000 kilowatt hours each year based on last year's projections. In the first year of operation, the wind farm is projected to incur almost *$4 million* in operating expenses. The total spent on operating and maintenance activities increases each year by the operating expense inflator [5]. If our wind farm were to continue operating for more than 20 years, then the amount spent on service and spare parts would need to increase more rapidly as the wind farm gets older.

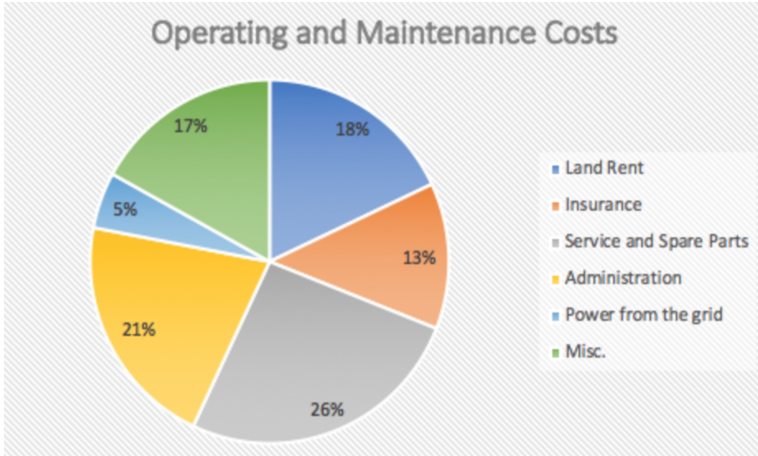

Figure 2: Breakdown of the cost of operating and maintenance expenses spent on the Ellensburg wind farm each year

The total spent on land rent would be *$713,124* per year. The Ellensburg wind farm is located on land owned by the county, the state, individual property owners, and institutional owners. We would need to develop individual land leases with all property owners, and the land rent expenses would be divided among them. The administration category would be used to pay any employees needed to run the farm as well as any other expenses to keep workers happy. The wind farm will also need to take power from the grid in order to run its substations, and that cost is also shown in Fig. 2. The turbines as well as the substations will need to be insured. There are specialized plans already developed for wind farms of this nature and specific insurance agencies that provide them.

<u>2.3 Cash Flows</u>

The technical calculations we performed to calculate the free cash flows can be found in Table 2 along with the specific costs of each category of operating and maintenance expenses. The cash flow calculation takes into account both the costs incurred each year and the revenue brought in. Equation 1 shows the formula to calculate the incremental after-tax cash flows:

$$Cash\ flow = Operating\ Profit \times (1 - Tax\ Rate) + Production\ Tax\ Credits + Depreciation\ Operating\ Profit = Revenue - Operating\ Expense - Depreciation \qquad \text{[Eq. 1]}$$

Before taking tax incentives into account, this wind farm project would have a net present value of *-$475 million*. Our net present value takes the incremental after-tax cash flows over the 20-year lifespan of the project and discounts them at a rate of 6.75% [6] in order to see the cost of the project in today's money. The revenue is taxed at a 21% federal income tax rate [7]. There is no income tax in the state of Washington; no state income tax was taken into consideration.

Wind farms receive federal production tax credits, but due to the success of the industry, the PTC program began phasing out after 2016 [8]. A tax credit allows the wind farm to take money directly off the amount owed in taxes to the federal government. For the purposes of this simplistic model, we assumed that this site would receive $0.023 of tax credits per kilowatt hour of energy produced for the first ten years of the project [9]. Including this assumption brought our net present value up to *-$453 million* with an internal rate of return at -9%.

Year		0	1	2	3
COD		$ 626,867,647.06			
Revenue	Power Purchase Agreement		$ 10,485,564.00	$ 10,653,333.02	$ 10,823,786.35
Operating Expenses	Land Rent		$ 713,124.00	$ 727,386.48	$ 741,934.21
	Insurance		$ 515,034.00	$ 525,334.68	$ 535,841.37
	Service and Spare Parts		$ 1,030,068.00	$ 1,050,669.36	$ 1,071,682.75
	General and Administrative		$ 831,978.00	$ 848,617.56	$ 865,589.91
	Power from the Grid		$ 198,090.00	$ 202,051.80	$ 206,092.84
	Misc.		$ 673,506.00	$ 686,976.12	$ 700,715.64
Depreciation	MACRS 5-year (Turbines)		$ 85,254,000	$ 136,406,400	$ 81,843,840
	MACRS 15-year (Site Access and Staging)		$ 940,301.47	$ 1,786,572.79	$ 1,607,915.51
	MACRS 20-year (Construction Finance, Foundations, Electrical Infrastructure)		$ 4,137,326.47	$ 7,965,732.56	$ 7,369,957.55
Operating Profit			-$ 83,807,863.94	-$ 139,546,408.33	-$ 84,119,783.44
Tax calculation	(Revenue-opex-depreciation)*tax rate		-$ 17,599,651.43	-$ 29,304,745.75	-$ 17,665,154.52
Production Tax Credits			$ 3,037,380	$ 3,037,380	$ 3,037,380
After Tax Profit			-$ 63,170,833	-$ 107,204,283	-$ 63,417,249
Depreciation			$ 90,331,628	$ 146,158,705	$ 90,821,713
Incremental After-Tax Cash Flows		-$ 626,867,647.06	$ 27,160,795	$ 38,954,423	$ 27,404,464

4	5	6	7	8	9	10	11	12
$ 10,996,966.93	$ 11,172,918.40	$ 11,351,685.10	$ 11,533,312.06	$ 11,717,845.05	$ 11,905,330.57	$ 12,095,815.86	$ 12,289,348.92	$ 12,485,978.50
$ 756,772.89	$ 771,908.35	$ 787,346.52	$ 803,093.45	$ 819,155.32	$ 835,538.42	$ 852,249.19	$ 869,294.18	$ 886,680.06
$ 546,558.20	$ 557,489.37	$ 568,639.15	$ 580,011.94	$ 591,612.17	$ 603,444.42	$ 615,513.31	$ 627,823.57	$ 640,380.04
$ 1,093,116.40	$ 1,114,978.73	$ 1,137,278.30	$ 1,160,023.87	$ 1,183,224.35	$ 1,206,888.84	$ 1,231,026.61	$ 1,255,647.14	$ 1,280,760.09
$ 882,901.71	$ 900,559.74	$ 918,570.94	$ 936,942.36	$ 955,681.20	$ 974,794.83	$ 994,290.73	$ 1,014,176.54	$ 1,034,460.07
$ 210,214.69	$ 214,418.99	$ 218,707.37	$ 223,081.51	$ 227,543.14	$ 232,094.01	$ 236,735.89	$ 241,470.60	$ 246,300.02
$ 714,729.96	$ 729,024.55	$ 743,605.05	$ 758,477.15	$ 773,646.69	$ 789,119.62	$ 804,902.02	$ 821,000.06	$ 837,420.06
$ 49,106,304	$ 49,106,304	$ 24,553,152						
$ 1,448,064.26	$ 1,303,257.84	$ 1,171,615.63	$ 1,109,555.74	$ 1,109,555.74	$ 1,111,436.34	$ 1,109,555.74	$ 1,111,436.34	$ 1,109,555.74
$ 6,818,314.02	$ 6,299,769.11	$ 5,836,388.54	$ 5,395,073.72	$ 4,986,857.51	$ 4,920,660.28	$ 4,920,660.28	$ 4,920,660.28	$ 4,920,660.28
-$ 50,580,009.21	-$ 49,824,792.27	-$ 24,583,618.40	$ 567,052.34	$ 1,070,568.93	$ 1,231,353.82	$ 1,330,882.11	$ 1,427,840.20	$ 1,529,762.15
-$ 10,621,801.93	-$ 10,463,206.38	-$ 5,162,559.86	$ 119,080.99	$ 224,819.48	$ 258,584.30	$ 279,485.24	$ 299,846.44	$ 321,250.05
$ 3,037,380	$ 3,037,380	$ 3,037,380	$ 3,037,380	$ 3,037,380	$ 3,037,380	$ 3,037,380		
-$ 36,920,827	-$ 36,324,206	-$ 16,383,679	$ 3,485,351	$ 3,883,129	$ 4,010,150	$ 4,088,777	$ 1,127,994	$ 1,208,512
$ 57,372,682	$ 56,709,331	$ 31,561,156	$ 6,504,629	$ 6,096,413	$ 6,032,097	$ 6,030,216	$ 6,032,097	$ 6,030,216
$ 20,451,855	$ 20,385,125	$ 15,177,478	$ 9,989,981	$ 9,979,543	$ 10,042,246	$ 10,118,993	$ 7,160,090	$ 7,238,728

13	14	15	16	17	18	19	20
$ 12,685,754.16	$ 12,888,726.22	$ 13,094,945.84	$ 13,304,464.98	$ 13,517,336.42	$ 13,733,613.80	$ 13,953,351.62	$ 14,176,605.25
$ 904,413.66	$ 922,501.93	$ 940,951.97	$ 959,771.01	$ 978,966.43	$ 998,545.76	$ 1,018,516.68	$ 1,038,887.01
$ 653,187.64	$ 666,251.40	$ 679,576.43	$ 693,167.95	$ 707,031.31	$ 721,171.94	$ 735,595.38	$ 750,307.29
$ 1,306,375.29	$ 1,332,502.79	$ 1,359,152.85	$ 1,386,335.91	$ 1,414,062.63	$ 1,442,343.88	$ 1,471,190.76	$ 1,500,614.57
$ 1,055,149.27	$ 1,076,252.26	$ 1,097,777.30	$ 1,119,732.85	$ 1,142,127.51	$ 1,164,970.06	$ 1,188,269.46	$ 1,212,034.85
$ 251,226.02	$ 256,250.54	$ 261,375.55	$ 266,603.06	$ 271,935.12	$ 277,373.82	$ 282,921.30	$ 288,579.73
$ 854,168.46	$ 871,251.83	$ 888,676.86	$ 906,450.40	$ 924,579.41	$ 943,071.00	$ 961,932.42	$ 981,171.07
$ 1,111,436.34	$ 1,109,555.74	$ 1,111,436.34	$ 554,777.87				
$ 4,920,660.28	$ 4,920,660.28	$ 4,920,660.28	$ 4,920,660.28	$ 4,920,660.28	$ 4,920,660.28	$ 4,920,660.28	$ 2,460,330.14
$ 1,629,137.19	$ 1,733,499.46	$ 1,835,338.26	$ 2,496,965.64	$ 3,157,973.73	$ 3,265,477.06	$ 3,374,265.35	$ 5,944,680.60
$ 342,118.81	$ 364,034.89	$ 385,421.03	$ 524,362.79	$ 663,174.48	$ 685,750.18	$ 708,595.72	$ 1,248,382.93
$ 1,287,018	$ 1,369,465	$ 1,449,917	$ 1,972,603	$ 2,494,799	$ 2,579,727	$ 2,665,670	$ 4,696,298
$ 6,032,097	$ 6,030,216	$ 6,032,097	$ 5,475,438	$ 4,920,660	$ 4,920,660	$ 4,920,660	$ 2,460,330
$ 7,319,115	$ 7,399,681	$ 7,482,014	$ 7,448,041	$ 7,415,460	$ 7,500,387	$ 7,586,330	$ 7,156,628

Table 2: Statement of cash flow for the Ellensburg wind farm

In order to predict revenue, it is anticipated that this wind farm could sell its energy for $0.0794 per kilowatt hour, which is the average price for energy from a wind farm in Washington [10]. Each year, over the 20-year lifespan of the project, the revenue increases by the inflation rate, which is currently at a low of 1.6% [11]. Changing markets could affect the amount the energy is sold for over time; increasing the revenue by the inflation rate is a simple projection. Additionally, it is clear that this wind project is not financially viable and would need to sell energy at $0.55 per kilowatt hour in order to have a positive net present value, which is high above industry standards and unlikely to find a viable energy buyer.

It is unlikely that the wind farm will be taken apart after the 20-year lifespan is completed; deconstruction costs can be much more expensive than salvage values. Because of this, it is probable that the site will be renewed after 20 years with the next generation of more advanced turbine technology and higher wind energy capture efficiency. Updating the wind farm will incur capital expenditure costs. However, they will not be comparable to the higher capital expenditure needed to develop a wind farm on a new site.

The wind turbines are depreciated on a 5-year MACRS schedule, which helps increase the cash flows in the later years. Site access and staging is depreciated on a 15-year MACRS schedule, and construction, electrical infrastructure, and the foundation are all depreciated on a 20-year MACRS schedule [5].

Both before and after taking into account tax incentives, this wind project is very undesirable. It has both a very negative present value and internal rate of return. This is largely due to the low net capacity factor, about 15%, and very high capital costs that this wind farm has. Wind farms in general have a high cost of development and high operating expenses; however, the Ellensburg site has an unusually high total cost of development. This wind farm will likely not produce enough energy to be a financially viable project without further help.

Additionally, there could be ways to lower the initial cost of development. These would include using different materials that are cheaper than what is currently budgeted or a different turbine that is less expensive. However, this is still not enough to make net present value positive. Using a turbine cost of *$150 million* makes net present value *-$81 million* and internal rate of return -2.85%. Another solution could be finding a site that has a much higher net capacity factor, somewhere closer to 30% to 45%.

Besides financial feasibility, the trend of renewable energy, like wind energy, exemplifies a person's, a business', and even a country's decision to implement more sustainable practices. As environmental degradation becomes exponentially more apparent, the world as a whole is able to experience just how much change is needed. Based on the financial analyses and the market trends of the wind energy sector, the construction and operation of wind farms have become more financially attainable, allowing for such renewable energy projects to become more profitable. However, to keep a well-rounded perspective of analysis, the second and third prongs of the triple bottom line, social and environmental cost and benefit respectively, must also be employed to make the optimal decision.

3. Environmental Analysis

Based on the U.S. Energy Information Administration's (EIA) current data and research for 2017, the U.S. in total consumes 97.7 quadrillion Btu, or about 28.6 trillion kWh [12]. About 89% [12] of that energy is being generated by non-renewable energy sources like crude oil for petroleum, natural gas, coal, and uranium for nuclear energy. Only 11% [12] of the total energy consumed is created by a renewable energy source. However, among the array of clean energy methods, wind power is second in line for a leading renewable energy source and is tied with biofuels.

Coupled with the promise of more innovative turbine technology, these statistics illustrate that wind energy production is one of the more integrated forms of renewable energy in our electricity profile, and that there is potential for increased wind energy production. Even though wind energy generation dims in comparison when looking at the U.S.'s energy portfolio, the 11% of wind energy generated is used in all sectors: transportation, industrial, residential and commercial, and electric power [12]. Therefore, implementing a wind farm will show promising environmental returns in generating clean energy for the grid, decreasing the country's carbon footprint and preventing human health impacts. On the off chance that turbines do emit anything, malfunctions are mainly contained to rare exceptions like leaked lubricating fluids that can be mitigated with regular maintenance checks. They also have relatively small physical footprints that have little interference with the rest of the land's uses.

Unfortunately for the Ellensburg site, there are several concerns that will deter the progress of site development. The most prominent obstacle is that the original site located along the Manastash Ridge, southwest of Ellensburg's city limits, will not be accepted by the city due to zoning regulations. Due to Chapter 17.61A of the Kittitas County Code [1], the county has designated indicated plots of land on the eastern border of the county to be used for all future wind energy projects. Seeing as our selected site is not in those zones, we will have a long, arduous, and most likely unfruitful negotiation where the county will deny our request.

Therefore, moving the site to the predetermined wind resource zones in Kittitas County will be recommended for this project to move forward. Not only do we have to choose those specific zones, but also any wind project looking to develop in the designated area would have the added benefit of a pre-prepared site analysis done by the state. According to the Kittitas County Community Development Services, the wind farm resource overlay zones were State Environmental Policy Act (SEPA) approved in the early 2000s, meaning that reports concerning wetland studies, migration patterns, streams, geotechnical studies, and along with others have already been completed and passed the state government standards. With this level of accreditation, the ecological analysis test for the land will already be deemed feasible for future wind projects.

4. Social Analysis

After researching and observing the renewable energy sector, market trends exemplify how the creation of sustainable energy has benefits that have transcended from micro to macro regarding the development of society. For example, this sector has been able to create more jobs. According to the International Renewable Energy Arena (IRENA), this sector continues to grow and has greater potential to keep globalizing. From IRENA's research, 70% [13] of the renewable energy jobs are in China, Brazil, US, India, Germany, and Japan. After solar photovoltaics, the leading industry representative in the clean energy sector, wind energy is the next biggest sector employing 1.15 million workers spread across China, Europe, and North America [13]. In the US alone, wind energy supports a strong domestic supply chain with the capacity to create over 600,000 jobs in manufacturing, installation, maintenance, and supporting services by 2050, according to the Department of Energy [14]. Bringing a wind farm to Ellensburg, a small city of about 20,000 people, would not only create more complementary jobs, but also stimulate opportunity and growth for the relatively rural demographic.

Due to the necessary specificity in weather conditions, the industry is geographically constrained. Fortunately, the wind farm site is on the western side of Ellensburg, where there is moderate wind generating capacity on the Manastash Ridge. Not only will the ridges be put to an environmentally good use, the landowners will be able to make a stable and long-term income off of their land. After using the *Kittitas County Compass Map* function, we were able to distinguish each and every parcel of land owned by a landowner, the county, or state entity. Whether it is owned by a person or an entity, they will be compensated for land that they would otherwise have little use for. From this additional source of revenue, individuals will be benefiting from a higher disposable income while the city or state governments will be able to grow economically in order to fund necessary programs, build fundamental structures, public programs, or supply other resources to improve their people's livelihood.

Concerning the regions in the US and around the world who consequently are not able to benefit from wind farms, the Department of Energy's *Wind Vision Report* predicts that all 50 US states will be able to implement infrastructure to contribute to wind energy [14]. As a result of a more reliable source of energy protecting electricity prices from the volatility of the non-renewable energy market, the electric utility sector will be able to confidently diversify their portfolio on a macro level, which prevents price fluctuation and vulnerability previously experienced from non-renewable energy. Therefore, in the long term, wind energy production provides cheaper yet more sustainable electricity prices.

Although there is a positive externality of wind farms in their capability to provide a sustainable source of energy on a macro level and provide for their community on a micro level, we believe that establishing a wind farm on the original site selected by 2018 SU team will provide more social harm than benefit. There might not be a dense population of people living on the site, but after considering the natural resources and recreational activities, a wind farm will disrupt the natural aesthetic and use of the land. For example, in and along the area of the site, there are hiking trails, campsites, the Manastash Ridge Observatory, and the Lazy F Camp and Retreat Center United Methodist that depend on and highly value the natural beauty of the surrounding environment. To the people of Kittitas County, the experience of nature and its beauty could be valued higher than the benefits of the wind farm and wind energy.

According to *A Visual Impact Assessment Process for Wind Energy Projects* from the Clean Energy State Alliance (CESA) [15], there are four general considerations of visual impact review that the report provides: level of review, area of review, resources evaluated, and public participation. The level of review for this project would be at the local county level, seeing as this land falls within their jurisdiction, and they would determine whether the area of land has cultural, scenic, or recreational value. Since people of the Kittitas County value the untouched land as all three of the mentioned determinants, the originally selected site has an unlikely chance of being approved. Using the location of the outermost turbines for the area review, the selected site might be too close to the city limits of Ellensburg and would need a viewshed analysis to predict how visible the wind farm will be to the city dwellers. If the view of the Manastash Ridge and the Okanogen-Wenatchee National Forest, which is west of Ellensburg and the site, is detrimentally impaired, there will likely be a vocal group of unhappy people especially if their property is adjacent to the site and the property value is dependent on the view. The type of scenic resources that are evaluated are areas that serve as significant community focal points and provide community experiences like the Manastash Ridge. Therefore, any activities or uses that deteriorate the natural resource is discouraged. Lastly, since there was no public participation in choosing the site location, the project negates the community's input and is less credible to the county. The site has more value and importance to the affected communities that our team may not know about, and the 2018 SU team should have conducted a public hearing process in addition to our feasibility test. Based on these four considerations, there is a high probability of being denied access by the state.

5. Recommendations

Based on the analysis in each aspect of developing the Ellensburg wind farm presented above, we have the following recommendations for developing a wind farm project nearby:

Financial

- Reselect a more advanced turbine model
    - higher hub height around 110-140 m in order to capture higher wind speeds
    - priced at $3 to $4 million each or $1200 to $1600 per kwh in order to lower cost of development
- Relocate to a site that allows for a higher annual net capacity factor around 35%

Environmental

- Continue to abide by environmental standards such as SEPA
- Conduct environmental feasibility test for wildlife protection and invasive practices

Social

- Abide by local or federal permitting zones
- Conduct deserved public process and public forums to account for all feedback regarding significant scenic, cultural, religious, and recreational value

6. Conclusion

From our in-depth analysis, the originally selected Ellensburg wind farm site fails to meet the triple bottom line of the industry. Despite being beneficial for the environment, it is not financially viable, and the site location would be rejected by the community for multiple reasons. After our analysis, there is a higher probability that the project would be a feasible option if our recommendations are implemented.

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