Virginia Tech

Project Development Report

Marino de la Tierra

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INTRODUCTION

The Wind Turbine Team at Virginia Tech, under the company name VTexas, has conducted thorough research to develop the 504 MW wind farm "Marina de la Tierra" off the coast of Galveston, Texas. Marina de la Tierra requires a total Capital Expenditure of $2.87 billion. VTexas is prepared to bid 87 million for the six necessary lease blocks to house Marina de la Tierra. Per the guidelines established in the 2022 CWC Rules and Requirements handbook, the following text will detail a broad understanding of the land development process with respect to the offshore wind industry.

SITING CONSIDERATIONS

Wind Resources Assessment

Wind resource assessment is critical to the planning phase of a wind farm as it allows for optimization of the farm's energy generation. To gather information, one met masts will be installed on-site for two years prior to construction. [1]. It will be installed at the same height as the nacelle, 150 m, to provide the most accurate data for the wind resource [2]. The met masts will also collect data on seawater temperature, marine life, and avian presences. [3]. Current data at 100 m shows the wind speed across the call area averages 7.4 m/s in a northwest direction (Figure 1) [4].

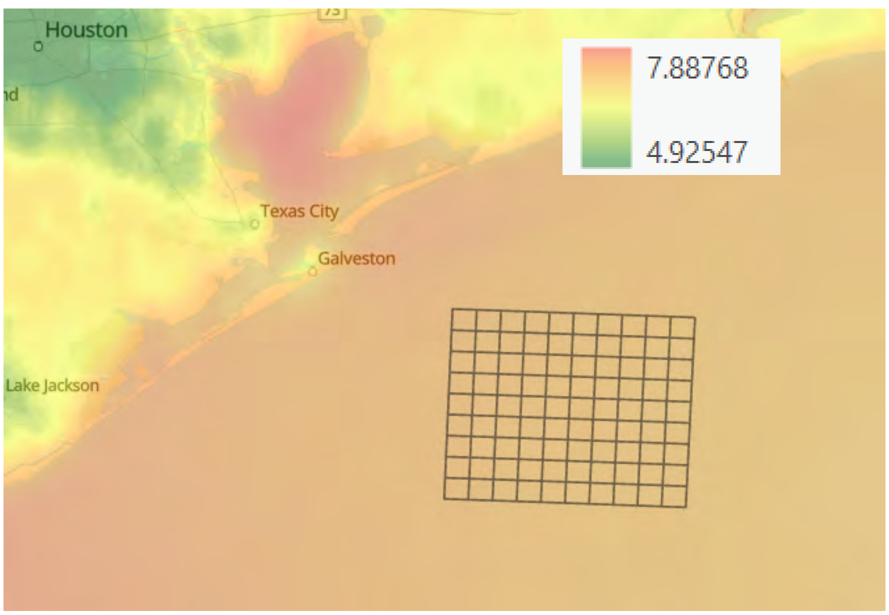

Figure 1: Wind Resource

Sensitive Environmental Factors

The Gulf of Mexico is an ecologically diverse area which will be impacted by offshore construction. Prior to construction, in-depth environmental studies will be completed on marine and aerial life to determine what species live within and adjacent to the project boundary and which best management practices can minimize impacts on these species.

Most of offshore wind's negative impact on marine life takes place during the construction phase of the project as a result of noise, increased vessel traffic, and physical impact on the seafloor [5]. The farm post-construction can actually play a positive role in the seafloor marine habitat, since foundations can provide habitat for coral reefs and the turbines themselves discourage fishing and other boating traffic [6].

Fortunately, there are no natural or artificial reefs or coral in close proximity to the call area [7]. The closest reef to the project boundary is the Flower Garden Reef [7]. However, there are a number of marine species within the project boundary, including Brown Shrimp, White Shrimp, Blue Crabs, young Bull Sharks, Gulf Menhaden fish, Red Snappers, the Red Drum, Kemp's Ridley Sea Turtle, and Atlantic Bottlenose Dolphin [7].

Blade strikes can kill birds during wind farm operation. Mitigation techniques vary by species since noise and environmental degradation can affect species differently. Potentially impacted bird populations include the Common Loon, Northern Gannet, Brown Pelican, Least Tern, Royal Tern, and Black Skinner [7].

There are several mitigation strategies to reduce the impacts of noise during installation. During pile driving, one method to reduce impact is to slowly increase the noise over 15 minutes or more to allow fish to leave the area before the noise reaches its full capacity [5]. Another strategy is to encircle the seafloor around the construction site with air-filled pipes; the air escapes the pipes through perforations and rises to the water surface, creating a "curtain of air" [8]. The curtain of air displaces and scatters sound waves, decreasing noise impacts in the surrounding water [8]. Mitigation strategies to limit the impact on seabirds include "grouping turbines to avoid key migration flight paths" and potentially shutting down turbines for short periods of time during peak migration [5].

Hurricane Impacts

Offshore wind farms are susceptible to severe weather, especially in the Gulf of Mexico. Hurricane season in the gulf runs from May to October, but rainfall is present throughout the year. Since 2010, the number of tropical storms and hurricanes has increased in this area due to climate change [9]. Projected precipitation changes in the Gulf are small, but also highly uncertain. Studies have shown that the most suitable type of foundation for severe weather is the twisted jacket foundation [10]. Two oil rigs with this type of foundation resisted a direct hit from Hurricane Katrina (category 5) in 2005 without damage[11, 12]. To prepare for similar events, wind turbines have the technology to analyze weather conditions. For instance, when wind speeds surpass a modern utility-scale turbine's rated wind speed, the blades begin to feather to reduce wind loading wind loading [13]. This technology allows the turbine to act according to current weather conditions and prevents damage to the equipment.

Ocean Activities

The most prominent activities in the ocean within the provided call area are shipping and oil & gas drilling. The shipping lanes provide safe passage for all ocean vehicles; therefore, infrastructure that could impede safe travel is not allowed within the shipping lanes [14].

The U.S. military conducts routine operations in the gulf [15]; however, none of the military warning areas overlap with the call area, so the stated project boundary will not be affected by military operations [15]. Since the site does not lie in state waters (within nine nautical miles of the shore) all fishing within the call area is regulated by the federal government [16]. The only fishing restriction in the call area restricts powerhead and roller trawls during the months of June through August to protect reefs adjacent to the coastline [17]. It is safe to assume that fishing will not have a large impact on the wind farm, but the construction and placement of turbines may have an impact on fishing. Prior to the auction, input on mitigation strategies will be sought from commercial and recreational fishing groups to understand how to best decrease the wind farm's impact on fishing.

There are several international airports nearby, but the call area is far enough offshore that construction and operation of turbines will not affect the airports' airspace [18].

Site Selection and Layout

Of the considerations presented thus far, VTexas prioritized the location of shipping lanes, pipelines, and oil & gas wells when narrowing down lease block selection. The proximity of the lease blocks to Gavleston and to one another were also considered leading to the initial lease block selection highlighted in green (Figure 2). These blocks avoid the worst of the shipping lanes (outlined in yellow), most major pipelines (red lines), and the worst of the oil and gas wells while still being close to Gavleston (Figure 2) [19, 14].

After limiting the project size to 42 turbines (504 MW), the lease block selection could be reduced further to 5-8 blocks. Upon further understanding of the complexity and cost of electric cabling, final lease block selection eliminated the need for array cables to cross a pipeline. The turbines within these lease blocks are shown in Figure x. Since wind speed remains relatively constant across the call area, a grid layout was chosen to maximize the number of turbines per block and minimize wake effects. The rows of turbines were placed at an angle so the typical northwest blowing wind would hit the turbines at a perpendicular angle. To reduce wake effects, the rows were spaced 10 rotor diameters (2200m) apart in the direction of the wind and 5 rotor diameters apart (1100m) in the perpendicular direction to the wind [20]. The offshore substation was located in the middle of the site to reduce array cable lengths which can impact electrical efficiency [21].

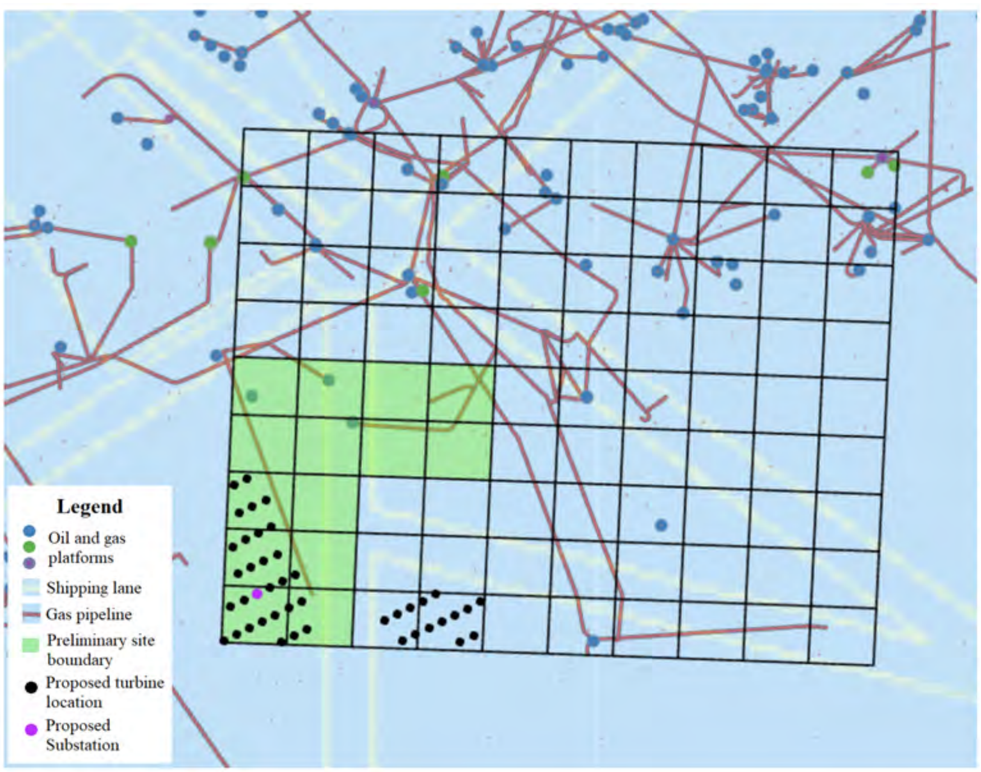

Figure 2 - CWC Call Area

Energy estimations were made using software including Furow and NREL's System Advisor Model (SAM) [22, 23]. A wind resource map was created for the block in the lowest left hand corner using wind data from NREL's WIND Toolkit, coordinates from ArcGIS, and Furow's bathymetric tools [4]. Unfortunately the limits in computing power made completing a wind resource map for all six chosen blocks impossible. Energy production was calculated for a possible 11 turbines in a single block. Furow estimated Marina de la Tierra's capacity factor to be 42.5% and total annual energy production to be 44.7 Million kWh/turbine which sums to a annual total of 1.88 Billion kWh [22].

VTexas used SAM primarily for the financial analysis of Marina de la Tierra. To do a comprehensive financial analysis SAM completes its own energy estimation using input parameters of turbine parameters, number of turbines, wind resource, and grid formation. SAM's energy estimation for Marina de la Tierra was 1.55 Billion kWh annually [23]. To reduce risk in the project, VTexas chose to use the conservative estimate of 1.55 Billion kWh during the financial analysis of the farm.

PROJECT TIMELINE

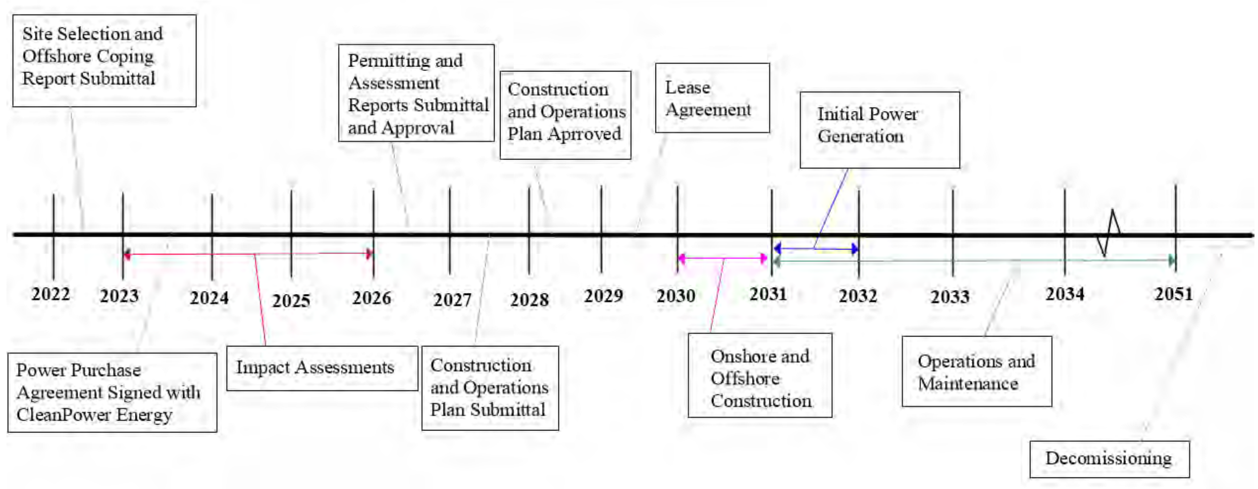

Figure 3 : Construction Timeline [24][25]

After a project is determined to be financially feasible, there is a lengthy planning phase essential to the success of a wind farm. This includes initial site selection, lease agreements, a Power Purchase Agreement (PPA), and a multitude of permits and studies [26]. The construction phase is shorter to reduce the amount of time that the area is being leased without producing energy. Post construction, the life of the farm will be 20 years. Mariano de la Tierra will be producing power from 2031 to 2051 with optional decommissioning at that point.

Planning Phase (2022 - 2029)

Upon completion of the site auction in 2022, the planning phase of project development can commence.

VTexas will work with the federal and local government to complete all required permits. First, the Offshore Scoping Report initiates the Environmental Impact Assessment process. The purpose of this report is to promote communication among consultees and regulators regarding the preliminary studies stage of the project [27].

Since this project will be under federal jurisdiction, the following applications must be submitted in accordance to the relevant federal acts: Site Assessment Plan, Facility and Design Report, Fabrication and Installation Report, and a Construction and Operations Plan [28].On average, it takes about one year to approve the submission of U.S. permits for an offshore wind farm [29]. Additional approvals for navigational lighting, submerged cables, and air quality & pollution prevention are also required in accordance with the following acts: the Magnuson-Stevens Fishery Conservation and Management Act, the Marine Mammal Protection Act, the National Historic Preservation Act, the Clean Water Act, and the Endangered Species Act [28].

The lease agreement will be signed before construction begins (2029). The Power Purchase Agreement will be signed early in this process (2023).

Construction Phase (2030)

There will be two types of construction during the construction phase, onshore and offshore construction. Offshore construction will be split into four phases: foundation installation, cabling, offshore substation installation, and turbine installation. It takes 2-2.5 days to install one wind turbine foundation [30]. The offshore substation will be pre-constructed onshore and transported to the site on a shear-leg crane barge which will hoist the substation onto its foundation [30]. It will take 5 weeks to install the substation and make the electrical connection with the submarine cables and cost an estimated $300,000 per day [30]. Cable installation will occur next, connecting turbine foundations to the offshore substation foundation, and the substation to landfall [30]. Array cable installation will take on average 1.5 days per array cable (cables between offshore substation and turbines), export cable installation will span one day for every 3 miles [30].The final phase of construction will be turbine installation. Specialized vessels are used respectively to transport and install the wind turbine towers, nacelles, and blades on their foundations at a rate of 2.5 turbines a day turbines for $270,000 per day [31, 30]. Heavy-lift vessels are optimized for transporting turbines from the port to the construction site while turbine installation vessels contain jack-up legs (supports which allow the vessel to sit on the seafloor) [32, 30, 33]

VTexas acts as the owner and operator of Marina de la Tierra and will be contracting out the construction of the project. Factors that were considered when selecting a project delivery method for the construction phase include the owner's influence on the project design, the cost, and the construction timeline [34]. Three delivery methods were considered: Design Build, Design Bid Build, and Construction Manager at Risk.

Ultimately, Construction Manager at Risk was determined to be the best option for the construction of Marina de la Tierra due to this method's proclivity for schedule acceleration and the owner's ability to influence the project. This method involves hiring a knowledgeable construction manager who will work closely with the owner throughout planning and construction phases. In the development and design phases, the construction manager will act as a consultant to the owner [35]. A Guaranteed Maximum Price (GMP) will be submitted by the construction manager which is non-negotiable following contract approval. If project costs exceed the GMP, the construction manager is contractually liable to make up this difference. If the project comes in under budget, the construction manager is compensated [36]. CMAR allows for a high level of communication between the owner, designers, and builders.

Operations and Maintenance Phase (2031 - 2055)

The operation and maintenance phase will last 20 years according to the lifespan of the project. During this time period routine maintenance checks will be performed every six months on each turbine using personal transfer vessels or helicopters [30,36]. An asset management plan includes designing and repairing cables, turbine performance analysis, technical operations management, and substation management [37]. With this plan, VTexas can optimize the cost of energy of the wind farm by replacing components when their decrease in efficiency costs the farm more than their purchase and installation price [37]. Leased office space necessary for operation control will be obtained by the year 2029.

Decommissioning (2051 - on)

At the end of a project's life there are several options including extending the life of the farm, repowering the farm, or decommissioning the farm [38]. A life extension is used when the farm integrity has been maintained to a degree that the farm will continue to be profitable over the near future. Repowering a farm requires replacing old components to increase the efficiency of the farm [38]. Decommissioning involves removing the turbines, foundations, offshore substations, and electric cabling. The removal of the foundations can cause environmental harm due to marine life's possible use of the foundation as an artificial reef. Additionally, electric cabling removal disturbs the seafloor and causes similar environmental harm to electric cable installation [38]. Decommissioning takes place when a farm cannot be profitable, even with the replacement of degraded parts. Decommissioning takes from one to five years and its associated costs are incorporated into the financing of the project [39]. VTexas plans to fully decommission the wind farm after the completion of its project life. Offshore wind energy costs are declining as the demand for wind energy grows across the world, and Marina de la Tierra's energy production will likely no longer be competitive in 2051, even with new components.

CAPITAL COSTS

Pre-Construction Environmental Monitoring

For environmental protection in the proposed lease area, geological/hydrological and environmental surveys must be conducted to determine whether construction can safely occur [40]. VTexas will conduct geological and hydrological surveys to locate geohazards that may affect the feasibility of foundation installation [41]. The main goal of these studies will be to locate geohazards that may affect the feasibility of foundation installation [41]. Geological surveys require 12-20 weeks to complete [30]. Environmental surveys conducted pre-construction will include the use of sonar, divers, and autonomous underwater vehicles to locate critical habitat and fish populations and can take 15-20 weeks to complete [42, 9, 30]. Geotechnical surveys involve boring and penetration tests, and collection of soil samples and require 8-20 weeks to complete [30]. The total cost for the necessary environmental assessments, surveys, application fees, permitting, and engineering consultants for Marina de la Tierra totals $9.5 million [26, 43].

Turbine Type

To determine the specific turbine for this project, research was conducted on turbines that will be in production well before construction begins in 2031. The wind speeds throughout the call area average approximately 7.4 m/s[44, 45, 4, 46]; therefore, focus was placed on turbines with a larger blade-swept area to take advantage of the site's relatively low wind speeds. Initially, the team narrowed selection down to the GE 12 MW Haliade-X or the Siemens Gamesa 11 MW turbines due to their production timeline and large nameplate capacity [2, 47]. Of the two options, the Haliade-X was chosen because of its larger capacity. According to Clay Gambill of BNSF Logistics, GE also has a more reputable experience with transporting turbines to the US. The 12 MW Haliade-X has a hub height of 150m with a rotor diameter of 220 meters [49]. 42 turbines will be used to achieve a total wind farm size of 504 MW.

Using the JEDI offshore wind model to estimate the total cost of the wind farm, parameters specific to the Haliade-X were utilized in accordance with GE's turbine description and various news articles [49, 50, 51, 52, 53, 54]. The combined cost of the nacelle, blade, and tower components for 42 turbines totals $656 million [49]. Turbine components make up 46.6% of the total capital expenditure [49]. A local content percentage – the percent of material that is purchased locally – of 0% was determined for the turbine component costs, as they are manufactured in France [49]. However these components are subject a foreign import tax of 6.5 % which totals $50.4 million [55]. The installation of the turbines on the foundations costs an additional $25 million. The components, taxes accrued, and installation of the turbines sums to $731 million.

Foundation

To determine what type of foundation would work best for the site, VTexas researched current foundation types used or proposed for offshore wind farms. Current foundation types include the monopile, gravity, tripod, jacket, twisted jacket, and floating foundation types.

After initial research into site conditions, VTexas eliminated two foundation types: floating and gravity. This decision was based on an analysis using National Oceanic and Atmospheric Administration's Bathymetric Data Viewer that found water depths on site ranging from 10-30 meters [56]. Floating foundations in an area this shallow would not be economical since floating foundations are meant to be used in depths exceeding 50 meters [57]. The gravity base foundation was eliminated because of its environmental impact and disruption of the seafloor. The dredging process used to install the gravity foundations causes vibrations and general disruption of the seabed that can injure or displace marine life [58].

Eliminating these foundation types left four foundation types to consider: the monopile, jacket, twisted jacket, and tripod. The monopile foundation is the most common type of foundation used in existing offshore wind farms, accounting for 80% of installed capacity worldwide [59]. Monopiles are cylindrical steel structures driven into the seafloor over which the tower component of the turbine is installed [59]. The jacket and twisted jacket are both constructed using a lattice-truss structure of hollow steel tubes [58]. The traditional jacket foundation uses a square design with four footings while the twisted jacket uses three legs angled around a central column [59]. Finally, the tripod foundation consists of a large central cylindrical column supported by a steel tetrahedral space frame with three footings.

Several parameters were chosen to evaluate each option including cost, environmental impact, maximum installation depth, and the stability of the foundation during extreme weather events. The monopile foundation is the simplest and most established type of foundation, making it the most cost-effective [60]. Alternative designs have added complexity in their manufacturing or installation processes which increases their costs [58,59]. Foundations which could be installed at greater depths (traditional and twisted jacket) would be able to withstand greater wave motion and would therefore be more durable during extreme weather [59, 61]. A twisted jacket foundation was ultimately chosen for Marina de la Tierra.

Within the JEDI model, the only foundation types included for cost estimation are monopile and semi-submersible foundations. Therefore, additional research was required to obtain realistic cost estimates of the selected foundation type. On average, twisted jacket foundations in water depths similar to those off the coast of Galveston cost approximately 2% more than monopiles, equating to a total cost of $120 million for the fabrication and installation of the twisted jacket foundations for this project [26].

Site Preparation

The installation of turbine foundations and offshore substation requires significant seabed preparation. The top layers of sediment as well as boulders will be removed from the turbine site and cable pathways to provide a smooth, rigid surface for pile driving and cable installation [62, 63]. The average cost of dredging in Galveston is $3.80/cubic yard [64]. Site preparation including seabed leveling and scour protection totals $5 million [49].

Electric Infrastructure

For Marina de la Tierra, VTexas will be laying two types of submarine cables. The 55 km connection between the offshore substation and landfall will require two 220kV cables. Two export cables are being used instead of a single higher voltage cable to create redundancy in the system and allow the farm to continue operations if one of the cables is damaged or malfunctioning. Array cables connecting individual turbines to the offshore substation will consist of 66kV cables.

The farm will use radial cross-linked polyethylene (XLPE) cables – the current industry standard for high-voltage, alternating current applications [65]. These cables consist of three conductor cores operating in three different phases [65, 66]. The insulated core also contains an optical fiber cable to transmit data; these four cables are contained in a metal sheath to protect the system from mechanical damage [66, 67, 68]. The total cost of these cables including installation is $262 million [49].

The 26th Street substation owned by CenterPoint Energy was selected to connect power from Marina de la Tierra to the grid. This substation was selected due to the proprietary company's vast electrical infrastructure throughout Texas [69]. CenterPoint Energy's 26th Street substation has 345-kV and 138-kV transformers and transmission lines [70]. The installed infrastructure has the potential to receive the 504 MW electrical capacity of Marina de la Tierra. Once power is collected at Marina de la Tierra's offshore substation, the voltage is stepped up to 220-kV by a step-up transformer in order to increase the voltage which consequently allows electricity to travel faster, by Ohm's Law [71]. At the onshore substation, the voltage is then stepped down to 138-kV to avoid overloading cable capacities during transmission to businesses and homes in the area. The substation is 55 kilometers from the offshore interconnection substation and an additional 4 kilometers from landfall. Retired electrical substations were considered, but decided against due to the cost of critical upgrades.

Once electric cables make landfall, VTexas plans to exclusively use Galveston City public right-of-ways along primarily 39th street and Church Street. These streets run between areas of the city with different zoning (different colors) which would decrease impacts to a singular neighborhood [72,73] (Figure 4). The substation connection is pictured with a solid black box. Electrical infrastructure costs include the onshore substation, offshore substation, electric cables, and all installation totals $262 million [49].

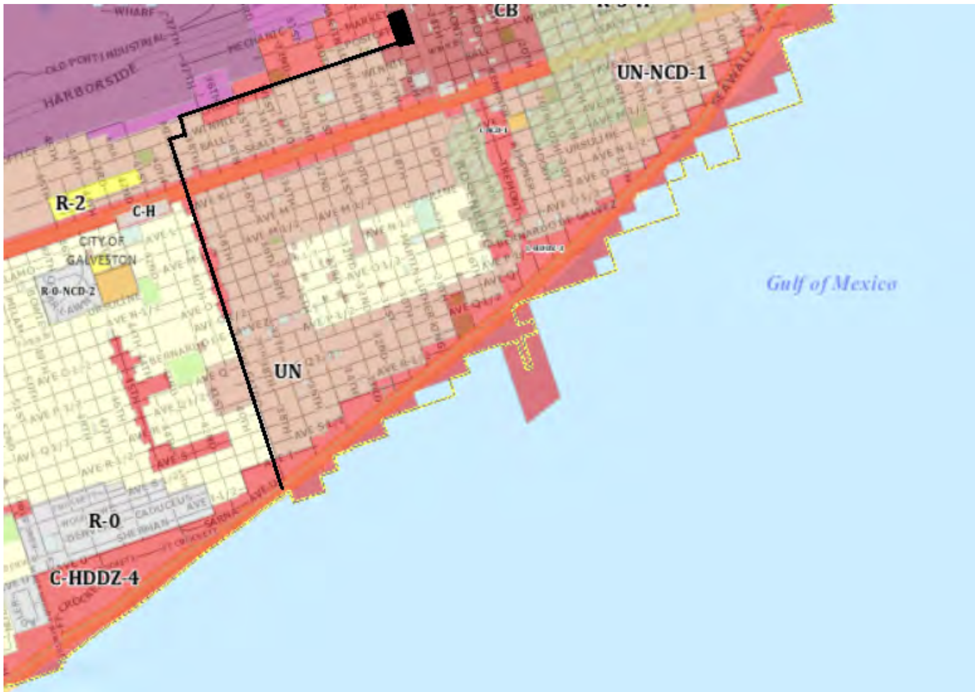

Figure 4: Onshore electric cabling path

Operation and Maintenance

For operation and maintenance of the farm, a 24/7 control room, helicopter storage and helipads (located within port space), training facilities, and a technician for each turbine is needed. Office space located at 4700 Broadway Avenue J in Galveston was chosen. The space provides 6,500 square feet at an expense of $2.10 million [74].

Operation costs of the wind farm focus primarily on maintenance. Through careful turbine selection and plans to conduct routine maintenance checks, larger maintenance expenses will ultimately be avoided. The selection of a twisted jacket foundation will ensure stability of turbines in harsh weather conditions and prevent damage [75]. A cost-effective strategy to minimize the need for corrective maintenance is to utilize sensor technology to monitor turbine operation, allowing technicians to predict turbine malfunctions [75]. Corrective maintenance is far more expensive than preventative measures, as the former repairs involve the costs of labor, spare parts, and reduced energy production due to turbines being fully inoperable during repairs [76]. Additionally, most problems encountered during corrective maintenance require additional parts for the wind turbines [76]. According to historical data, 12.1% of offshore wind turbines fail due to malfunctions within the generator. Similarly, a turbine's gearbox and blades are responsible for 7.6% and 6.2% of offshore wind turbine failures, respectively [77]. These failures deal mostly with repairs than replacement [77]. When isolating failures that require major replacements in parts, gearboxes and generators failures result in 0.154 and 0.095 failures per turbine per year, accounting for 95% of all major part replacements [77]. Due to this, VTexas plans to hold replacement gearboxes and generators on hand to minimize turbine downtime during repairs. This requires spare parts to be stored within 50 miles of the Port of Galveston to eliminate the possibility of delays [77]. For this reason, parts will be delivered to the Port of Galveston and transported to a warehouse facility in Hitchcock, TX. The renting costs of this 10,000 sq ft facility will cost $16 per square foot annually, which totals $4 million across the planned 20 years of operation [78]. The cost of operations and maintenance including office space, spare parts, long term storage, long term employees, and insurance sums to $63 million/year [49]. Over 20 years this totals $1.26 billion.

Ports

For the staging of construction materials for Marina de la Tierra, VTexas will be using the Port of Galveston. This port was chosen due to its proximity to the lease area and its extensive use for the current transportation of onshore wind turbine components [79]. Break Bulk ships transporting turbine components will unload with Metro Ports with nearby storage at gate 40. In meeting with Clay Gambill from BNSF Logistics to discuss the transportation and storage of its turbines, VTexas confirmed that it would not need a distribution outside of Metro Ports' storage, due to the farm's rate of construction. Costs were calculated based on data about the size of the Haliade-X and the various rates and fees that the Port of Galveston charges depending on the size and weight of the cargo. These calculations resulted in an expense of $3,700/turbine [52, 80, 81, 51 82, 83]. Demurrage fees – charged by the port for storage of cargo exceeding 15 days – will total $5,500/month [84]. In total, port fees over the construction phase will cost $610,000 [49].

Shipping/Transportation

VTexas will be using break bulk vessels to transport the turbines from GE manufacturing facilities in Saint-Nazaire, France to the port of Galveston, Texas. As a reference vessel, VTexas chose the Erna Oldendorff to plan the delivery of its 42 wind turbines [84]. The Erna Oldendorff has experience with transporting wind turbines and features a deadweight tonnage of 38,600 metric tonnes, which represents the maximum weight a ship can hold [84]. Each turbine will be transported as six individual components (two tower pieces, nacelle with hub, and three blades). The components will be stacked during transport; blades will be placed on shelves stacked three high [85]. Chartering a vessel is expected to cost $40,000/day with a carrying capacity of 3,000 20-foot containers [86]. The trip from Saint-Nazaire to Galveston is approximately 19 days, and the estimated weight of cargo for all components taken in one trip is 23,000 metric tonnes. The total cost of transportation is approximately $3.4 million [49].

Project Management

Project management costs include overhead costs and other soft costs like insurance. VTexas will purchase construction insurance and operations insurance equating to $12.9 million annually which protect against liability for accidents or mistakes made during the construction of the project [87, 88, 49]. Annual operations, management, and general administration costs given by JEDI are $1.71 million [49].

Total Costs

The total cost of the wind farm over the life span of 20 years is $2.87 billion (Figure 5) based on calculations made by NREL's JEDI model which changes made for the specificity of costs associated with Marina de la Tierra. For example, costs associated with transportation, taxes, leasing office space, port storage, permitting, and foundations were either adjusted or calculated by hand to be as accurate as possible[44, 45, 4, 46]. Port Costs and Project Management costs make up less than 0.1% of the total costs and are not pictured

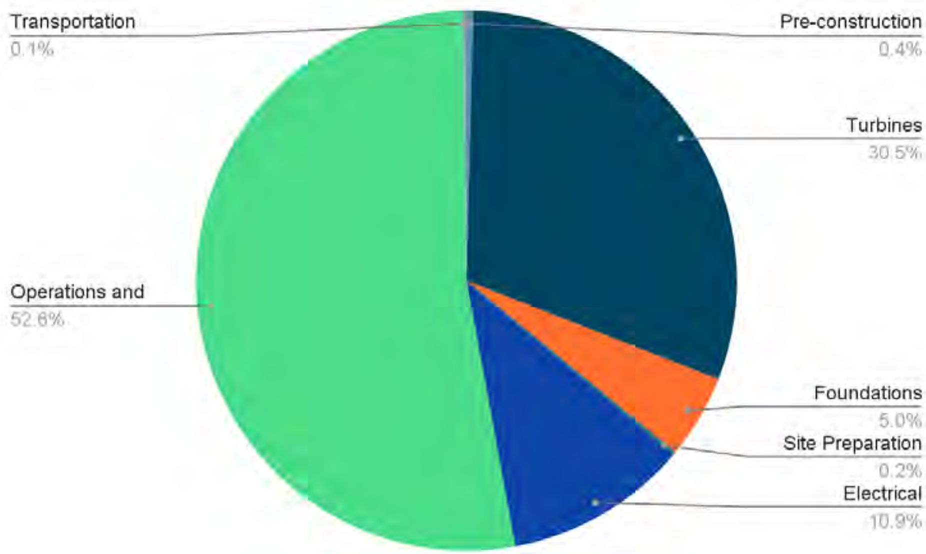

Figure 5: Cost Percentages

FINANCIAL ANALYSIS

As an energy producer within Texas, VTexas must collaborate with Transmission and Distribution Utilities, in order to connect to Texas' electricity grid. VTexas has chosen CenterPoint Energy to distribute produced energy within the ERCOT grid. CenterPoint Energy has committed to achieving net-zero carbon emissions by 2035 [89]. To do this, CenterPoint Energy plans to retire coal-fired generation plants and enter into several agreements with renewable energy projects. With this in mind, VTexas would make an excellent addition to CenterPoint Energy's existing partners, as the Marina de la Tierra would significantly aid CenterPoint Energy's push towards renewable energy. This collaboration is represented by a power purchase agreement, which is a contract between two parties where one party generates power and the other purchases it. A levelized power purchase agreement is a figure that is the basis of this agreement, declaring the price at which one party agrees to purchase energy from the other.

Investment Tax Credit

The Energy Investment Tax Credit (ITC) exists to incentivize the transition to renewable energy. This is achieved by a portion of eligible property expenses being exempt from tax by the federal government [90]. Currently, the ITC credit rate for offshore wind is 30% and will expire in 2025 [90].VTexas conducted the financial analysis under the assumption that the ITC will be extended through the construction of Marina de la Tierra. Texas does not have any state or regional incentives to increase investors in renewable energy [91].

System Advisor Model (SAM) and Levelized Cost of Energy

For the calculation of VTexas' financials, based on the wind resource within the firm's wind farm, System Advisor Model was used. SAM is developed by the National Renewable Energy Laboratory and allows users to calculate the Levelized Cost of Energy of a business model. Levelized Cost of Energy or LCOE is the average net present cost of electricity over the lifetime of the generator. With it, VTexas, and other energy producers, have a standardized measure to compare themselves to other firms.

Financing Plan

A majority of VTexas' expenses take place within the startup of the wind farm. Due to this, and the lack of production tax credits available in 2030 when construction is started, debt and equity financing is required to cover the high initial costs of VTexas' wind farm. Debt financing involves the borrowing of a third party's capital to fund business needs. Equity financing involves the partial sale of a company to an investor as another way to raise capital for businesses. To cover the high initial costs of the wind farm, VTexas will acquire multiple construction loans throughout its one-year construction period to cover the expense of the assembly and installation of the 42 turbines. Construction loans are short-term loans that provide capital for the construction costs of a project at a high-interest rate.

To combat high construction loan interest rates, VTexas will acquire an 18-year loan to extend the forecasted costs of construction through the duration of the project, resulting in a positive cash flow, following year 1. This loan, based on historical interest rates, will have an interest rate of 4% over its 18-year lifetime. Along with this, the loan will require an upfront fee that can make up 1% to 3% of the loan's principal value and debt closing costs of approximately $450,000 [23]. All in all, 80% of VTexas' financing will come from debt. Equity will make up 20% of VTexas' financing through capital from investors, as wind energy becomes more profitable. VTexas plans to advertise to individual investors to raise the equity capital needed to finance the project.

Cash Flow Model

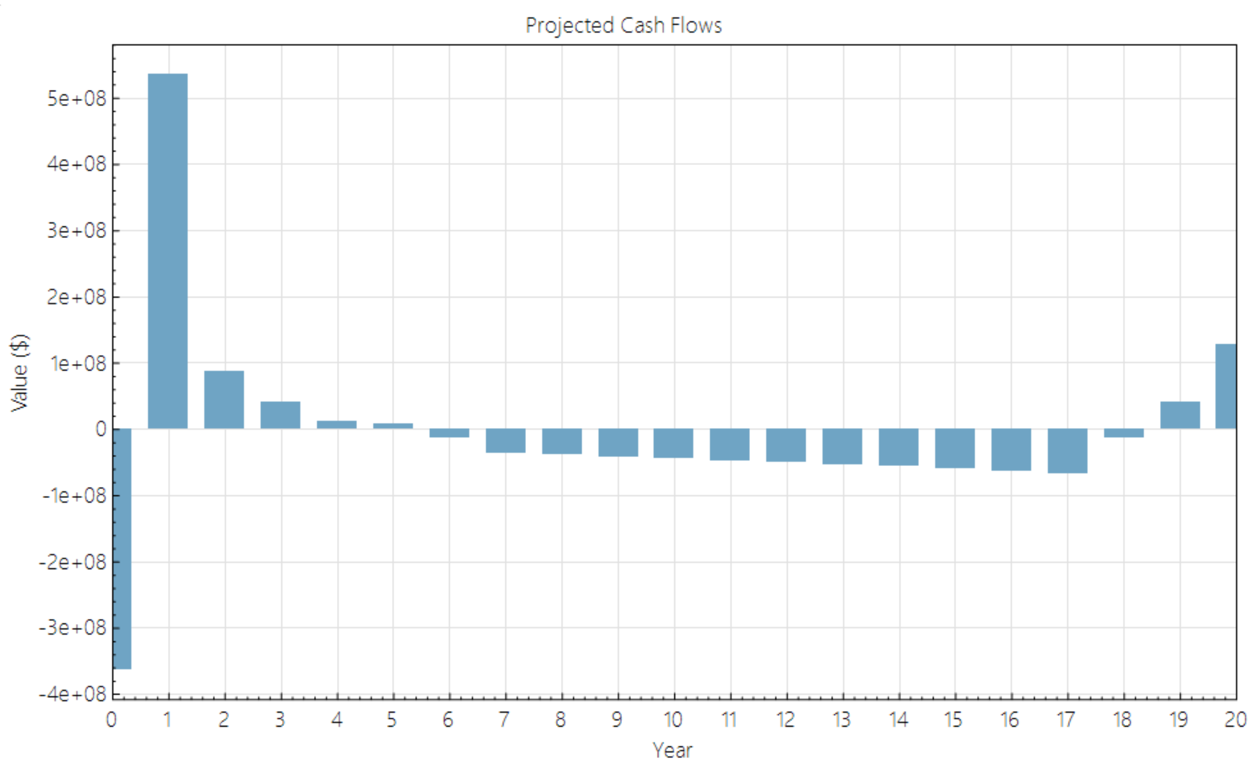

Figure 6: Projected Cash Flows

Through simulating the Marina de la Tierra wind farm in SAM, the LCOE, and Levelized Power Purchase Agreement prices were calculated as 9.64¢/kWh and 10.08¢/kWh, respectively. With plans of distributing energy in Texas, these figures were compared to the cost of electricity within the state. As of January, the average residential cost is 12.24¢/kWh in Texas, exceeding VTexas' LCOE and Levelized Power Purchase Agreement price [92]. While competitive with the state of Texas, VTexas' distribution with CenterPoint Electric would keep VTexas' energy within the southeast area of Texas. Due to its proximity to this area and VTexas' wind farm, electricity rates from the Galveston area were used as a benchmark for the Marina de la Tierra. Within that area, the lowest residential electricity rate is 11.8¢/kWh with an average rate of 14.4¢/kWh, which is favorable for VTexas, as its LCOE and Levelized Purchase Price Agreement are both less than the market rates [93]. The net present value of the wind farm is $67.3 million, which is promising for stakeholders, as a large positive net present value represents a profitable business plan. As for the net capital cost of the Marina de la Tierra, a cost of $1.81 billion was calculated, consisting of $362 million in equity and $1.45 billion in debt. These costs will be covered by the annual energy production of 1.55 billion kWh at the wind farm's initial capacity factor of 35.2%. VTexas anticipates a degradation value of 1.6% each year for the wind farm [94].

Model Iterations

A second iteration of the financial model was performed, using SAM, to determine the effects of a decrease in energy production. In this model, the permanent loss of two turbines would lead to a loss of 193 million kWh in the wind farm's first year's energy production alone, resulting in an LCOE of 10.01¢/kWh. This is 0.37¢/kWh higher than the previously estimated LCOE, which is disadvantageous for VTexas. However, this LCOE is still competitive compared to the local average electricity rate of 14.4¢/kWh, allowing for the Marina de la Tierra to operate, competitively, under capacity.

A third iteration of the financial model was performed under the assumption that VTexas would enter a partnership flip with debt. With this iteration, Marina de la Tierra would feature an investor NPV of $68.5 million, however, the developer's NPV over the project's life is a negative value of $95,900. These values were calculated, assuming all 42 turbines would operate at their capacity factor of 35.2% in year 1. Due to this slim margin, and negative net present value for VTexas, this would not be financially feasible.

AUCTION BID

The bid price is the maximum price that VTexas is willing to pay for the chosen lease blocks. This price is based on the cost of energy, as well as a cash flow analysis for the 20-year life of the project that takes the initial capital cost, annual operating expenses, net annual energy production, market conditions, financing plans, and incentives into account [95]. Based on market analysis, an acceptable maximum LCOE of 11¢/kWh was chosen and iterations were run in SAM to estimate the maximum possible least cost. VTexas's bid for all six required lease blocks is $87 million or $14.5 million per lease block.

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