UCLA Wind Project
Project Development Report
2022-2023 Collegiate Wind Competition
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1.0 Site Selection

1.1 Site Block

The Bruin Wind Farm (referenced as BWF going forward) has selected lease block ST90, depicted as the shaded grid square in Figure 1, as the location to develop our wind farm. ST90 lies in the northern-central area of the available lease blocks and minimizes overlap with undesirable siting factors, e.g shipping lanes, while maximizing desirable siting factors, e.g proximity to land and port infrastructure. To select a site, relevant factors were partitioned into two groups: absolute factors which could not be ignored, e.g overlap with commercial shipping lanes, and non-absolute factors, which could be ranked and treated collectively. Other factors considered but ultimately not relevant to the site selection process as they did not overlap with the available site blocks include avoiding Weather Radar Impact Zones and the revenue sharing border established by Section 8(g) of the Outer Continental Shelf Lands Act, which entitles states to a portion of wind farm revenue when a federal lease is within three miles of the Submerged Lands Act (SLA) boundary [1]. After obtaining data for all these factors from [1] and overlaying them onto a map of the available lease blocks, ST90 was deemed the most optimal site.

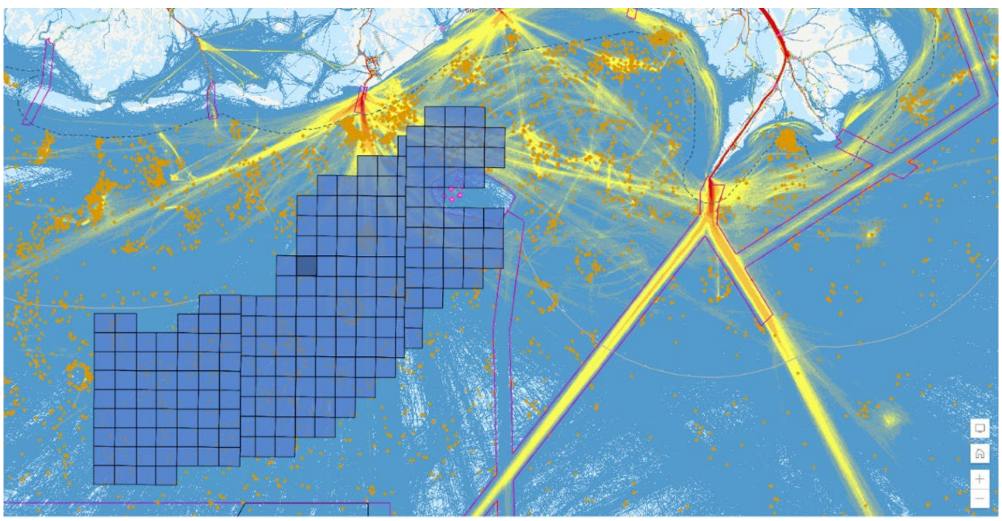

Figure 1: Map of lease blocks overlaid on top of shipping lanes (pink outlines in water), AIS vessel traffic in 2021 (blue and yellow lines in water), and oil rigs (orange points). Grid squares are possible lease blocks, the shaded square is our selected block.

1.2 Physical Characteristics

For our site block, the bathymetry in the area is relatively consistent and less than 100 meters deep as we are still on the continental shelf and in a shallow area [2]. The sediment in this area, specifically the loose sediments on the ocean floor, are reflective of fine sandy mud and muddy sand with inconsequential amounts of gravel that would not affect our foundations [2]. Fine sandy mud is defined as greater than 20 percent silt and finer grains with higher clay content while muddy sand is classified as having less than 50 percent sand. Our wind resource would be coming from the south-east direction from the prevailing trade winds which have minimal fluctuations in direction due to seasonality and the nature of trade winds [3]. The area also has an average ambient wind speed of around 7 meters per second [3]. The overall mean wave power density is less than 20 meters [2]. As for hurricanes, our chosen lease block will encounter all levels of hurricanes (1 -5) and will need to withstand at least wind speeds of 64 knots as there has been a 64-knot occurrence every 8 years or so [2]. The nearest port is Port Fourchon and is 1300 acres of land with 83,000 feet (about 25.3 km) of linear waterfront property and is one of the premier oil and gas seaports. This port is the nation's only deep-water port which can allow large supertankers named Louisiana Offshore Oil Port or LOOP ("Port Fourchon") [4].

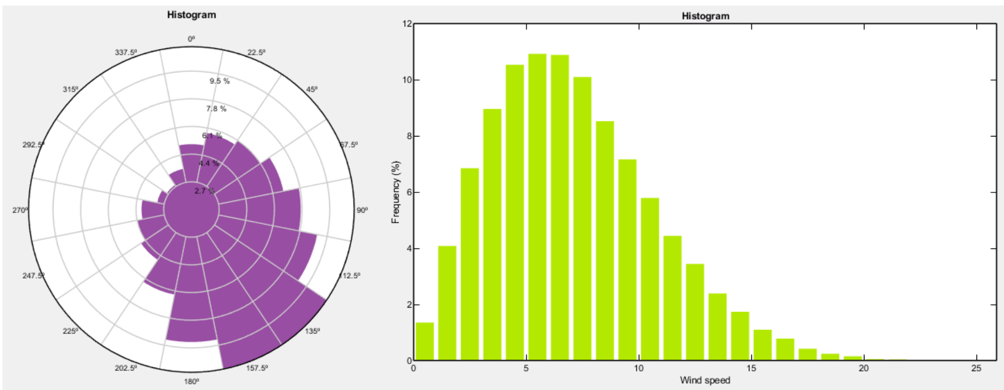

Figure 2: Furow Analysis of Wind Resource [3]

1.3 Ocean Activities

After evaluating the restricted areas, former defense sites and military operating areas we concluded that there was no overlap in our given lease block. There are permanently abandoned oil and gas deposits near our lease block but there would be no overlap or interference. In terms of all vessel traffic, as of 2021 there was a maximum of 100 vessels in our lease block with the average being less than 25 vessels [5]. Other than these vessels, our lease block is clear of shipping lanes, submarine cable lines, and any wrecks and obstructions.

2.0 Finalized Site Design

2.1 Wind Turbine

After reviewing both the available wind turbines to choose from and reports from previous years, we will be deploying an array of 26 Vestas V164-8 MW turbines to our chosen site block, with a total installed capacity of 208 MW. Our turbine was chosen due to its high capacity, well documented track record of use across the world, and the large amount of public data available for this and other 8 MW turbines. While there are larger capacity turbines available, the lack of public data and studies on high-capacity turbines will lead to inaccurate estimations and data. Additionally, the choice of a smaller turbine was chosen due to the wind resource available, as the smaller turbine size allowed us to increase capacity factor and reduce costs. This turbine has a cut-in speed of 4 m/s, a rated speed of 13 m/s, a cut-out speed of 25 m/s, and ability to withstand up to 50 m/s, which is an important design choice given that the Port Fourchon area has a large number of hurricanes [6]. This turbine has a rated power of 8 Megawatts with a blade diameter of 164 meters, and hub height dependent on the site [7] [6]. Due to the wind resource available in the lease area, we decided to choose a hub height of 150 meters to reach the larger wind resource available at higher altitudes. A summary of turbine characteristics is provided below.

Table 1: Selected Turbine Characteristics

Vestas 164-8 Turbine					
Cut in Speed	**Rated Speed**	**Cut out Speed**	**Rated Power**	**Rotor Diameter**	**Hub Height**
4 m/s	13 m/s	25 m/s	8 MW	164 m	150 M

With our turbine chosen, we moved on to designing our wind farm layout. We decided to choose a value of 26 turbines to fit into our lease area. This number was chosen to comfortably fit as many turbines as possible within our given lease area and given that we have chosen a turbine with a large diameter, allowing each turbine adequate spacing in order to minimize loss. Using Furow, we determined the spacing and angle of the rows in order to minimize wake losses during operation, shown below in figure 4.

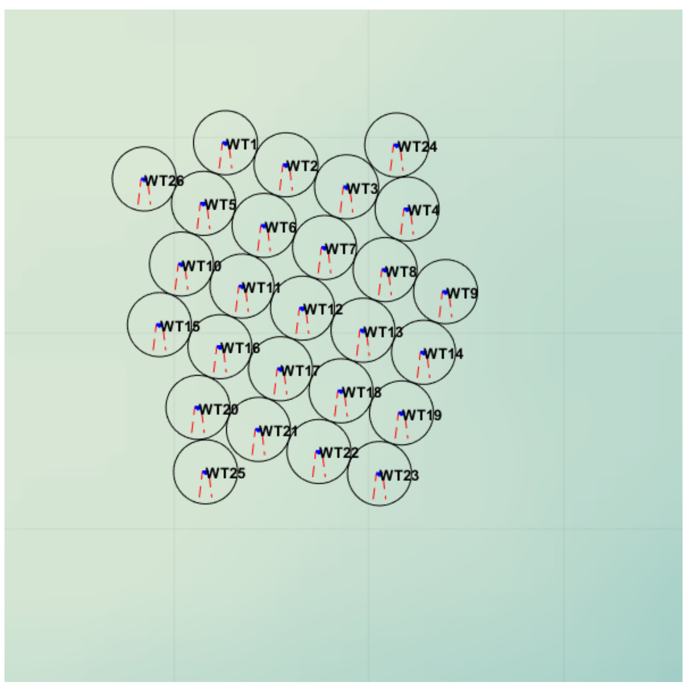

Figure 3: Wind Farm Layout

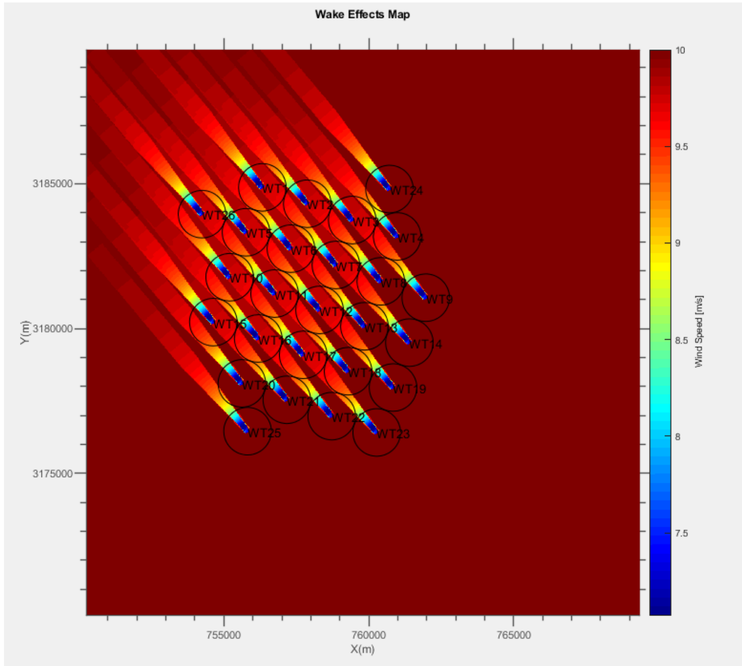

Figure 4: Analysis of Wake effects with angle of wind set at 140 degrees

2.2 Foundation Type

Our team then went on to pick our foundation type. It was important to pick a foundation that could withstand the strong vertical loads of the wind turbine weight, as well as the strong horizontal loads coming from ocean currents, strong waves, and hurricane conditions that are prevalent in the area. Additionally, within our decision we wanted to aim to minimize the effects we had on the local marine life, as both the construction and operation of the wind turbine strongly impact the local ecology. We then set out to research the various types of offshore turbine foundations, drawing from both online sources and past CWC team reports. After taking all of our design factors into account, we decided to pick a jacket foundation type for our proposed wind farm. Jacket foundations are used in the majority of current and proposed offshore wind projects, so there is a known effectiveness of this variant [8]. Jacket foundations are also one of the more economically sound options for foundations, as they take advantage of simpler manufacturing techniques, and the installation technique is simpler for less chance of complications. The soil type in our chosen lease area are muddy sand and other denser soil types, which is perfect for a jacket foundation installation [8]. Additionally, when considering the ecological impact, jacket foundations are easily the best choice. The other fixed-base foundation types: gravity-based, monopile, and tripod, all have significant marine life impact, as both the installation and design of the foundation displaces and disrupts the local ecosystem in a significant manner. By contrast, since the jacket foundation type consists of a lattice structure of smaller poles, the installation requires less displacement of local marine life, and the larger surface area of the lattice can allow for the creation of an artificial reef, where native marine life can establish new habitats and homes [8]. Finally, jacket foundation types can reach larger depths than other foundation types, which is important for deeper offshore projects, as well as being able to withstand larger horizontal forces without breaking or deforming, which will be much needed in the hurricane prone area that our block resides in.

2.3 Interconnection Site and Transmission Plan

Given the location of our site block, the options for transmission and grid connection are limited to the Port Fourchon area, as setting up transmission further would be very costly. Thankfully, Port Fourchon is a large industrial port, and the primary electrical grid company in the southern Louisiana area, Entergy, is dedicated to bolstering its transmission network in the area. Entergy is building a 21 mile, 115 kV transmission line running along highway 1 in southern Louisiana, bolstering their support and access to the Port Fourchon infrastructure [9]. Utilizing this, since our site block lies roughly 15.5 miles offshore the Port Fourchon area, we will be choosing our interconnection site as Port Fourchon, as shown below in Figure 5 [5]. Our wind turbines will use high-voltage seabed transmission cables to transmit power to an offshore substation near the farm, which will step up the voltage before moving the power along undersea cables to our onshore substation, where it will then connect into the existing Entergy systems, transmitting our power along 115 kV transmission infrastructure to millions of customers. This strategy of interconnecting substations is the industry standard and minimizes the power loss from transmission. Importantly, Port Fourchon lies about 60 miles away from New Orleans, so our transmission plan will also allow us to deliver power to this significant market.

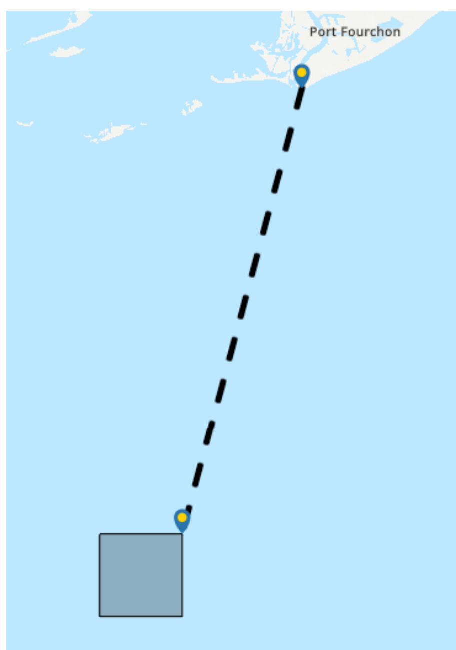

Figure 5: Interconnection Plan to Port Furchon

2.4 O&M Maintenance Ports and Vessels

When considering what port we will access to ship our material and vessels out of, the choice was fairly simple for our chosen lease block. Given that Port Fourchon is one of the largest ports in the United States for oil imports and distribution, much of the infrastructure needed will already be there. This will include infrastructure to load our operation vessels, as well as the necessary harbor depth and width to accommodate our vessels [4]. Port infrastructure for offshore wind farm construction is important, as structural conditions need to be satisfied in order to handle the construction, storage, and movement of wind turbine blades, towers, and components. However, given that Port Fourchon is a bustling industrial port, and is capable of accommodating dozens of oil tankers daily, we have no concerns about whether this port will fit our needs.

Offshore wind turbine installation and operation require specific vessels to be utilized and chartered. For instance, an offshore wind turbine installation vessel needs the ability to not only hold multiple turbine towers and blades, but often have some form of jacking mechanism in order to reach the proper heights to install blades and turbine components. With these factors in mind and researching available options, for surveying and installation we will be chartering the Dominion Energy Charybdis vessel, a new vessel aiming to be completed by 2023 . This installation vessel can carry and install several offshore wind turbines in a single trip, alongside a stable working platform regardless of ocean conditions. In addition to the capabilities of this vessel, this vessel will also be Jones-Act compliant, allowing us to save money in the transportation of our components and vessels [10]. For our field development vessel, we will be choosing the Triumph Subsea Services FDV Chronos vessel, projected to be available in 2023 as well. This FDV vessel is capable of all necessary subsea construction tasks, and will be running off a hybrid engine, allowing our farm development to be more sustainable [11]. For our O&M procedures, we will be utilizing the Ulstein SX195, which has accommodation for up to 120 personnel, a record of excellent station-keeping capabilities, and low fuel consumption [12].

2.5 Sensitive species and Environmental Concerns

As for wildlife in the area, the blacktip shark, blacknose shark, various reef fish, and brown and pink shrimp live in the area. None of these species are protected under Endangered Species Act, however the blacktip and blacknose shark are “near threatened” so their population and our potential impacts would have to be monitored. The endangered species of the Gulf of Mexico, the gulf sturgeon, staghorn and elkhorn corals and the small tooth sawfish, are not in our lease block but potential impacts should still be monitored to make sure there would be no negative impacts on their population [2]. The Gulf of Mexico, including our lease block, is also under the jurisdiction of the Marine Debris Research, Prevention and Reduction Act which would monitor us to make sure that no marine debris occurs during construction and development with our wind farm.

3.0 Financial Analysis

3.1 Capital Expenditures and O&M Costs

Capital expenditures for the BWF are summarized in table 1 below. Our estimates were found and determined through industry research and governmental market reports. Our turbine costs were estimated using information from our manufacturer, Vestas, and their recent activity [13]. Information on the rest of the capital expenditure breakdown came from both the tools available in the System Advisory Model (SAM) and the NREL Cost of Wind Energy Review [14, 15]. These costs may decrease in the future as our project comes online, as industry trends show that costs for offshore wind farms are quickly decreasing as deployment and adoption increases [16].

Table 2: Capital Expenditure Breakdown

Cost	Value ($/kW)	Value ($)	Percentage of total
Turbine	$1,068.00	$222,144,000.00	30.87%
Development and Project Management	$91.00	$18,928,000.00	2.63%
Substructure and Foundation	$496.00	$103,168,000.00	14.34%
Electrical Infrastructure	$693.00	$144,144,000.00	20.03%
Assembly and Installation	$408.00	$84,864,000.00	11.79%
Soft Costs	$704.00	$146,432,000.00	20.35%
Totals	$3,460.00	$719,680,000.00	100.00%

Operation and Maintenance costs were determined to be set for 60 $/kw-year, for a total of $12.5 million $/year. This value was determined similarly by examining recent market trends for similarly sized wind farms and how O&M costs have evolved over time [16]. Just like with the change in capital expenditures, the cost of O&M for offshore wind show a noticeable trend downwards as economies of scale take effect. In our simulations, we set an escalation rate of roughly 2.3% in order to account for inflation as our project ages.

3.2 **Market Conditions**

BWF connects to the bulk power grid in Port Fourchon and will correspondingly sell its electricity in the centrally dispatched wholesale markets operated by MISO, the Midcontinent Independent System Operator. UCLA will participate in two of the four markets [17] that MISO operates: the Real-Time (RT) Energy Market, which balances energy supply and demand on five-minute intervals, and the Day-Ahead (DAH) Market, which determines optimal unit commitment for the following day.[1]

The median annual average wholesale electricity price across all nodes in MISO in 2022 was 61.8 (2022$)/MWh with a 10th percentile price of 38.9 and 90th percentile of 68.6 $/MWh. [18]. As seen in Figure 6, these prices are significantly higher than the market norm in previous years and from 2014 – 2020 the median price across the ISO trended downward but remained in a comparatively small range of 22.6 - 43.7 $/MWh. Moreover, from 2015 - 2020 the annual median price never differed from the following year by more than 6 $/MWh. Nodes near Port Fourchon followed the ISO-wide trends with prices trending downwards from 2014 - 2020 but spiking in 2021 and 2022 (Figure 6).

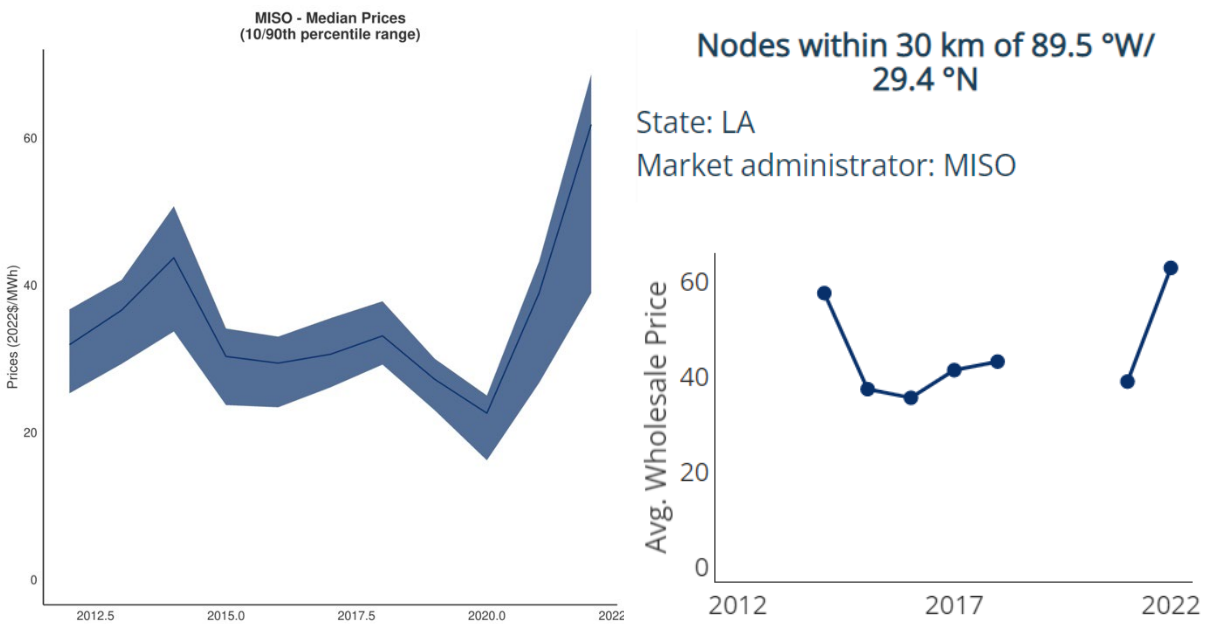

Figure 6: (Left) Average wholesale electricity prices across all nodes in MISO by year. Center line plots the median of average annual prices by node and the blue boundary marks the 10th and 90th percentiles of those annual prices. (Right) Average annual electricity price for all nodes within 30 km of 89.5 °W/ 29.4°N, the closest region in our data source to Port Fourchon. Port Fourchon is ~75 km southeast of this plotted data's centroid.

The increases in wholesale electricity prices in MISO in recent years have been driven by rising natural gas and increased capacity prices [19]. In MISO's 2022/23 Planning Resource Auction, capacity prices in northern and central zones were 236.66 $/MW-day, up from 5 $/MW-day in 2021/22. In southern zones, including Local Resource Zone (LRZ) 9 wherein Port

[1] MISO also operates a Capacity Market and a Financial Transmission Rights (FTR) and Auction Revenue Rights (ARR) Market. The Capacity Market is discussed later and UCLA may find a place for it in future operation plans. Similarly, UCLA could derive value from FTRs, e.g., by implementing them to hedge against increased congestion cost volatility due to future offshore wind build-out off the coast of Louisiana. However, the market awareness and analytical experience required to take advantage of the FTR and ARR market is deemed beyond the current capacity of UCLA staff.

Fourchon is located, capacity prices were 2.88 $/MW-day, up from 0.01 $/MW-day in 2021/22 [20, 21, 22]. Coal and oil were the majority of cleared capacity in 2022/23 but scheduled retirements for half of MISO's coal fleet by 2030 provide an opportunity for new market participants in the future [23][ee]. Moreover, developments like the Louisiana Wind Energy Hub at University of New Orleans [24] and the Shell Gulf Wind Technology Accelerator [25] indicate preparations for an offshore wind build-out in Louisiana that could take advantage of these capacity markets.

In 2022, the average LCOE for commercial fixed-bottom offshore wind was 84 $/MWh with a range of 61 – 116 $/MWh, reflecting differences in location, technology, site characteristics, and estimation methodology [16]. Offshore wind LCOE's are predicted to fall in the next decade, lying in a range of 54 – 97 $/MWh for plants with Commercial Online Dates (CODs) in 2025 and 42 – 72 $/MWh in 2030. Similarly, the average global strike prices for fixed-bottom offshore wind are predicted to decrease in coming years. For fixed-bottom offshore US plants with CODs between 2022 and 2025, levelized power purchase agreement (PPA) and renewable energy certificate (REC) prices range between 75 –103 $/MWh with lower capacity projects having higher prices [16]. In contrast to decreasing PPA prices for offshore wind, average MISO PPA prices[2] for land-based wind projects have trended upwards in the past years, as seem in Figure X [26].

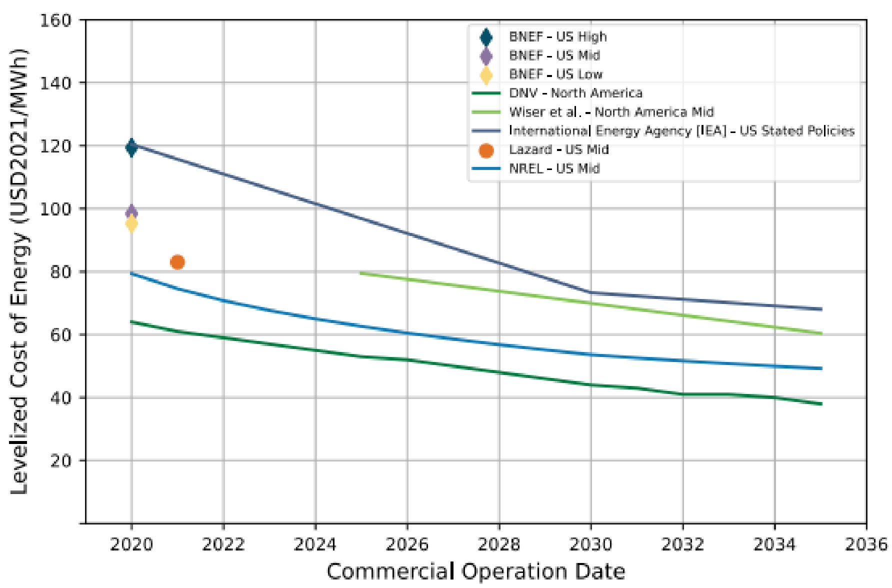

Figure 7: LCOE estimates for fixed-bottom offshore wind energy in the US from the Offshore Wind Market Report: 2022 Edition [16]

[2] Technically, we refer not to individual PPA prices but to LevelTen's P25 Price Index. This index tracks the average 25th percentile of PPA prices in each of the seven large wholesale markets in the US. Note that the tracked PPA prices are based on prices that developers offer, not transacted prices. Consequently, the index is likely biased high compared to trends in transacted PPA prices. A free Executive Summary of the report is available for download from the LevelTen website: https://www.leveltenenergy.com/ppa.

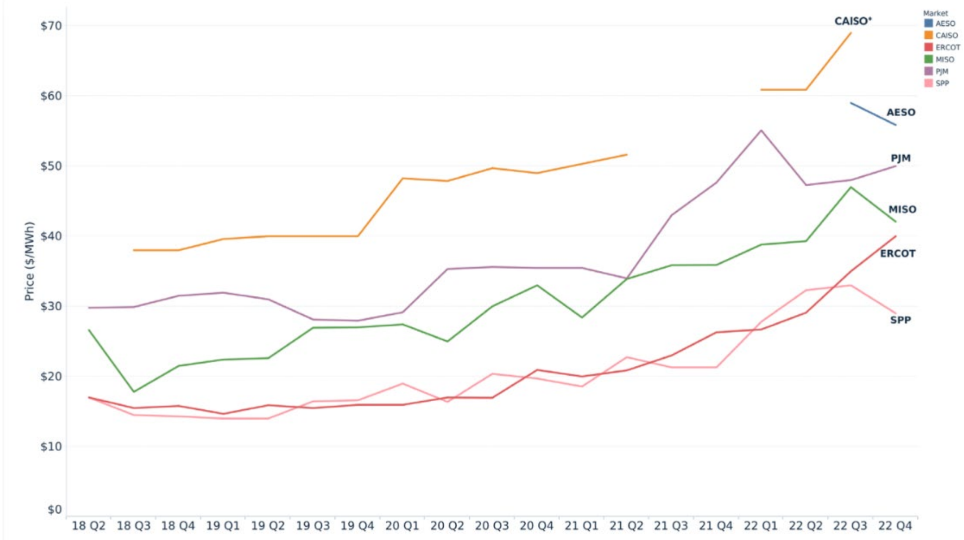

Figure 8: Wind PPA prices by year and wholesale market at measured by LevelTen's P25 index. [26]

3.3 Power Purchase Agreement (PPA)

BWF will sign a 20-year virtual (also known as 'financial' or 'synthetic') PPA with Shell Global at an initial strike price of 0.08 $/kWh and annual escalation rate of 3%. The stability of having a guaranteed off-taker through a PPA was deemed critical to attracting investors and obtaining financing. Shell's Long-Term credit ratings of A+ from S&P and Aa2 from Moody's make it a desirable corporate partner [27]. Moreover, Shell owns or part-owns 2.2 GW of offshore wind capacity worldwide, including two US plants on the East Coast, and has significant experience managing and participating in PPAs [28]. This will decrease contract negotiation length which will speed up financing. As interconnection queues across all ISOs in the US, MISO included, have ballooned in recent years, speeding up financing is a nontrivial factor to ensuring BWF gets built [29, 30]. Also, Shell has operated in Louisiana for over 60 years and has an established place in the local industry [25]. Consequently, working with them will provide name recognition and can hopefully be part of a new chapter in the oil industry's relationship with Louisiana communities that is not based on environmental destruction and local health tragedies, e.g., those mentioned in [31, 32, 33].

A PPA between BWF and Shell provides value to Shell as well as to BWF. First, a PPA with BWF will serve as a hedge for Shell against electricity price fluctuations.[3] Second, Shell has publicly indicated that offshore wind is one of its "key growth area[s]" and being an early participant in offshore wind in Louisiana is in line with this goal [34]. Furthermore, oil is a fossil-fuel and the burning of fossil-fuels needs to be curtailed rapidly and drastically in the coming years to avoid many significant and irreversible impacts to the environment [35]. By signing a PPA with BWF, Shell will move to diversify its income and business base from oil to

[3] Physical PPAs are generally better hedges against electricity price volatility than virtual PPAs as their settlement location is typically close to the off-taker. However, Shell has operations in Louisiana, e.g., Shell's Convent Refinery between New Orleans and Baton Rouge, so a virtual PPA should still provide hedging capacity.

clean, renewable energy, in line with the aforementioned urgency of reducing fossil-fuel consumption.

3.4 Incentives

There are no identifiable state incentives, tax-based or otherwise, offered to offshore wind developers in Louisiana. Consequently, the majority of tax incentives will be from federal sources. To this end, the primary tax incentives that BWF qualifies for are the Clean Energy Investment Tax Credit (ITC) and Clean Energy Production Tax Credit (PTC) contained in the Inflation Reduction Act. The ITC provides a Base Credit of 6% the qualified investment and the PTC provides a Base Credit of 0.3 cents/kW (inflation adjusted). Both credits can increase by five times by BWF meeting Davis-Bacon prevailing wage and registered apprenticeship requirements. Furthermore, the credits can increase by 10 percentage points by meeting federally specified "domestic content requirements for steel, iron, and manufactured products," something that BWF plans to do [36]. In addition to these two tax incentives, the Department of Energy Loan Programs Office (LPO) can provide "loan guarantees for Innovative Clean Energy Projects under the Title 17 Innovative Clean Energy Loan Guarantee Program" [37]. However, technologies eligible for the Title 17 loan must be "innovative" and not be "commercial technology," defined to be "technology that has been installed in and is being used in three or more commercial projects in the United States in the same general application as in the proposed project," [38]. Consequently, it is unlikely that BWF could qualify for a Title 17 loan.

3.5 Investor Partnership

The BWF has secured financing for our proposed farm. The estimated capital cost of $720 million USD will be funded with a combination of tax equity and debt. The BWF will be partnering with JP Morgan to secure our tax equity, given that JP Morgan has shown significant interest and investment in the offshore wind market in Europe and the United States [39]

Our tax equity will be structured as a partnership flip with our investor, JP Morgan. BWF has secured a 95/5 tax flip and a 20/1 cash flip. With this agreement, until year 4 when our investor's desired IRR is reached, they will claim 95% of the tax benefits from the project and 20% of the project cash. After the flip in year 4, they will continue to claim 5% of the tax benefits and 1% of the project cash. This structure is beneficial to the investor because our main incentive for this project, the investment tax credit (ITC), takes affect in year 1 of our project, so JP Morgan is able to claim this tax benefit early on, decreasing the time to reach our flip year. For the developer, BWF will be claiming 5% of tax benefits and 80% of project cash until year 4, where we will claim 95% of tax benefits and 99% of project cash until the end of project life.

The rest of the financing will come from project debt, where we target a debt service coverage ratio (DSCR) of 1.4. This debt will have an upfront fee of 2.75% with an annual interest rate of 4% paid over the debt's life span. Based on industry trends we feel that these are fair terms for our project debt.

3.6 Risks

Risks to the successful construction and operation of BWF broadly fall into three categories: weather-related, political, and economic. The weather-related risks primarily pertain to Louisiana's infamous hurricane season which may bring delays in construction or significant damage and repair costs during operation [40].

Among political risks, there are both federal and state level risks. As BWF will rely on ITC and PTC tax breaks to attract financing and to simply make the project profitable, there is the constant risk that Congress will decrease the magnitude or limit access to these breaks. However, the IRA guarantees the incentives for eight years to plants with CODs in 2025 or later which is a positive sign [36]. In addition to repealing tax incentives, permitting and interconnection have been brought up in numerous recent political conversations [41, 42]. While many current conversations focus on speeding up permitting and interconnection, there is always a clear and present risk of political gridlock preventing these improvements from continuing. These permitting and regulatory risks extend to the state level, for instance when North Carolina lawmakers called for a "10-year moratorium on the issuance of any required state permits for offshore wind-power projects within state waters" [43].

The primary economic risk to BWF is uncertainty in Cap-Ex. The process of bidding on a lease block often takes place years before construction of a wind farm is completed. As such, the initial financial estimates that advise the bid price can vary significantly from the prices during production. For instance, if the price of steel goes up between the time that the BWF makes its bid and before it begins construction, the Cap-Ex estimates used to inform the bid price will be biased lower in comparison to their realized value [44]. An additional risk to BWF is the scarcity of Jones-Act compliant wind turbine installation vessels in the United States. BWF plans to use Dominion Energy's Charybdis vessel for installation but if for some reason that vessel is unavailable, the impact would be significant if not fatal to the construction of BWF.

4.0 Optimization

One of the largest optimization changes that we made was the changing of our turbine choice. During the preliminary design report, we initially reported that we would be choosing the Vestas V164-9.5 MW turbine as our deployed turbine, due to its large capacity. After running several rounds of SAM software iteration, we examined the wind resource and turbine choice, and found that the lower capacity turbine was a much better choice for our wind farm. Since the 8 MW turbine has a lower cut in speed than the 9.5 MW turbine, the 8 MW power curve performs better at lower wind speeds, and since the wind resource does not reach the rated wind speed very often, the smaller turbine was the best choice. When we made this switch, it allowed our capacity factor to increase to 29.9% [14], and since our costs determined by nameplate capacity, led to our overall costs significantly dropping. With these lower costs and increased profit margins, we were able to reduce our required PPA price to meet targeted IRR and NPV values, creating a more financially feasible project.

Within our financial parameters, our main optimization process was with regards to our financial parameters. This included iterating through values for our equity share, share of project cash, and share of tax benefits, with our result variables as: price of PPA to achieve a set flip year and IRR, developer and investor IRR at end of project, and developer and investor NPV at end of project. These iterations were done using both manually changing values, but also using the SAM parametric feature to quickly iterate through hundreds of combinations to achieve our best results. Our optimization process was run to maximize values of IRR and NPV while minimizing the PPA price to keep our offer competitive and financially feasible.

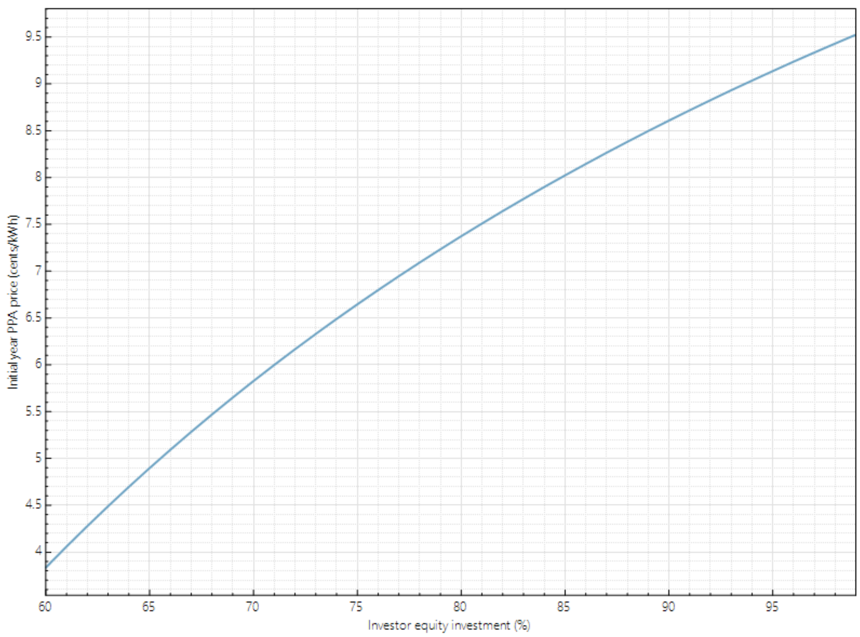

Figure 9: SAM Parametric output showcasing investor equity (%) vs. Initial year PPA Price

5.0 Bid Price

After considering our capital costs and land available to use for wind farm development, the BWF has decided to put forth an initial bid of $14 Million USD for site block ST90 in the Port Furchon land lease blocks. This bid price amounts to for roughly 2% of our net capital costs, or equal to an amount of 67 $/KW.

BWF determined this number as a feasible bid price by examining recent BOEM offshore auction prices in the United States. As of 2018 in Massachusetts, the bid price for a lease sat at 56 $/kW, or 2% of capital costs [16]. Similar auctions have also taken place in New York and New Jersey, but the costs of these leases were abnormally high, likely due to the popularity of the area and its land. When considering a siting area in the gulf of Mexico, a relatively untapped potential for offshore wind, we feel that this high price will not apply, and so our estimate is accurate.

Finally, this bid price is only an initial bid, and since at our current financial conditions we are set to have significant profit margins and NPV, BWF is willing to increase our bid price if needed to secure our site block.

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