2023 Collegiate Wind Competition

OSU CYCLONE COWBOYS

SCHOOL OF
ELECTRICAL AND COMPUTER ENGINEERING
College of Engineering, Architecture and Technology

PROJECT DEVELOPMENT REPORT

Project Development Team:

Hunter Reitze - Project Development Lead

Sahir Virani - Cyclone Cowboys Team Lead

Brady Amox - Financial Analysis Lead

Peter Tikalsky

Alyssa Miller

Evelyn Baker

Gus Cowan

Isaiah Cotton

Calvin Ward

Tucker Meredith

Mazyad Abusheeba

Madeline Duncan

Faculty Advisor:

Nate Lannan

Pete’s Power Plant

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Introduction

The Cyclone Cowboys' project development team has been working deliberately to design Pete's Power Plant (PPP) off the coast of Port Fourchon to compete in the 2023 Collegiate Wind Competition. In this report, the finalized wind farm design and research will be covered in detail. The wind farm design has a total output of 399 MW, utilizing 42 Vestas wind turbines. Simulations and analysis of the site were completed using Furow, Windographer, System Advisor Model, and ArcGIS software.

Site Description

Site Selection and Characteristics

The main concerns for the farm were water depth and existing infrastructure. Data showed that the average wind speed was 6.5m/s throughout the given lease blocks with a minimal amount of deviation. Therefore, during the property analysis phase, wind speed was not a main concern. The lease blocks had a depth of 42ft – 140ft, the plots farthest to the south-east being the deepest.

Port Fourchon serves 90% of the Gulf of Mexico's deep-water oil and gas activities, and more than 18% of all US crude oil and natural gas. There is a significant amount of active drilling leases, pipelines, and existing wells running throughout the lease blocks, all of which need to be avoided as the construction of the farm could interfere with the operation of the existing equipment (Figure 1). Most of the active drilling leases are in the eastern half of the lease blocks, but wells and pipelines cover most of the given area. All the shipping lanes run through the far east blocks so there is not much concern when avoiding them. We avoided lease blocks with large quantities of existing infrastructure to maximize our investment on the property and allow the investment to reach its full potential.

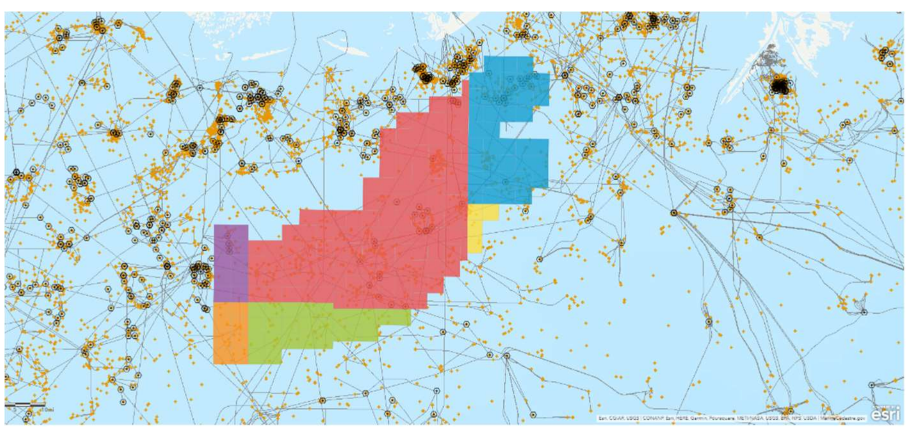

Figure 1 - Property analysis of oil pipelines, drilling platforms, wells, and shipping lanes

After the property analysis phase, multiple lease blocks remained that were within 50 km of the nearest substation (Figure 2). The team ran simulations over five possible lease blocks. The only neighboring lease blocks without major interference from our chosen constraints were lease blocks 83, 90, and 91. The team chose to build Pete's Power Plant on these three lease blocks as we wanted to maximize wind farm area. In addition, these three lease blocks are oriented in a way that favors minimizing wake effects and maximizing undisturbed turbine surface area. Lease block 90 has a slight obstruction due to a pipeline crossing over the south-east corner. After research and analysis of the lease blocks, the team decided the negative impacts of this obstruction to be minimal. These lease blocks have an ocean floor that is not heavily sloped, which will ease the construction process by strengthening the integrity of the turbines. Also, the chosen lease blocks are subjected to minimal amounts of vessel traffic and out of any military territories.

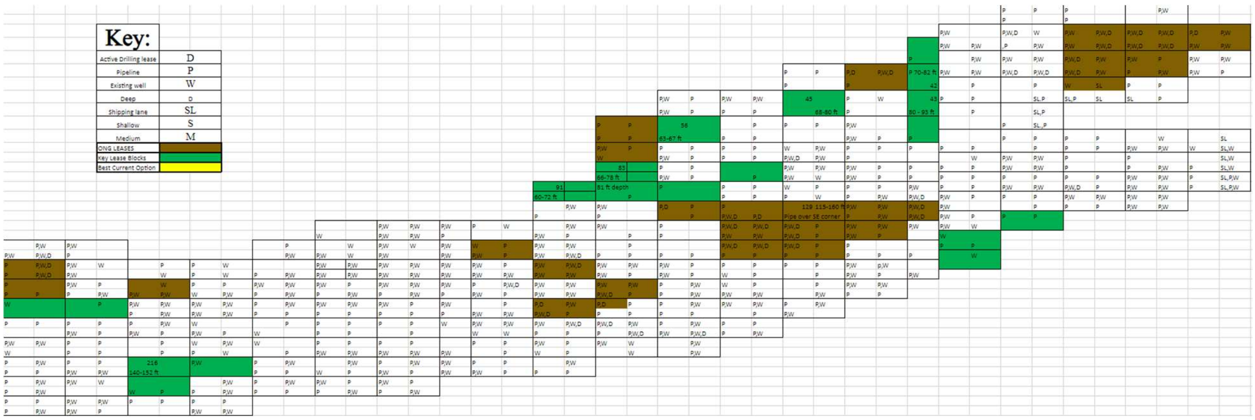

Figure 2. Lease block decision matrix

Site Layout

The site layout is based on 42 Vestas V-164 9.5MW wind turbines [1,2]. Each turbine has a diameter of 164 meters and a hub height of 150 meters. Using the industry standard, turbines are separated at a minimum of four times the rotor diameter. This 4-diameter separation minimizes wake effects, maximizing energy output, in addition to minimizing wind turbine failure risks. The wind turbines' placement was oriented to maximize uninterrupted surface area on the east and southern border of the lease blocks (Figure 3). The location of the turbines was optimized by analyzing the wake effects of turbine placement, utilizing the Furowake model to minimize wake losses and improve final turbine placement. We optimized the layout manually, as the team encountered the same issues previous year’s teams had when running the optimizer tool within Furow. Manually optimizing led us to better results than those the optimizer produced. Utilizing this wind farm layout in lease block 83, 90, and 91, we have a total energy yield of 1700 GWh. This design also includes two wind turbines south-east of an existing oil pipeline. The turbines are placed over 500m from the pipeline, which is much higher than the total height of the turbines, to maintain a safe distance per Offshore Wind Submarine Cable Spacing Guidance [3]. Additionally, the two turbines will only be installed if an agreement between the pipeline owner and PPP employees is made concerning our cables crossing the pipeline, per Offshore Wind Submarine Cable Spacing Guidance.

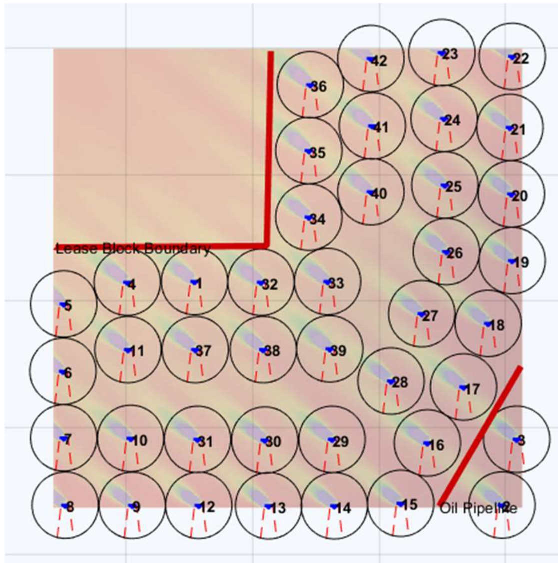

Figure 3. Turbine positions with average condition wake effects

Wind Resource

Utilizing the Vestas V164-9.5MW wind turbine, our site has an estimated annual energy production of 1,700 GWh. The turbines are powered by an average of 7m/s wind (measured at 10m above sea level) coming from the southeast, mainly at 128.7 degrees. This data, obtained from the National Data Buoy Center, was also checked by using Windographer, software designed to analyze wind resource data. Being that the turbines are in the Gulf of Mexico, extreme wind speeds from hurricanes were accounted for when choosing a turbine and foundation type.

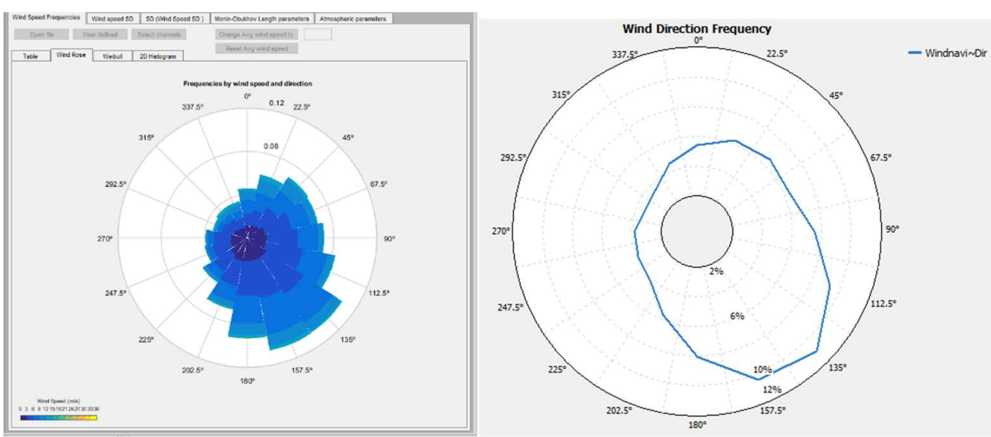

Figure 4. Furow (left) and Windographer (right) frequency by wind speed and direction

Turbine Selection

Three total turbines were analyzed to be utilized in PPP. Based on analysis within Furow, the Vestas V164 proved to be the most efficient. Its high rated power compared to its rotor diameter allowed for a substantial reduction of wake losses and high energy production. Also, because of its smaller rotor diameter, the design included more wind turbines.

Turbine Name	Rated Power (kW)	Rotor Diameter (m)
Vestas V164 9.5MW	9500	164
IEA 15 MW RWT	15000	240
DTU 10 MW RWT	10000	178.3

Figure 5. Analyzed Turbine Characteristics

Transmission Plan

PPP will be utilizing five 66 kV array cables to connect to our offshore substation. From the offshore to the onshore substation, a 345 kV single circuit transmission will be utilized [4]. The cables and substation will be operated in HVDC [3]. All cables will be buried greater than 5 ft below the sea floor [5]. The onshore substation we will be connecting to is the Leeville substation. It is near Port Fourchon in Leeville, Louisiana. We need to stay within the industry standard of 50km (about 31.07 mi) from a substation to keep power loss at a minimum. Currently, Pete's Power Plant offshore substation is 49 km (about 30.45 mi) away from the substation. According to Scott Baltic, the Leeville substation is "designed to 230 kV standards and hardened to handle 150 mph winds, which exceeds National Electrical Safety Code criteria for a Category 5 hurricane" [6]. In addition, this is one of the only nearby substations in service.

Foundation Type

We need to consider several metrics in order to choose a foundation type for this project. The foundation type needs to be versatile in location, economically efficient, safe for the environment, able to withstand vertical forces from the structure itself and withstand lateral forces from the wind and waves. The foundation also needs to have a high integrity in a mainly clay-based seabed. Given all these factors, a twisted jacket best fulfills the listed metrics. The twisted jacket has high structural integrity and provides a habitat for surrounding species. The twisted jacket can also act as an artificial reef for surrounding ocean species and leatherback turtles. The chosen lease blocks have a depth range of 61 – 81 feet, which the twisted jacket foundation is well suited for. At this depth, our other possible foundation choice, monopile foundation, has been ruled out. The monopile is better suited for shallow waters and disrupts more of the ocean floor and surrounding ocean species. In addition, given the seafloor geology, a composition of mud and clay, the twisted jacket is best suited for our wind farm.

Using the twisted jacket, we will get the advantage of having a cheaper and more eco-friendly installation. Also, the twisted jacket fits our area well as there is an extensive range of wave heights when accounting for hurricanes. Twisted jackets will be able to withstand the waves within a low number of wave-induced vibrations. In addition, twisted jackets are generally light when compared to other foundation types. This benefits us by reducing material costs and making installation easier than other options. Lastly, we are confident in our choice of foundation as it has been used in the oil and gas industry for many years and has been used in offshore windfarms in the UK [7].

Environmental Mitigation Strategies and Characteristics

Prior to our construction phase, we will complete a pre-construction monitoring phase. This phase will be utilized to assess environmental characteristics even deeper; therefore, after construction, we will have a better understanding of our environmental impact. This process is practiced for European wind farms.

Upon further inspection of the bird, marine, mammal, and fish data provided from the United States Department of Agriculture, the lease area is within the confines of endangered avian species and marine life. In the following segments, the risks for avian species, marine life, and human impact from the offshore wind farm will be discussed. This will also include mitigation strategies implemented worldwide that will be used for PPP.

Avian Mitigations

Millions of avian species cross the Gulf of Mexico annually for migration purposes. Near the lease area there are nine endangered species that are protected under the endangered species act. Of these nine endangered species four of them migrate. These species are the Avian-Black-bellied Whistling-Duck, Fulvous Whistling-Duck, Mottled Duck, and Whooping Crane.

The lease area will consider radar, sensors, GPS, ultrasonic boom boxes, and shut down periods as mitigation strategies for the avian species. Radar and GPS will be employed to track the migration period; this period typically takes 18 days between April 19 and May 7 (DOI). During these migratory dates, the lease will invoke a shutdown period to ensure the safety of the avian species during the migration. However, during normal run times the site will incorporate ultrasonic boom boxes and impact sensors. The ultrasonic boom boxes will emit frequency of 20,000 to 45,500 Hz. This level of frequency can only be heard by avian species due to humans only hearing at most 20,000 Hz. The boom boxes will be placed around the perimeter of the wind farm. The impact sensors will be incorporated into each wind turbine blade. This will stop the turbine if an impact is to occur. The impact sensors will not only reduce damage to the turbine, but also reduce avian loss.

Marine Mitigations

Fish behavior is affected by noise. High intensity sounds can permanently damage fish hearing. Most fish hear best within the range of (30Hz-1000Hz). Wind turbines generate low frequency noise below 200Hz which could affect some species in the surrounding area. The presence of noise could keep fish away from preferred spawning sites and change their migration routes. It could also mask natural sounds that are important to the fish, such as communication sounds from other fish, and sounds produced by prey and approaching predators. Some federally endangered or federally threatened species in Port Fourchon include the Atlantic sturgeon, West Indian manatee, leatherback turtle, sperm whale, and Hawksbill turtle. Also, to reduce our environmental impact on marine species, maintenance teams will be required to inspect and ensure the turbines are not leaking fluids or lubricants into the ocean.

Site Development

Planning

In the planning phase, the site must first be evaluated to see if the land is suitable for development. Once it is determined that the location is good to develop, an in-depth survey of the selected area will need to be conducted to ensure that the proposed turbine and cable placement is not in conflict with existing infrastructure. After analyzing the land, the communities' needs will be assessed. Talking to the people of Port Fourchon and other local communities will help determine how the wind farm will benefit them. Through these conversations, the opinions of the people will be heard and considered when implementing the design. After talking with the local communities, the design will be finalized and the process of discussing partnership with electric companies in the area, like Entergy, can begin [8]. Finally, the plans for development will be submitted to the proper local and federal governments to receive proper permits to begin construction.

Pre-assembly

Before being prepared to be loaded and set up in the desired location, certain components may be required to be pre-installed before the vessels take them out. These operations include tower sections being assembled into the complete tower, fitting different pieces to the desired locations for example the rotor hubs to nacelles, preparing the internal electrical components that go into the turbine and the gear and equipment that goes along with it. It is easier to install a few of the components onshore due to access being easier for set up. Throughout the year weather can make these operations risky/dangerous for installation. Working offshore also makes it expenses with the use of installation vessels and crane systems. Pre-assembly methods can make the whole process easier and safer while cutting a percentage of construction time, and cost.

All vessels used during transport and installation of the offshore wind farm should comply with national and international requirements applicable to the specific vessel. Factors that influence vessel selection include the amount of space required for storage of components that ensures continuous safe access, the nature of voyage(s) to be undertaken and other activities to be carried out, the experience of vessel owner and crew in carrying out the intended voyage(s), sufficient deck strength for point-loads that will be exerted by the components when loaded, suitability of the vessel for the intended operating port and anticipated met ocean conditions, the availability of suitable accommodation and facilities for personnel to be deployed onboard, and the appropriate certification and other regulatory approvals for the nature of intended voyage(s). There are two types of vessels to be used, either a vessel to transport the materials or one that does both transportation and installation of the materials. Tug and barge, general cargo, self-elevating (jack up/ lift boat), and semi-submersible heavy lift vessels are all used for the transportation of the offshore wind farm. A self-elevating heavy-lift crane (jack up/ lift boat), floating heavy-lift crane, semi-submersible heavy-lift crane, and sheer-leg crane barge vessel can all be used for both the transport and installation of an offshore wind farm. There are two methods used in the installation process being either "fetch" or "feeder" solution. In fetch, we see components loaded directly onto an installation vessel at the load out or marshaling port, transported out and then installed, while in the feeder method the vessel remains within the location of the wind farm and is moved between the installation sites. In this method, the components would be provided by secondary vessels. It is noted that secondary vessels pose risk to the project but can also hold gains in efficiencies and other innate benefits. One such benefit includes addressing restrictions in section 27 of the Merchant Marine Act of 1920, known as the Jones Act, which requires all cargo shipped within two points in the United States to be owned, operated, and registered/flagged in the United States.

Load out operations include the transfer of the heavy components from the quayside onto the vessel. Components can also be transferrable from one vessel to the next, and these vessels may be floating, elevated, or grounded to the seabed. The transfer can also be done from trailers, cranes, and skidding arrangements.

Construction

In this section we break the construction phase of the offshore turbine into four parts, the foundations installation, the wind turbine installation, the laying of cables and the offshore installation. The average time for a wind turbine to be installed is 2.5 days. Prior to these four parts, the seabed must be prepared to make sure it is level. The first installation that takes place is the foundation installment. A derrick barge will be used to carry the twisted jacket out to the wind turbine site. The twisted jacket structures must use multiple pin piles and then are grouted into the seabed. For the wind turbine installation, jack up vessels and crane barges will be used to transport the structure. Using the jack up installation allows the structure to be installed in water around 100 feet deep. The cost for the wind turbine to be installed is around $150,000 per day. For cable laying, the most environmentally friendly method is horizontal directional drilling [9]. The final stage, offshore installation will take place on large heavy vessels with cranes that can carry 900 to 3,000 tons. The structures are manufactured on the shore and transported by the vessels after manufacture.

Operations and Maintenance

For emergency maintenance, a workboat and specialized employees are available near the site 24/7 in case a turbine shuts down for any sudden reason. For the regular maintenance, the whole stage will last 20 years since this is the life span of a contemporary and good quality offshore wind turbine. During this stage, every six months there will be a maintenance checkup for any leaks, technical, or mechanical issues [10].

Financial Analysis

Financial Objectives

For the financial part of the project, we used the tool SAM to estimate the finances for Pete's Power Plant. The software was created by NREL for many different types of renewable energy projects as well as the ability to conduct financial analysis for different wind farms projects. Our financials analysis is based off SAM assuming our farm would be producing 1500 GWh instead of using the 1700 GWh provided to us by Furow. We took a more conservative approach to our financials to make sure we weren't providing unfeasible finances and to not overestimate the financial values used for our project.

Market Analysis

One of the sections that required inputs for SAM are operating costs for the project based fixed annual cost, fixed cost by capacity, and variable cost by generation. We used fixed cost by capacity for the project to input our annual operating cost of the project based on the name plate capacity per year. We chose an operating cost of **$50/kW-yr** which is the same value we found was included in the DOE's offshore wind market report [11]. This value will be calculated at an escalation rate of **2.5%**. When choosing turbine size and types we had to consider the capacity of the turbines because having bigger turbines allows us to lower the amount of turbines needed to reach the same capacity desired, thereby allowing our project to have a lower operating cost for the wind farm.

Concerning the financial parameters of the project we pulled our values straight from the Louisiana Department of Revenue to find accurate and up to date values on the state's income tax, property tax, and sales tax values indicated by the state. For project tax and insurance values, our project will experience a federal income tax of **21%/year** and a state income tax of **7.5%/year**. There will be an annual insurance rate of **1%** of total installed costs; the project will also experience a sales tax **4.45%** of total direct costs. Property tax values have been estimated to be an assessed percentage of **3%** of the installed cost at a rate of **2%/year**. We also assumed a salvage value of 1% which SAM calculates an end of analysis period value $21,429,531.90.

Project Term Debt

The project has assumed a DSCR value of 1.3 during a tenor of 10 years, at an interest rate of 3.75%. We have also assumed a debt closing cost of $450,000 and an up-front fee of 2%. LPO loans are found by combining treasury bond rates over the same time frame, as well as a credit spread rates which is found to be lower than 200 basis points. Long term treasury rates sit around 3.45% [12]. We estimated our credit spread to be 0.83%, outputting a value of **4.3%** interest rate.

Depreciation

For the depreciation portion of the project, our wind farm will have a 5-yr MACRS allocated at 100% of the project. Using MACRS allows for accelerated depreciation of the project's assets which allows the project to take larger tax deductions in the early years of the project's life and in the later years of the projects life less and less will be deducted from the asset's life [13]. Our project will utilize a bonus depreciation rate of 50% and will then phase out to 0% by the end of 2026, which will help further lower the taxable net income of our project, thus reducing our tax liability.

Overall Pricing Calculations

Finding accurate values for project costs can be incredibly tedious and time consuming due to the vast amount of research done for the wind industry but finding a common value across all web articles is not going to happen. So, finding a reasonable value that won't be considered an extreme outlier is a large part of the pricing calculations. According to the DOE, wind turbine prices have steeply declined over many years. From $1,800/kW in the year 2008, to $770-$850/kW [14]. Taking this into account for offshore turbines we assume the turbines to cost much more than $770/kW, so we increased the price and assumed the construction of a turbine to be approximately **$1,200/kW**. This turbine value is estimated with all the required accessories that are included in the turbine's construction such as: radars, GPS, boom boxes that were discussed during the environmental mitigation section of the report, and the impact sensors that were also discussed in the environmental section. This gives our project a total construction cost of the turbines to come out to **$504 million**. For the Balance of system cost we used SAM to give us an estimated value for the BOS, which the software considers tons of inputs about the substructure & foundation, electrical infrastructure, assembly & installation, development, and port & staging. Almost all the values we used were the set default values provided by SAM which resulted in $3,750/kW for the BOS. To account for a potential increase in our estimate project costs, we rounded up to a higher value of **$3,900/kW** which isn't too far off from the CapEx estimated by the DOE [11]. This outputs a total BOS cost of approximately **$1.638 billion**.

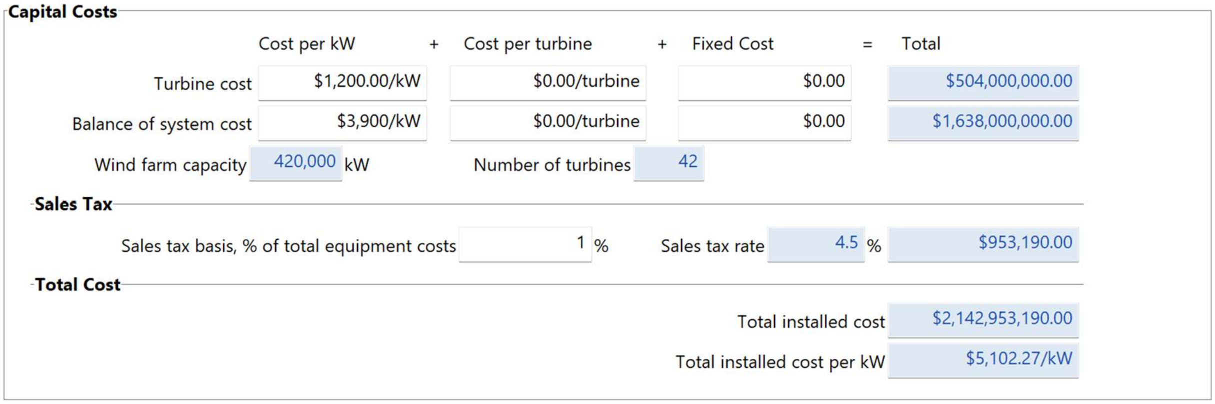

Figure 6: Estimated Capital Costs

After all our inputs are put into the software and using the estimated values from SAM, the software outputs a total installed cost for the project of **$2,142,953,190**, and a total installed cost per kW of **$5,102.27/kW**.

Incentives

Pete's Power Plant and other renewable energy projects are eligible for tax incentives given by the Federal Government. This project will be able to utilize an **investment tax credit (ITC) of 30%**. This amount of credit is issued to offshore wind farms that begin construction before December 31st, 2025 [15]. Pete's Power Plant is also eligible for PTC due to the Inflation Reduction Act (IRA) which came into law in August 16, 2022, which extended the time frame for wind energy projects to be eligible to investment and production tax credits through 2024 if the project began construction prior to January 1, 2025, per Production Tax Credit and Investment Tax Credit for Wind Energy [15]. After 2025 tax credits for wind projects will be replaced by technology-neutral credits for the generation of low-carbon electricity. These credits will have a phase out date of 2032, or if the U.S. power sector greenhouse gas emissions declines to 25% of the levels reported in 2022 [15]. The project will be earning a PTC value of **2.5 cents per kilowatt-hour** at an escalation rate of 2.5% per year. PTC & ITC both greatly benefit our Pete's Power Plant because it offers the project a huge gain for the project right at the beginning of the project's life.

Purchase Power Agreement (PPA)

Pete's Power Plant will utilize a Purchase Power Agreement (PPA) in Louisiana. We will utilize a PPA of **$0.11/kWh** during the first year and will experience an **escalation rate of 4%** each year. We chose this escalation rate to compensate for the change in some areas that currently affect the sales of wind energy. One of the reasons in the drastic rise in price of natural gas is due to countries that relied on Russia for fuel now must find new ways to import the natural gas the countries so desperately need [16]. Another reason for the higher escalation rate is the slow production of natural gas in the U.S., where we are currently experiencing historical below averages to produce natural gas. This will output a real and nominal value of **$0.1195/kWh and $0.1448/kWh** respectively.

Cash Flow Analysis

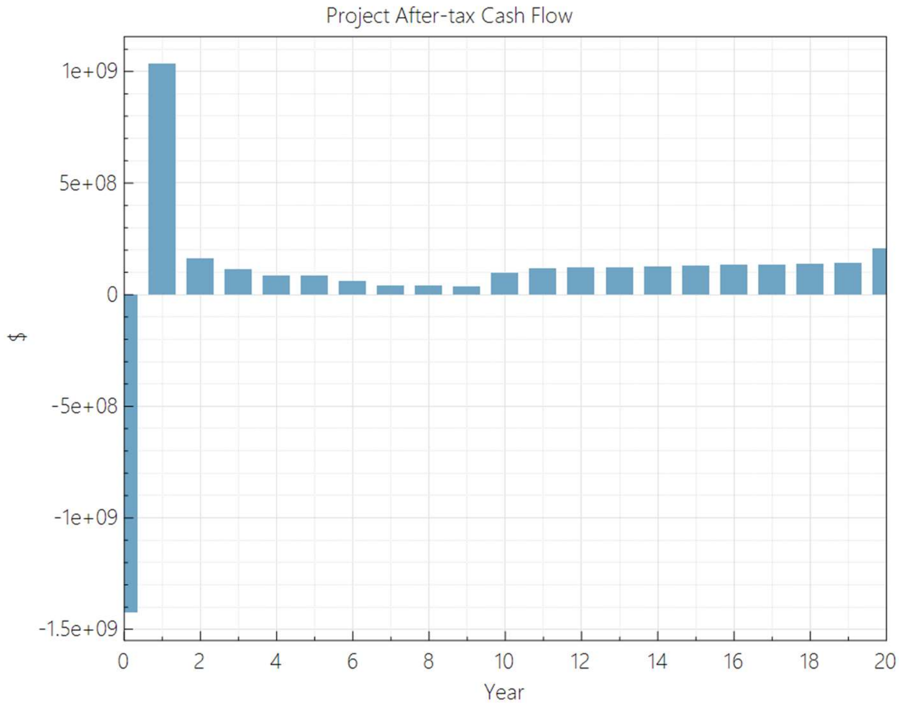

Figure 7: Project After-Tax Cash Flow

Looking at the cash flow plot above, the first year indicates a negative cash flow from the very large capital expense for the construction and procurement of the project. Year one indicates a large positive spike in cash flow from the ITC and PTC earned with our project. At year 10, the cash flow begins to flatten out until the end of the project where the cash flow increases once again. Overall, the project generated **$1.67B after-tax**.

Final Financial Metrics

Metric	Value
Annual AC energy in Year 1	1,506,044,672 kWh
Capacity	420,000 kW
Capacity factor in Year 1	40.9%
PPA price in Year 1	11.00 ¢/kWh
PPA price escalation	4.00 %/year
LPPA Levelized PPA price nominal	14.48 ¢/kWh
LPPA Levelized PPA price real	11.95 ¢/kWh
LCOE Levelized cost of energy nominal	11.86 ¢/kWh
LCOE Levelized cost of energy real	9.78 ¢/kWh
NPV Net present value	$333,901,920
IRR Internal rate of return	15.09 %
Year IRR is achieved	20
IRR at end of project	15.09 %
Net capital cost	$2,265,834,496
Equity	$1,426,163,328
Size of debt	$839,671,296
Debt percent	37.06%

Figure 8: Overall Project Financial Metrics

Shown above is the output given to us by SAM that tells us a large chunk of the final financial metrics through the entire course of the project's life. We began simulating the financials for three different wind farms of different sizes. The first we tested was our largest wind farm of 55 turbines, the second largest was 42 turbines, and the smallest size we simulated was 41 turbines. Our reasoning for simulating different number of turbines was to find the approximate number of turbines we could use to maximize financial results.

We discovered initially that the financials for our project increased in both IRR and NPV as we lowered the number of turbines from 55 to 41. This gave us the idea of increasing the number of turbines by one more to 42 to see if the financials continued to increase. We assumed correct and found that the 42 turbines gave us the best financials out of the three different wind farms we tested. We planned to continue testing different size farms to find the exact optimal number of turbines we could use to maximize the finances before the finances began to drop back off again. This would have allowed us to show the exact number of turbines you would have to implement before no longer experiencing an increase in the project financials.

Shown below is a cash flow statement that lists the main financial areas of the project from initial year 0 to the year 20. This cash flow is based on our 42-turbine wind farm that was yielding the best results according to SAM. Optimizing the financials took more than 10 iterations just for the 42-turbine farm to get our values to what we felt was optimal for our project. The IRR between the 55-turbine farm and the 42-turbine farm were 13.98% and 15.09% respectively. This is an IRR difference of 1.11% which over the course of the project can drastically affect the total amount of money the project is projected to make over its lifetime.

	Year					
	0	1	5	10	15	20
Electricity to Grid (GWh)	-	1506.04	1446.7	1375.8	1308.37	1244.25
Project Returns After-Tax (M$)	$ (1,426.16)	$ 1,033.33	$ 83.22	$ 97.22	$ 127.59	$ 206.34
EBITDA	-	$ 121.95	$ 135.70	$ 154.77	$ 176.08	$ 221.18
Total Revenue	-	$ 165.67	$ 186.17	$ 215.40	$ 249.22	$ 309.79
Cumulative After-Tax IRR (%)	-	-27.54	1.95	8.67	13.36	15.09
Annual PPA Revenue (M$)	-	$ 165.67	$ 186.17	$ 215.40	$ 249.22	$ 288.36
Annual Costs (M$)	$ (1,426.16)	$ 867.67	$ (102.95)	$ (118.19)	$ (121.64)	$ (82.02)
O&M Capacity Based Expense	-	$ 21.00	$ 25.53	$ 32.58	$ 41.58	$ 53.07
Federal Taxable Income Including Incentives (M$)	-	-1245.31	-7.49	139.67	163.30	205.10
State Taxable Income Including Incentives (M$)	-	-366.46	-149.19	150.99	176.54	221.73

Figure 9: Simplified Cash Flow Statement

We also conducted financial analysis over a 30-year life of the project to see where the project's ability to produce revenue would be if the project's life were to be extended by the investors. After extending the project to a period of 30 years we noticed that after tax project returns increased from $1.67 billion for the 20-year life to $3.35 billion for the 30-year life. Another enticing part of the wind farms longer lifespan is the amount of annual revenue generated as the project continues. At the end of 20 years the total revenue is $309 million but at the end of the 30th year the total revenue generated is approximately $408 million. Of course, operational & maintenance costs increase annually and are much higher at the end of the project's life, but this to ensure that the wind turbines receive the proper maintenance needed to maximize the life of each turbine and limit the amount of wind turbines that may need to be replaced due to wear of the turbines. This may be rather enticing for potential investors to increase the project's life in the future to allow for far greater revenue generation of the project.

Optimization

The optimization process began with site layout optimization within Furow. We manually modified our original layout to minimize wake losses and maximize undisturbed surface area of our wind turbines. During the process, the number of turbines, turbine type, and rotor separation were analyzed within Furow and SAM. Next, the team began to optimize this layout by analyzing the hub height of the turbines to maximize energy production and financial gain, using Furow and SAM. Multiple iterations took place for hub heights ranging from 100m-175m. The final hub height chosen is 150m, the team found this to be a happy medium to keep risks to a minimum and keep energy production high. The final wind farm layout was chosen to minimize wake losses, construction and cabling costs, environmental impact, and wind turbine failure risks.

Conclusion

In the academic year, the Cyclone Cowboys have created a complex wind farm design and plan off the coast of Port Fourchon, Louisiana. Researching industry standards and guidelines has ensured the wind farm to be engineered safely and complaint with federal law. Additionally, financial research and models have proved our wind farm to be a lucrative project, while also benefiting the entire world by reducing carbon emissions by over one million metric tons [17]. Pete's Power Plant will be producing 1,700 GWh annually, which will be sold at $0.11/kWh. At this rate and production, the Cyclone Cowboys will propose a bid on lease blocks 83, 90, and 91 for 45 million USD. This bid was chosen based on a rate of $3000/Acre for offshore land purchase and past Gulf of Mexico lease sales. Our chosen bid is much higher than past bids when comparing acreage. The team estimated our bid should be higher than average because of our relative distance to the coast. Additionally, because of the profitability of PPP, we can afford to increase our bid, which will highly increase the odds of winning this bid.

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