Siting and Project Development Report

2022 Collegiate Wind Competition

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WIND POWER
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Executive Summary

The California Polytechnic State University Wind Power Club has prepared the Siting and Project Development Report for the 2021-2022 Collegiate Wind Competition. The site for the offshore wind farm in the Gulf of Mexico auction area near Galveston, Texas, will be in blocks A62, A63, A64, 235, 236, 260, 261, 263, 264, and 292. This section of the auction area was selected due to the optimal wind resources, lack of shipping lanes and other activities that would cause conflict with the approval of the wind farm, proximity to the coast, and more. The wind farm consists of 60 Gamesa G132 5.0MW Class S offshore wind turbines being placed in rows of staggered lines. Overall, the proposed wind farm will produce a total of 701,586 MWh of power over its 20-year lifespan. Also, it will cost $1,580,658,187.50 to create the wind farm, but it will produce a net revenue of $326,734,960. The auction bid for the wind farm is $112,253,760, based on existing auction bids for offshore wind leases and the LCOE of offshore wind in 2021.

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1. Site Design and Wind Resources

The siting and design of an offshore wind farm presents more challenges than onshore wind farms. New factors such as the ocean environment and water depth play a role, and each turbine requires a foundation for stability. Offshore substations are needed to provide power to the interconnection site on coast, and multiple permits are needed for the approval of the wind farm. The Gulf of Mexico, an area with no existing wind farms, has high potential for producing large amounts of power if the ideal site is found (Musial et al., 2018)

1.1 Lease Area Description

The lease area picked is the area contained in the blocks numbered A64, A63, A62, 263, 261, 235, 236, 260, 264, and 292. The area has optimal wind resources and was carefully picked with regards to environmental factors, social factors, and infrastructure factors. The site is located outside of significant sediment resources and hurricane paths or other extreme weather events. The soil composition of mud and sand will help with the jacket foundation selected for our turbines. Unfortunately, there are several sensitive species such as shrimp, reef fish, multiple shark species located in the entire auction area, so no matter where we sited the wind farm, it would impact the lifestyle of these species. In regard to social factors, the site is outside of shipping lanes and fishing areas, preventing land-use conflicts from popping up. Gas and oil pipelines are common in the Gulf of Mexico, so it is difficult to site a wind farm without being in their presence. Placing a few turbines near a structure is acceptable though, as they are a low priority. The water depth is small at the site, with a maximum depth of 20 meters. Wind speeds are fair with a mean wind speed of 6-7 meters per second. Given the multiple factors to take into consideration, the overall wind resource is strong. The risks and flaws of the area consist of but are not limited to: a failure to obtain permits or complying with state and federal regulations, presence of endangered wildlife habits, visual considerations, effects on local fishing and hunting, and more (Thomsen, 2014). These flaws have been mitigated though by careful analysis of the auction area in ArcGIS Pro, as the team made sure to stay out in areas that were significant to the local town or state.

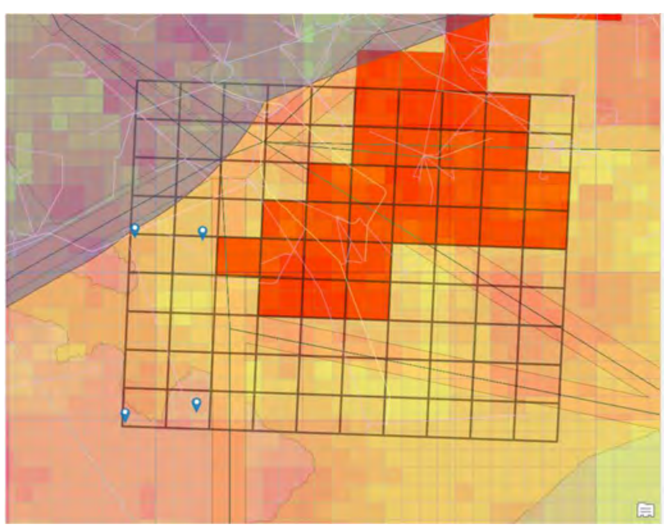


Figure 1: A screenshot of the ArcGIS map with the layers of different data.

The site is a 300MW wind farm composed of 60 Gamesa G132 5.0MW Class S Offshore wind turbines located in the lower-left corner of the auction area. The G132 5.0MW turbine has a hub height of 92 meters and a rotor diameter of 132 meters. Although this turbine has less output than other standard offshore wind turbines, such as the Vestas V132-8MW turbine, the turbine produces a respectable amount of power. In addition, the turbine's data is in Furow's turbine database, which was the wind software used for calculating the energy yield of the farm. The team preferred to work with a turbine with data provided by Furow that yielded accurate power curves, output, and other characteristics. In contrast, other sources of turbine information available online were often insufficient. The turbine layout consisted of several columns of turbines spread out across the auction blocks used. Figure 2 displays the final layout of the wind farm in Furow.

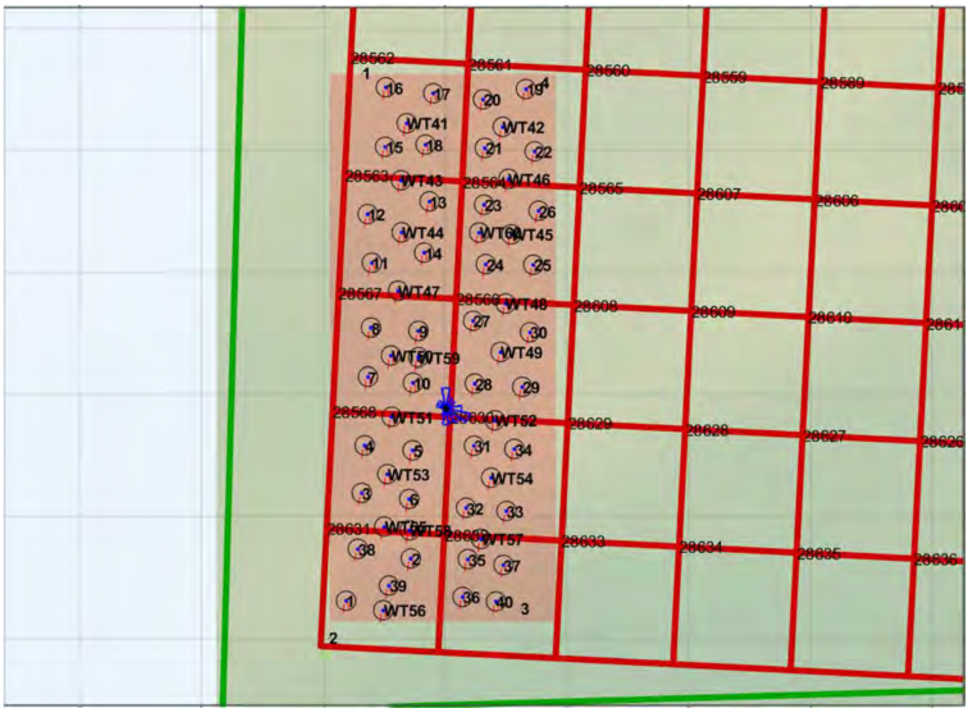


Figure 2: Final Wind Farm Layout in Furow

1.2. Foundation and Interconnection Design

For the wind farm, the jacket foundation will be utilized. Although this foundation type is more expensive to manufacture, install, and maintain, it is more environmentally friendly than other grounded foundations. For example, jacket structures can create an artificial reef effect due to the increased surface area of the lattices. Additionally, the wake effects are smaller due to lower overall volume of the structure compared to other foundation types. Also, the effects associated with sediment release during installation are minimized if we install the foundation with suction caissons (Horwath et al., 2021*)*.

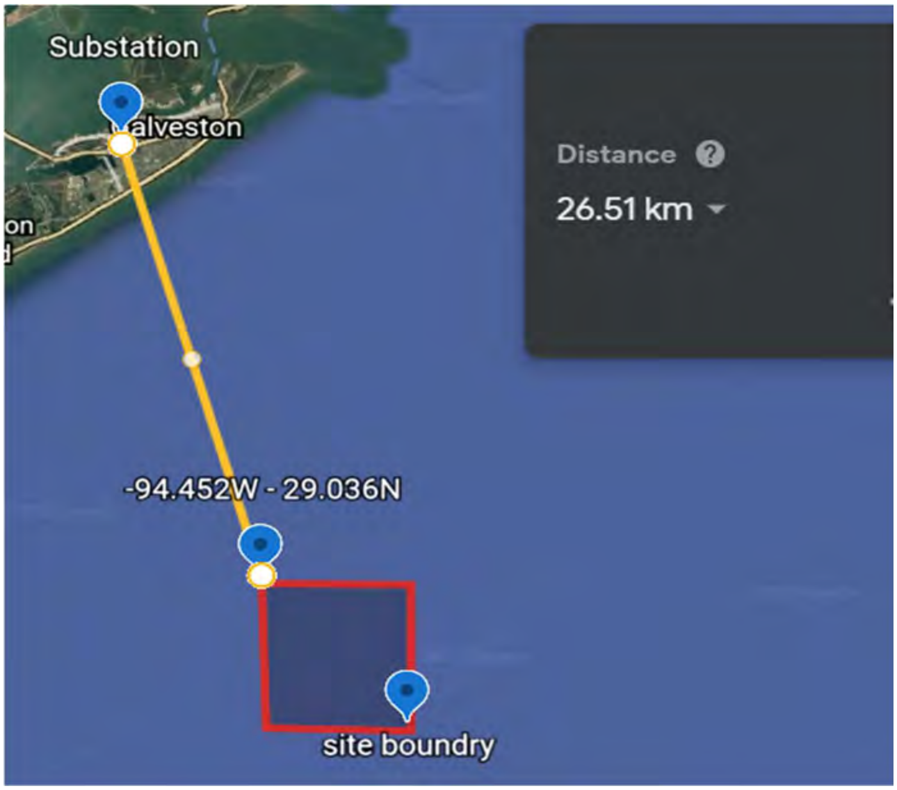


Figure 3: Google maps; site boundary to interconnection distance

The interconnection plan for the wind farm is 66kV transmission lines from the wind farm substation to the onshore substation. The onshore substation is 138kV owned by ONCOR ELECTRIC DELIVERY CO. It is currently in service, and Figure 3 illustrates that it is 26.51km from the farm. This substation has a voltage high enough for the farm to connect to and it is one of the only nearby substations in service. All the turbines will connect to a substation on the top left corner of the red box in Figure 3.

1.3. Environmental Mitigation Strategies

While building the wind farm, there are three specific environmental mitigation strategies used by European wind farms that will be utilized. The first strategy is pre- and post-construction monitoring of the site for potential impacts to the environment. As seen in Germany, there will be two years of pre-construction monitoring and three to five years of post-construction monitoring to assess the impact of the wind farm on affected species and environment (Campo and Allen, 2020). The second strategy, which is less involved, consists of sharing monitoring data across different federal and state entities to promote cooperation between them. This would result in “a better understanding of project-specific as well as cumulative impacts from offshore wind energy development” (Campo and Allen, 2020). The third strategy is creating an outline enhancement strategy for the wind farm, as done by the developers of the upcoming Hornsea Four wind farm. The outline enhancement strategy will list biodiversity enhancement strategies that can be implemented on the onshore aspects of the wind farm, such as the substation location (Get Nature Positive, 2021). By utilizing these environmental mitigation strategies, the Gulf of Mexico wind farm will decrease its impact on the environment and aquatic and migratory wildlife, both onshore and offshore.

1.4. Permitting and Leases

Although the wind farm has been sited in an ideal location, there are multiple needed permits and leases required for the approval and construction of the wind farm. Many of these leases require cooperation with state and federal agencies. The most important leases and permits needed for the wind farm are as follows:

- A wind lease of 55,572 acres for the Gulf of Mexico auction area
- The Energy Policy Act (EPA) of 2005 requires an environmental impact statement (EIS) to be submitted as part of the wind farm proposal, as part of the National Environmental Policy Act. The EIS helps ensure environmental impacts of the project are considered and available for the public to read. Also, the EPA requires consultations with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS) (Vann, 2021).
- The Marine Mammal Protection Act (MMPA) protects marine mammal species from being hurt, captured, or killed, and restricts any activity that could endanger marine mammals. The proposed wind farm would require a permit as a non-fishing activity to be built.
- The Endangered Species Act protects against the harming or killing of threatened or endangered state and federal wildlife, and the wind farm developers will require approval from the FWS and NMFS. A permit will be granted to the developers under "reasonable and prudent measures" that allow for incidental taking of some endangered wildlife (FWS, 2003).
- Under the Migratory Bird Treaty Act (MBTA) of 1918, the wind farm developers will need authorization from FWS to construct the wind farm and limit any potential effects to birds listed under the act (Migratory Bird Treaty Act of 1918).
- Multiple Galveston regional permits, a standard permit and consultation with the Army Corp of Engineers are required for building the wind farm (Obtain a Permit).

2. Optimization Process

In the process of finalizing our site for the wind farm, we found a few issues that we had to fix. For example, we decided to change the number of turbines from 40 to 60. Also, the model was changed from the Vestas V132 8MW to the Gamesa G132 5MW. The reason for these changes is because we wanted the final site to have similar energy production compared to the preliminary site. In addition, Furow's turbine database, which had the Gamesa G132 5MW, had more accurate and detailed information in contrast to the specifications given by Vestas on the internet. The meteorological data taken from the National Data Buoy Center would suffice for both turbines, but only the Gamesa turbine would provide a more accurate energy curve. In terms of cost, 20 more turbines may have an overall higher net cost because of the additional jacket foundations that have to be installed. In contrast, the additional foundations may yield additional benefits to wildlife due to the artificial reef effect provided by the lattice structures of the foundation.

3. Financial Analysis

The most important procedure of any wind farm proposal, along with the siting, is the financial analysis. Offshore wind presents more uncertainties than onshore winds, and because of this uncertainty, the total cost of offshore wind farms is higher than onshore wind. Despite this, the energy production potential and revenue are similarly higher due to stronger winds and bigger turbines being used. The team believes the proposed wind farm can generate optimal profits despite the high cost of the wind farm.

3.1. Initial Capital Cost

After modeling our farm in Furow, we turned to NREL's JEDI and SAM software to complete the financial analysis portion of our project. By inputting all the project data that we had received from Furow into the JEDI offshore wind model, we were able to calculate the project costs. The JEDI model makes this step easy as it breaks the costs down into capital expenditures and operating expenses. The total capital costs amount to $1,580,658,187.50, which is equal to $5,269 per kW. The breakdown of our initial capital costs can be seen in Table 1 below.

Item	Cost	$/kW
Turbine Component Costs	$ 390,300,000	$1,301
Substructure and Foundation	$361,972,745	$1,207
Electrical Infrastructure Components	$239,352,982	$798
Assembly and Installation	$103,765,157	$346
Sales Tax	$2,958,187.50	$10
Ports and Staging	$40,885,886	$136
Development and Project Costs	$227,032,538	$757
Construction Operations	$21,000,000	$70
Commissioning	$13,200,000	$44
Decommissioning	$17,400,000	$58
Construction Finance	$54,900,000	$183
Construction Insurance	$13,200,000	$44
Contingency	$94,800,000	$316
Total	**$1,580,658,187.50**	$5,269

Table 1: Capital Expenditures

3.2. Annual Operating Expenses

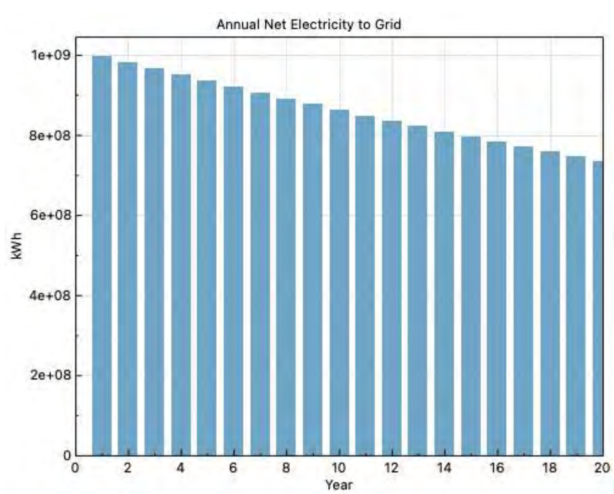
In addition to the capital costs, there are annual operating expenses that add to the overall cost of the wind farm. Operating costs cannot be predicted accurately due to environmental factors and turbine degradation, but they can be accounted for. In SAM, a turbine degradation factor of 1.6% was used for financial analysis. This factor was taken from a 2013 report on wind turbine degradation by Iain Staffel and Richard Green. The degradation factor may be even higher, however, as the turbines analyzed in the report were onshore turbines, which encounter less environmental effects than offshore ones. As a result, offshore maintenance costs will likely start off small and increase as time goes on, and the costs might be higher than expected. Despite this, the annual operating expenses listed below are an accurate representation of the costs accrued by the wind farm per year.

Item	**Cost**	**$/kW**
Offshore Maintenance	$24,406,626	$81.36
Onshore Electric Maintenance	$182,139	$0.61
Operation, Management and General Administration	$1,019,978	$3.40
Operating Facilities	$473,561	$1.58
Environmental, Health and Safety Monitoring	$182,139	$0.61
Insurance	$7,649,838	$25.50
Annual leases and fees	$1,748,534	$5.83
Total	**$35,662,815**	**$118.44**

Table 2: Operating Expenditures

3.3. Net Annual Energy Production

After developing the wind farm layout in Furow, it was necessary to obtain meteorological data for the energy yield calculations. Data was obtained by obtaining the daily meteorological data from a buoy located adjacent to the auction area. After inputting the obtained data into Furow, the team found the net energy yield of the wind farm to be 701,586 MWh. The wind farm has a net capacity factor of 27%, which is comparable to other offshore wind farms (Andrew, 2022)



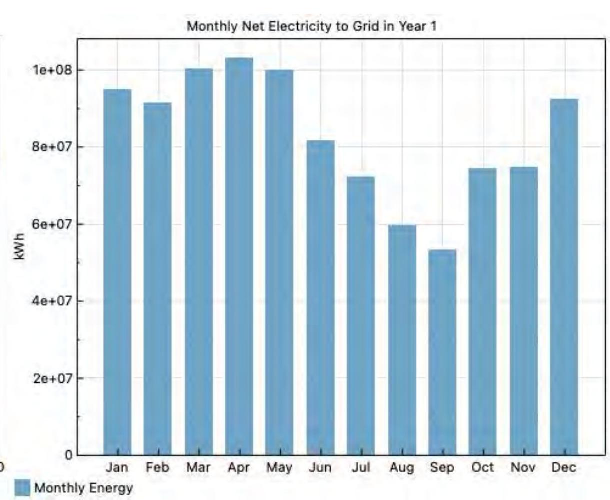


Figure 4: Net Annual Energy Production, showing decline with degradation

Figure 5: Net Annual Energy Production broken down by month

Using the Furow modelling software and the SAM software, we found that our farm would face losses in energy production due to a few varied factors. Wake losses occur in wind farms when turbines are placed downstream of other turbines and receive slower winds after having passed through the first turbine. Due to the constricted layout of our farm, we will have 4.62% of our energy lost due to wake. The second highest loss we face is 5.5% due to availability losses. This is calculated from the amount of energy that could have been harnessed while our turbines and electrical systems are not ready. We also found that due to uncontrollable environmental elements, we will lose about 2.4% of our electricity. This stems from factors that affect our turbines and cause degradation and hinder performance. Another issue our turbines will face is operating performance losses, as they will not always work as well as the OEM power curve suggests. Finally, we will lose around 2% due to electrical failures in transmission lines, collection lines, and transformers.

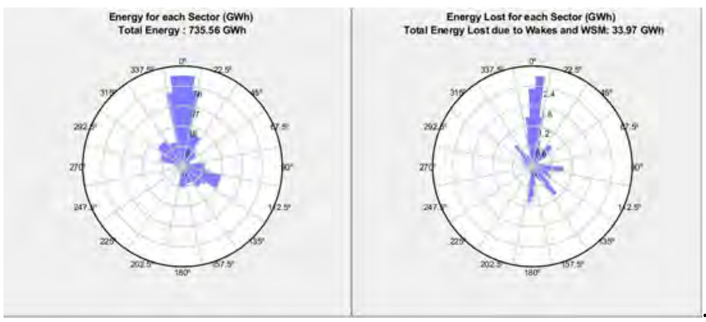


Figure 6: Gross energy yield of wind farm and energy lost due to wakes and other effects

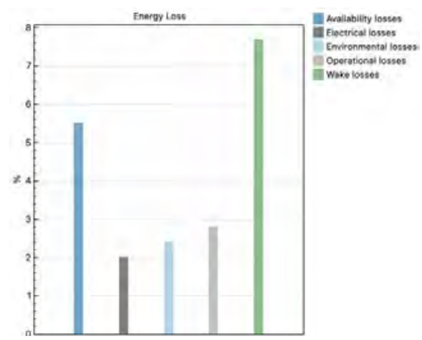


Figure 7: Factors of energy losses

3.4. Market Conditions and Tax Incentives

As the wind farm will be located right off the coast of Galveston, Texas, the wind farm will fall under Texas rules and regulations. Texas is different from other states due to its deregulated power market, meaning customers can pick their power provider. The wind farm will fall under the regulation of the Public Utility Commission of Texas, who will oversee the electric services provided by the wind farm. In Galveston, Texas, multiple retail energy providers (REPs) can provide energy to consumers. The main REPs in Galveston include Frontier Utilities, Gexa Energy, 4Change Energy, and others. These REPs would be responsible for distributing energy from the proposed wind farm to Galveston and other neighboring towns. The team believes that the wind farm would be attractive to the PUCT because of the substantial amount of clean energy generated and because of the 2021 power crisis, where millions of homes and businesses were left without power and several hundred people were killed or injured (Sullivan, 2021). In the wake of this disastrous event, the proposed wind farm would be able to limit the effects of future extreme weather events.

There are a handful of tax incentives and credits that will help the proposed wind farm be built and financed. The Database of State Incentives for Renewables and Efficiency®, established by the North Carolina Clean Energy Technology Center in 1995, was used for obtaining information on tax incentives. The Solar and Wind Energy Business Franchise Tax Exemption created in 2000 will waive the franchise tax away from companies installing wind energy in Texas, and there is no ceiling on this exemption. The proposed wind farm is also eligible for a 30% tax credit due to the Business Energy Investment Tax Credit (ITC), which will reduce the income taxes of the project. The production tax credit (PTC) for the wind farm will be $0.015/kWh according to the Renewable Energy Production Tax Credit, further reducing the income taxes on the wind farm.

4. Financing Plan

The preliminary finance plan is incredibly important for both developers and investors as they plan out and propose building the wind farm. At this stage, there is still a lot of uncertainty, so it is up to the project development team to make the best estimations and predictions, to set the project up for success. An inaccurate financial plan can destroy operations and cause the wind farm to fail. To best estimate the finances for this farm, we utilized a method employed by NREL, which follows a high and low cost LCOE analysis. An LCOE analysis is a summary of the total project costs discounted to present value terms over the expected lifetime of the farm. We found our LCOE's in the SAM modelling software by changing the target internal rate of return (IRR) in and a few of the other key financial parameters. For the high-cost finance scenario, we calculated our data using a target investor IRR of 14%, with a 14-year repayment term, and with debt comprising 35% of the project's capital. In the low-cost finance scenario, the target investor IRR is set at 10%, with an 18-year repayment term, and debt making up 40% of our project capital.

4.1. Tax and Sponsor Equity

When looking at our tax and sponsor equity, there are two key periods. These periods define the terms for sharing of tax benefits and cash flow between a third-party tax investor and the developer. The first of these is the pre-flip period. In our financial plan, the investor will receive 98% of the tax benefits and project cash, while the developer will receive 2%. The share of equity is split similarly, also following a breakup of 98% to the investors and 2% to the developers. This period comes to an end once the wind farm has generated enough money to reach the target IRR, which was set for both the high- and low-cost financial scenarios. The year that the project reaches this target is called the "flip year". After the flip year, the model moves onto the next phase, which is called the post-flip period. In the post-flip period the benefits switch to the developer, with the tax benefit split becoming 90% for the developer and 10% for the tax investor. The after-tax cash flows can be seen in figures 8 and 9, which detail this equity flip structure in both our high-cost and low-cost financial plans.

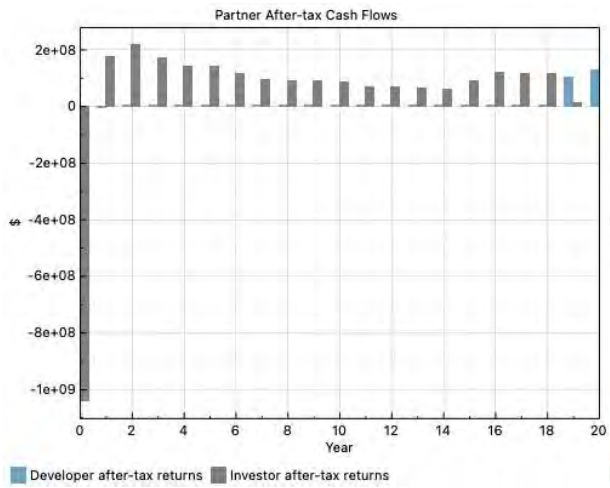


Figure 8: Graph of after-tax cash flows for low-cost analysis

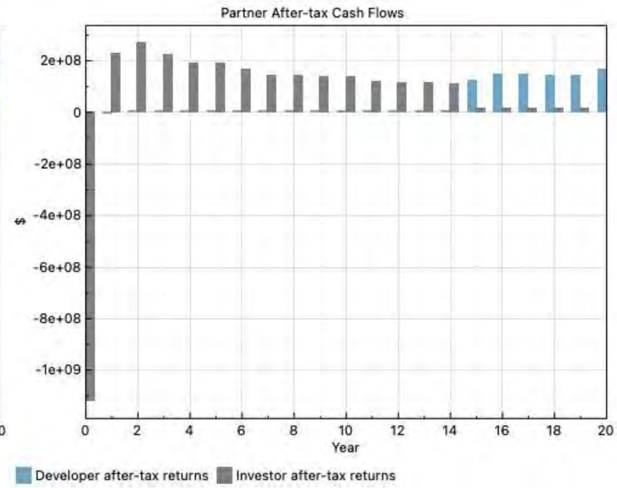


Figure 9: Graph of after-tax cash flows for high-cost analysis

As seen in the figures, the set flip year changes based on the cost model. In our low-cost model, the flip year is set for year 18 while the high-cost model is set for year 14. Using this flip debt financial structure, we were able to simulate the net present value (NPV) for both the developers and investors using the SAM software. For the low-cost scenario, the NPV for the investor will be $57,388,500 and the NPV for the developer will be $81,541,104. For the high-cost scenario, the NPV for the investor will be $287,922,976 and the NPV for the developer will be $232,285,840.

4.2. Long Term Debt

Part of our financial plan is the project term debt, which dictates what percent of the project capital the debt will comprise. In the low-cost analysis, this was set at 40%. In the high-cost analysis, this was set at 35%. Both scenarios follow a tenor of 15 years and a 5% interest rate. Using the debt parameters with the target IRR and target flip year, we can use SAM to simulate the LCOE and PPA prices. The levelized cost of energy (LCOE) shows the amount of money it takes to generate electricity in $/kWh. The power purchase agreement (PPA) determines the price that the energy can be sold at to the market. For the wind farm to be profitable, the PPA must be larger than the LCOE, so that the market is paying more than it costs to generate. The more the PPA price exceeds the LCOE, the greater the revenue surplus (Schwabe et al., 2017). Looking at Table #3, you can see that in both the high and low scenarios, the nominal LCOE is lower than the levelized PPA. Our SAM analysis resulted in an LCOE premium of 1.56 ¢/kWh for the high-cost financing scenario relative to the low-cost financing scenario.

SAM Model Inputs	**Low-Cost Analysis**	**High-Cost Analysis**
Target IRR	10%	14%
Target Flip Year	18 years	14 years
Debt Percentage	40%	35%
Debt Interest Rate	5%	5%
Debt Loan Term	15 years	15 years
Levelized PPA Price (nominal)	**24.01 ¢/kWh**	**30.25 ¢/kWh**
Levelized COE (nominal)	**22.77 ¢/kWh**	**24.33 ¢/kWh**
Price Difference	**1.24 ¢/kWh**	**5.92 ¢/kWh**

Table 3: Levelized PPA Price and COE across Low-Cost and High-Cost Analysis

4.3. Income Tax

Texas is one of nine states that does not have an income tax. This being said, the project will still have to follow federal income tax which we set at 21% per year in our SAM parameters. Additionally, our project follows the Texas state sales tax of 6.25%. The sales tax rate applied both to the financing program and to the calculation of the capital costs, as we had to calculate sales tax on supplies and materials purchased.

4.4. Depreciation

To handle the depreciation of our assets, our team decided to use the 5 year Modified Acceleration Cost Recovery System, also known as MACRS. This is the current method used in the US to determine the depreciation deductions for federal income. In the SAM modeling software, we determined that the depreciation schedule from year one to six is as follows: 20%, 32%, 19.24%, 11.5%, 11.5%, 5.76%.

5. Auction Bid

The auction bid for the proposed wind farm will be $112,253,760. This value is taken from NREL's 2021 Offshore Wind Market Report, where it was estimated that the levelized cost of energy is $160/MWh. Since the wind farm will produce 701,586 MWh of energy during the project lifespan, we can find out the price of the farm by multiplying the LCOE by the energy yield of the wind farm. This number is typical of other offshore wind farms auction prices, such as in 2018 when Equinor Wind, Mayflower Wind Energy, and Vineyard Wind were able to obtain wind energy leases in Massachusetts for $135 million each (Business Network for Offshore Wind). The total land of the proposed wind farm site is 57,522 acres, which is much less than the acreage of the Massachusetts wind sites. However, the team believes that the proposed price is accurate due to the annual energy yield of the farm and the social, environmental, and infrastructure constraints present in the auction area.

6. Conclusion and Recommendations

The team has determined that the best location for installing a wind farm in the Gulf of Mexico auction area is in the blocks numbered A64, A63, A62, 263, 261, 235, 236, 260, 264, and 292, all of which are in the lower left. This section of the auction area was selected due to the optimal wind resources present, a lack of shipping lanes, fishing areas and other protected activities that would cause conflict with the neighboring cities, good soil conditions, and proximity to the coast. The wind farm will consist of 60 Gamesa G132 5.0MW Class S Offshore wind turbines installed in several columns, and it is projected to yield 701,586 MWh of electricity in its lifespan. Over the course of its lifespan, the wind farm will generate an estimated $326,734,960 of revenue. The total capital costs are expected to be $1,580,658,187.50, which equates to $5,269 $/kWh. Using a leveraged partnership flip with debt financing plan, the wind farm will flip in about 18, or possibly 14 years. Regardless of the high-cost or low-cost analysis, the wind farm will be selling its energy for more than it costs to generate it.

Given the energy production and financial analysis of the wind farm and considering the auction bids of previous wind farm leases and the 2021 LCOE for offshore wind, the team is willing to spend $112,253,760 on the chosen lease area. It is important to note that in the process of doing research and utilizing SAM and other software for the project, not every factor used was fully known. All these factors combine to create a percentage of uncertainty with the wind farm and how it will operate if built. Other external factors such as the market conditions and the Gulf of Mexico weather are also unpredictable, but the financial analysis and wind energy estimation were done with the goal of reducing uncertainties encountered. The team believes that the proposed wind farm will be successful and act as a strong beginning to wind energy in the Gulf of Mexico.

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