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I Introduction

The development of a hypothetical wind farm allows students the opportunity to consider many aspects of design, construction, and financial implications. As defined by the CWC, the land available for the development of the wind farm resides in the lease blocks bounded by the grey lines in Fig.1. Initially, The CU team determined A63 and A52 as ideal zones for construction as there is a limited number of obstructions (i.e. oil wells, pipelines, fishing/transportation lanes, and drilling platforms). However, in order to increase the power production of the wind farm from this first iteration of 38 wind turbines and to create more efficient spacing, 2 additional lease blocks were added. Purchasing blocks HIA63, HIA64, HIA52 and, HIA53 provides the necessary area to evenly distribute 45 wind turbines and improve the viability of the entire project. This report will outline the layout developed through Furow and provide the logistics for the construction and operation of the wind farm. This latter process was carried out through the System Advisory Model (SAM) that tracks the financial costs and benefits of the project and provides wind resource data. Overall, the report discusses the necessary details to reach a conclusion regarding the viability of the wind farm and determine the maximum feasible bid price for the lease blocks.

II Site Description and Energy Estimation

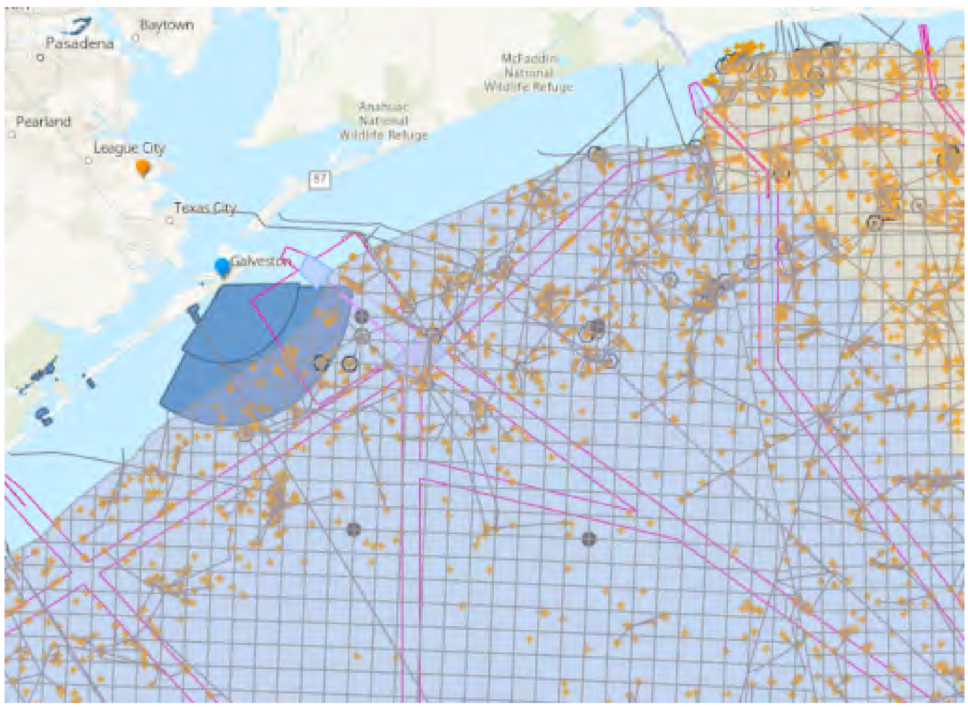

Figure 1: Map of the surrounding area the grey lines indicate oil pipelines, orange Xs represent oil well, and the pink lines show shipping paths.

II.A Site Layout

The site layout is based on the implementation of 45 14 MW Siemens Gamesa turbines each with a 222 m diameter. Given that this wind turbine generator (WTG) has yet to be put into mass production, it was not available in Furow for modeling purposes. To approximate this turbine, the team evaluated the properties associated with Siemens Gamesa WTGs currently available in Furow. These properties include the hub height, power curve, and operating conditions for several models. The most appropriate model has a hub height of 140 m (the same as the height of the wind resource data downloaded from SAM) and cut in and cut out conditions of 3 m/s and 25 m/s. In order to calculate the power curve, the G132 Class S Offshore 5MW Gamesa Turbine power curve was scaled up by 3 to approximate 15 MW of power output. These assumptions will allow the team to track the power production of the wind farm.

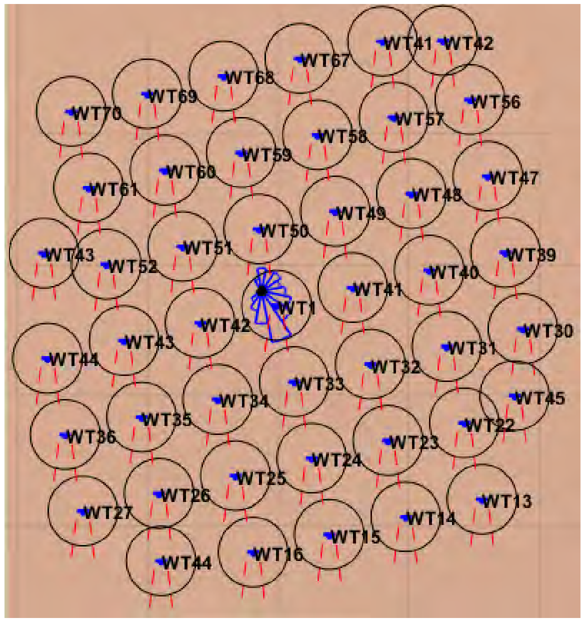

Figure 2: Wind farm layout of SG 222D turbines in the selected lease blocks

To determine the direction of the wind farm layout, the team utilized wind data provided by SAM for a 140m wind height. It was then possible to calculate a wind rose located at the center of the acquired land. From this, 145 degrees appeared to be approximately perpendicular to the direction of the wind.

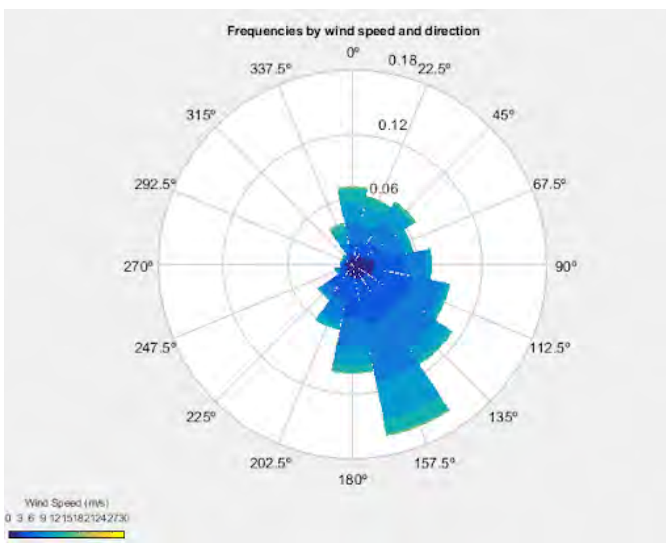

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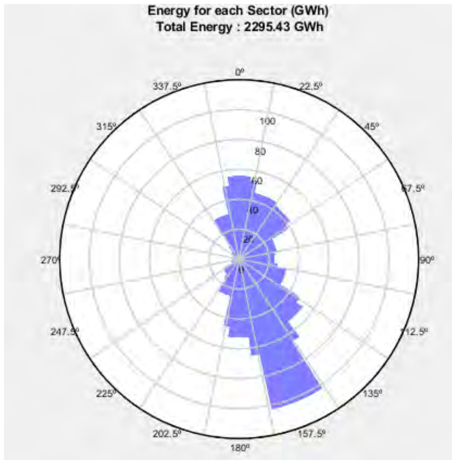
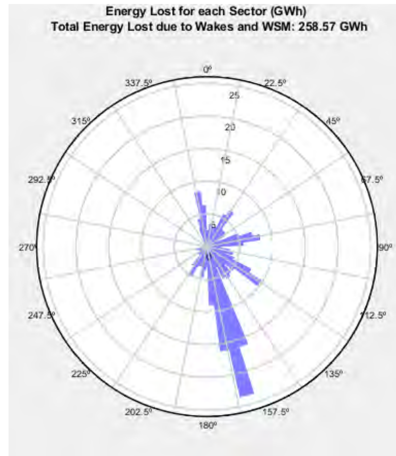
Figure 3: Wind rose at the center of the selected lease blocks

Using a Jensen wake model, the energy rose of the wind farm can be modeled. It is clear from the energy roses that the primary directional source of energy is roughly perpendicular to the directions of the wind turbine rows. This makes sense as it aligns with our wind rose for the region, seen in Fig.3. It is also shown that the wind farm loses about 1/10th of the energy that it can produce in line with the wind farm rows. This may be because of the fact that the turbines are aligned in rows and may require a more optimized spacing. This was explored and a better line spacing was not readily found. However, the given layout has a total power production capacity of 630 MW and an estimated gross yield of 2,295,433.3 MWh per year[1]. This exceeded the team's goal of developing a 600 MW wind farm.



(a) Energy Rose



(b) Lost Energy Rose

Figure 4: Energy roses from the center of selected lease blocks

The electrical transmission plan has been largely unchanged from the preliminary design report. This is because, after continuous research, high voltage direct-current (HVDC) technology results in significantly lower costs than high voltage alternating-current (HVAC) technology. For the inter-array cables, the wind farm will utilize 66 kV inter-array cables as they are capable of carrying significantly more power with less losses than the typical 33 kV inter-array cables used in most offshore wind farms. This results in fewer cables needed and fewer offshore substations. This results in significant cost savings and smaller energy losses which is preferable. The inter-array cables will be routed to an offshore substation near the wind farm. Here, AC current will be transformed to DC current and stepped up to a voltage of 220kV. This is done to reduce losses during transmission. HVDC cables will transport the generated power 82 km to the PH Robinson onshore substation located in Bacliff, Texas where it will then be stepped up once more to 345 kV as per the substations max voltage rating. The HVDC cables will utilize mass-impregnated paper-insulated transmission cables which are capable of transporting voltages at 220kV and are produced in sufficient lengths to reach the point of interconnection.

The offshore substation will be a topside steel jacket design. This design is becoming common in the industry at shallow water depths, lowering costs and providing further benefits for the wind farm. This style of the substation can be pre-fabricated and doesn't require heavy-lift or jack-up vessels for installation, reducing financial and time costs. The substation will be equipped with a helicopter landing pad for transporting equipment such as the main transformers and switchgear, and for necessary accommodations and crew and emergencies. There will also be a boat landing, SCADA facilities, and necessary communication infrastructure.

II.B Turbine Type

The chosen turbine is the Siemens Gamesa Offshore 14 MW Turbine series with a 222 m rotor diameter that will come into production in 2024. The blades will be sourced from IntegralBade which has developed a recyclable blade type. This will allow turbine blades to be decommissioned, reused, and put back into the market, mitigating the environmental impact of these components.

II.C Foundation

The team first considered the most common types of foundations including monopiles, floating structures, and jackets. The main concern is whether the foundation can adequately support the turbines. The soil conditions in the Gulf Coast of Mexico are not conducive for the monopile foundation type. The depths of the leases are also such that there will not be a benefit to creating a floating wind farm as the ocean floor is between 20 - 50 m below the surface.

[1]There is a slight discrepancy between the estimated annual generation calculated in SAM and Furrow due to variances in the software and inputs

For this reason, the jacket foundation type is ideal for the location of the wind farm. This decision is in agreement with BOEM's recommendations. It is also vital to minimize the environmental impacts associated with the wind farm construction. Starting with the installation, jacket foundations have a lower carbon footprint than gravity-based foundations, making them the better option. Furthermore, The fact that jacket foundations are temporary allows for the possibility of micro-siting, resulting in the ability to avoid sensitive and rare habitats. The noise from the installation of the jacket foundation is comparable to that of other pile-driven foundations, giving no distinct disadvantage. In order to further reduce the environmental effects of the foundation during operation, there is evidence that it could double as an artificial reef. This is assisted by the fact that jacket foundations inherently have a larger surface area than other foundation types due to the lattice design. Finally, it is important to consider wake effects. Due to the low density of these structures, there are minimal wake interferences compared to more traditional foundations such as monopiles. In conclusion, due to the increased surface area of the jacket foundations, similar noise of installation, and better wake characteristics, jacket foundations are the ideal design. [1][2]

III Sensitive Environmental Regions and Species

According to IPaC (Information for Planning and Consultation), there are no endangered or threatened species in the space approximating the available lease blocks. However, there are several species nearby that should be consistently monitored in case their migratory pathways change and they become negatively impacted by the wind farm. For example, off of the gulf coast, the West Indian Manatee is a threatened species and is protected under the Marine Mammal Protection Act. This species does not have a critical habitat in the defined zone of the wind farm, but the health of local wildlife should be studied consistently. A thorough environmental impact assessment would also be conducted by local professionals prior to the project being approved.[3]

III.A Avian Survey

In order to be granted the lease blocks for wind farm development and to ensure that the construction of the wind farm will not negatively impact the migratory/local species, an Avian Survey is also necessary. [4]

According to the Texas Parks and Wildlife services, a large number of birds follow the Trans-Gulf Migratory pattern. This pathway begins at the Yucatan Peninsula and ends at the U.S. Gulf Coast in either Texas or Florida. The bird species that carry out this journey include the Chimney Swift, Ruby-Throated Hummingbird, and the Belted Kingfisher, as well as many others. Both NEPA and the Migratory Bird Treaty require in-depth surveying protocols to fully understand the impacts of offshore wind projects. Multiple survey visits must be carried out throughout this process to adequately track changes in the bird species and migratory patterns. [5]

IV Reasons for Site Selection

The site selection took into account several features of the area from the nearest onshore substation to the environmental effects. The PH Robinson substation in Bacliff, Texas, has been chosen for its proximity to the available lease blocks. This requires the least amount of undersea cabling, reducing the overall cost of the wind farm. Shipping lanes and human structure obstructions are of concern for the four lease blocks chosen. However, the official shipping lanes are located to the east of the blocks and there are minimal obstructions located in the desired area. The depth is fairly consistent across all four lease blocks, thereby confirming jacket foundations as the appropriate structures for all the turbines. This minimizes tooling and unique engineering solutions, again, reducing cost.

V Risks and Fatal Flaws

The risks associated with this site development should be studied carefully ahead of construction. Given that the wind farm is located 82 km from the onshore substation, it is possible the cable laying process will face heavy delays due to obstructions. This includes navigating around oil wells, shipping lanes, and fishing vessels. There are also greater costs associated with the large amount of fuel required to transport construction teams and materials far from shore. In case there is an emergency, backup teams will be delayed due to the amount of time to reach the site. However, given that the installation vessels will be docked in Mexico, the chosen lease blocks are the closest for these ships. It is also appealing that the wind farms will be outside of the field of view, preserving the local scenery.

VI Financial Analysis

VI.A Financial Potential of the Project

The energy provided by the offshore wind farm will connect directly to the Electric Reliability Council of Texas (ERCOT) grid. ERCOT currently has 26 million customers and is likely to continue growing. Texas wind farm projects will utilize the skills and expertise of people already living in the area, due to the oil and gas industry. According to American Clean Power,

> Offshore wind taps into the skills of U.S. oil and gas workers, who have decades of experience with ocean energy infrastructure - American Clean Power [6]

Average Retail Price of Electricity to Residential Sector, December 2021 (cents/kWh): $0.1255 [7]

VI.B Incentives

In terms of tax incentives, the team's wind farm has just missed out on the production tax credit (PTC) that the federal government ended in 2020 providing 2.5 cents/kWh of rated installed capacity per turbine. The only available incentive from the federal government is the investment tax credit (ITC) at 30% which is available for any offshore wind project that begins construction after 2016 and before 2026. [8]

VI.C Required Capital

Siemens Gamesa has recently come out with the SG 14-222, which will be released for production in 2024. We are planning on using this turbine on our farm because of the large power output from each turbine. This will in turn reduce the transportation and installation costs since we can have fewer turbines and can achieve the same power output for the wind farm. According to Offshore Engineer, the turbine is estimated to cost $12,300,000. While the cost of each turbine may be a bit more expensive than most, the reduction in turbines means a reduction in foundation structures, and this is where capital costs can be reduced the most since each foundation can add $3 million to $4 million depending on the foundation type. Also, according to Rystad Energy, there is about a $500,000 to $1,000,000 cost to install the turbine and a $1,000,000 to $1.5 million cost to install the foundation amounting to a possible $2.5 million per turbine. Therefore, fewer turbines will also reduce the overall installation cost. [9]

Table 1 shows a breakdown of the initial capital costs required for the project. The turbine capital cost is based on the 45 SG 14-222 turbines purchased at a price of $12,300,000 per unit. The balance of system cost and soft costs are calculated based on the 2020 NREL Cost of Wind Energy Review.

	14.0 MW Jacket Foundation Offshore Wind Turbine ($)	14.0 MW Jacket Foundation Offshore Wind Turbine ($/kW)
Turbine Capital Cost	553,500,000	879
Development Cost	53,550,000	85
Engineering and Management	1,260,000	2
Substructure and Foundation	298,620,000	474
Electrical Infrastructure	417,060,000	662
Assembly and Installation	245,700,000	390
Lease Price	107,100,000	170
Balance of System	1,122,660,000	1,782
Insurance During Construction	20,790,000	33
Decommissioning Bond	69,930,000	111
Construction Financing	91,350,000	145
Contingency	220,500,000	350
Plant Commissioning	20,790,000	33
Soft Costs	423,360,000	672
Total Capital Expenditures	2,099,520,000	3,333

Table 1: Initial costs of wind farm development

VI.D Financing

Project finance is the best option for raising capital for the project. This type of loan is great for large infrastructure projects that only generate revenue after construction is complete. The remaining financing for the project will be raised by selling equity in the project. Senior debt for the project will be raised through long-term loans from numerous banks. This capital structure will mimic the financing plan for the Vineyard Wind project where nine banks contributed $2.3B for the construction of the project. This strategy allows for loans with long maturity periods of up to 15 years which is favorable for our project that won't generate revenue until construction is complete. Additionally, it is unlikely that our development company would have a large enough tax liability to use the 20% Investment tax credit (ITC). So, the 20% ITC equity would be shared among the investors in this deal.

Financing efforts may be led by an experienced financing firm such as Santander, and the financial council would be led by a firm such as Norton Rose Fulbright. These organizations worked on the Vineyard wind project and have experience negotiating offshore wind energy deals. It is unknown what interest rate would be secured in our deal, but 7% is about average for a construction loan. [10] [11]

VI.E Key Assumptions (e.g. project marginal costs)

In order to determine the financial viability of the wind farm, several variables were assumed:

Inflation Rates: 2.5% per year (uncertain due to changes in the national economy)

Federal Income Tax Rate: This value should be at 21% per Federal guidelines [12]

Sales Tax: One-time tax included in the project's total installed cost. This is calculated by multiplying the sales tax rate by indirect capital costs and the total direct cost. 6.25% is the approximate value for Texas [13]

VI.F Project Potential Through Cash Flow Analysis

Depreciation The depreciation schedule currently used for most renewable energy projects is the Modified Accelerated Cost Recovery System (MACRS). It is a 5 year schedule with the depreciation percentages being 20%, 32%, 19.2%, 11.5%, 11.5%, and 5.76% (years 1-5). This depreciation schedule is important because it allows for quicker recovery of capital costs and increases revenue, thus making the project more appealing to investors. Furthermore, consumer prices can be lower making the project more competitive with traditional production of energy such as gas and coal. Ultimately, this leads to more renewable energy projects being built. [14]

Discount Rate and Internal Rate of Return (IRR) Based on NREL's 2020 Cost of Wind Energy Review, the discount rate for an offshore wind farm is 5.29%. This is the required return on investment that investors will need to see in order to invest in the project and thus we have set the discount rate as such in our System Advisor Model (SAM). The way to determine if this return is achieved or not is by determining the Net Present Value (NPV) and Internal Rate of Return (IRR). If the NPV is greater than 0 and the IRR is greater than the discount rate, then this project is a good project to undertake. [15]

Monthly Energy Production Through a SAM simulation, the monthly energy production was calculated using the coordinates of the wind farm and the turbine specification (Fig.5). This generation profile should remain approximately constant throughout the life of the wind farm (assuming minimal equipment degradation).

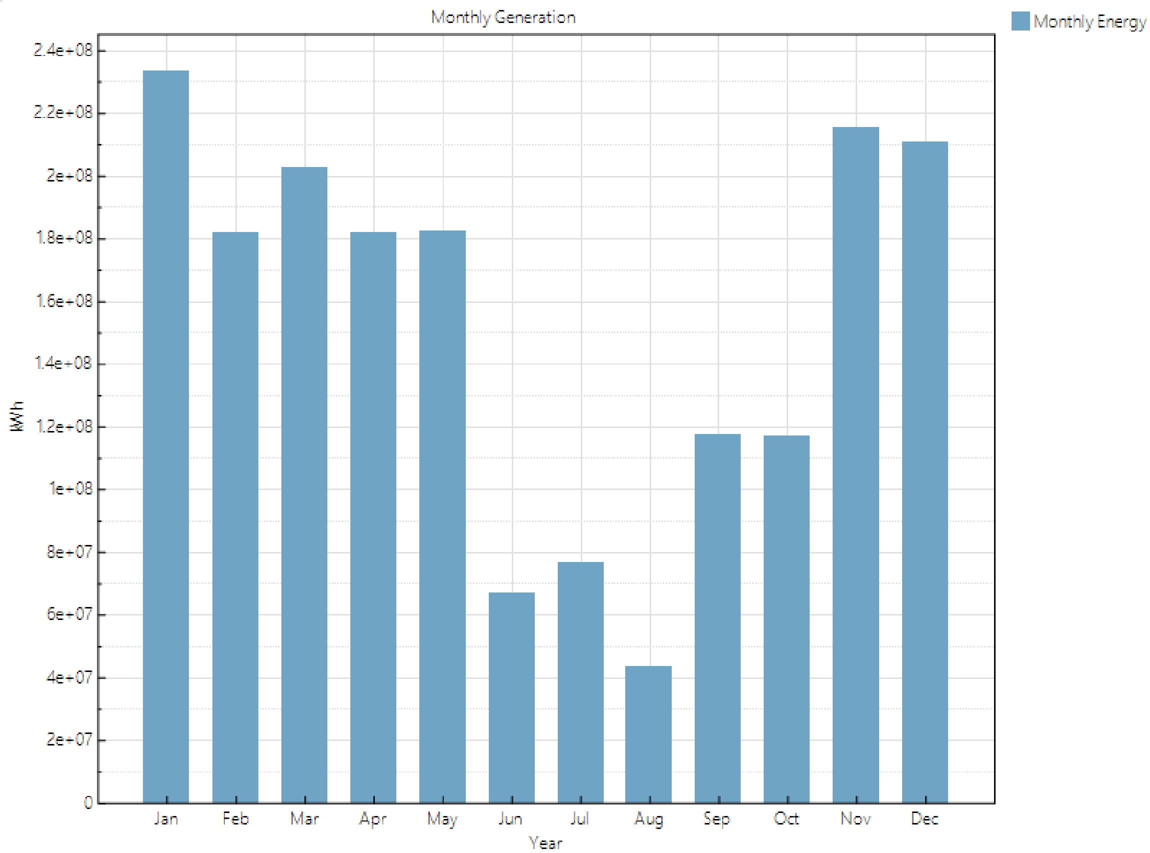


Figure 5: Monthly Energy Production

Revenue and Annual Expenses For the base case, a lease price of $107,100,000 was calculated based on the $170 per kW value in the 2020 Cost of Wind Energy Report. By inputting this into SAM, it was found that the energy would need to be sold at a PPA price of $0.1215 per kWh in order to reach the 5.29% internal rate of return goal (IRR).

Fig.6 shows the total annual revenue earned by selling the generated energy at the PPA price. The PPA price increases by 1% per year and the annual generation stays constant. Also shown on Fig.6 is the total pre-tax cash flow from the project. This is calculated by subtracting the annual expenses from the total revenue. These annual expenses are broken down further in Fig.7. Note that the state and federal tax expenses are negative for the first five years of the project due to depreciation.

VI.G Discussion of Optimization Process

The preliminary site design was used to establish a general understanding of all aspects of a wind farm design. It was quickly realized though that the team's initial site layout consisting of 190 MW total capacity did not generate enough revenue over a 20-year period to be financially feasible. Costs related to electrical infrastructure, assembly, and installation far exceeded that of turbine costs and made it nearly impossible to recover capital expenditures. Thus, the team opted to increase the size of the wind farm to 45 turbines with a total nameplate capacity of 630 MW. This takes full advantage of the expensive electrical infrastructure that would have to be installed anyway because, at peak power generation, all the power generated can be transmitted at one time.

Initially, the year to reach the target discount rate was set to year 20. This did not make the project financially viable as it resulted in a negative NPV value. In order to achieve a positive NPV and an IRR greater than the specified discount rate of 5.29%, the target year to reach the discount rate was shifted to year 15 instead of year 20. By the end of the project's life, the IRR achieved is 9.14% with an NPV of $61,124,880.

VI.H Maximum Lease Price

It would not be reasonable to sell electricity for more than the average retail rate in Texas of $0.1255 per kWh. SAM was run multiple times while varying the lease price input parameter until the PPA price rose to 0.1255 per kWh. The maximum lease price came out to be $214,830,000 or $341 per kW.

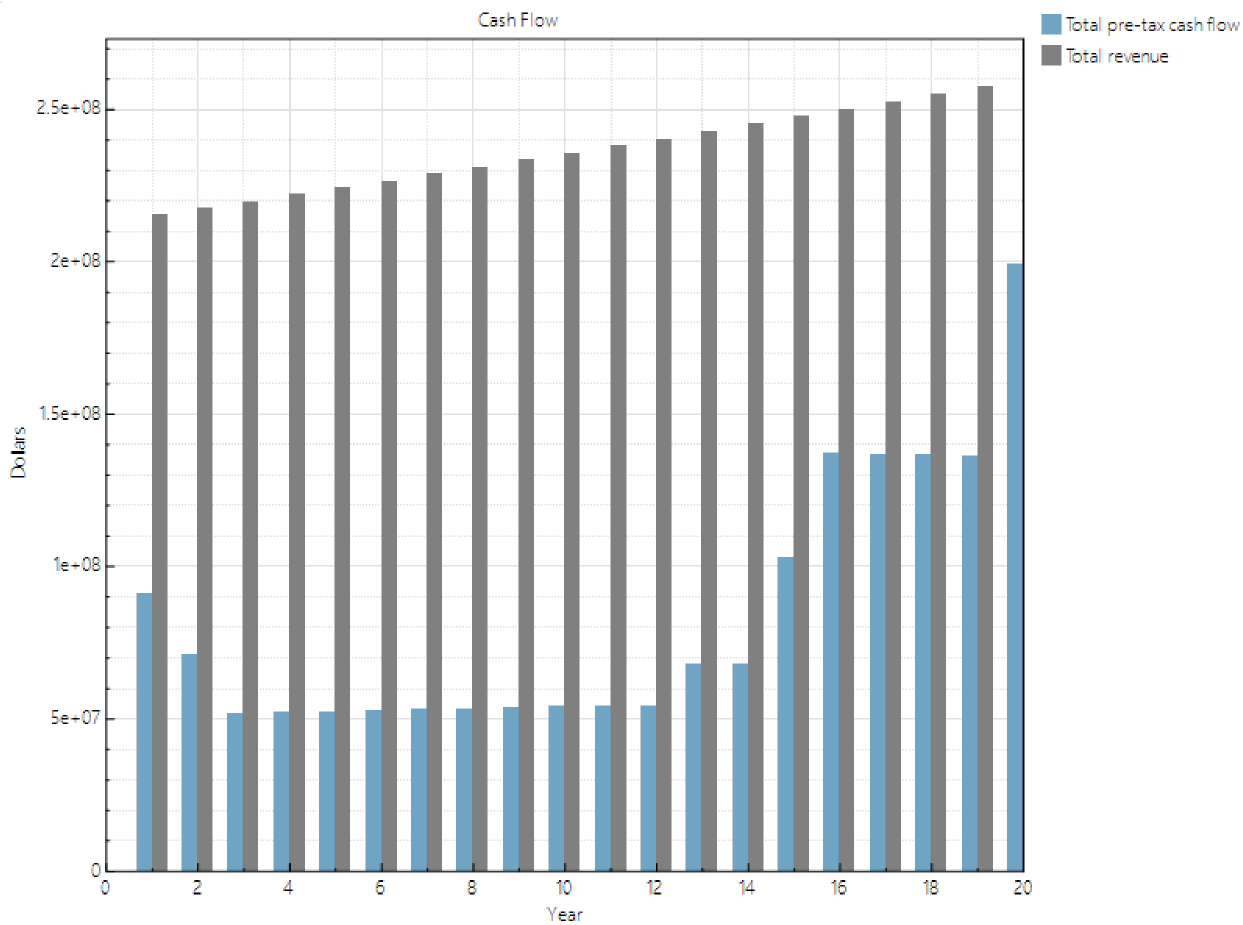


Figure 6: Total Cash Flow

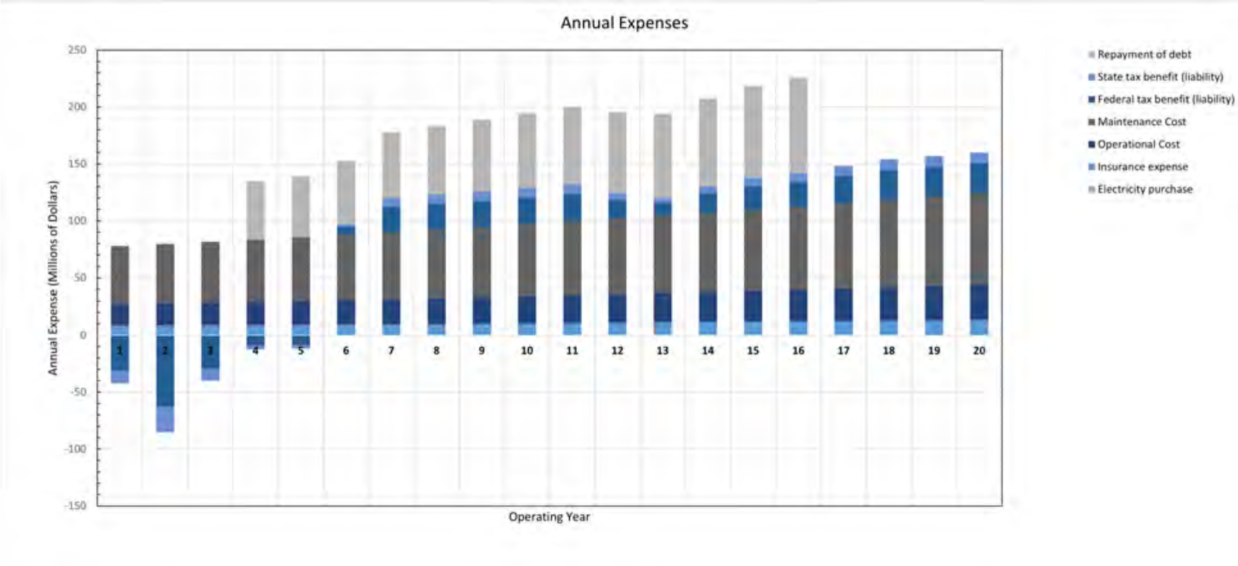


Figure 7: Annual Expenses

VI.I Financial Summary

Metric	Value
Net electricity to grid (year 1)	1,830,289,792 kWh
Capacity	630,000 kW
Capacity factor (year 1)	33.2%
PPA price (year 1)	12.15 ¢/kWh
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	13.05 ¢/kWh
Levelized PPA price (real)	10.60 ¢/kWh
Levelized COE (nominal)	12.71 ¢/kWh
Levelized COE (real)	10.32 ¢/kWh
Net present value	$61,124,880
Internal rate of return (IRR)	5.29 %
Year IRR is achieved	15
IRR at end of project	9.14 %
Net capital cost	$2,157,768,448
Equity	$1,294,661,120
Size of debt	$863,107,392
Minimum DSCR	1.63

Table 2: Summary Table

VII Site Preparation

VII.A Site Assessment Plan

The Site Assessment Plan must be evaluated by BOEM to ensure that adequate site assessment testing and limited installation of relevant technology(buoys, MET towers, etc.) will be carried out under the commercial lease. [16]

VII.B Construction and Operations Plan

The COP provides an overall description of the proposed site and highlights the necessary structures that will be constructed as well as a decommissioning plan. The COP also defines the "Potential Project Impacts." The areas that can be influenced by the development of the wind farm include water quality, air quality, marine habitats, fishing industries, and vessel traffic. In order to build in the OCS, it is vital that interested parties carry out in-depth assessments of the negative impacts that may result from the construction of the wind farm. It is also necessary that the lessee must consider methods to reduce these impacts in order to satisfy the various institutions such as the Fishing and Wildlife Service, The National Environmental Protection Act, The Marine Mammal Protection Act, and the Migratory Bird Treaty Act. [1]

While this report will not be as comprehensive as a fully developed COP, the following outline provides insight into the construction activities that are less impactful the environment. [17]

In regards to the Jacket foundation installation, the standard process is the pile-driving method. For pile driving, a large industrial hammer drives the foundation struts into the ocean floor. This method, however, creates vibrational frequencies that can be harmful to marine life. Instead, the pile jacking method is a less nosy alternative as it implements "hydraulic rams" which produce less impactful frequencies. Furthermore, a reduction in noise propagation during construction as well as general operations of the wind turbines can be mitigated through the implementation of ABM technologies. This company has developed large arrays of Helmholtz resonators, tuned to specific frequencies, to capture and mitigate noise from various noise sources. [18]

One important component of the construction of the wind farm is cable laying. One method to reduce the environmental impacts of this process is through the implementation of the jet plow method. This method is used for the weak clay sediments and is carried out in a much shorter time frame compared to Horizontal Directional Drilling (HDD). As it is a much quicker process, the sediments settle in a smaller time frame, which is ideal for surrounding marine life. Burying the cables, in general, is environmentally conscious.

VII.C Jones Act Compliance

In order to construct the wind farm on the Gulf Coast, there are several obstacles that increase the difficulty of the process. In the United States, the Jones Act states that non-U.S. flagged vessels are prohibited from transferring materials from the coast out to the wind farm site location. Therefore, it is necessary to develop a system so that the Panamanian Wind Turbine Installation Vessel (WTIV), titled the SCYLLA, is able to erect the turbines out at sea. To begin the development process, U.S. barges will transport the turbine components out to the wind farm location. The WTIV will be docked off of Mexico and will meet the barges at the site location. The SCYLLA will then install the foundations, turbines, and blades in separate stages and will stay at the site for as long as possible by resupplying materials using barges. Given that these installation vessels have a day rate cost of approximately $200,000, they are one of the most expensive components of wind farm development. To get around this issue, wind farm investors are looking toward the development of the first Jones Act compliant WTIV Charybdis in 2023. The availability of this vessel will reduce fuel costs and the need for barges during construction. However, given that this vessel will be involved in the Coastal Virginia Offshore Wind project, it is unlikely that it would be available in time for construction on the Gulf Coast. Therefore, the team will prioritize the use of barges and the SCYLLA ahead of 2030.

VIII Operations and Maintenance

Due to the offshore component of the wind farm, the degradation of the turbines is much more uncertain as this is a new area for wind turbine development. There are new weather patterns that need to be kept track of, erosion from the saltwater on the foundations, as well as general maintenance of the turbine to ensure all parts are functioning correctly. Many things need to be considered when deciding the maintenance schedule for the wind farm. Some considerations include the environmental impacts of running a vessel out and back numerous times a year as well as marine safety when performing maintenance on the foundation and turbine. According to Zhengru et al., O&M costs account for about 23% of the total investment cost for offshore wind turbines, as compared to only 5% for onshore costs. This increases the Levelised Cost of Energy (LCOE) immensely. Offshore wind turbines mainly have a larger maintenance cost due to the distance from the ports/shore since there will need to be more downtime required from the reduced accessibility due to changing weather conditions as well as specialized equipment required. There are numerous components in offshore wind turbines that need maintenance and their failure rates vary depending on the location of the farm, drive train type, and foundation type.

After extensive research into maintenance types, a preventative maintenance strategy seems like the best option in terms of reducing the overall costs of operations and maintenance. The preventative maintenance strategy is a more proactive strategy where scheduled maintenance takes place at a predetermined period or a given level of power generation (certain power generation corresponds to the degree of degradation of the turbine). This is the preferred method for larger wind farms as it eliminates unplanned maintenance, avoids excessive spare stock of parts, and combines maintenance and repairs all in one trip. Although this maintenance method could increase the downtime of a turbine because maintenance is only performed at certain times of the year, the hope is that consistent and thorough maintenance during each trip will mean less turbine downtime. Also, even though there would be more frequent visits throughout the year leading to a 166% increase in costs of supply vessels and crews, the reduction in downtime of the turbines will lead to a 24% total cost reduction as compared to reactive maintenance. On average, crews will visit the wind farm two or three times each year to inspect and maintain the wind farm, but the actual number of visits will vary depending on capacity factors, weather-related accessibility, and leveled production costs for the site. There are numerous parts of the turbine that need to be inspected and maintained during each visit, and their failure rate and downtime are listed below in Table 3.

Turbine Component	Failure Rate (10 years)	Downtime per Failure (days)
Drive Train	1	5
Structural Parts	1.5	3
Generator	1.5	7
Gearbox	1.5	7
Rotor Blades	2	3.5
Sensors	2.5	2
Electrical System	5.5	1.5

Table 3: Failure rate and downtime of each failure for main components of a turbine. *The failure rate is defined as the number of incidents every ten years of turbine service (e.g. the electrical system will fail on average 5.5 times every ten years).

As noted in Table 3, the electrical system is the most likely component to fail throughout the lifetime of the turbine. This can be an issue with preventative maintenance as crews will oftentimes not be able to fix the turbine in a reasonable amount of time since there are only two to three visits each year.

Another desirable perk of the preventative maintenance strategy is that you are able to minimize the effects of unpredictable weather conditions by scheduling maintenance during optimal times of the year. According to Zhang et al. from the University of Texas at Dallas, preventative maintenance should be planned during time periods when a turbine shutdown will have the least impact on the net energy production capacity. Essentially, this means that the turbine maintenance should occur during times of the year when the average wind speed is the lowest to minimize losses from a turbine being shut down. To understand when the best time of year is to perform maintenance, the Unrestricted Wind Farm Layout Optimization (UWFLO) model is used. This model mainly considers wind speed, wind gust, air temperature, and wave height. For smaller vessels carrying out preventative maintenance, wind speed must be less than 13.8 m/s, wind gusts must be less than 17 m/s, wave height must be less than 2 meters, and a reasonable working temperature range is 24°C to -26°C.

IX SCADA Systems

The SCADA system allows remote users to supervise the major components of the wind farm (turbines, MET Towers, and the substation). [19][20]

Siemens Gamesa has incorporated the Multilevel Wind SCADA center for control monitoring of offshore turbines with the SIMATIC WinCC Open Architecture SCADA System as the foundation. [21]

The benefits of the data include, secure, event-oriented, encryptable, and seamless communication - data consistency in the control center is ensured in the event of connection failures - [22] as well as containing SNMP network monitoring. This system ensures live data updates that are secure for individual users. It is vital that this system remains up-to-date and configurable so that the turbines can be properly monitored and maintained. In order to access data from the turbine, the wind farm will be designed such that each turbine is connected to a turbine server. The data will be transferred using wireless optical links. The construction of permanent meteorological masts is necessary in order to accurately monitor the wind resource data.

IX.A Insurance

To protect those involved in the wind farm project (developers, investors, etc.), it is necessary to ensure the duration of construction, operation, and project breakdown. Travelers, an insurance company focused on protecting renewable energy projects, covers a wide range of liabilities. The Builder's Risk Coverage protects property (temporary and permanent) and covers equipment failure. The plan includes "extensive definitions" of soft costs that occur during the project. The company provides further protection of the equipment through the EnergyMax 21SM package. The plan includes an extensive list of covered equipment and failure events. As the offshore wind industry is characterized by harsh installation and construction, this coverage is necessary. This company is also a desirable option for the Travelers ECP CustomSM Environmental and Contractors Professional Liability policy. As stated by the company, the policy "protects against environmental and contractors' professional business exposures" in addition to the Travelers Commercial General Liability policy. It is meant to cover all scenarios of pollution exposure. Finally, the Travelers CyberRisk policy is necessary for protection against any cyber breaches that occur within the SCADA or internal systems such that the wind farm's functionality or the private information of employees becomes compromised. [23]

Hull insurance will protect the installation vessels as they are out at sea. According to the Travelers Hull and WaterCraft Insurance, the company "provides coverage for physical damage to the hull, machinery, and equipment of commercial vessels" including collisions with other vessels. The policy is necessary not only for vessels but for the employees on board in case of injury. [24]

Travelers Ocean Marine Cargo insurance will cover damage to the turbines and other construction/O&M material shipped out to the development zone. *The Cargo Elite* ® "provides Provides automatic, all-risk* coverage for international shipments of new merchandise transported by sea. Additional coverages automatically provided include concealed damage, shortage from the container, control of damaged goods, and consolidation." [25]

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