Project Development Report

Washington State University-Everett with Everett Community College

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I. Introduction

With populations growing at an exponential rate and traditional methods of energy generation struggling to keep up with the demands, alternate, renewable energy generation methods are needed. One of these renewable energy sources is wind energy. Wind carries a tremendous amount of unharnessed energy and is essentially an endless energy source. Wind turbines are capable of harnessing this energy, but are expensive, long-term devices, so a lot of planning must be put into setting up a wind farm to ensure they are worth the investment. Both a detailed financial analysis and an in-depth siting analysis are necessary to create a successful wind farm.

For the 2020 Collegiate Wind Competition (CWC), we designed a wind farm for Eastern Colorado which would produce up to 100 MW. We developed a new wind farm on a site currently not used for wind energy which we picked based on a number of criteria, such as wind resource, proximity to transmission lines, and available site area. We chose to develop our wind farm on a brownfield site, which is unusable for most other development purposes but viable for wind farms. We used GIS data to select our site, using a program called QGIS to select a site in Yuma county. Our site is currently being used as a landfill and for gas pumping. It has the space and the wind resource to be a viable wind farm, and the landowners in the area have a history of leasing out their land.

To design the turbine layout of our wind farm, we used a wind farm analysis tool called Openwind, which optimizes the layout of our turbines on the site and predicts the amount of power our wind farm would produce. Openwind can model the wakes of the turbines and the wind velocity over a given terrain and uses these to find optimal turbine placements. The wind farm we designed has 30 GE 3MW-117 turbines, which are rated for 3 MW, bringing our project size to 90 MW. Since the site is currently being used to pump gas, there are many existing service roads. The turbines were placed to make as much use of the existing roads as possible and to limit the amount of new construction needed for our wind farm. Openwind also used detailed wind data that we purchased from UL to give an annual energy capture report, which we used to conduct a financial analysis to determine if our planned wind farm was economically viable. This financial analysis includes the JEDI model, initial capital cost annual operating expenses, land lease, financing options, loan, depreciation, return on debt and equity, tax, and annual revenue required.

We discuss our site selection process in **Section II** and give more details on how we selected our exact site. The analysis that led to our turbine placement can be found in **Section III**. The details of our financial analysis are in **Section IV**, and our conclusion is in **Section V**.

II. Site Selection

The first step in the design of our wind farm was to select a site. We chose to build our wind farm on a brownfield site, which is a site designated by the Colorado Department of Public Health and Environment that has been contaminated in some way and is unsuitable for redevelopment. While these sites might be unusable for agricultural use or urban development because of their contamination, they can be used as wind farm sites, turning an otherwise useless piece of land into an energy source. The state of Colorado has designated sites across the state that can potentially be repurposed for renewable energy sources. This includes sites such as landfills, abandoned warehouses, and other facilities that are either serving no purpose, or could have their usage increased. Brownfield sites are designated by the state as needing a new purpose. This indicates that the state, or whoever else owns the land would be interested in the possibility of building a wind farm on that site. Additionally, we reduce the amount of environmental concerns by building on a brownfield site. By using a contaminated site which is already not viable for agricultural purposes, minimal animal habitats and farming land are disturbed.

To locate suitable brownfield sites, we used GIS (geographic information system) data, which the state of Colorado provides in a downloadable format. GIS data contains detailed geographic information of many different types of information, such as average wind speed, transmission line location, and brownfield site location. We used a program called QGIS to import the different GIS files. While Openwind, the tool we used to place our turbines, also has GIS capabilities, QGIS was better suited to site selection than Openwind. Openwind was intended for wind farm planning on a given site, and most of its GIS capabilities are intended for site analysis, not site selection. QGIS can import a wider variety of GIS files, and is capable of more complex GIS data manipulations than Openwind is.

We learned about GIS data and how to use QGIS from David Puckett, a consultant at Bright Rain Solutions with over 20 years of GIS experience who offered his time to teach us. He met with us on a weekly basis and provided GIS labs for us to work through. From David Puckett, we learned how to import maps and GIS data into QGIS as well as how to use QGIS to process that data and return sites that matched a set of criteria.

For the selection of our site, we first used QGIS to find brownfield sites in Eastern Colorado. We used QGIS to compare the available wind resource, site area, and proximity to roads, transmission lines, and substations at each site. Additionally, sites were avoided if they were listed as a habitat for sensitive species. Specifically, we narrowed our list of brownfield sites down to ones that had a wind speed of at least 6 m/s at a hub height of 80 m and that were less than two miles from roads, transmission lines, and substations. Out of the remaining sites, each site was evaluated as far as wind resources, buildable land, and accessibility. Using these criteria, three main candidates were selected: the Yuma county landfill, the Walsh city landfill, and the Phillips county landfill. All three of these landfills are in extremely rural farming areas with very little population base. However, all three of them are close enough to supply power to the Denver metropolitan area. Of the three sites, the Walsh landfill had the best wind resources and an adjacent substation. However, the land surrounding the landfill would have been nearly impossible to use as a large wind farm due to the limited space, topography, and proximity to town. Thus, the Walsh site was the first one to be eliminated. Between the Yuma and Phillips county landfills, the differences were more subtle. They shared nearly identical wind resources and topography but not buildable land. The Yuma county landfill has a large, relatively flat area surrounding it that is ideal for wind turbines. Due to the vast disparity of potential buildable land, Yuma was selected for further research.

Though a landfill itself cannot have turbines built in it, the surrounding area had a relatively flat, open area with no crop fields. The reason that no turbines can be built within the confines of the landfill itself is because of regulations dealing with disturbing topsoil in and surrounding land. Due to the toxic nature of landfills, digging in it could potentially cause severe environmental damage. Pinned between the landfill, and fields, the buildable area is the perfect size to be able to build a wind farm of around 100MW. Upon further investigation into the location, it was discovered that there are a large number of access roads throughout the property. Through research it was found that the seemingly random roads served the double purpose of access for cattle and maintenance of gas pumps. The presence of these roads reduces the initial investment cost of needing to build access roads for building the turbines. Another fantastic characteristic of the property is actually the gas pumps. The area is filled with gas pumps meaning that the land is not suitable for anything else other than cattle grazing. Since both the gas pumps and wind turbines have a small footprint, they can be interspersed throughout the property without interfering with each other. This greatly increases the productivity of the land. Instead of just one energy source, it would have two. One other subtle upside to the presence of the gas pumps is the willingness of the property owners to lease their land for energy generation. Through extensive research, we found that on average, leasing the land for a year only costs approximately $25-$50 per acre with the catch being that each turbine would be considered a acre due to leasing codes. The exact amount that a lease would cost is unknown because leasing information is completely confidential due to the competitive nature of energy generation.

III. Site Design

Once the Yuma landfill was chosen for the location of the wind farm, the design process began. The first step was to determine the boundary for the project. **Figure 1** shows the Yuma landfill highlighted in blue, the boundary in red, and the surrounding area.

Figure 1: *Yuma Site Wind Farm Project Boundary*

The first important piece of information about the development of the site is that no turbines could be placed within the confines of the landfill. Because of this, attention was turned to the surrounding area. As seen in the figure, there is a large area of land (in excess of 4 square miles) not being used for agriculture. Instead, it has cattle and gas pumps, and provides the ideal spot for wind turbines.

The turbines used for modelling this project are Alstom ECO 100 3.0 Class 1A turbines, which have a rotor diameter of 50 m, and a hub height of 100 m. We used this turbine in our analysis because it was available in Openwind, but the turbines used in our wind farm are GE 3MW-117. These are the same size and capacity as the Alston turbines, but Alstom went out of business a few years ago and their turbines can no longer be purchased. We used the GE turbines because they are currently available, but the Alstom turbines are still a good model of the turbines we chose for our site.

Within the scope of the now defined area, several additional constraints in addition to the boundary and landfill were needed for turbine placement. The next constraint was roads. There are a few farm roads that pass through the project boundaries in a neat and tidy grid. In addition to these permanent farm roads, the site has many access roads. In designing the turbine layout, all turbines must maintain a minimum distance of at least 20 meters from any access road, 50 meters from a main road, and 50 meters from a gas pump. To accomplish these constraints in Openwind, each road had to be marked by hand since there was no existing GIS data. This was accomplished using line layers in Openwind to create custom GIS data. Fortunately, the state of Colorado keeps detailed GIS data on the exact location of each of the gas pumps. Within the Openwind software, buffers were assigned to the roads and oil pumps so that a turbine could not be placed within a restricted zone.

After completing the constraints, the wind resources were added to the study. To acquire wind data for this study, virtual MET mast data was purchased from UL (Underwriters Laboratories). This was 1 years' worth of modelled wind speed and direction for our two chosen MET mast locations. One location was in the middle of the west side of the project and one in the middle of the east side of the project. This data was then used in conjunction with elevation and terrain data to generate a wind resource map for the project. Using this wind data and the constraints, an optimization was run on the project. Openwind takes this information along with considerations of wake modelling and turbine proximity to place turbines in what seems to be the best configuration. It determines the optimal locations of the turbines by wake modelling, which calculated how much the turbines' wakes interfere with the other turbines. It continues to test different configurations, constantly improving the layout until stopped by the user. For this wind farm, over 500 iterations for the turbine locations were run. The reason that more iterations were not run is that the improvements from each iteration of the optimizer were becoming insignificant as can be seen in **Figure 2**.

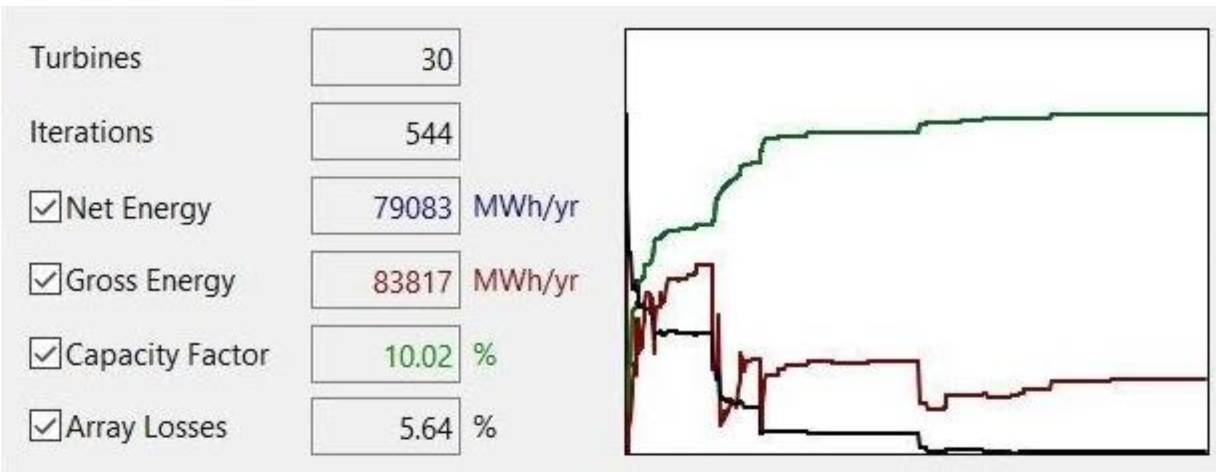

Figure 2: *Openwind optimizer results*

Figure 2 also shows the predicted energy produced by our wind farm operating at the expected capacity of about 10%, which is about 79,083,000 kWh/yr. The figure also shows that Openwind predicts wake losses of 5.64%.

Figure 3 shows the locations of all 30 turbines in the project. These are represented by the large circles with the pink numbering. The black circle surrounding each turbine indicates a diameter four times larger than the rotor diameter, therefore, the circle has a diameter of 200 m. As seen in the figure all of the turbines are at least the minimum distance from the gas pumps and the roads represented by the smaller dots and multicolored lines respectively.

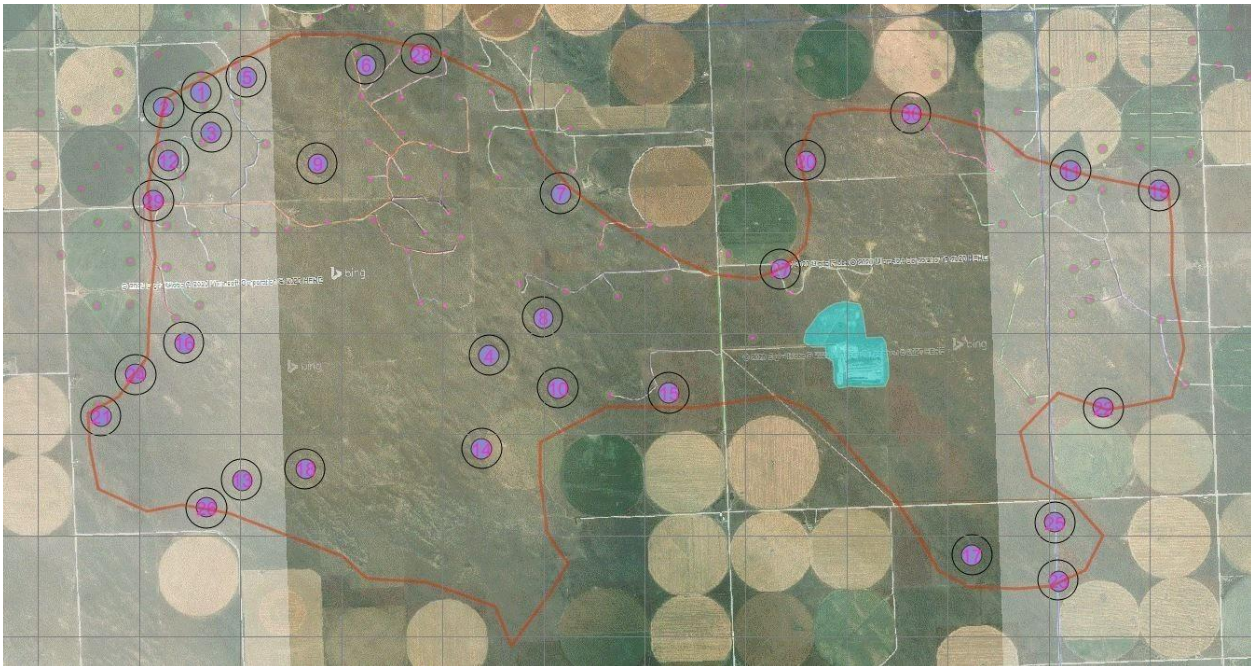

Figure 3: *Turbine layout for Yuma site, as determined by Openwind*

IV. Financial Analysis

A. JEDI Model

Our cost analysis data came from NREL Transforming Energy- JEDI Model [1]. According to nrel.gov, the JEDI Model allows the user to estimate the economic development impacts. JEDI Model required the user to enter input which included: construction materials and labor costs, turbine, tower, blade costs, and local content information, utility interconnection, engineering, land easements, and permitting costs, annual operating and maintenance costs, and tax, land lease, and financing parameters [1]. The basic data that we had inputs into the JEDI model were the location, year of construction, and the turbine size. Our JEDI model is in **Table 1**.

B. Initial capital cost

Table 1: *JEDI Model*

Detailed Wind Farm Project Data Costs	**Colorado**	
Construction Costs	**Cost**	**Local Share**
Equipment Costs		
Turbines	$57,586,626	0%
Blades	$13,481,819	0%
Towers	$14,926,300	0%
Transportation	$10,303,962	0%
Equipment Subtotal	$96,298,706	
Balance of Plant		
Materials		
Construction (concrete rebar, equip, roads and site prep)	$13,915,163	90%

Transformer	$1,574,093	0%
Electrical (drop cable, wire,)	$1,659,201	100%
HV line extension	$3,030,806	70%
Materials Subtotal	$20,179,264	
Labor		
Foundation	$1,251,030	95%
Erection	$1,416,970	75%
Electrical	$2,064,951	70%
Management/supervision	$1,071,507	0%
Misc.	$4,969,260	50%
Labor Subtotal	$10,773,719	
Development/Other Costs		
HV Sub/Interconnection		
Materials	$956,336	90%
Labor	$292,945	10%
Engineering	$1,301,334	0%
Legal Services	$709,227	100%
Land Easements	$0	100%
Site Certificate	$331,840	100%
Other Subtotal	$3,591,681	
Balance of Plant Total	$34,544,664	
Sales Tax (Materials & Equipment Purchases)	$3,079,046	100%
Total Project Costs	$133,922,417	

The total of BOP which included all the materials and labor costs is $30,952,982.72. For the equipment costs which included turbines, blades, towers, and transportation, the total cost is $96,298,706.

C. Annual Operating Expenses

Table 2: *Annual operating costs*

Wind Farm Annual Operating and Maintenance Costs	
	Cost
Labor	
Personnel	
Field Salaries	$255,693
Administrative	$40,911
Management	$114,750
Labor/Personnel Subtotal	$411,354
Materials and Services	
Vehicles	$85,949
Site Maintenance/Misc. Services	$33,520
Fees, Permits, Licenses	$16,760
Utilities	$67,040
Insurance	$644,618
Fuel (motor vehicle gasoline)	$33,520

Consumables/Tools and Misc. Supplies	$217,881
Replacement Parts/Equipment/ Spare Parts Inventory	$1,909,358
Materials and Services Subtotal	$3,008,646
Sales Tax (Materials & Equipment Purchases)	$64,182
Other Taxes/Payments	$0
Total (with Sales Tax and Other Taxes/Payments)	$3,484,182
Debt Payment (average annual)	$14,764,212
Equity Payment - Individuals	$0
Equity Payment - Corporate	$4,682,358
Property Taxes	$510,831
Land Lease	$270,000
Total Annual Operating and Maintenance Costs	$30,615,765

The total annual operating and maintenance costs are $30,615,760, as seen in **Table 2**. The total of sales tax and other taxes are $3,484,182. For the total of materials and services is $6,017,292.18. The annual debt payment is $14,764,212; however, since the debt payment is ten years period. After ten years, we don't have to pay the debt payment anymore which decreases the total annual operating and maintenance costs.

D. Land Lease

The land easements and the land lease expenses from the JEDI model are based on the land lease contract signed by the landowner. To be able to use the land, Land use permit is required. We are currently (or we intend) to negotiate leasing with the various landowners listed with expected annual leasing costs of between $25-$50 per year, per acre based on the past experiences.

E. Financing Options

According to the "ITC or PTC for Your Renewable Energy Project?", by Greg Pfahl. "Projects that require a heavy upfront investment may be more suited to the ITC. They might include geothermal, biomass, or clean coal. Solar projects aren't eligible for the PTC; it might be a better option for wind companies" [2]. The Production Tax Credit (PTC) will be the most economical plan for our project.

According to the windexchange.energy.gov: "The Production Tax Credit (PTC) provides a tax credit of $1–$2 per kilowatt-hour for the first 10 years of electricity generation for utility-scale wind [3]. PTC applies to the first 10 years of operation's project.

Table 3: *Wind energy production tax credit*

If construction begins	The estimated allowable tax credit is
After Dec. 31, 2016	1.9 cents / kWh
By Dec. 21, 2017	1.8 cents / kWh
By Dec. 31, 2018	1.4 cents / kWh
By Dec. 31, 2019	1 cents / kWh
By Dec. 31, 2020	1.5 cents / kWh

F. Loan

The entire project cost $133,922,417 to start up. $133,922,417 will be financed by Colorado RENU Loan. According to the energyoffice.colorado.gov: "the Colorado RENU Loan is a statewide residential loan program sponsored by the Colorado Energy Office in partnership with Elevations Credit Union [4]. The Colorado RENU Loan Terms offer finance up to 100% of project cost, low and fixed interest rates, and

3,5,7,10 and 15-year terms. The Colorado RENU Loan has separated into two parts which are for homeowners and contractors.

G. Depreciation

Table 4: *Modified Accelerated Cost Recovery System Depreciation*

5 years MACRS	MACRS	Depreciation Rate for Recovery Period
Year 1	$ 133,922,417.00	20.00%
Year 2	$ 107,137,934.00	32.00%
Year 3	$ 64,282,760.00	19.20%
Year 4	$ 38,569,656.00	11.52%
Year 5	$ 23,141,794.00	11.52%
Year 6	$ 7,713,931.00	5.76%

The depreciation schedule is followed by the Modified Accelerated Cost Recovery System (MACRS) and was calculated by the MACRS Depreciation Calculator [5]. MACRS depreciation is an essential calculator for the operations to recover the capital costs over the operation's lifetime. MACRS depreciation also allows the operations to deduct the depreciable basis over five years reduces tax liability and accelerates the rate of return on other energy industries [6].

H. Return on Debt and Equity

In the return on debt, our wind farm is 80% of capital cost in debt while the annual interest rate is 6%. The debt will be paid off at the end of ten years. Therefore, the debt annual payment will be roughly around $14,764,212. For the return of equity, the wind farm is 20% in equity and is 100%, corporate investors. The annual interest rate is 12% and the equity will be paid off within a ten-year period. The equity payment will be $4,682,358.

I. Tax

According to the "The United States' Corporate Income Tax Rate is Now More in Line with Those Levied by Other Major Nations" written by Kyle Pomerleau. Kyle mentions that Colorado corporate tax rate is 4.6%. On the other hand, Colorado states and the federal corporate tax rate is 24.7% [7]. Based on the JEDI model, the sales tax which included the materials and equipment purchase is $ 64,182.

Our income statement can be found in **Table 5**, and our balance sheet can be found in **Table 6**.

Table 5: *Income statement*

Income Statement	
Revenue	$ 3,558,735
Expenses	
Labor	
Field Salaries	$ 255,693
Administrative	$ 40,911
Management	$ 114,750
Labor/Personnel Subtotal	$ 411,354
Materials and Services	
Vehicles	$ 85,949
Site Maintenance/Misc. Services	$ 33,520

Fees, Permits, Licenses	$ 16,760
Utilities	$ 67,040
Insurance	$ 644,618
Fuel (motor vehicle gasoline)	$ 33,520
Consumables/Tools and Misc. Supplies	$ 217,881
Replacement Parts/Equipment/ Spare Parts Inventory	$ 1,909,358
Materials and Services Subtotal	$ 3,008,646
Operating Expense	
Depreciation	$ 26,784,483
Sales Tax (Materials & Equipment Purchases)	$ 64,182
Other Taxes/Payments	-
Total (with Sales Tax and Other Taxes/Payments)	$ 3,484,182
Debt Payment (average annual)	$ 14,764,212
Equity Payment - Individuals	-
Equity Payment - Corporate	$ 4,682,358
Land Lease	**$ 270000**
Total Annual Operating and Maintenance Costs	56,889,417
Net Loss	$ (53,330,682)

Table 6: *Balance sheet*

Balance Sheet			
Current Assets			
	Cash		$ 133,922,417
	Accounts receivable		$ 756,000
	Inventory		$ 3,008,646
		Total current assets	$ $137,687,063
Fixed (Long-Term) Assets			
	Long-term investments		$ 133,922,417
	Property, plant, and equipment		$ 96,298,706
		Total fixed assets	$ 230,221,123
Total Assets			**$ 367,908,186**

Liabilities and Owner s Equity			
Current Liabilities			
	Accounts payable		
	Short-term loans		$ 53,061,692
	Current portion of long-term debt		$ 14,764,212
		Total current liabilities	$ 139,037,058
Long-Term Liabilities			
	Notes Payable		$ 54,444,529
	Long-term debt		$ 147,642,117
		Total long-term liabilities	$ 202,086,646
Owner's Equity			
	Share Capital		$ 26,784,483
		Total owner's equity	$ 26,784,483
Total Liabilities and Owner's Equity			**$ 367,908,187**

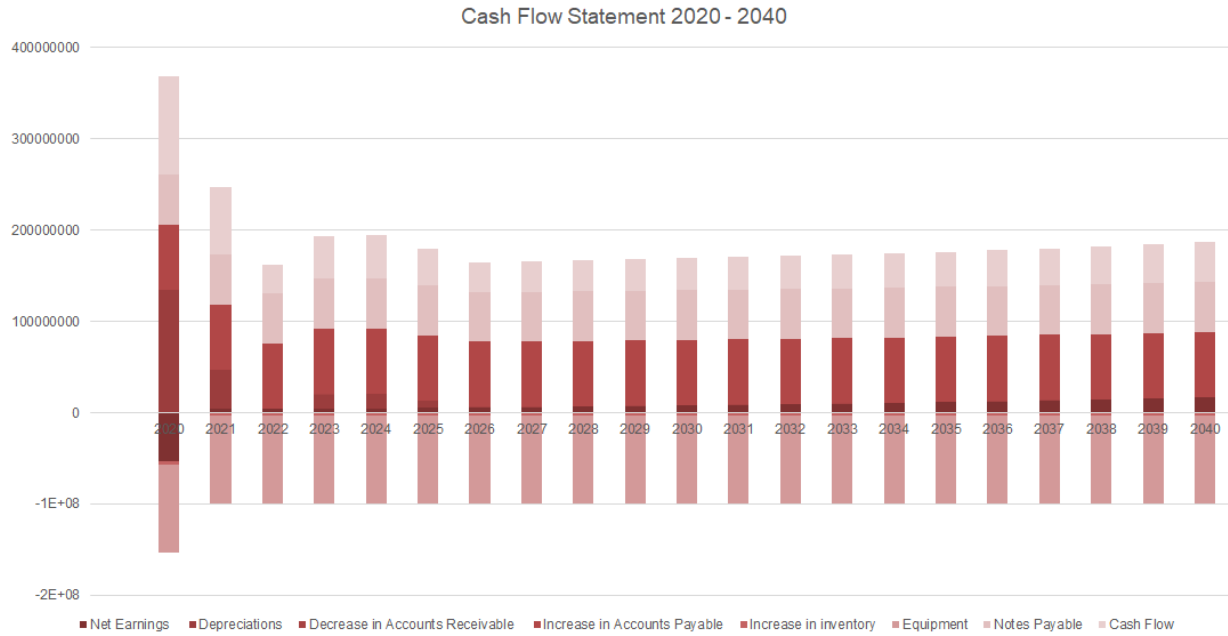

Figure 4: *Cash flow statement*

To be able to calculate the cash flow statement, we adjusted two parts of the cash flow statement which included the net earnings and the depreciation, the other parts remain consistent. US wind power grew 8 percent in 2018 amid record demand (American Wind Energy Association, 2018) To calculate the net earnings for the next 20 years, we use the following formula.

$$net\ earnings = (net\ income\ of\ previous\ year) + (net\ income\ of\ the\ previous\ year)(8\%)$$

Since the depreciation is a 5-years MACRS schedule. After 5 years, there is no more depreciation cost in the cash flow statement. Our cash flow statement is shown in **Figure 4**.

J. Financial Analysis Summary

With the annual Operating and Maintenance expenses that were approximately predicted before and the cost of depreciation, the total annual expense will be $57,400,248 in the first year, $30,616,765 after the 5-year depreciation period, and $15,851,553 after the 10-year loan period. With the size of the project that was predicted, there will be 3 MW of turbine size with 30 turbines in total can be provided. NexEra, which is known for the leading corporation of providing wind energy, has been putting their price at 3 cents per kilowatt hour. Openwind predicts that our wind farm will produce 79,083 MWh/yr, and with the local price of electricity, we predict a revenue of about $2,272,490. Assuming construction can start before December 31st, 2020, as seen in **Table 3** we can claim an additional 1.5 cents per kWh generated tax credit, which would increase our expected revenue to $3,408,735. However, this revenue is lower than our anticipated expenses, leading to the conclusion that this site is not economically viable under current conditions.

V. Conclusion

This year we developed and analyzed a wind farm for Eastern Colorado. We used GIS data to select a site, used Openwind to place turbines, and conducted a financial analysis to determine the economic viability.

We determined that the site we selected was not economically viable under current conditions, but we learned a lot about planning a wind farm and plan to use our experience to improve our site planning next year. We learned how to interact with and filter through GIS data, which will help us select a site sooner next year. The assistance we received from David Puckett at Bright Rain consulting was very helpful for this, and we intend to use the material he taught us for reference in future years. We also learned how to optimize wind farm layouts with Openwind, which we will be able to do faster next year. This year, learning how to select a site and optimize our wind farm took most of the year, but next year we should be able to do this for multiple sites, which will hopefully help us select an economically viable site.

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