WASHINGTON STATE UNIVERSITY
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COMMUNITY COLLEGE

Project Development Report

Washington State University-Everett with Everett Community College

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Report Prepared By

Eric Martin
Everett

James Garfield
Everett

Quinn Yackulic
Everett

Team Members

Zach Epperson
Everett

Mariana Nicole Tejada
Everett

Yulia Fedorchenko
Everett

Kaitlin Jones
WSU

Garrett Bassen
Everett

Advisors

Dr. Gordon Taub
WSU-Everett
Principle Investigator

Joe Graber
Everett
Co-PI

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I. Introduction

Offshore wind might be necessary to meet the United States' decarbonization goals.[1] It may also improve Texas's resilience against winter storms.[2] When compared to other solutions, like reinforcing the grid with Bitcoin, wind power seems like a potential start.[3] The East Coast is where the majority of offshore wind development has occurred, with some exceptions to development along the West Coast.[4] Developing in the Gulf Coast has been mainly limited to offshore oil. This project aims to shed light on the feasibility of offshore wind in the Gulf Coast.

This report proposes a 375 MW wind farm. The farm will have 25 Vestas V236 15 MW wind turbines and will activate in 2025. It will provide electricity at LCOE of 10.29 cents per kwh. The proposed project is projected to provide an overall investor rate of return of $257 million over 25 years.

II. Site Description and Energy Estimation

Environmental Impacts

General Considerations

Within the site selected for the wind farm, there are no known shipwrecks or other sites of scientific interest. Additionally, no native populations or cultures use this area in any capacity. As such, this area is of no known cultural significance. As this is an offshore installation about 27 nautical miles from shore, there will be no additional noise impact or visual obstructions to residents onshore. However, during the construction phase, there will be additional ship traffic and noise around the port areas which may impact nearby residents.

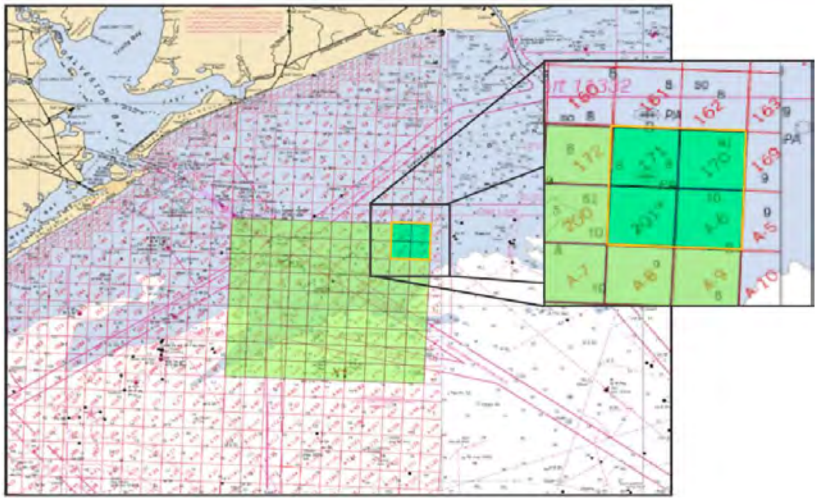


Figure 1: Location of Selected Lease Blocks, the numbering system is based on a NOAA map. The selected lease blocks consist of 170, 171, 201 and A-6.

Avian Species Impact and Considerations

Offshore wind development poses several risks to native and migratory species, including birds, bats, and ocean-dwelling species. For example, wind turbines pose specific risks to migratory birds which includes noise damage, physical harm due to moving turbines, and disrupted migration paths.[5]

During Spring migration, an estimated 2.1 billion birds travel through the Gulf of Mexico in route to Mexico, along the so-called Mississippi Flyway.[6]

Figure 2: Flight paths of migratory birds. The Galveston lease block area is in the path of the Mississippi Flyway.

Most notably, about half of these birds will fly over in about an 18-day period between April 19 and May 7.[7] While not all of these birds will fly over the lease block, it is reasonable to assume that a relatively large number will, via the Mississippi Flyway.

To reduce the accidental harm of the migratory birds, Ultrasonic Acoustic Deterrences will be installed to encourage birds to avoid the area. A study by Texas State University, NRG and Duke Energy estimated that these deterrences reduced bat fatalities by about 50%.[8] These results translate to reducing bird fatalities as well.[9] The noise produced by the Acoustic Deterrence Systems will be of no contribution to the underwater or onshore noise pollution. This is because the primary cause of underwater noise in wind turbines is from the components inside the nacelle and the distance from shore is too far for any significant sound to reach.[10]

Based on the recommendations from mentors from ENEL, research was conducted into the benefit of increasing cut-in speed for migratory bird populations. Researchers from three separate universities have found that bats are most active during low wind speeds. As such, by increasing the cut-in speed of the turbine, they have observed that, “bat fatalities were reduced by 50 to 87%”.[11] Arnett et al. noted in a 2009 report that “there was no difference between the number of fatalities for C5 [5 m/s curtailment] and C6 [6.5 m/s curtailment] turbines Total fatalities at fully operational turbines were estimated to be 5.4 times greater on average than at curtailed turbines (C5 and C6 combined).”[12] As such, the cut-in speed will be increased from 3 m/s to 5 m/s. This results in minimal impacts to energy production while still helping to reduce bird fatalities. Although both studies referenced bats, lessons learned from the results may likely be applied to bird populations as well.

Aquatic Species Considerations and Impacts

Wind turbines also pose challenges to aquatic species, not just to migratory birds and bats. One of the primary concerns with offshore wind farms, aside from potential habitat loss, is the potential impact of noise on marine life. While these impacts are relatively small compared to those from offshore oil facilities or sonar from military operations, any impact from wind turbines should be considered permanent. One study that examined the impact of underwater noise from wind farms on harbor seals and porpoises in the area concluded that, “Behavioral reactions to noise from the three turbines are not expected for porpoises and seals unless the animals are in the immediate vicinity of the foundation.” In addition, these frequencies had very limited capability to injure or mask important signals for seals or porpoises.[13] A meta-analysis by Tougaard, Hermannsen and Madsen confirms this, “The noise levels from the individual offshore wind turbines reported in the literature were low …and comparable to or lower than noise levels measured within 1 km from commercial ships. The highest level reported was 137 dB re 1 μPa at a distance of 40 m. The noise level appears to decrease rapidly with distance."[14] Whales and porpoises and in particular species like the Bryde's whale, which is endangered and endemic to the Gulf region, should be carefully monitored and protected.[15]

There will be an additional impact on aquatic species due to the jacket foundation used for this wind farm. Due to the soil conditions within the lease block, a jacket type foundation is required. Unfortunately, this means there may be more noise produced during the construction phase when compared to a steel monopile foundation. One study found that, "the overall energy needed for the complete piling [for jacket foundations] was 58% higher for the 49 jackets than for the 56 monopiles. The normalized at 750 SEL was also higher for jacket than for monopile foundation piling."[16]

To reduce habitat loss and hearing damage to aquatic organisms in the area, two systems will be implemented as mentioned in the following study. First, a bubble curtain will be installed around the construction site, to reduce some of the noise due to construction. One study found that, "The bubble curtains thus effectively reduced the temporary habitat loss and risk of hearing loss. The 2 bubble curtains each attenuated the noise by between 7 and 10 dB, when used separately, and 12 dB when used together." This study used an "acoustic deterrence device" to keep seals away from the construction site. It is reasonable to assume then that this device will also work for other aquatic organisms like whales and dolphins.[17]

To reduce the negative impact of construction on benthic populations, several strategies will be implemented. First, to dig the trenches required for cabling, a jet plowing method will be used instead of mechanically digging the trenches. This will ensure that less sediment is disturbed. Additionally, all cabling will be shielded to reduce impact of heat and electromagnetic radiation on organisms on the ocean floor. After the cables have been laid and construction has completed, the beds of the ocean floor will be reseeded with native plant life, to encourage species to return to the area.[18]

Decommissioning

After the 25-year lifespan of the wind farm, the turbines within the farm will be decommissioned. At this time, a study will be conducted to evaluate how marine life has adapted to the wind turbine, and will influence the method of removal of the various components. Each of the main components of the turbine will be removed and transported to land, where they will be sorted and recycled. Any remaining parts that are unable to be repurposed or recycled will be placed in a landfill. The components above sea level will be removed offshore in pieces and disassembled onshore. A study will be conducted to evaluate the health of the ecosystem surrounding the foundation and further action will be taken based on the results of the study. All efforts will be made to reduce negative impacts on the ecosystem surrounding the foundation. If minimal coral has developed on the foundation, then to reduce costs and unnecessary disturbances to benthic populations, the foundation will be cut below the mudline, removed and the remaining portion below the cut will be left in place. The authors of the following study note that, "Cutting and leaving in situ the rest is usually the preferred option as it reduces the risks, it is more economical to perform, and the site is disturbed less."[19] Additionally, any buried cables that do not pose a risk to the marine environment will remain in place.

Bathymetry and Soil Composition

Bathymetry – the measurement of depth of the ocean – is a crucial element to siting an offshore wind farm. It determines the foundation type, variety of turbine, and other environmental questions. The approximate depth of the lease block area is between 70 to 120 feet.[20] According to John B. Anderson, Former Maurice Ewing Professor of Oceanography at Rice University, the area under consideration is located in the “Trinity/ Sabine incised river valley and Heald Bank.”[21] The sediments within “10 meters of the sea floor are marine mud which is fairly unconsolidated as it is Holocene in age.”[22] Figure 3 is a map of this area.[23] These factors informed the decision to choose a V236 turbine and jacket-type foundation.

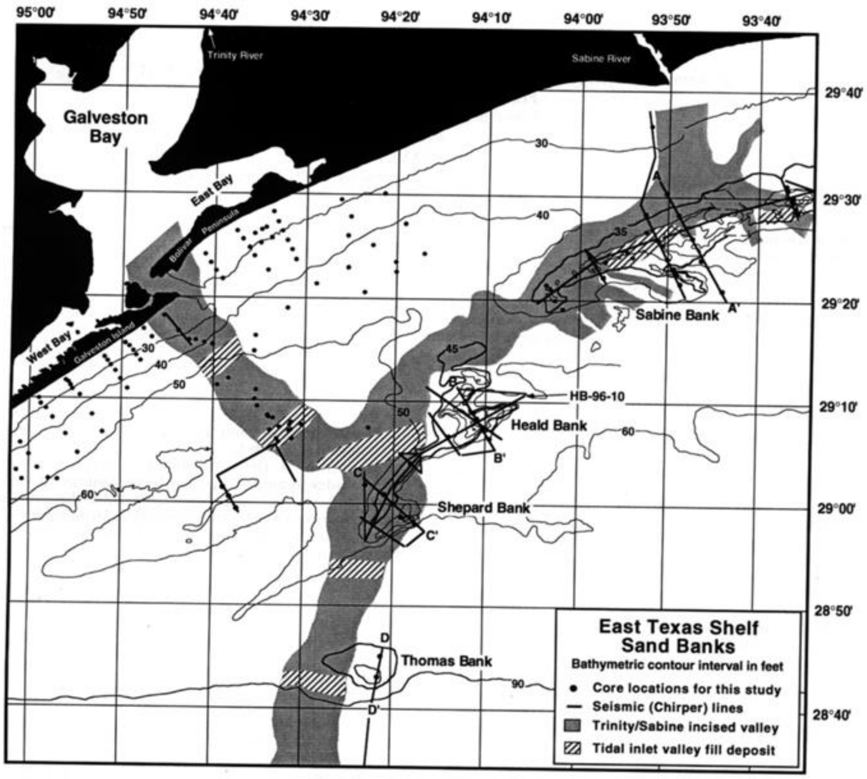


Figure 3: Bathymetric map of East Texas shelf.

Permitting

Following the permitting guidelines is important in order to ensure that the wind farm is compliant with all of the legal and regulatory structures, including federal, state, and local laws. One important factor is whether the project is in State or Federal waters. This affects the permitting guidelines for this project. Under Section 388 of the Energy Policy Act of 2005, the Secretary of the Interior has the final authority over offshore development.[24] The proposed wind farm site is more than 30 miles offshore, so the project is within Federal jurisdiction. The Texas General Land Office might be responsible for some of the permitting. However, it might be outside of their purview. According to Alan L McWilliams, Deputy Director of Leasing Operations at the Texas General Land Office, there is no standard approach to permitting yet because offshore permitting is a nascent procedure.[25] Given that permitting for offshore wind is a new procedure, and considering offshore wind development in other states and offshore oil development in the Gulf, several permitting guidelines were inferred. For instance, Considering the Coastal Zone Management Act (CZMA) makes sense; it is something oil developers have to consider. The CZMA “focuses on the states’ coastal natural resource areas.”[26] To conform to CZMA standards, it will highlighted how wind farms pose fewer environmental hazards than oil rigs, which have approval for development in the Gulf. Additionally, this project would have to meet National Environmental Policy Act (NEPA) standards.[27] Current offshore wind development standards are unclear, because there is little regulatory framework to reference. However, according to the congressional research service,

> Potential environmental impacts of offshore wind energy projects include, but are not limited to, impacts on existing resources of alternative sites in terms of physical oceanography and geology; impacts on wildlife, avian, shellfish, finfish and benthic habitat; impacts on aesthetics, cultural resources, socioeconomic conditions; and impacts on and air and water quality. Human uses such as boating and fishing may also be affected and must be considered in a NEPA analysis.[28]

Additionally, the Bureau of Ocean Energy Management (BOEM) guidelines were considered, because BOEM is responsible for “managing energy and mineral resources on the Outer Continental Shelf (OCS).”[29] The Bureau of Ocean Energy Management recommends consulting the following, other permits: National Historic Preservation Act, Endangered Species Act, Marine Mammal Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act.[30] Another useful mechanism, though not quite a permit, is to apply to Title 41 of the Fixing America's Surface Transportation Act (FAST-41).[31] This will expedite the permitting process. These permitting guidelines are not exhaustive, but offer a start towards approaching the permitting process.

In addition to BOEM and related permitting, the Federal Aviation Administration was consulted. The FAA requires notification for structures 200 feet above ground level or greater, but lighting/marking requirements are governed by BOEM beyond 12 nautical miles from the shore.[32] Notification to the FAA for new constructions 200 feet above ground level is governed by 14 § 77.9.[33] Essentially, notice must be filed with the FAA for proposed construction that exceeds this limit within the U.S. National Airspace System. An FAA publication indicates that U.S. airspace extends beyond 12 miles from the coast "in those areas where there is a requirement to provide IFR en-route ATC services and within which the U.S. is applying domestic procedures.”[34] It is assumed the Gulf of Mexico is one such area, since a flight from Florida to Texas would use domestic procedures. Additionally, lighting requirements for structures exceeding 200 feet above ground level are laid out in FAA Advisory Circular 70/7460 (note that advisory circulars are not mandatory compliance publications, but rather a 'best practice’).[35] It is worth noting that there is a section in this advisory circular specifically dedicated to wind turbines and turbine farms. That section mentions that the Bureau of Ocean Energy Management (BOEM) maintains jurisdiction beyond 12 nautical miles from shore, and recommends the same lighting requirements as the FAA. It is worth noting that the proposed lease block is outside of this range. It is prudent to follow these guidelines for safety reasons and to be in accordance with federal regulations.

Energy Markets

Energy Markets in Texas are deregulated, which means “that power generation companies sell their production in a competitive market.”[36] The Texas market was deregulated in 2002.e[37] Consumers choose their electricity provider and plan. Understanding these markets is necessary when developing an offshore wind farm in Texas.

The Electric Reliability Council of Texas (ERCOT) operates the grid and ensures transmission of electricity from generation to use by consumers. Different portions of the grid are operated by distinct utilities, which are coordinated by ERCOT. The electricity generated from energy projects, like the proposed offshore wind project, is sold to Retail Electricity Provider who sell it to customers. Transmission and Distribution Utilities, like Texas New

Mexico Power (TNMP), deliver electricity to consumers, by maintaining the poles and wires, handling service outages, and reading customers' meters, and TNMP is the utility to initially manage the electrons developed by the Galveston wind project.

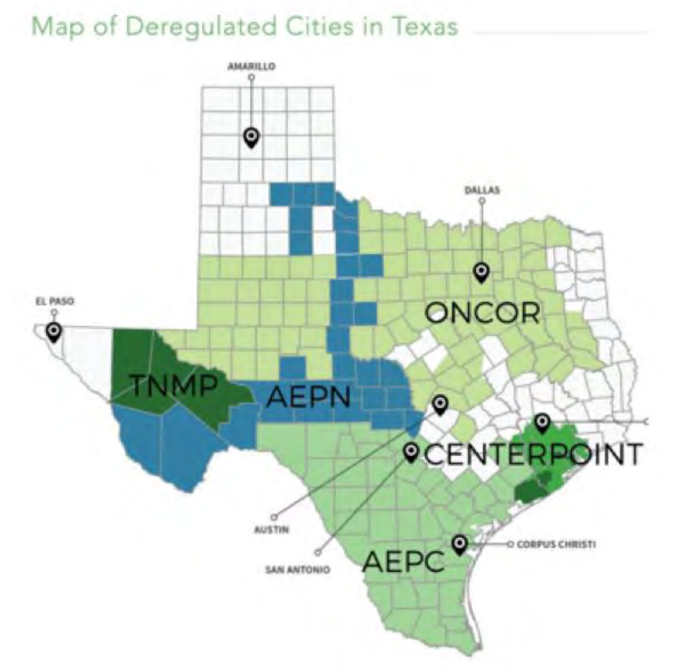


Figure 4: Map of Texas Electrical Grid.

The company will then likely offer a "wind power option to its customer pending rate approval from the Texas Public Utility Commission (PUC)."[38] This would be similar to TNMP's purchase of 2 MW of wind power from a development near Fort Stockton, Texas. The developers of the Galveston wind project will need to coordinate with TNMP. This effort is important to ensure transmission, distribution and maintenance are all handled appropriately, something discussed in the *Transmission* section. Another relevant consideration is whether to include Power Purchase Agreements along with the development. A power purchase agreement is "an arrangement in which a third-party developer installs, owns, and operates an energy system on a customer's property. The customer then purchases the system's electric output for a predetermined period."[39] PPAs are legal in Texas. This kind of arrangement may benefit businesses in Galveston county or the Houston area who want a clean source of electricity. Although a PPA is appealing, its feasibility may be of concern because the wind farm will be offshore. That is a long way for electricity to travel. While there is a lack of technical understanding to assess whether such a PPA is realistic, it is recommended that it be considered.

Site Layout

Site layout is an essential part of designing an offshore wind farm. How the turbines will be oriented and positioned in the lease-block area can contribute to the efficiency and profitability of the wind farm. Several software models exist for modeling offshore wind farms. The team initially started modeling the site with Furow however, numerous technical roadblocks while trying to learn the software were encountered. Industry mentors suggested that Furow seems to work at a "high level" because it linearly distributed wind data. It is understood that this type of modeling is too simplistic for industry use. This then prompted a switch to OpenWind. While OpenWind was easier to use and operate, there were still problems encountered. The main problem was that the selected turbine could not

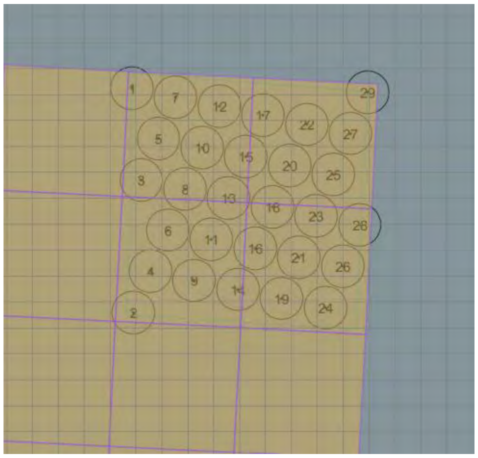


Figure 5: Graphic of possible turbine placement from OpenWind.

be loaded into OpenWind. Underwriters' Laboratories, who makes OpenWind, was very responsive to requests for help. In particular, UL said they could load the desired turbine into the program. Unfortunately, they were not contacted with enough time to complete this request, to include it in the modeling of the site layout. Instead, a 10MW NREL reference turbine in OpenWind was used for modeling. While this could not be used for energy capture data, it gave a rough estimate of the general site layout. Energy capture estimates were calculated using SAM, as discussed below. Additionally, the Project Development team used the offshore wind speed map in conjunction with private met mast data, as shown in Figure 7, while designing the wind farm, to gain an understanding of the wind speeds in the Galveston area.[40]

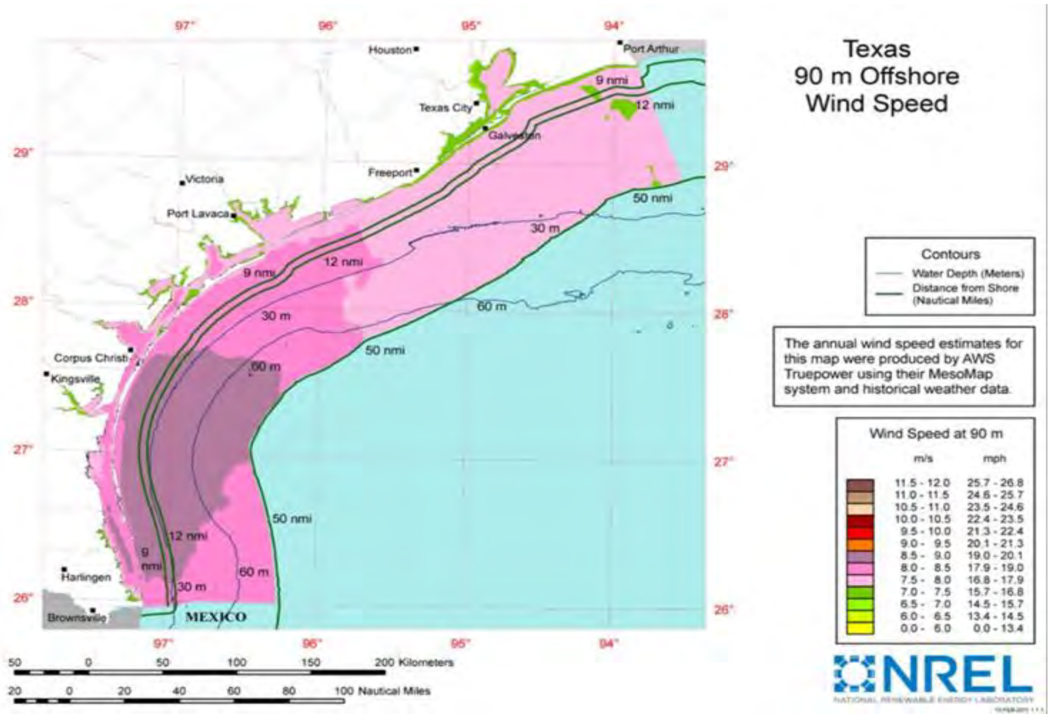


Figure 6: Graphic with offshore wind speeds at 90m hub heights, along the Texas coast.

Transmission

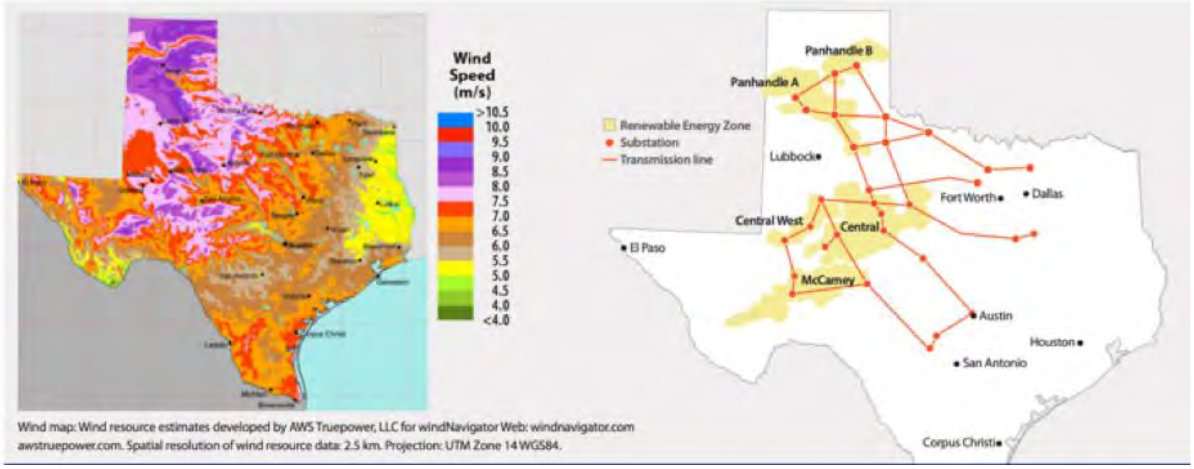
The proposed offshore wind farm near Galveston needs transmission cables to integrate to the Texas grid. While the Texas grid is complicated, several insights have been found for connecting to it. Texas' grid is unique for several reasons, including its use of Competitive Renewable Energy Zones (CREZs) and its general structure under the Electric Reliability Council of Texas (ERCOT), which will be discussed in greater detail in the Energy Markets section. These unique features, though different from other coastal regions, like the Eastern seaboard, do not preclude Texas from being a viable offshore wind site.

The first CREZ was in Texas, according to a NREL study.[41] This is significant because it designated five Renewable Energy Zones (REZs) in Texas and built transmission before projects were developed, unlike how in other areas developers did not always have access to transmission. Unfortunately, as Figure 8 demonstrates, Galveston is not in a CREZ.[42] This poses a challenge for offshore development in that region, because access to transmission is complicated by a dearth of access to suitable lines. This can be mitigated by relying – and updating – existing substation and transmission infrastructure in the Galveston area.

Figure 7: Galveston substation on the middle RHS of the image. AC transmission lines are blue.

In order to access the grid, this project will rely on existing on-shore infrastructure as well as create new offshore transmission capabilities. The lease block area does not have access to a CREZ, so new lines are necessary. Fortunately, existing Alternating Current (AC) transmission lines can be used once the cables reach the nearest onshore substation, which is in Galveston. All of the onshore lines are AC.[43] This poses another challenge because offshore transmission lines are recommended to be High Voltage Direct Current (HVDC) so that they can travel longer distances.[44] Also, HVDC is preferable if the wind farm is organized as a planned mesh network, according to Jon Wellinghof, former FERC Chairman. Once the offshore HVDC transmission reaches the Galveston substation, it will need to be converted to AC at the Galveston substation.

It is uncertain if the Galveston substation has the ability to convert from HVDC to AC, so it may need to be retrofitted. The substation could be converted using a HVDC converter transformer, which is designed by Siemens.[45] Despite not having access to the onshore CREZs, the offshore wind farm has viable options, by utilizing HVDC transmission lines, to integrate into ERCOT.



Wind map: Wind resource estimates developed by AWS Truepower, LLC for windNavigator Web: windnavigator.com awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: UTM Zone 14 WGS84.

Figure 8: Map of competitive renewable energy zones.

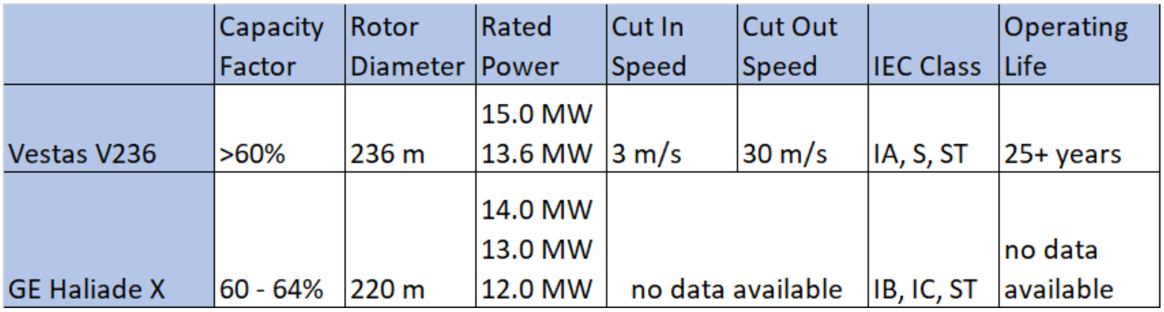
One final transmission-related consideration is whether to build interconnection between neighboring states. Pursuant to FERC Order 1000, “each public utility transmission provider must participate in a regional transmission planning process that has a regional costs allocation method for new transmission facilities selected in the regional transmission plan for purposes of cost allocation.”[46] ERCOT is working with Southeastern Electric Reliability Council (SERC) to build a HVDC bi-directional transmission line “that will connect ERCOT to SERC.”[47] This will benefit Texans because of enhanced grid reliability because more power will go to homes during peak times; and additional revenues will benefit ERCOT ratepayers. If more transmission and interconnection is built for the Galveston wind, there may be a larger benefit to the region.

Turbine Selection

Due to the specialization and scarcity of offshore wind turbines, the options for suppliers were rather limited. For companies that have US based manufacturing facilities, GE Wind, Siemens Gamesa, and Vestas were the companies that showed the most promise. Looking through options for turbines narrowed the list further, showing that GE and Vestas had the most applicable turbines for the project’s needs. Needing a turbine with a large diameter to maintain power generation during low wind speed conditions, that could also withstand an extreme weather event such as a hurricane, the Vestas V236-15.0MW was chosen.

The decision was made after comparing many factors between GE and Vestas including turbine specifications, manufacturing locations, turbine availability, cost and customer service. Between the GE Haliade-X and The Vestas V236-15.0MW the turbine specifications are very similar, both have a capacity factor of 60% or greater and the Vestas V236 has a slightly larger rotor diameter (a difference of 16m).[48] The Haliade-X has 12, 13, and 14MW options, whereas the V236 is a 15MW turbine with a 13.6MW option if needed. While the Haliade-X is designed for medium to higher wind environments, the V236 can operate at a larger variety of wind speeds, with a cut in speed as low as 3m/s.[49] [50] Comparing the Haliade-X to the V236 in terms of manufacturing and transportation also showed similarities with slight differences. It is worth noting that the production facilities for both turbines is overseas, with GE using a facility in France and Vestas producing their turbine in Denmark. Vestas also has a production facility in nearby Colorado where some of the components could be made and transported by rail.[51] Additionally the modular nacelle design that is used on the V236 would reduce shipping constraints thereby reducing the cost of delivery to the port before being installed on site.[52] This consideration was substantial as portions of the turbine could be manufactured closer to the site and help stimulate the economy within the United States as well.

Table 1: Table of technical data used for turbine selection.



	Capacity Factor	Rotor Diameter	Rated Power	Cut In Speed	Cut Out Speed	IEC Class	Operating Life
Vestas V236	>60%	236 m	15.0 MW 13.6 MW	3 m/s	30 m/s	IA, S, ST	25+ years
GE Haliade X	60 - 64%	220 m	14.0 MW 13.0 MW 12.0 MW	no data available		IB, IC, ST	no data available

Most importantly with the average annual wind speed in the area being just under 7.5 m/s, and normal wind speeds ranging from 0.17 m/s to 22.96 m/s the turbine needed to work well in lower wind speed conditions as well as continue producing power above the peak wind speed. With the Haliade-X lacking a vast amount of technical data available, the V236's specifications fit the necessary range precisely; cutting in at 3 m/s and out at 25 m/s. Considering adverse weather events, these two turbines were selected from other options specifically because they either had or were expected to have their class T certification, giving peace of mind that they could withstand wind speeds up to 57 m/s which is on the higher end of a class 3 hurricane, noting that the area has experienced such storms multiple times within the last 50 years.[53]

While the Haliade-X is already in production, it should be noted that the V236 is not scheduled for serial production until 2024.[54] The team decided that this factor was less of an issue as it provided the opportunity to place an advance order, while also permitting time for site preparation, foundation installation, and any additional surveying and/or permitting of the proposed wind-farm location should problems or delays arise. Cost and customer service were considered together, as cost is a very important factor but working relationships are also essential for the life of any large-scale project; if there is maintenance or replacement parts that are needed, it is always better to have a supplier that is attentive and available. Vestas' customer service was easier to communicate with and responded quickly to requests. These interactions implied that Vestas would be easier to work with long term, and were ultimately more transparent about their products and services.[55] Additionally, the decision to use the Vestas Turbine is supported by the fact that Empire Wind, the joint venture between BP and Equinor, chose the Vestas-236 turbine in the new offshore development on the East Coast.[56]

Transportation Constraints

Working out a contract with Vestas would determine the final transportation constraints, however making full use of their Brighton, CO facility to manufacture the nacelles for this project would mean that these components could easily be transported by rail to the port in Galveston. With the rail line running directly through the nacelle factory in Brighton, CO, and Union Pacific either owning rail or having trackage rights on a route from the factories in Colorado to the port in Galveston, this made transporting the components through Union Pacific the most viable option. Additionally, the V236 uses a modular nacelle design which is engineered to conform to standard shipping weights and dimensions, helping to reduce the cost of shipping.[57] Vestas also has a contract with a third party to manufacture their towers in Pueblo, CO which would likely either need to be transported by truck or via a second deal with Burlington Northern Santa Fe, as there is a lack of trackage rights information for that portion of track.[58] This is the most viable option as other farms in Texas have been built using the components manufactured in Colorado, indicating that the necessary infrastructure to support this delivery is present.[59]

It is certain that the blades for these turbines would need to be manufactured overseas at Vestas' offshore production facilities in Denmark and shipped by boat directly to the port in Galveston, TX.[60] Delivery by ship would allow for the blades to be shipped as single units rather than segmented, giving the benefit of structural integrity and less build time on site. While the transport of the blades would require specialized shipping vessels.[61]

Upon reaching the port in Galveston, due to Jones Act restrictions and a lack of Jones Act compliant Wind Turbine Installation Vessel in the US, foreign flagged WITV's will have to be parked on site and supplied with components from US based feeder vessels. Based on the proposed timing of the project, it may be possible to utilize one of the first Jones Act compliant vessels which is scheduled to be finished in 2023, however there will also likely be a large demand in addition to the vessel intended to be used primarily for East Coast operations.[62] It will therefore be more prudent to employ the feeder vessel strategy for the sake of project completion in a timely manner.

III. Financial Analysis

Initial Capital Costs

To estimate the cost of the Vestas V236-15 MW turbine, the cost of the Vestas V136 4.2MW turbine was used and found to be about $3.57 million.[63] From this, the cost per kW of the turbine was calculated and applied to the Vestas V236-15MW. Based on the fact that the Vestas V236-15 MW is a larger and newer turbine, a 10% additional cost was applied. As such, the cost of the turbines will be about $935/kW (see cashflow analysis in Appendix), or $350 million for the 375 MW farm. The balance-of-station costs were estimated to be about $1,782/kW.[64] As such, the total installation cost is about $1.018 billion. Factoring in the distribution of development costs of $30.56 million, the equity closing costs of $300,000, and total construction financing cost of $19.1 million, the total sale of property cost is $1.068 billion.

Annual Operating Expenses

The standard annual operating and maintenance costs for US offshore wind farms was determined to be about $66/kW.[65] Based on the hurricanes and inclement weather in the Texas Gulf area, this was rounded up to $70/kW. Factoring in the cost of electricity and developer operating margin, the operating costs in year 1 are $83.4 million. This value increases by about 2.5%/year to a maximum value of $157.6 in year-25.

Market Conditions

Based on the financial analysis conducted using the System Advisor Model, the real LCOE for this project is about 10.52 cents/kWh. This is outside the global average LCOE of $95/MWh for fixed-bottom offshore wind farms.[66] Furthermore, LCOE trends are expected to only decrease and are predicted to be about $56/MWh in 2030.[67] As the project is expected to be operational by 2025 and average LCOE for offshore wind farms are expected to decrease further by this point, the financial model is not competitive with current market trends.

Financing Plan

A single loan will be taken out, which will cover 100% of the installed costs with an up-front fee of 1% of the principal and annual interest rate of 3.5%. An equity closing cost of $300,000.00 was applied with a development fee of 3%. Using parametric analysis, the developer operating margin was set to $18/kW with a margin escalation of 1.5%/year. This reduced the LCOE and year-1 PPA price, while not significantly impacting the developer's Net Present Value (NPV) over the project's life.

Incentives

Since construction is expected to begin before 2025, an Investment Tax Credit of 30% was applied.[68] Based on the American Recovery and Reinvestment Act of 2009 (ARRA), this project is eligible to apply an Investment Tax Credit in-lieu of a Production Tax Credit. This would allow the project to deduct 30% from eligible costs and results in a larger contribution than the 1.5 cent/kWh from a PTC.[69]

IV. Discussion of Optimization Process

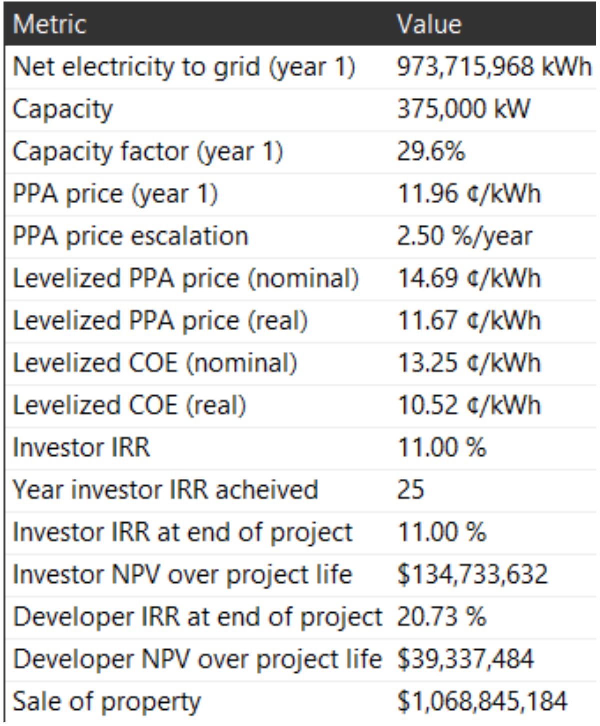
Parametric analysis was conducted for the developer operating margin and margin escalation rate and was set to $18/kW and 1.5%/year, respectively. This was done to determine the lowest Levelized Cost of Energy (LCOE) and PPA price and had a minimal impact on the developer's NPV after the project's lifetime. Additionally, parametric analysis was conducted for the number of turbines per row, number of rows, turbine spacing, row spacing, offset and orientation and no significant impact on the project's real LCOE or PPA price was found.

Research was conducted to determine the investment tax credit rate, estimate the cost per turbine, total estimation costs and fixed annual operating costs. As no information was published for the maximum coefficient of power, maximum tip-speed and maximum tip-speed ratio for the Vestas V236-15MW, the values for the IEA Wind 15 MW reference turbine were used instead.[70]

V. Auction Bid

A summary of the SAM PPA analysis is presented as follows:

Table 2: Summary of metrics calculated using a Sale Leaseback PPA.



Metric	Value
Net electricity to grid (year 1)	973,715,968 kWh
Capacity	375,000 kW
Capacity factor (year 1)	29.6%
PPA price (year 1)	11.96 ¢/kWh
PPA price escalation	2.50 %/year
Levelized PPA price (nominal)	14.69 ¢/kWh
Levelized PPA price (real)	11.67 ¢/kWh
Levelized COE (nominal)	13.25 ¢/kWh
Levelized COE (real)	10.52 ¢/kWh
Investor IRR	11.00 %
Year investor IRR acheived	25
Investor IRR at end of project	11.00 %
Investor NPV over project life	$134,733,632
Developer IRR at end of project	20.73 %
Developer NPV over project life	$39,337,484
Sale of property	$1,068,845,184

Accounting for the sum of the operating margins (which don't include the lease payment) for each of the 25 years, the total operating margin is $2.88 billion. Subtracting the total sale of property cost of $1.07 billion results in a net gain of $1.81 billion. While the project will be profitable and after the first year of operating the investor will have a pre-tax return rate of $7.3 million, which increases by 1.3%/year, the real LCOE rate is unrealistic given current market trends.

Based on the sale of six lease blocks in the Eastern Seaboard area, which totaled 4.37 Billion dollars for 488,000 acres.[71] This is a rate of $8955/acre. The wind farm mentioned in the report has a calculated energy production density of 14.3 kW/acre, which is similar to the 16.3 kW/acre energy production density for the Galveston Lease Block project. As such, it is reasonable to estimate a similar rate for the Galveston Lease Block project. Based on this rate, the maximum bid price for this project is $206.32 million for the 4 lease blocks. Factoring this amount in, and the total investor return of $257.13 million, the project should remain profitable with this bid price.

VI. Conclusion

To meet decarbonization goals, the Gulf Coast is technically feasible for offshore wind development. We concluded this by doing an in-depth analysis of a lease-block area outside of Galveston, Texas. We analyzed the environmental impacts, bathymetry, permitting, the Texas energy market, transmission issues, the appropriate turbine for the site, and transportation constraints. These factors indicated that a project would be technically feasible. However, the financial analysis indicated that the project would not be profitable. The real LCOE we estimated is above the highest competitive rate that we could find. The project would technically be profitable, but we think that we would not be able to offer a competitive rate for electricity. Although this is unfortunate, we recommend further study of the Gulf Coast, because the region shows potential for offshore wind development.

Appendix

See sections III, IV and V:

Year	**0**	**1**	**2**	. . .	**25**
ENERGY					
Electricity to grid (kWh)	0	973715968	973715968	. . .	973715968
Electricity from grid (kWh)	0	0	0	. . .	0
Electricity to grid net (kWh)	0	973715968	973715968	. .	973715968
REVENUE					
PPA price (cents/kWh)	0	11.9586	12.2575	. . .	21.6298
PPA revenue ($)	0	116442536	119353600	. . .	210612624
Federal PBI income ($)	0	0	0	. . .	0
State PBI income ($)	0	0	0	. . .	0
Utility PBI income ($)	0	0	0	. . .	0
Other PBI income ($)	0	0	0	. . .	0
Salvage value ($)	0	0	0	. . .	4238520
Total revenue ($)	0	116442536	119353600	. . .	214851152
Property tax net assessed value ($)	0	1018875008	1018875008	. . .	1018875008
OPERATING EXPENSES					
O&M fixed expense ($)	0	0	0	. . .	0
O&M production-based expense ($)	0	0	0	. . .	0
O&M capacity-based expense ($)	0	26250000	26906250	. . .	47479056
Electricity purchase ($)	0	35055	36068	. . .	69455
Property tax expense ($)	0	0	0	. . .	0
Insurance expense ($)	0	0	0	. . .	0

Developer (lessee) operating margin ($)	0	6750000	6851250	...	9649144
Total operating expense ($)	0	33035054	33793568	...	57197656
OPERATING MARGIN				...	
Total revenue ($)	0	116442536	119353600	...	214851152
Total operating expense ($)	0	-33035054	-33793568	...	-57197656
Operating margin not including lease payment ($)	0	83407480	85560032	...	157653488
PURCHASE OF PLANT AND SALE OF PROPERTY CALCULATIONS				...	
Purchase of Plant Calculation:				...	
Total installed cost ($)	-1018875008			...	
Equity closing cost ($)	-300000			...	
Total construction financing cost ($)	-19103906			...	
Purchase of plant ($)	-1038278912			...	
Sale of Property Calculation:				...	
Total installed cost ($)	1018875008			...	
Distribution of development fee ($)	30566250			...	
Equity closing cost ($)	300000			...	
Total construction financing cost ($)	19103906			...	
Other financing cost ($)	0			...	
Sale of property ($)	1068845184			...	
OPERATING MARGIN					
Total revenue ($)	0	116442536	119353600	...	214851152
Total operating expense ($)	0	-33035054	-33793568	...	-57197656
Operating margin not including lease payment ($)	0	83407480	85560032	...	157653488

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