Project Development Report

Wildcat Wind Power
Kansas State University

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Introduction

This paper details Wildcat Wind Power's iterative site development process. Our analysis model incorporates site characteristics to minimize costs and prioritize local and environmental interests. With this model, we created a site design, identified mitigation techniques, and projected long-term solvency.

Site Characteristics

Wind Resource and Bathymetry

The Bureau of Ocean Energy Management's (BOEM) ArcGIS [1] wind resource tool indicates an average wind speed of 6.90m/s in the provided lease plots, with minimal variation over the lease area.

A key parameter in our model was depth, which can significantly influence foundation type and construction cost. The average plot depth was 37m, with the deepest plots (to the south and east) near a depth of 105m.

Land Use

The Gulf of Mexico (GOM) is heavily occupied with oil and gas infrastructure, including drilling, support, and maintenance platforms. There are approximately 6,000 structures as of 2020, the majority of which include nearby pipeline networks [2].

A farm may be developed on existing oil and gas leases, but this requires a utility easement secured through government action or private agreement, which is not desirable. In general, the farm's array cables should cross as few pipelines as possible.

Transport Considerations

Due to their weight, turbine components should travel by rail when possible. However, railroad infrastructure in Louisiana is limited, and there are limited lines that reach all the way into ports. This means that oversized load trucks will be required to transport the tower and blades to the port staging area. [3]

Data Summary

Much of the presented information has been compiled from online ArcGIS maps overlaid on the provided leasing area. This data was combined with onshore considerations in a spreadsheet to produce a graphic decision matrix of possible farm locations. The matrix can be seen in Figure [1] below, and full list of online GIS sources used can be found in the bibliography.

Research was conducted to identify specific criteria within our plots such as depth, existing oil and gas infrastructure, etc., which were placed in a table modeled after our lease plots, each plot was divided into quadrants to have a higher fidelity of data. From there a weight was decided for every research component. Finally, a set of calculations was used to give each plot a score, where a high score (red) was viewed as negative while a low score (green) was viewed as a desirable plot to buy. The highest weighted parameters were active leases and migratory patterns, which would likely prevent a project from occurring.

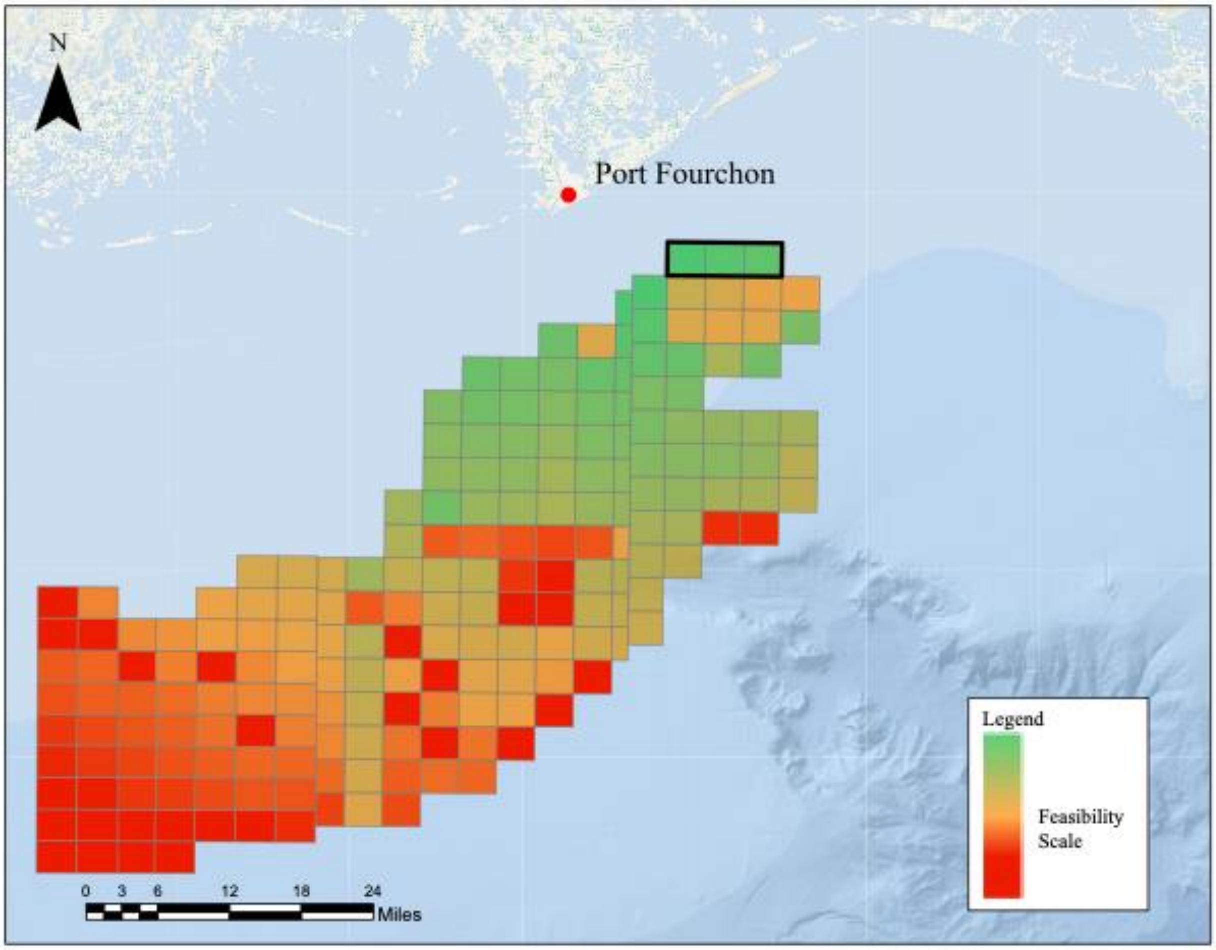

Figure 1: Feasibility scale based on weighted decision matrix analysis model.

Chosen Lease Area

The matrix identified Plots 34, 35, and 36 in the north-east corner of the lease area as the optimal location. The wind resource is above average in this area, and the only obstacles are pipeline interference in Plots 35 and 36 and a decommissioned oil platform in Plot 34 on its Western edge. The benefit of choosing emptier plots is that each piece of land can be used to its full energy capture potential, maximizing return on investment for the price of the lease. The average depth of the selected plots is 21 meters, which is shallower than the overall average depth of the lease plots.

The team believes that undersea transmission costs will be significant and wants to reduce the distance to shore as much as possible. These lease plots are the closest feasible build area to shoreline. The proximity of interconnection points proved negligible due to the nearly uniform presence of 115kV points.

Project Design

Turbine Selection

The entirety of the available lease plots have relatively modest wind speeds, mostly class 2. Lower wind speeds require larger turbine rotors with lower specific power ratings. Research indicates that turbines designed for the conditions near the Port Fourchon site would have a specific power of ~280W/m^2 [4]. These reference designs have a hub height of 130m and a rotor diameter of 213m. However, these are only reference models, and many large offshore turbines have been developed already for European

North Sea markets. Some available data about these turbines is shown in comparison in Figure [2] below. All turbines considered are pitch-regulated variable speed models designed for class 1 winds. As can be seen from the comparison, the only turbine that has a specific power rating close to the necessary value is the 12MW GE Haliade-X model with a blade length of 222m. This is within the reasonable specific power range for the GOM, and is the turbine that will be chosen for the rest of the site. Other factors beyond the specific power play into the choice of the GE model, including the significant blade length and the fact that GE already has experience building offshore turbines in the North American Block Island farm [5]. A potential issue, litigation between GE and Siemens Gamesa regarding alleged patent infringement, has been resolved, and is no longer a concern for the project [6]. None of the turbines considered are designed specifically for the lower wind speeds seen in the site region, and it is possible more varied turbines would be available in the future.

Turbine	Rated Power (MW)	Swept Area (m^2)	Specific Power (W/m^2)
Vestas V236-15MW [18]	15	43742	342.9
Vestas V164-10MW [18]	10	21124	473.4
Vestas V174-9.5MW [18]	9.5	23779	399.5
SG-14-222 DD [19]	14	39000	358.9
SG-8.0-167 DD [20]	8.0	21900	365.3
GE Haliade-X 12MW [21]	12	38000	315.8

Figure 2: Turbine Model Comparison

Design Characteristics

We believe a 130m hub height would present the best balance between stronger wind resource and increased construction costs, while clearing potential storm surge. Since our lease plots are relatively shallow, we determined that most foundations other than semisubmersible platforms would work well. Sea floor sediment affects the type of foundation that can be used. Our lease plots have mostly “muddy” sediment types which allows for a wide variety of foundations to be used [7].

Foundation

Another crucial factor in determining the foundation type was the size of our turbine, the GE Haliade-X 12MW model. Research indicates that monopiles are not cost-effective for turbines larger than 5MW [8]. After further research we identified two foundations commonly used in the GOM in oil and gas operations; Gravity Based Foundations (GBFs), or Jackets (traditional or twisted). GBFs use a heavy ballast to counteract the forces that the turbine will experience. However, GBFs require increased seabed preparation to allow for the GBFs to lay on grade, this can necessitate dredging which is incredibly disruptive. Some estimates indicate that up to 7% of the wind farms’ total seabed footprint can be disturbed [9]. The final option is a jacket foundation, either traditional or twisted. Traditional jackets have been proven in multiple projects ranging from oil and gas use to other wind farms. Twisted Jackets are a relatively new foundation type with the aim of reducing the overall amount of steel used, thus reducing the cost; however their long-term efficacy is unproven. Even so, research indicates that several different types of twisted jackets can withstand typical loading on a wind turbine [10].

Farm Design Assumptions

Due to the infancy of the American offshore wind industry, several design assumptions were made. The general plan for the site was a farm of 200-300MW. The decision matrix of all the given plots showed a number of available locations, but few contiguous sets of plots. Construction over a spread-out area will be more expensive due to the increased infrastructure costs, and many of these larger areas will be far from shore as well. Additionally, there are many unknowns associated with the performance and longevity of offshore turbines in a hurricane-prone area. Given that this would likely be the first offshore development in the region, lenders and investors may be hesitant to support a larger project without concrete evidence that similar sites have survived severe storms.

Site Layout

The plot locations were loaded into Openwind alongside a wind resource grid file for the location. A site boundary was placed around the chosen plots (34, 35, and 36), and space was delineated where the plots intersected with a pipeline. Layout optimization for different amounts of turbines was performed with the goal of minimizing array losses and maximizing energy production. A 10MW reference turbine was used for analysis and 7% array loss was identified to be the acceptable maximum value [11]. It was determined 17 turbines could be arranged in the site without increasing the array loss beyond this value, bringing the farm to a nameplate capacity of 204MW with the 12MW GE turbines. The layout of the site is shown in Figure [3] with the overlaid plot grid and site boundaries.

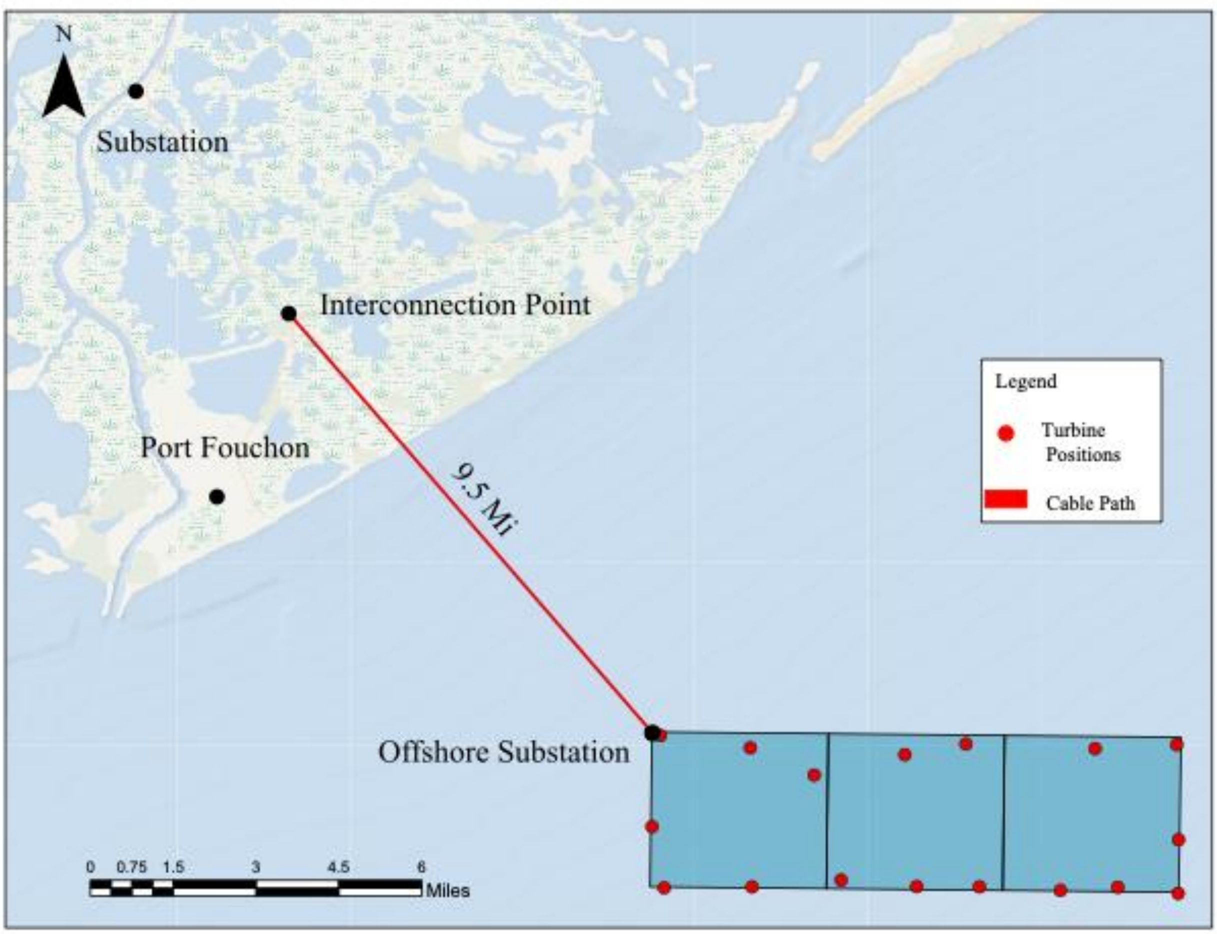

Figure 3: Site layout map

Energy Production

As discussed, the site was designed and simulated in OpenWind to calculate losses due to wake effects, then transferred into System Advisor Model (SAM) to simulate cashflow and production. The SAM simulation yielded a gross energy production of 616,942kWh. This is reasonable compared to National Renewable Energy Laboratory (NREL) calculations and data. [12]

Transmission Design

There is a significant lack of interconnection points near the provided lease plots [13]. Figure [4] below contains a map of interconnection points in the area, all of which have the capacity for at least 200 additional MW.

All interconnection points near to the coast are 115kV. This low interconnection voltage means we will need to either step down at the interconnection point or transmit it as such. Both will require larger gauge transmission lines and transformers, which raises the farm's construction costs. The nearest interconnection point with higher voltage (138kV) is near the town of Gibson, LA. However, the onshore cable to reach this interconnection point would cost more than the transformer equipment required for closer alternatives.

The nearest interconnection point to the site plots is in Port Fourchon, approximately 11 miles from the offshore substation. The official designation is 3FOURCHN. Onshore cables will still be required, but this is by far the shortest distance to an interconnection point. It is connected into New Orleans (in the MISO power market), which will likely be a key city in the power market, or an ideal location to sell our power as a private utility company.

The Leeville substation on Old Highway 1, owned and operated by Entergy, which is 115kV, has the capacity to add our farm's power. This site can be expanded for the project if needed based on the undeveloped area around it. Transmission lines need to be built to connect the wind farm to the substation, then existing MISO lines will take the power throughout the grid. The project is under the generally accepted "critical distance" (50km) from a transmission interconnection that would necessitate the use of High-Voltage DC technology, so the export cables from the offshore farm would be AC. However, the project is also far enough from shore that the transmission voltage would need to be higher than typical collector system voltages (34kV), so an offshore transformer and substation would be required [14]. Thus, the export cables would be at the interconnection voltage of 115kV. The system can be seen in a simplified illustration in Figure [3].

Figure 4: Map of MISO Interconnection Points

Port Selection

Operation and Maintenance (O&M) activities require very few upgrades to a standard port. Ideally the port would have storage areas for extra parts and maintenance equipment as well as space for any operations that would need to be done by helicopter. Because of the relatively light constraints on the port with lighter equipment and smaller vessels, it is possible that the ports at Port Fourchon or Grand Isle could be used due to their proximity to our lease plots.

Construction and staging operations are much more demanding on ports because of the extreme size of the GE Haliade-X 12MW. After researching the specifications of our wind turbine, we found that the turbines' main components would have an average bearing stress of 12.1 tons per square meter. Reports have recommended a ground bearing capacity greater than 10 tons per square meter at staging and manufacturing ports. There would also likely need to be heavier cranage than what is typically available [15]. We prefer a port with few Horizontal Clearance or Air Draft Restrictions to allow our large installation vessels to pass through [16]. -n

Ideally, having our port meet these requirements from the start would be better than upgrading existing ports as we might be able to avoid some of the monetary and time costs associated with upgrading and permitting new construction of this size. Luckily, in the Louisiana area there are two ports that are currently being expanded/built that could serve our purposes.

Port Fourchon is the nearest of the two, which mainly serves the oil and gas industry. Because of this existing infrastructure, the port is deep enough to accommodate most ships and has no Horizontal Clearance or Draft Restrictions. Additionally, this port is being expanded with dredging in process to accommodate more slipways. It is possible that we could request our deck have a ground bearing capacity larger than the 12.1 tons that our turbine will require. It is also possible that a turbine manufacturer could use this port as a manufacturing hub, further facilitating our logistical processes [17].

Grand Isle is also very close to our build area, however, it was quickly disregarded due to its very small size.

A potential alternative is the Louisiana International Deep Water Gulf Transfer Terminal (LIGTT) project. This is a new project located east of the mouth of the Mississippi River [18]. As this project is in its initial stages it has very little information available, however, its website touts it as a possible location to expand the wind industry in the area. The port would be designed for the incredibly large Panamax class cargo ships. Again, Horizontal Clearance and Draft Restrictions would not be an issue.

Due to its proximity to our lease area and its current expansion, we have determined that Port Fourchon will be the best port for us to operate our construction and staging out of.

Crowley, a large port and maritime engineering firm, recently reached an agreement for Right of First Refusal. This agreement allows a Wind Terminal at Port Fourchon. It can be as large as 40 acres and could have 2,200 feet of waterfront.

Crowley will have experience building these wind ports as they are also developing a port in Salem Harbor in the Northeast. Impacts for the Salem project are expected to reach up to 400 full time jobs during revitalization and 500 jobs during the first five years of construction, it is likely that our numbers would be similar as this project is 42 acres vs our 40 acre site. Because this project is in the initial design stages, little is known about any complications during construction [19].

Vessel Selection

The Merchant Marine Act of 1920 (known as the "Jones Act") requires all cargo shipped between U.S. ports to be carried by ships built and registered in the U.S. This includes cargo carried by Wind Turbine Installation Vessels (WTIVs). Wind farm developers are permitted to use "foreign" WTIVs, but they must be supplied by Jones-Act-compliant barges [20].

Only one Jones-Act-compliant WTIV will be available in the near future: the *Charybdis* [21]. A rendering of the vessel can be seen in Figure [5] below. Installation of the nacelle and blades requires exceptional stability and precision; as offshore turbines grow taller, WTIVs (which typically lift from the water with jacks) must meet higher standards. 15MW turbines, expected to be widely available by 2025, will necessitate upgrades to all existing WTIVs [22]. The *Charybdis* shown is under construction at Keppel AmFELS in Brownsville, Texas, and is expected to be finished in 2023 [23].

Figure 5: Rendering of the Charybdis

Other operations, such as foundation installation and maintenance, do not require the unique capabilities of WTIVs. In April 2022, U.S. Customs and Border Protection ruled that foreign cable-lay vessels are permitted under the Jones Act [24]. Though the Jones Act requires cargo vessels to be built in the U.S., others (such as cable-lay vessels) are exempt. We recommend use of the Mariner, a shallow-water geotechnical survey vessel, based in Nassau, operated by Dutch company Fugro [25].

Physical site survey includes both bathymetrical and geotechnical data. Bathymetrical data for the selected area is made publicly available by the National Oceanic and Atmospheric Administration (NOAA) [26].

In some cases, developers choose vessels that can gather bathymetrical and geotechnical data simultaneously. However, BOEM requires that soil borings be collected for each turbine and substation foundation [27]. As such, we will use the available bathymetrical data and gather geotechnical data with an independent, specialized vessel.

Impact Mitigation

Construction Phase Environmental Concerns

Construction poses potential environmental impacts. To minimize environmental impacts, Haliade-X turbines are largely assembled on land with only the final assembly occurring offshore. One major concern in the installation phase is the long-term effect of using pile drivers to hammer in the jacket systems on marine ecosystems. However, studies have shown that the effects are short-term, and fish and wildlife typically increase to higher levels than before operations because of the habitats created by the foundations [28].

The hammering of jacket foundations cause significant noise pollution. To mitigate the impact to local fauna, acoustic bubble curtains will be used. This technique uses perforated pipes to produce air bubbles around the construction area of the wind turbine and absorb much of the sound pollution [29].

Construction of the transmission lines can cause damage to ecosystems by disturbing both the seabed and organisms that occupy the area. Disturbing the seabed can also increase turbidity in the water, which could harm nearby plankton populations [30].

It is also vital to ensure that cable materials are chosen to prevent both electrical losses to the project and pollution. A lead extruded sheath is the only currently accepted method to prevent water intrusion. Non-magnetic sheathing will be used to prevent losses in efficiency and reduce magnetic fields that might affect marine species [31].

Operation Phase Environmental Concerns

Due to the lack of United States legislated guidelines on the environmental impacts of offshore wind, we have determined the project will adhere to current European ordinances [32].

Migratory birds and bats are major concerns around wind turbines. They collide with the turbine's blades, are excluded from foraging grounds, and are forced into longer migratory paths. Unfortunately, the entirety of the possible lease plots contains high migration traffic, meaning the design and construction of turbines will be far more influential than the specific lease plot area for avian impacts [33].

Specific animals of concern are sea turtles, sharks, and whales, so our lease areas avoid the highest areas of migration for these marine animals. While the location of wildlife reserves may impact the decision of wind farm placement in other areas, none are located in or near our lease plots [34].

One bird species in particular with a migration path through the lease plots is the wood thrush, which has a "near threatened" conservation status [35]. Countermeasures to protect birds and bats include raising the cut-in speeds to around 5.0m/s, employing market-available tools such as the Merlin Advanced Avian Monitoring System to stop turbines while large flocks fly through the farm, and using ultrasonic sound boxes to prevent bats from roosting [36].

The coast of Louisiana is an aquatic dead zone due to eutrophication [37]. The presence of a wind farm will not affect environmental processes due to the damage already done. A study by the American Chemical Society shows that the presence of algae increases the corrosion of steel as does seawater, which is a pollutant [38].

Operational sound pollution is a concern, but the GE Haliade-X turbine doesn't approach problematic decibel levels. Foundation and cable maintenance will be important to eliminate polluting rust and depreciation, which will in turn prevent metal contamination in the surrounding water [39].

Local Impact Concerns

A primary focus of the team this year was the minimization of the farm's impact on not only the environment, but the people that live near the farm. To prevent local tourism impact, the turbines are located outside of visual range from the coastline. This was calculated using the formula illustrated as Equation [1] below. As Louisiana's coast is low-lying, often a few feet at most above sea level, two meters was used to approximate the average viewer's eye-level height. The calculated horizon is given in a best-case scenario to give an idea of the upper boundaries of aesthetic impact. [40]

The fishing industry is not present in the lease plots area due to federal protections. The short-term impact will consist of an influx of jobs and community investment as the project begins construction. In the long-term, electricity prices are likely to decrease in the area, as seen in a United States Department of Energy study [41]. A common concern with renewable energy projects is property value decreases. These are unlikely to be a concern for this project due to its position in a port city. Port Fourchon is known for three things: surfing, nature, and industry [42]. The wind farm is positioned far enough away from the coast to not impact surfing and nature viewing and is likely only to be a beneficial addition to the energy-heavy economy already housed in the town. The nearest housing in Port Fourchon is over 7 miles away, meaning only residents in three-story buildings may be able to see the wind farm. Structures of this height are nearly nonexistent in the area, so this is not a concern.

Risk Analysis

The project faces risks inherent to all offshore construction projects, and some unique ones due to its location. Environmental risks such as hurricanes, which are more dramatic at this site than farms in the Atlantic region, are a major consideration and will necessitate the procurement of applicable insurance and design measures to mitigate damage [43]. It will be a major responsibility of the developer and insurer to decide whether to insure the project against the full replacement cost or insure it against some portion of that loss based on probabilistic studies. Other risks must be analyzed as well, beyond those that threaten the structural integrity of the plant in operation. Although construction risk is generally lower for wind projects than other energy projects, it is still the riskiest period of time of the development due to its incomplete nature. Project lenders might try and mitigate construction risk by ensuring that reserves for construction cost overruns are funded before construction begins, or by asking for periodic updates on the completion of the project that they can review themselves.

Earthquakes are a relatively common disaster scenario for wind farms on the West Coast; however, Louisiana has very little seismic activity and likely will not experience a damaging earthquake in the life of the wind farm [44]. The most pressing risk for the potential wind farm is that of hurricanes. According to the National Oceanic and Atmospheric Administration, hurricanes make landfall in Louisiana once every 2.8 years. [45] The risk can be split into two categories: waves and wind. For waves, damage can be mitigated by ensuring strong and well-made anchoring cables and keeping the turbine's blades well above the 15.4m peak wave crest experienced during Hurricane Katrina [46]. The lowest height the farm's blades will reach is 20m above sea level, so this risk is mitigated.

Wind speeds, particularly during a hurricane event, can be catastrophic for a wind farm. To address this, our farm will be equipped with back-up generators that power a yaw system. This system will continuously angle the turbine nacelle directly into the strongest wind and suffer the least stress. The back-up generators ensure that this can be performed even if the turbine itself has lost power [47].

While risk due to low electricity price exposure will be minimized, there is always the risk of the farm not producing planned quantities of electricity due to seasonal changes in weather trends. This resource risk can result in shortfalls in revenue that can make it difficult for the project to service debt. Oftentimes projects such as this one will engage in weather or price-related hedges to ensure a constant revenue stream [48].

Project Construction

Permitting Procedure

BOEM is authorized to issue leases and permits for development on the U.S. Outer Continental Shelf (OCS) by the Energy Policy Act of 2005 [49]. It is BOEM's responsibility to coordinate with state and local governments as well as ensure that proper environmental and safety procedures are followed.

BOEM guides wind turbine development through four phases: planning, leasing, site assessment, and construction/operations [50]. The planning phase is internal to BOEM and generates lease plots. The leasing phase allows developers to obtain lease plots (potentially through competitive sale) but does not permit construction. When a lease is obtained, the developer is given 12 months to submit a Site Assessment Plan (SAP), which BOEM may accept, reject, or modify.

When the SAP is finalized, the developer collects site characterization studies (environmental, local impact, site survey, etc). When complete, the developer will submit a Construction and Operations Plan (COP), which BOEM may similarly accept, reject, or modify. When the COP is finalized, construction may begin [50].

Staging and Loading

The construction of the project can be reasonably divided into onshore and offshore activities. Offshore activities all necessitate the use of the *Charybdis*, which dramatically changes the parties and processes involved. Onshore port activities mainly include construction staging and ship loading, while offshore includes the physical construction of the farm such as foundation installation.

A critical element to the farm's construction is the distance to the factories producing the underwater transmission cabling. Ideally, the developer of this project will also facilitate the construction of transmission line factories in Port Fourchon, which is possible as seen in the Port Selection Section above. The prefabricated components of the Haliade turbine will arrive at port in staged deliveries. Due to the size of the components, they will likely arrive by train, as discussed in the Onshore Considerations Section above, and be stored in nearby warehouses. Turbine towers will be staged and assembled onshore before loading. Another critical port action is loading the jacket foundations. This will be performed similarly to the rest of the turbine elements with a crane, but the foundations will be completed earlier in the installation process and without the use of the *Charybdis*. Once it is deemed that enough components have arrived for effective loading of the *Charybdis*, a crane will position itself to load Self-Propelled Modular Transports (SPMTS) which will move the components to a point where the cranage system (likely two sets of 600-ton cranes) can effectively maneuver the components onto the *Charybdis*. This loading process can take several hours per component and will need to be done a multitude of times throughout the construction of the wind farm, thus proper training of staff is imperative. With the *Charybdis* loaded, it will depart from port to install the towers, nacelles, and blades. Finally, the port would be continually used for O&M operations. However, these can typically be performed out of any port and likely will have to be stationed out of multiple ports if there are numerous projects in the GOM region.

We expect the transformer to be too heavy for road travel. One option is to have it constructed onshore, transported by train to the nearest possible station, then disassembled. The pieces could then be transported by truck to the staging area in Port Fourchon. Unfortunately, this plan is labor intensive and may result in reassembly error onsite.

An alternative option is to send it by railroad to Port Sulpher (Northeast of Port Fourchon,) then loaded onto a boat and shipped down the Mississippi River to the staging area. In this scenario the transformer would likely be manufactured by Coilcraft Inc., which is based out of Cary, IL [51].

A third option is to have the transformer manufactured in a port city, then sent by ship to Port Fourchon. In this scenario, the transformer would likely be manufactured by Endicott Coil Co, Inc., which is based out of Binghamton, NY [51]. This plan would achieve the fastest result but would incur high shipping costs. Comparing labor costs with shipping costs to determine the most efficient solution, option two was selected.

Financial Analysis

Market Analysis and Revenue Calculation

The project is located in the MISO Power Market as part of the Eastern Interconnection. A dual interconnection with the ERCOT Power Market in Texas was examined but determined to be unfeasible due to distance.

The use of a power purchase agreement (PPA) would guarantee revenue but decreases the likelihood of a higher Internal Rate of Return (IRR). This is the ideal option though due to the volatility of merchant projects. There is room for a higher IRR, but there is also a higher risk of failure due to its reliance on power market stability. If the farm produces more than the PPA requires, excess power can be sold with the merchant system due to the two not being mutually exclusive.

To acquire a PPA, reaching out to some of the large coastal companies in the area such as Accruent, AECOM, Bernhard MCC, Boeing, etc. is the primary course of action. These companies have done PPAs in the past due to tax benefits in the long-term as well as less expensive electricity bills. Historically there have been PPAs up to $3 billion, well above what is needed for our farm. This could eventually become a partnership flip reducing income tax for both parties creating a mutually beneficial system. If this PPA does not give the required funds, the Department of Energy's Loan Programs Office (LPO) could provide the remaining funding in a debt financing format [52]. Another option is a long-term bank loan, which is similar to the loan from the LPO if the Department of Energy's loan is not accepted or is not sufficient to cover the outstanding funds required. This is not preferable due to higher interest rates. These will be discussed further in the Financing Section below.

A revenue calculation was performed through the SAM Merchant Plant model. It would be equally valid to assume that the plant could operate through a SAM PPA framework, given the wide variety of potential power buyers in New Orleans and Port Fourchon. The SAM calculation shows the annual revenue increasing over the life of the farm by 1.99% per annum. The farm's year one revenue was shown to be $24.7 million, and the year 20 revenue was shown to be $36.0 million not including salvage value.

Incentives

Wind farms are allowed to take advantage of either the Production Tax Credit (PTC) or the Investment Tax Credit (ITC). The PTC provides a tax credit based on hourly production, while the ITC gives a one-time credit of a percent of investment costs.

The 2022 Inflation Reduction Act established new incentives related to renewable energy production, which includes up to two 10% stackable credits towards either an ITC or PTC. The requirements for attaining these include meeting domestic content thresholds and/or being located in a fossil fuel dependent energy community. For this project, we have selected to utilize an ITC, which would yield 50% due to our component procurement and farm location. The project area does qualify as a fossil fuel dependent energy community according to BOEM, and, since all turbine elements will be manufactured in the U.S., the domestic content threshold will be met. Additionally, we will be seeking a 18% ITC from the state of Louisiana. The state provides an ITC up to 40% for motion picture companies, a 7-18% ITC for advanced drive train and biofuel industries, and myriads of residential solar panel ITCs. An offshore wind energy ITC would be new for the state, but the large number of existing incentives means it's possible [53].

Initial Capital Cost

Many factors contribute to the cost of the project, and we attempted to refine as many of them as possible to develop an estimate for the total capital cost of the farm. SAM was used for project analysis, which has nearly 250 parameters that come together to produce a finalized project cost. Many of the parameters had to be adjusted and changed, both as research on typical values became clearer, but also to produce a viable cost estimate that could yield a financially solvent project. While not every input can be discussed in this document, the main cost estimates that we have researched and used in the calculation are identified below as well as how they are reflected in the farm's outputs. Of particular note is the turbine capital cost. Reports have shown a cost of 1,301$/kW for Atlantic Coast projects [54], but we assume a slightly lower cost due to the necessarily lower rated power for GOM turbines and future cost reductions in offshore wind technology.

Parameter	Value
Substructure	Jacket
Anchor	Suction Pile
Max Water Depth	20.5m
Interconnect	115kV
Distance to Landfall	10.7km
Distance to Port	12km
Array Cable Voltage	64kV
Vessel Strategy	Primary (WTIV)
Distance over Land	4.8km

Figure 6: Selected Installation Cost Parameters

Parameter	Value
Turbine Cost	1030 $/kW
Substation Design Cost	$4.5M
Substation Fab. Cost	$14.5K
Array Cable Current Rating	300
Endangered Species Act Compliance Cost	$3M
NEPA Environmental Impact Study Cost	$1.5M
Site Assessment Cost	$410K
Number of Feeder Barges	2

Figure 7: Selected Installation Costs

Levelized Cost of Energy

The final installation cost for the site is shown below. The project will have a Real Levelized Cost of Energy of 49.80$/MWh or 0.04980$/kWh and a total Net Capital Cost of $1,030,583,808.00. The impacts of these numbers will be discussed further in the Cashflow Section below.

Component	Cost ($/kW)	Rated Capacity (kW)	Cost ($M)
Turbine Cost	1030.00	204000	210.1
BOS Cost	3756.00	204000	797.4
Total	**4796.00**	**204000**	**1.013.1**

Figure 8: Final Installation Costs

Financing

The setup of the project as a merchant independent power producer, rather than as a seller through a PPA, exposes the operating company to a level of merchant price risk. The signing of a PPA with a creditworthy entity offers a level of assurance to lenders of continued profitability, and the lack of one could keep the project from ever getting off the ground. The uncertain future of global natural gas markets may guarantee a high floor in MISO wholesale electricity prices, but it may not be enough for the project to secure financing from commercial lenders. Thus, new financing options may need to be found.

The LPO may be able to provide some of this financing, as it offers debt financing for technologically innovative large-scale energy projects. Concerning large-scale renewable energy projects, LPO provides access to capital for projects that would be genuinely innovative in their space through the Title 17 Innovative Energy Loan Guarantee Program. In order to prove that the project is innovative, we would argue that the fact that the project would likely be the first offshore wind farm in the region and would require different foundation and turbine designs than have been seen in Europe and will be seen in the Atlantic qualifies it for the financing. Even if the LPO limited its financing of the project below what is needed, their presence as part of the lender group could encourage commercial lenders to invest as well. The LPO also provides in-house legal, technical, and environmental support to projects, which would be useful as the developer navigates the BOEM lease process.

A major piece of funding needed for the project is a term loan, offered at some ratio of available cash flow to the debt service interest payments that would be necessary (DSCR). Our research indicates that, without the LPO being involved, this project might see a DSCR as high as 1.4, but we believe that they would be willing to offer lower DSCR conditions given their mission and goals. DSCR is often calculated by lenders based on mid and worse-case production and revenue scenarios [55]. Other major types of project funding, like sourcing it from the bond market, offer more complex tax situations and would typically not be used in this situation. Construction loans are also an important portion of funding for offshore wind development. They mature over a shorter-term period and are often slightly cheaper than the longer-term loans over the life of the project. If LPO funding was available, it is possible that the construction loan could be refinanced into a longer-term loan with lower interest rates upon completion of project's construction. Even if the LPO only agreed to provide the term loan, their presence in the project might sway other investors into providing the necessary loans needed for the project during construction.

Assumptions

NREL SAM Software was used for financial modeling and analysis, and the inputs to the software are cataloged below as a way of describing the system model.

Considering the analysis of operating costs, research was performed to find out what typical offshore farms in Europe see in operational costs, as well as estimates for future farms in North America [56]. From the research, it was assumed that the project would see $100/kW-yr in fixed capacity-related costs, and $20/kWh in variable generation costs, with a 2.5% escalation rate. The estimates were placed between European statistics and North American estimates. The lower water depths and wind speeds could lead to cheaper maintenance than the North American Atlantic Coast estimates, but the North American industry hasn't reached the scale that the European markets have to bring down the operational costs.

Most assets in renewable projects qualify for the Modified Accelerated Cost Recovery System (MACRS). We have assumed that the majority of the project (95%), qualifies for 5-yr MACRS, while 3% qualifies for 15-yr MACRS and 2% is non-depreciable. MACRS is very beneficial during the first years of the project, as it provides useful tax deductions that can offset taxable income early in the project's life.

Regarding the loans that the project would receive, we will continue with the assumption that the unique project design would qualify it for assistance from the Department of Energy LPO. Thus, it might qualify for a lower DSCR for the term loan than otherwise might be possible given the site conditions. We have assumed a DSCR of 1.1, over a tenor of 18 years, and at an interest rate of 3.75%. The interest rate of LPO loans is calculated from a combination of the treasury rate for loans over the same period, and a credit-based spread that is usually under 200 basis points. With long-term treasury rates hovering around 3.67% [56], we estimated that the credit based-spread would apply at 155 basis points, yielding the interest rate of 3.75%. We also assume $450,000 in closing costs for the debt and a 2% fee upfront. For the construction loan, we will continue with similar assumptions, and assume an interest rate 50 basis points lower than the term debt [28], or 3.25%. We will give a conservative estimate for the portion of the project construction costs funded by the construction loan, at 70%, and assume a 1% up-front fee for the loan as well.

For other general financial parameters, we assumed an insurance cost near 1% of the total installed cost and assumed that the sales tax of 6.25% seen for most goods in Louisiana would apply to the direct costs in the installation. We assumed a salvage value of roughly 1% of project installation costs [57]. We have assumed an inflation rate over the project period of 2.5% and a real discount rate of 6.4% [58]. Property tax was assumed to be assessed only on the onshore (or within state waters) portion of developments, roughly 3% of project costs, at a 2% rate. It is common for project lenders to require reserves to be set aside for debt service or O&M costs, and we have assumed reserves of 10 months of operating costs to satisfy potential requirements from lenders.

The largest assumption of the project is Louisiana's ability and willingness to provide the 20% ITC of approximately $100M. This is a large stipulation, but the State's unique pre-existing ITC's may allow it to be possible. As discussed in the Incentives Section above, the state currently provides a litany of ITCs, including ones for Biofuel development. An offshore wind energy ITC would be new for the state, but the large number of existing incentives means it's possible [59].

Cash Flow

Cash flow analysis of the simulated project showed a farm that was profitable under the planned 2030 operational conditions with significant incentives. A reduced cash flow statement for the 20-year operational life of the project is shown below. The Levelized Cost of Energy for the project sits at 49.80$/MWh or 0.04980$/kWh, which is slightly lower than NREL estimates for the site. It also comes in slightly lower than the region's average LCOE of 51.68$/MWh [62]. The model shows an IRR of 3.55% and a Net Present Value (NPV) of -$82,771,344.00. While a positive NPV would have been ideal, financial analysis shows that the positive IRR percentage is far more valuable when determining fiscal solvency. NPV is less important since the project will be decommissioned at the end of its 20 estimated useful life and no reinvestment will be attempted.

Year	0	1	5	10	15	20
Total revenue	$-	$24,714	$26,751	$29,536	$32,610	$46,136
Total operating expenses	$-	$14,323	$15,376	$16,848	$18,512	$20,396
EBITDA	$-	$10,391	$11,375	$12,688	$14,098	$25,740
Debt interest payment	$-	$(5,978)	$(5,222)	$(3,878)	$(1,989)	$-
Cash flow from operating activities	$-	$4,670	$6,430	$9,116	$12,445	$25,995
Cash flow from financing activities	$1,030,584	$(4,413)	$(6,153)	$(8,810)	$(12,108)	$-
Total after-tax returns	$(871,158)	$705,504	$25,377	$13,893	$(2,415)	$37,532
After-tax cumulative IRR	0%	-19.02%	-3.03%	2.38%	1.84%	3.55%
After-tax cumulative NPV	$(871,158)	$(224,263)	$(125,482)	$(87,829)	$(91,244)	$(82,771)
Federal ITC total income	$-	$489,527	$-	$-	$-	$-
State ITC total income	$-	$195,811	$-	$-	$-	$-

Figure 9: Cash Flow in Thousands of Dollars (Negative)

Optimization

Due to offshore wind's exceedingly high initial and operating costs, significant financial optimization was performed in SAM. The most dramatic measure was the usage of SAM's electrical cable cost optimizer, which reduced construction costs by approximately $10M by cable sizing refinement. Research conducted on design and construction management costs in the State of Louisiana allowed us to lower that input to 2% of the overall project cost. Data from the Block Island Wind Farm construction costs allowed us to lower the $/kW installation costs by 11% to closer reflect the costs seen there. The actual change was 16%, but we chose to leave an additional 5% contingency due to the difference and location.

Auction Bid

Due to the positive IRR, we could reasonably develop a bid price for the 15,000-acre lease area. Lease prices as high as $9,000/acre were seen in some regions on the Atlantic Coast [60] and the recent California auction resulted in a max bid of $2,517.71/acre [61]. The average price for these plots was $2,061.41/acre. These conditions are comparable to our farm's so we can assume similar bids. Interpolating based on these numbers, we would be willing to auction up to $2,100.00 per acre or $30,500,000.00. These prices also come with incentives for workforce training and community improvement plans, which we plan to utilize. This raises our total farm costs to $1,062,083,808.00, and the cash flow statement above reflects this price in the installation cost and LCOE metrics. We arrived at this lease price by comparing the financial output parameters of SAM under different price scenarios to find a competitive price that would still give the project a positive IRR by the end of the farm's life. This results in a positive IRR of 3.55% achieved in year 20, which we consider to be fiscally viable.

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GIS Data Sources

Type	Name	Link
ArcGIS Online Source	Gulf of Mexico HAPC Areas	https://portal.gulfcouncil.org/arcgis/rest/services/Hosted/Gulf_of_Mexico_HAPC_Areas/FeatureServer
ArcGIS Online Source	U.S. Military Installations—Data provided by the Military Surface Deployment and Distribution Command- Transportation Engineering Agency, 2014.	https://services.arcgis.com/hRUr1F8lE8Jq2uJo/arcgis/rest/services/milbases/FeatureServer
ArcGIS Online Source	Fairways	https://services5.arcgis.com/g7OtfotLzNoMMSUp/arcgis/rest/services/Fairways/FeatureServer
ArcGIS Online Source	MISO Transmission _115 kV and above_	https://services3.arcgis.com/fwwoCWVtaahwlvxO/arcgis/rest/services/MISO_Transmission__115_kV_and_above_/FeatureServer
ArcGIS Online Source	Major Hurricane Tracklines	https://www.arcgis.com/home/item.html?id=248e7b5827a34b248647afb012c58787
ArcGIS Online Source	BOEM Platforms Pipelines Active Lease in the Gulf of Mexico (GCOOS)	https://services1.arcgis.com/qr14biwnHA6Vis6l/arcgis/rest/services/Platforms_Pipelines_ActiveLease/FeatureServer
ArcGIS Online Source	BOEM Platforms Pipelines Active Lease in the Gulf of Mexico (GCOOS)	https://services1.arcgis.com/qr14biwnHA6Vis6l/arcgis/rest/services/Platforms_Pipelines_ActiveLease/FeatureServer

ArcGIS Online Source	BSEE US GOM Pipelines	https://www.arcgis.com/home/item.html?id=446f760c682e4750ab6910523b77ff91
ArcGIS Online Source	Shipping Fairways	https://www.arcgis.com/home/item.html?id=7ba696c12aa34f2f8c19c96c4a70091f
ArcGIS Online Source	Essential Fish Habitat - Areas Protected from Fishing	https://services2.arcgis.com/FiaPA4ga0iQKduv3/arcgis/rest/services/Essential_Fish_Habitat/FeatureServer
Online Mapping Tool	MISO Points of Interconnection Map	https://giqueue.misoenergy.org/PoiAnalysis/index.html
Online Mapping Tool	Depth Map: Gulf of Mexico	https://usa.fishermap.org/depth-map/gulf-of-mexico-tx-fl
Online Mapping Tool	OpenWind	https://www.ul.com/services/openwind-wind-farm-modeling-and-layout-design-software
Data File	Vortex Wind Resource Grid File	Locally Saved