Techsan Wind Project Development Report

Texas Tech University

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EXECUTIVE SUMMARY

Throughout the past year, the Techsan Wind team has worked towards designing an offshore wind project in the High Island auction area of the Gulf of Mexico for the 2022 Collegiate Wind Competition. For this project, the team conducted a wind and site resource analysis to determine the location, optimal turbine design and foundation, and best point of connection for an offshore wind site in this region. This data was utilized to create a pro forma that details initial capital expenditures and annual operating costs over the life of the project based on incentives, Levelized Cost of Energy (LCOE,) the power purchase agreement, and the expected net energy production.

The resulting project is located 29 miles southeast of High Island and is comprised of 16 Repower 6.15m turbines. WAsP software was utilized to determine a total Annual Energy Production (AEP) of 317.66 GWh, Net AEP of 309.524 GWh, and wake loss of only 3.07%. Capital expenditures are $304,000,000 with an annual operating cost of $48,000,000 when accounting for debt payments. After 15 years, it will drop to $31,000,000 per year.

SITE DESCRIPTION AND ENERGY ESTIMATION

After analyzing the given location of the TX-7 High Island auction area, the following lease blocks were chosen for the Techsan Wind project site: HI-174, HI-173, HI-198, and HI-199 (Figure 1). The considerations for this decision included: the distance from the site to the shore, proposed placement alongside existing shipping lanes, environmental concerns, and overall change of depth within the leasing area. Moreover, lease blocks to the south and east of the proposed area are located further away from the point of interconnect without substantially higher wind speeds or more compatible water depths. Thus, the northernmost lease blocks were the most viable for this project. These blocks allow for lower wake loss and the most efficient direction orientation for the rows of turbines in the design while using the fewest lease blocks, thereby decreasing the overall cost of the project. In contrast, other leasing blocks on the western side of the proposed auction area would require more rows with fewer turbines each, due to the proximity of major shipping lanes; thus, creating power loss from wind wake and requiring more leasing blocks to produce the same power output. The chosen lease blocks for the project are located on the East Mexico Shelf, constituting a relatively flat ocean floor and a depth of 20-30 meters throughout the proposed project site. The ocean floor is also predominantly mud and sand throughout the auction area.

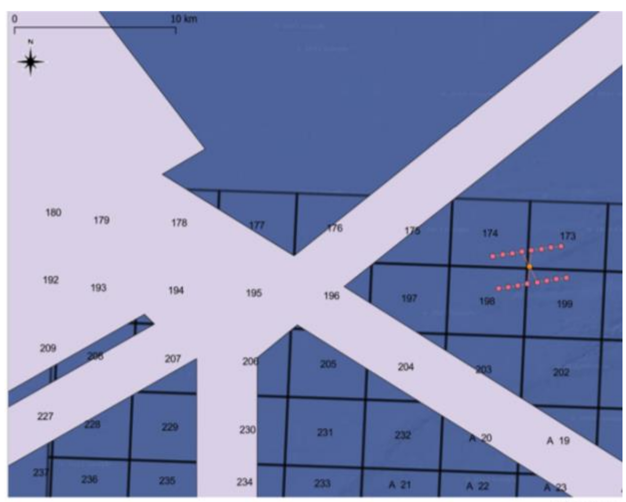


Figure 1

These factors of depth, soil composition, and uninterrupted layout will help with a consistent construction timetable and less variable cost, something other lease blocks could not provide.

Preliminary Site Layout

In the pursuit of accurate and reliable resource data for this project area, research was conducted on numerous possibilities for wind data in the region. With the difficulty of the remote location and the absence of any major energy projects in the area; information from the NOAA buoy 42035 located 20 kilometers northwest of the project location was chosen to be used. This buoy has historical data starting in 1993. Data from the MERRA atmospheric satellite was used to extrapolate wind speed in conjunction with the information gathered from the buoy.

Figure 2

Using the wind siting software WAsP, and the REpower 6.15m turbine, numerous configurations, and layouts of potential project designs were tested to discover the most efficient site arrangement. The chosen layout is comprised of two straight rows of eight turbines directly perpendicular to the prominent wind direction of 165 degrees, southeast. The turbines in the layout maximize production and limit wake loss through their staggering of location between a turbine and the row behind it (Figure 2). In this configuration, one turbine will appear directly between the two turbines in front of it, in the row ahead. Additionally, this layout benefits the transmission design by allowing for four turbines per electrical string, and four strings in total in a radially operated star-shaped design: all converging at a central collection platform at the center of the project (Figure 3). The project will be oriented perpendicular to

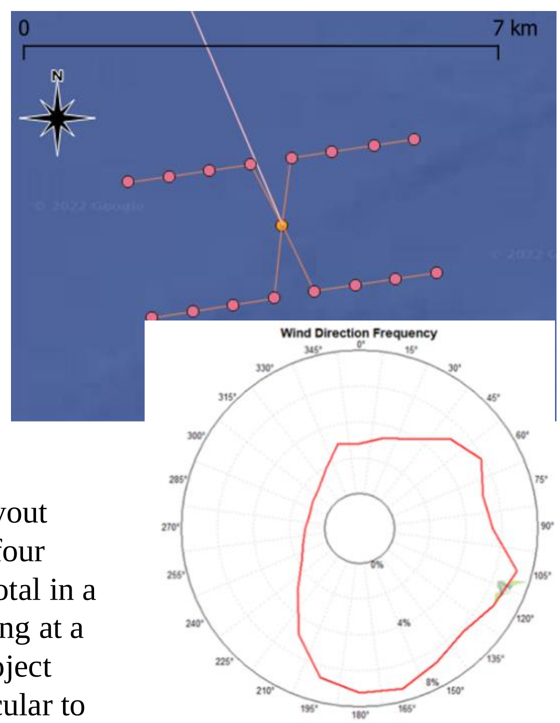
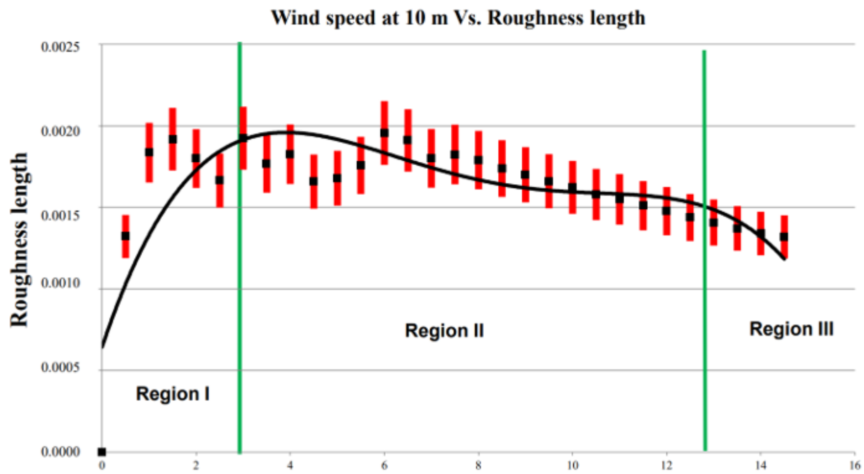


Figure 4

the predominant wind direction at an angle of 165 degrees (Figure 4). With the site layout established, further experimentation with the power calculation system built into WAsP, with an industry-standard surface roughness of 0.001m, was conducted. These preliminary calculations resulted in a total Annual Energy Production (AEP) of 319.337 GWh, Net AEP of 309.524 GWh, and wake loss of only 3.07%.

Wind Resource and Surface Conditions

This total AEP of 319.337 GWh is only a preliminary estimation due to the effects of variable surface roughness from ever-changing surface conditions, and the limitations of the program WAsP being capable of only a single value for surface roughness during its calculations. As wind speed in the area intensifies, so does the wave height of the surface and the correlating surface roughness length. While unassuming the wave height creates an everchanging surface



Variable Roughness length vs. percent of time it occurred					
	Roughness Length (m)	Percent of time in effect	Weighted total AEP [GWh]	Weighted Net AEP [GWh]	Wake loss [%]
Variable Roughness	0.0013	1.76%	5.605424	5.4325568	0.05421
	0.0014	1.00%	3.16977996	3.0720126	0.03068
	0.0015	0.45%	1.42473856	1.3807853	0.0138
	0.0016	8.92%	28.3568259	27.481141	0.27566
	0.0017	29.61%	94.0865037	91.17979	0.91501
	0.0018	19.29%	61.2746716	59.380583	0.59612
	0.0019	28.77%	91.3703983	88.546518	0.88912
	0.002	10.20%	32.356891	31.356762	0.31503
Total		100.00%	317.645	307.830	3.09
Industry Standard	0.0010		319.337	309.337	3.07

Figure 6

roughness length that affects the turbine output and the AEP of the project. This effect leads to an overall inaccuracy of the initial calculations of the project, as the true surface roughness will be different than that of the industry standard of 0.001 meters. While only a small impact, this phenomenon is calculated in all experiments performed and accounted for in the final Annual Energy Production estimation of the project. To do this, the curve of roughness (Figure 5) was studied and its precise generation conditions to determine exactly what wind speed would cause specific surface roughness values. This data was then used to calculate the percentage of the time in which each surface roughness value was in effect, rounded to the nearest ten-thousandth meter. After the values had been determined, the previous roughness value of 0.001 meters was replaced with each of the roughness variables and totaled the AEP of each value generated by the percentage of time it occurred (Figure 6). These calculations were finalized to create a new AEP total of 317.645 GWh which accurately reflects the surface roughness of the project and will be used in the following financial calculations.

The average wave height in the area is 0.89 meters, with a maximum wave height of 3.81 meters, according to measurements taken by the NOAA's National Data Buoy Center Station 42035. The only major weather phenomena in the area are hurricanes, which are both incredibly powerful and unpredictable in long-term forecasts. These hurricanes and traditional severe weather should be monitored, and procedures should be created utilizing current industry standards. The financial and physical preparations for these events have been researched and are further detailed in this report.

Turbine Selection

Currently, offshore turbines use the IEC 61400-01 standard and can survive 112 mph average wind speed of up to 156 mph gusts; these constitute a category 3 hurricane (Masters 2019.) Two viable options in the industry to combat hurricanes higher than a category 3 are typhoon-class wind turbines and down-wind turbines. Typhoon-class turbines are relatively new and predominantly used in Asian markets where typhoons are prevalent and expected yearly. However, these turbines are designed exclusively for high average wind speeds and would be inefficient when used in this region. Another possible option would be to use downwind turbines, such as the turbine designed by NREL (National Renewable Energy Laboratory); this design features multiple components such as a twisted foundation and a flexible rotor configuration that faces away from the wind. These components work in tandem to create a turbine that prevents the blades from hitting the tower and is more resistant to high-speed wind gusts. Unfortunately, this technology is still in its research and development stages and is currently unavailable to be used commercially; but could provide a viable option in the future (Hartman 2018). Despite this, the region's modest temperature, wind speed, and wave height make it a hospitable area for offshore wind energy.

After securing wind resource and climatological information, an appropriate IEC turbine classification was needed for the site. With wind speeds reaching 7.96 m/s at 95m high the IEC 61400 guidelines were used to determine that a class III wind turbine generator class would be optimal for this site. This is due to the low wind speed as well as the historical wind data giving little indication of a significant increase in wind speeds during the lifetime of the project. Hurricane instances at the site region also suggest a typhoon class turbine (T) would be ideal. The T-classification is a recent development of turbulence classification and is intended to give manufacturers a reliable rating process for the requirements of turbines that will be located offshore in the pacific. This region of the world is prone to seasonal typhoons which traditional S-class turbines could not withstand. This is particularly useful to turbine selection in the project area, because while it does not have typhoons; the presence of hurricanes in the Gulf of Mexico presents a unique challenge. A typhoon-rated turbine could provide the necessary strength to reliably withstand hurricanes that might impact the site location.

With a wind class of III and turbulence intensity of T selected, investigations into turbines that could meet these requirements began. However, research revealed that there are currently no turbines available on the market that exactly match these requirements. T-class turbines are designed for areas with annual typhoons but also require a higher average wind speed than this project location can regularly achieve. Alternative models that could be placed at the site prioritizing the low wind speed requirements over that of the turbulence intensity will be required. With this reduced requirement, the team expected to make significant progress due to the wide array of offshore turbines currently available on the market; however, the team encountered significant difficulties acquiring reliable power curves for present-day turbines, as the information is proprietary, and the rules of the competition forbade any stakeholder outreach. While these constraints were challenging, the team procured the power curves of some older offshore turbine models including the Windtec DD 3000 and the Goldwind 140/3.4 and was able to make an informed decision on turbine selection.

For this competition, the Repower 6.15m offshore turbine was selected as the optimal turbine for this site design. This turbine combines low-speed efficiency with reliable performance and a large hub height to create the best available turbine for the project site. The Repower 6m is an IEC IIIS turbine with a rated power of 6.15 MW, a hub height of 95 meters, and a rotor diameter of 126 meters. The cut-in wind speed is 3.0 m/s and the cut-off wind speed is 30.0 m/s, reaching rated power at 15.3 m/s. The wind speed in the area at the hub height of 95 meters has been calculated to average 7.96 m/s, which will produce an estimated total Annual Energy Production of 317.645 GWh (See Figure 5). The average wind speed was determined and extrapolated using the wind law and MERRA data as previously mentioned in this report. This wind speed matches with the NREL's Wind Integration National Dataset (WIND) which defines wind speed in the project area at 7.3 m/s at 100 meters.

Foundation

Jacket substructures were selected for this project due to the combined factors of ocean floor makeup and relative stress durability at the specific depth compared to the hub height of the turbines. Monopile supports are proven to be less reliable during severe weather events and therefore carry a higher risk of failure.

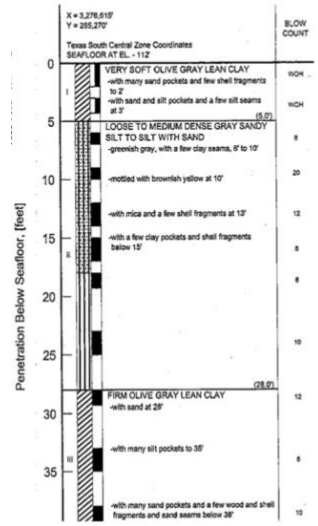


Figure 7

Underwater foundation and substructure research indicated a need for a jacket foundation for this project. While monopile substructures are more commonly used at the depths found in this project area, the abundance of soft soils requires a foundation that can distribute the mass and loads of the turbines. A geotechnical engineering firm, Furgo (2008), conducted a study in the Gulf of Mexico 40 miles from our proposed location in Galveston lease block A25. The study found that 25 feet below the seafloor was predominantly composed of very soft olive-gray lean clay and loose to medium dense sandy silt. (Figure 7) . A monopile design is not the optimum selection given the precluding analysis. A jacket substructure provides greater stability. and have also been determined to promote biodiversity by protecting and growing reef ecosystems. (Degraer, et al. 2020.)

Grid Connectivity

The collection system was designed using the wind industry's average of 0.55 economic carrying capacity (ECC). Losses that occur when above 55% are too high to be financially viable, so cables must be chosen with amperage maximums nearly double that which the cable will carry.

A 34.5 kV voltage was assumed for the collection system, so finding maximum amperage per phase was a calculation of I=Wattage/(sqrt(3)*Voltage). Turbines produced 103 Amperes. Every turbine added an additional 6.15 MW to the collection line to the next turbine, so amperage would increase by 103 amperes for each additional collection wire. Thus, multiple sizes of collection lines were used. Using the underwater wire chart from Gonzalez-Rodriguez, 2 underwater wires were chosen based on their ampacity ratings multiplied by the economic carrying capacity (2017). These were 400mm^2 and 630 mm^2 wire sizes. Using the losses section of the table, given in W/m, a resistance per meter was calculated. This resistance per meter multiplied by the length of cable and amperage squared resulted in 16 Kw of losses per "trunk line" and 64 Kw of losses for the whole collection cabling system. These losses are negligible because the cables have an ampacity rating near double that of what the wire will be carrying, and because the distance each wire runs is only 608 meters.

A 220 kV high voltage AC (HVAC) export cable was chosen to get the power from the offshore substation to the onshore substation. Though many offshore wind energy projects use high voltage DC (HVDC), the industry standard in Europe is HVAC if the project is less than 50

Kilometers away from shore and HVDC if the project is more than 50 kilometers away from shore (Soares-Ramos 2020). Moreover, the 220 kV was chosen over another industry standard of 132 kV because losses are a product of Amperage. Lower losses would be present when using an increased voltage (thus decreased amperage). The export cable was chosen in a similar way to the array cables. ECC was considered, and Amperage was calculated using the formula previously used for finding array cable amperage. A 500 mm^2 cable with an ECC rating of 137 MW was chosen based on the export cable table given by Gonzalez-Rodriguez, though no losses or resistance values were given. Thus, a loss percentage of 4% was used (International Electrotechnical Commision 2007). The same cable would be used for the onshore export to the substation section. The substation loss was assumed to be 5% (International Electrotechnical Commision 2007).

The onshore transmission infrastructure is poorly structured for offshore wind energy. Transmission lines between Galveston and Port Arthur are only rated at 138 kV (gained through QGIS), nearing that of distribution voltage. The team contacted Mark Grey, a systems design manager at SGS Engineering. The wires that cover this section of the coast have a maximum ampacity of 765 Amps. After accounting for the ECC, the most that could be put on the transmission lines would be 100.5 MW. Higher ratings of voltage are found much further inland. This restricts the size of the project and makes further project expansion difficult.

Risks and Fatal Flaws

Challenges in the lease area include two large shipping lanes coming and going from the Port of Galveston, which may present a challenge for transportation access to the project area. (See Figure 1) These lanes are heavily trafficked by cargo ships, oil tankers, cruise ships, lays, and rigs; however, the leasing blocks chosen for this project lie outside the area of the shipping lanes to prevent interference during construction and maintenance. Our project design also utilizes the Port of Galveston to be used for operations and maintenance of the project and the port of Houston for all staging and construction needs.

Additionally, surveying for this area would be best conducted by Swift Surveying and Mapping Inc, located in Odem, Texas, due to their proximity to the site and experience in the Gulf of Mexico. Currently, the design anticipates using the Charybdis as the installation and construction vessel as it is a Jones Act compliant offshore-wind installation vessel and is the best option to meet all construction needs. This ship is capable of handling wind turbine sizes of up to 12 megawatts and will also be able to install foundations; while currently under construction in Texas by Dominion Energy, the ship is expected to enter service in late 2023 or early 2024. (Mercure, 2021)

Critical Habitats and Wildlife Analysis

The primary environmental concerns for this area include severe weather, wave height, and effects on the habitat of Eastern Oyster Reefs which are prevalent inside the leasing area. This species promotes biodiversity within the region and is used as an indicator of the overall health of the ecosystem throughout the region (Love, et al. 2013). Therefore, it is important to note their exact locations when beginning construction although it does not pose a risk to the continuation of development.

The Kemp Ridley's Sea Turtle is listed as an endangered species and found throughout the Gulf of Mexico, including in and around the project area. Appropriate approval must be acquired from BOEM, under the Endangered Species Act and the Marine Mammal Protection Act of 1972. This will require a Habitat Conservation Plan (HCP). Under the BOEM Renewable Energy Program Regulations (30 CFR 585), Subpart H: once notified of the existence of endangered or threatened species in the vicinity of the lease, BOEM will consult with appropriate State and Federal fish and wildlife agencies to identify whether, and under what conditions, the project may proceed (Bureau of Ocean Energy Management, 2014). Migratory birds are also prevalent in the area although none are registered as endangered. However, Brown Pelicans are classified as threatened in the state of Texas; there are also no NOAA Critical Habitats found within the leasing area.

Permitting

Through the development process, the exact location of the project was regularly reviewed to determine the project's legal jurisdiction. The center of the project site lies 46 kilometers (28.5 miles) from the Texas coast and therefore lies outside the state's legal boundary and will require permitting from the following federal agencies:

Federal Governing Agency	Permitting Requirement
Bureau of Ocean Energy Management (BOEM)	Commercial lease of submerged lands for renewable energy development Site Assessment Plan (SAP) approval Construction and Operations Plan (COP) approval Facility and Design Report (FDR) approval Fabrication and Installation Report (FIR) approval
National Oceanic and Atmospheric Administration (NOAA) Fisheries, United States Fish and Wildlife Service (USFWS)	Consultations for: Magnuson-Stevens Fishery Conservation and Management Act, Marine Mammal Protection Act, National Historic Preservation, Endangered Species Act Authorization for incidental take or harassment under: Marine Mammal Protection Act, Endangered Species Act, Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act
United States Army Corp of Engineers (USACE)	Permit for subsea cables under the Clean Water Act
U.S. Coast Guard	Navigational Lighting Permit

Department of Defense (DoD), Federal Aviation Administration (FAA)	Consultations pertaining to siting
Environmental Protection Agency (EPA)	Air quality and pollution prevention permits

FINANCIAL ANALYSIS

Following the preliminary milestone report, an in-depth financial analysis was conducted to determine profitability and optimize project design. Pro-forma was utilized to goal-seek a lease bid price at breakeven Net Present Value (NPV) at 20 years. It considered Capital Expenditures (CAPEX), Operations Expenditures (OPEX), Taxation, Depreciation, WAsP findings (Gross AEP, Wake Loss, zGross Factor), financial assumptions, and site-specific assumptions. Finally, an operating cash flow accounting for all elements was created. values for net present value (NPV), internal rate of return (IRR), and debt service coverage ratio (DSCR) are outputted.

Market Conditions

This project poses a greater investment risk than that of traditional energy ventures. While standard renewable energy projects include political risk, they also contain development risk, competition in the market, and regulatory uncertainty (Feldman 2020). The Techsan Wind project would be "first of a kind" project as it would be the one of the first offshore wind energy projects in the United States, the first in the Gulf of Mexico, and the first to connect with the Electricity Reliability Council of Texas (Levitt 2011). This brings inherent uncertainty financially to the project and its continued development. Debt Interest rates were set at 4.5% for this project and required equity returns at 11%, which is higher than most other renewable projects (Feldman 2020). The average required DSCR to acquire debt funding was assumed at 1.4 which is like that of onshore wind but is higher than Utility Scale PV (Feldman 2020.) In an abundance of caution, the team also elected to reflect some increased costs associated with the project in their calculations of the Operational expenses. Offshore development is inherently more cost-prohibitive than traditional onshore turbines, and that fact is compounded by the lack of infrastructure and support in the region.

Capital Expenditures

Due to the inability to reasonably acquire live prices of physical units, coupled with the variability of raw materials both in time and market, mathematical approximations were used in financial calculations for portions of this report. Components of Capital Expenditures (CAPEX) such as turbine, substation, cabling, and substructure unit costs were approximated utilizing formulas and reasonable information. These units have variable costs associated with site-specific features such as water depth, distance to shore, capacity, and unit design. This approach increases CAPEX accuracy influenced by environmental aspects and design decisions of the project.

In financial calculations of the turbine acquisition cost, it was calculated using the formula Cost £=1081*MW_Capacity^.9984. This is then converted to dollars using the rate from March 10, 2022, and multiplied by 0.85 as the acquisition price accounts for 85% of "total" turbine price (Gonzalez-Rodriguiz 2017). The remaining 15% accounts for installation and turbine electrical costs. The formula was found by correlating capacity and cost for 14 offshore sites (Gonzalez-Rodriguiz 2017). Foundation unit and installation cost were calculated using the formula cost Jacket=(16558*water_depth_meters) + 284. This formula was found by correlating 14 wind sites by water depth and substructure type (Gonzalez-Rodriguiz 2017). "Home Run" cabling was calculated using the formula €cost = 3135*MW_load*Kilometer_Length and Substation costs were calculated using €cost= (Girard 2021). Soft costs, which are not as related to site attributes, were also considered. Development costs (which account for design, surveying, legal consent, wind data procurement/cleaning, etc.) were calculated as a group. They account for 2.2% of total Capital expenditures on average (stehly 2020). Financing costs "the costs to raise money" are 2% of total CAPEX (stehly 2020). Installation costs that were not tied to the researched unit cost were calculated using the ratio between the average unit and installation cost (Cavazzi 2016).

	cost/unit	Total
Consent & Development		$ 6,532,657.72
Foundations unit and installation	$ 4,717,355.01	$ 75,477,680.15
Turbine & Tower (Including 2 year warran	$ 6,189,528.92	$ 99,032,462.73
Turbine and Tower Installation/Electrical	$ 1,067,693.74	$ 17,083,099.82
Substation	$ 7,727,155.20	$ 7,727,155.20
Substation Installation	$ 1,103,879.31	$ 1,103,879.31
34.5 kV Collection System	$ 5,527,428.00	$ 5,527,428.00
Export Line (220 kV)	$ 338,869.67	$ 15,926,874.68
Transmission Lines Installation	$ 609,965.41	$ 28,668,374.42
Lease Block Costs	$10,000,000.00	$ 40,000,000.00
Financing Cost		$ 7,741,900.89
	[redacted]	
	Total Capex	$ 304,821,512.92

Annual Operating Costs

The project is being produced in an emerging market: therefore, the conservative approach is to subcontract operations and maintenance to a third party. It was assumed that Operations costs (OPEX) (payments for maintaining and fixing turbines, labor, routine testing, etc.) would cost $37/MW. This is slightly higher than average for offshore wind projects worldwide because it incorporates the "First of a Kind" effect on pricing. The Port of Galveston has the largest O&M space available in the region. Dock leasing is $3.97 per foot of ship, per day of lease. For a 150 ft vessel this is $595.50 per day, amounting to $217,357.50 per year. Discounts are available from the Port of Galveston for a long-term lease covering the life of the project, however those are not determined until time of contracting. Assuming full-price for a 25-year lease, this comes out to $5,433,937, although after discounts could be as low as $2,716,968.75. Debt is on a 15-year term at a 5.5% interest rate which results in payments of $11 million per year.

Incentives

With the major push towards green energy, the Federal government has stepped in to aid the growing renewables industry. The primary method of this has been through the investment tax credit (ITC) and the production tax credit (PTC). The PTC creates another form of raising money through tax equity which can be treated as a form of subordinate debt in a pro forma, as the tax credit is tied to production. the PTC was rated at 1.5cents/kilowatt in 2021, but its future is reliant on the renewal of the program by the federal government. The Business Energy Investment Tax Credit was recently reallocated for offshore wind and is applicable for any offshore wind project that begins construction by 2025 (Griskonis 2021). It can account for 30% of initial expenditures, which accounts for $91,727,000 of CAPEX. The ITC was chosen because it is less dependent upon congressional whims and does not vary year to year. AEP can vary year to year, and because the PTC is dependent upon generation, it is a riskier option for investors.

Pro Forma

The elements of CAPEX and OPEX, taxes, depreciation using the modified accelerated cost recovery system, ITC, Net Generation (gained from WAsP), and financial assumptions that match market condition were combined for cash flow analysis. The model also considered losses from wake effect and transmission. The model ran for 25 years (as wind turbines often last longer than their debt payments and life expectancy). This model considered the overall CAPEX, Annual OPEX, the ITC, PPA price, debt service, and gave outputs of net present value (NPV), Internal Rate of Return (IRR), and debt service coverage ratio (DSCR).

OPTIMIZATION

In the iterative design of the project, the team continually updated the design and layout of the project to determine the best possible design. In contrast to the preliminary report by the team earlier this year, the current design has many changes and alterations that help to create a more efficient project. One of the largest changes the team made was to replace the selection of the turbine to be used from the Windtec DD 3000 with their current selection of the REpower 6m. This turbine is similar in many ways, but with added reliability and environmental appropriateness. Additionally, the team increased the number of turbines in the project from 12 to 16; these extra turbines allow for better financial performance without requiring significant alteration to the preliminary transmission plan.

Risk Management Plan

Risk is inherent with any project, but proper guidelines and safety protocols can help mitigate these risks. One of the easiest ways to prevent injuries during construction and operation is through training and assessment of any person at the site, staging area, or Operations and Maintenance facility. The team recommends, as a minimum, that any person involved in any physical aspect of the project complete the OSHA (Occupational Safety and Health Administration) 10-hour workplace safety course. Additionally, appropriate action must be taken by the operator to prepare for severe weather conditions and lightning possibilities. As with traditional wind projects, the team recommends halting work and exiting the turbine, or proceeding to a safe location whenever lighting is present within 30 miles of the project site. Also, the local weather conditions and the predicted forecast should be closely monitored by the operators to ensure wind conditions are within safe work thresholds both at hub height and the surface. Workers will need to transfer from the transit vessel onto the turbine, and high wave conditions could make this process needlessly difficult or even unsafe. Lastly, the long-term weather forecast for the Gulf of Mexico should be referenced especially during hurricane season. As hurricanes pose the single most destructive threat to the project, the operations and maintenance should strictly adhere to work requirements by local and federal entities; and the safety of all personnel must be the priority throughout the lifetime of the project.

AUCTION BID

With all the inputs, the operating cash flow outputs a breakeven 20-year NPV when the PPA price is $70.33, and the lease bid is at $10,000,000 per lease block. The Investor rate of return is at 11%, which is what would be necessary according to offshore wind's market conditions. Our average debt service coverage ratio needed to be above the 1.4 ratio given by the market conditions, while also having a minimum above 1.0, so that debt payments could be made every year. This occurred when the split between debt and equity was 55%-45%, with an average debt service coverage of 1.7 and a minimum of 1.1. The combination of IRR reaching 11% by year 20 and DSCR averaging higher than 1.4 makes the project financially viable with the help of the recently passed ITC of 30%.

CONCLUSION

For this competition's preliminary design, we will be utilizing the REpower 6m offshore wind turbine through its placement in two rows of 8 turbines each, within a radially operated, star-collection layout producing an estimated gross annual energy production (AEP) of 309.337 GWh. Jacket foundations have proven a favorable substructure due to their proficiency in the soft soil that constitutes much of the seabed in the project area and their potential benefit to marine ecosystems in the form of artificial reefs. By locating our project in lease blocks HI-174, HI-173, HI-198, and HI-199 the project takes advantage of the best wind resource while simultaneously minimizing wake loss and avoiding major interference with shipping channels and maritime activities. This project presents a fantastic opportunity to bring clean, efficient energy to High Island, Galveston, and the greater Houston area while protecting the ecosystem and encouraging new energy initiatives.

References

Bureau of Ocean Energy Management. (2014, July). BOEM Renewable Energy Program Regulations (30 CFR 585). https://www.boem.gov/sites/default/files/uploadedFiles/30_CFR_585.pdf

Cavazzi, S., Dutton, G. (2016). An Offshore Wind Energy Geographic Information System (OWE-GIS for assesment of the UK's Offshore Wind Energy Potential. *Renewable Energy*, *87*, 212-228 https://doi.org/10.1016/j.renene.2015.09.021

Degraer, S., Carey, D., Coolen, J., Hutchison, Z., Kerckhof, F., Rumes, B., & Vanaverbeke, J. (2020). Offshore Wind Farm Artificial Reefs Affect Ecosystem Structure and Functioning: A Synthesis. *Oceanography*, *33*(4), 48–57. https://doi.org/10.5670/oceanog.2020.405

Damiani, R., Dykes, K., & Scott, G. (2016). A comparison study of offshore wind support structures with monopiles and jackets for U.S. waters. *Journal of Physics: Conference Series*, *753*, 092003. https://doi.org/10.1088/1742-6596/753/9/092003

Girard, Y., et al. (2021). Compaing Regulatory Designs for the Transmission of Offshore Wind Energy. *Economics of Energy & Enviornmental Policy*, *10*(1) DOI:10.5547/2160-5890.10.1.

Gonzalez-Rodriguez (2017). Review of Offshore wind wind farm cost components. *Energy for Sustainable Development*, *37*, 10-19. https://doi.org/10.1016/j.esd.2016.12.001.

Griskonis, M., Rodgers, M. (2021). “Financing US offshore wind.” *WhiteCase.com*. https://www.whitecase.com/publications/insight/fast-forward-us-offshore-wind/financing-us-offshore-wind

Feldman, D., et al. (2020). “Current and Future Costs of Renewable Energy Project Finance Across Technologies.” *National Renewable Energy Laboratory.* (Technical Report /TP-6A20-76881). https://www.nrel.gov/docs/fy20osti/76881.pdf

Fowler, A. M., Jørgensen, A. M., Svendsen, J. C., Macreadie, P. I., Jones, D. O., Boon, A. R., Booth, D. J., Brabant, R., Callahan, E., Claisse, J. T., Dahlgren, T. G., Degraer, S., Dokken, Q. R., Gill, A. B., Johns, D. G., Leewis, R. J., Lindeboom, H. J., Linden, O., May, R., . . . Coolen, J. W. (2018). Environmental benefits of leaving offshore infrastructure in the ocean. *Frontiers in Ecology and the Environment, 16*(10), 571–578. https://doi.org/10.1002/fee.1827

Furgo. (2008). (Report No. 0201-6501). https://txsed.glo.texas.gov/dsweb/Get/Version-7924/FMMG342Core3.pdf

Hartman, L. (2018). *Wind Turbines in Extreme Weather: Solutions for Hurricane Resiliency*. United States Office of Efficiency and Renewable Energy. https://www.energy.gov/eere/articles/wind-turbines-extreme-weather-solutions-hurricane-resiliency

International Electrotechnical Commision (2007). “Efficient Electrical Energy Transmission and Distribution.” https://demo.openeclass.org/modules/document/file.php/DEMO-A1153/%CE%A3%CE%B7%CE%BC%CE%B5%CE%B9%CF%8E%CF%83%CE%B5%CE%B9%CF%82%20%CF%80%CF%81%CE%BF%CF%82%20%CE%BC%CE%B5%CE%BB%CE%AD%CF%84%CE%B7/EFFICIENT%20ELECTRICAL%20ENERGY%20TRANSMISSION%20AND%20DISTRIBUTION%20.pdf

Masters, J. (2019). *Offshore Wind Farms: Allaying Concerns About Hurricanes and About Fishing*. Weather Underground. https://www.wunderground.com/cat6/Offshore-Wind-Farms-Allaying-Concerns-About-Hurricanes-and-About-Fishing

Mercure, M. (2021, June 4). *Charybdis Turbine Installation Vessel Setting Sail for East Coast*. North American Windpower. https://nawindpower.com/charybdis-turbine-installation-vessel-sets-course-for-the-east-coast

Musial W, Beiter P, Stefek J, Scott G, Heimiller D, Stehly T, Tegen S, Roberts O, Greco T, Keyser D (National Renewable Energy Laboratory and the Alliance for Sustainable Energy, LLC, Golden, CO). 2020. Offshore wind in the US Gulf of Mexico: regional economic modeling and site-specificanalyses. New Orleans (LA): Bureau of Ocean Energy Management. 94 p. Contract No.: M17PG00012. Report No.: OCS Study BOEM 2020-018.

NDBC - Station 42035 Historical Data. (2020). Www.Ndbc.Noaa.Gov. https://www.ndbc.noaa.gov/station_history.php?station=42035

New York State Energy Research and Development Authority. (n.d.). Permitting Requirements for Offshore Wind - NYSERDA. NYSERDA. Retrieved April 20, 2022, from https://www.nyserda.ny.gov/All-Programs/Offshore-Wind/Focus-Areas/Permitting

Levitt, A., et al. (2011). Pricing Offshore Wind Power. *Energy Policy*, *39* https://doi.org/10.1016/j.enpol.2011.07.044

Love, M., Baldera, A., Yeung, C., & Robbins, C. (2013). The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas. New Orleans, LA: Ocean Conservancy, Gulf Restoration Center. https://oceanconservancy.org/wp-content/uploads/2017/05/gulf-atlas.pdf

U.S. Department of Commerce. (2019, July 1). *U.S. Census Bureau quickfacts: Galveston City, Texas*. QuickFacts: Galveston City, Texas. Retrieved December 16, 2021, from https://www.census.gov/quickfacts/galvestoncitytexas

Stehly, T., et al. (2020). “2019 Cost of Wind Energy Review”. *National Renewable Energy Laboratory.* Technical Report (TP-5000-78471). https://www.nrel.gov/docs/fy21osti/78471.pdf

Soares-Ramos, P., et al (2020). Current status and future trends of offshore wind power in Europe. *Energy*, *202*(117787) https://doi.org/10.1016/j.energy.2020.117787