Project Development Report

Johns Hopkins University Collegiate Wind Competition 2022

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Executive Summary

The [Johns] Hopkins Student Wind Energy Team (hereafter, referred to as "HSWET," the "developer," or the "sponsor") has developed a report for a 370.5 MW wind farm off the coast of Galveston, Texas. After extensive research into the siting characteristics and financials for the region, HSWET has created a development plan for an offshore wind project featuring 39 Vestas Turbines. Siting aspects of the project were visualized using Furow (by Solute) while the financial analysis for the project was done using the System Advisory Model (hereafter, referred to as "SAM"). The project offers attractive economics to both the sponsor equity and tax equity investor with 9.94% and 7.65% returns, respectively, along with a high-capacity factor of 40.0% and competitive LCOE of 53.5$/mWh.

The wind farm is attractive to investors for various reasons, including HSWET's optimized layout and energy transmission plan, attention to environmental risks. HSWET's capital stack contains tax equity, sponsor equity, and back-leveraged loans with refinancing options, and cash flows are 100% guaranteed through an as generated bus bar PPA with an investment-grade oil and gas company.

1.0 Site Analysis

To select a site within the auction area, HSWET analyzed ocean and atmospheric conditions and the ocean activities. The wind speeds across the auction area are uniform, averaging approximately 7 m/s.[1] The water depth ranges from 12 to 27 meters, with significant wave height ranging from 1 to 3 meters and high threat of hurricanes throughout the auction area.[2] The composition of the ocean floor is muddy sand, and geotechnical data indicates that there are no significant areas of rock or gravel in the seabed of the proposed lease region.[3]

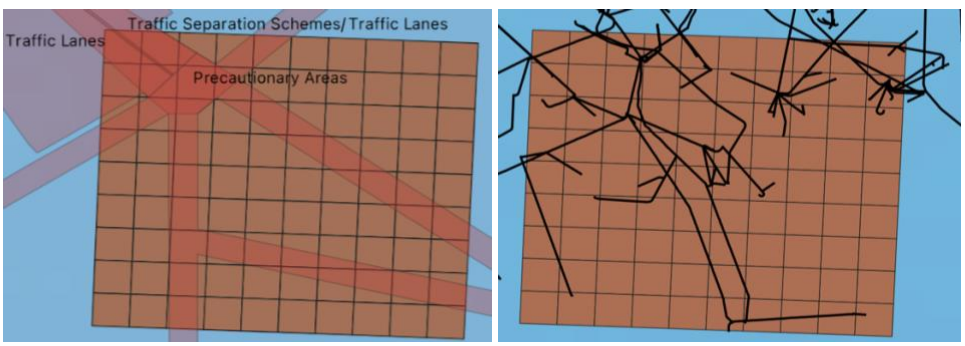

Figure 1A-B: GIS images indicating shipping lane restrictions (red) in the auction area (brown) and oil pipelines (black) present in the auction area.

It is also important to consider various commercial and government-sponsored marine activities that can impact the choice of a lease area. These include commercial shipping lanes which are federally designated areas where construction is not allowed. Per Title 33, Chapter I, Subchapter P, Part 166 of the Code of Federal Regulations, artificial structures are prohibited within these areas. Several of these lanes cross through the auction area as seen in **Figure 1A**, reducing allowable regions.[4]

Another activity to be aware of is oil drilling within the lease area. There are several existing oil extraction platforms in the lease area, concentrated around the northern border. Shown in **Figure 1B**, several oil pipelines exist on the sea floor within the proposed area. These pipelines pose risks to a potential wind farm due to damage and leakage. Though these do not prevent siting within a lease block, they do require that turbines not be placed on top of pipes and that pipes are avoided during construction. Even damaging unused pipes can lead to residual oil spills into the ocean and surrounding environment, affecting aquatic life and resources.[5] However, due to the almost universal preponderance of these pipelines, this is a risk that must be assumed.

Finally, within the auction area, HSWET must consider any military operations that may occur. There are no Coast Guard or Naval Base operations that prevent the use of the proposed auction area. The area is under jurisdiction of the U.S. Coast Guard Sector Houston-Galveston and there are no waters within the area designated for security or military purposes.[6]

Based on this characterization of the auction area, HSWET will bid on blocks 235 and 236. HSWET will follow the Submerged Lands Act and leasing process through the Department of Interior and Bureau of Ocean Energy Management (BOEM).[7] These blocks are located on the southwest side of the auction area, avoiding the federally marked shipping lanes. This side of the auction area also exhibits shallower waters and is located close to the Port of Galveston and Port Houston for construction and operation access. This site location provides nearby options for energy transmission, reducing the distance that energy will need to travel. Wind speeds and the composition of the ocean floor are relatively uniform, so these were not key factors in selecting these lease blocks. A key downside of these lease blocks is that a couple of oil pipelines pass through the blocks. While this increases the risks associated with this project, the only way to avoid oil pipelines is by siting further to the southeast which would increase transmission distance, access distance, and water depths, all of which are unfavorable.

1.1 Wind Farm Design

With site characteristics in mind, HSWET has selected turbine and foundation types and designed a layout for the offshore wind farm. This project will feature 39 Vestas V164-9.5 MW offshore wind turbines, with a total installed capacity of 370.5 MW. The V164-9.5 MW turbine is used on offshore farms across the globe, making it a reliable and well tested option.[8] While HSWET acknowledges that turbines with larger rotor diameters and therefore greater efficiency are on the market, these turbines have less accessible information, creating the potential for inaccurate predictions and extrapolations in the HSWET models. Furthermore, the financial gain of increased efficiency of a larger turbine is limited due to the relatively low average wind speeds in the Gulf of Mexico; the shift in the power curve at 7 to 8 m/s wind speeds was not significant for larger turbines.[9] The V164-9.5 MW turbine is a balance between efficiency, capital costs, and modeling accuracy. This turbine, with specifications summarized in **Table 2**, has a rotor diameter of 164 m and a nominal voltage of 66 kV.

Table 2. Turbine Specifications

Vestas V164-9.5 MW Turbine						
Rated Power	Rotor Diameter	Hub Height	Cut-in Speed	Cut-Out Speed	Nominal Voltage	Wind Class
9500 kW	164 m	160 m	3 m/s	25 m/s	66 kV	IEC S

HSWET then selected a foundation type for the turbines. The foundation of the turbine largely determines the extent of environmental impacts to underwater species at the leasing site. From relevant literature, the use of gravity-based structures has been suggested because they can be installed without pile driving;[10] the resulting noise is a major contributor of harm to pelagic species.[11] However, a drawback of gravity foundations is their large base (in comparison to a standard monopile foundation), which covers and disturbs a greater area of the seafloor habitat and thus puts benthic species in greater harm.[12] Furthermore, noise is a short-term consequence that lasts the duration of wind farm construction, and it is unclear if it has long-lasting impacts. With these in mind, HSWET has selected a twisted jacket foundation type for the wind turbines. This foundation is a compromise between impacts to the pelagic and benthic species, as it requires some pile driving to be installed, but not as much as a monopile, and it has smaller areas of entry to the sediment, protecting benthic species. It also has the potential to enhance artificial reef effects due to the larger amount of surface area on its lattice column structure.[13] In addition, jacket foundations have great potential to withstand tropical storms, which are known to affect the leasing area. A twisted jacket foundation used by some oil and gas companies withstood Hurricane Katrina.[14]

While it is more common for monopiles to be used in shallower waters, a twisted jacket will mitigate impacts to the environment and risk of damage from hurricanes.

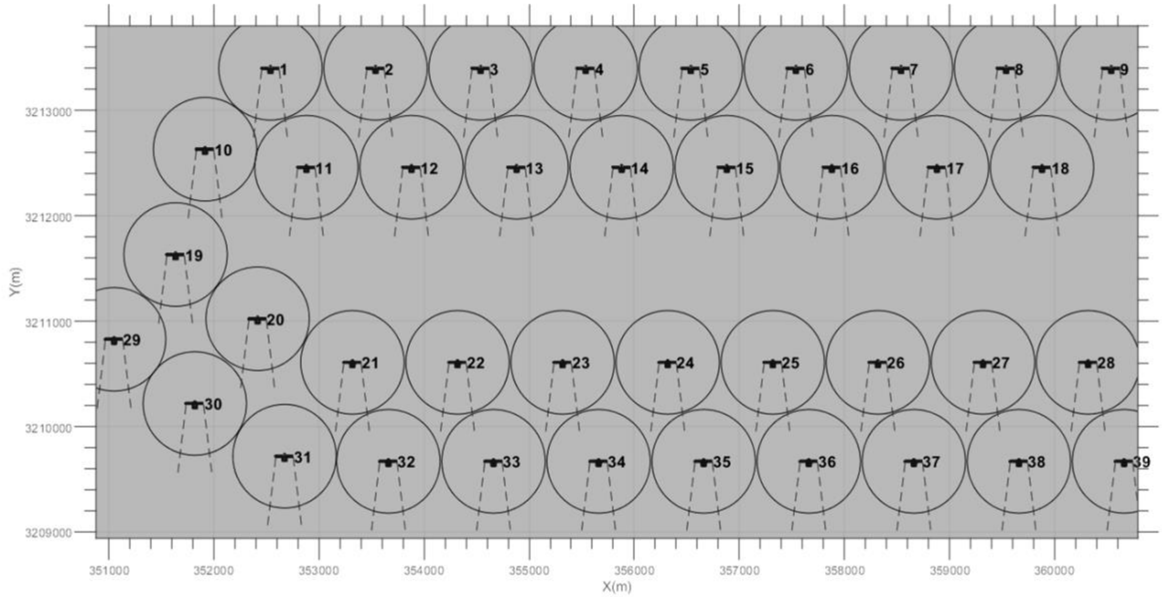

Figure 2: Site layout of 39 V164-9.5 MW turbines located in lease boxes 235 and 236. A substation will be in the northwestern corner of block 235, the upper left corner of this figure.

With the turbine and foundation types selected, HSWET designed an optimized wind farm layout. Using the Furow siting software, HSWET sought to minimize the wake effect energy losses based on the Bastankhah wake model while balancing the costs of additional turbines and transmission cabling.[15] Bathymetry, wind speed data, climate data, and turbine specifications were all imported into Furow. **Figure 2** illustrates HSWET's optimal design within lease boxes 235 and 236 (See **3.0 Optimization**). The 39 Vestas turbines each have a circle drawn to indicate the standard 3 rotor diameter distance from the hub. The layout features two parallelogram sections in a flared layout, with a 70º angle between turbines in each section as shown in **Figure 3.** This site plan will have a substation located in the northwest corner of the lease blocks with transmission lines that will run down the middle of each section to the substation.

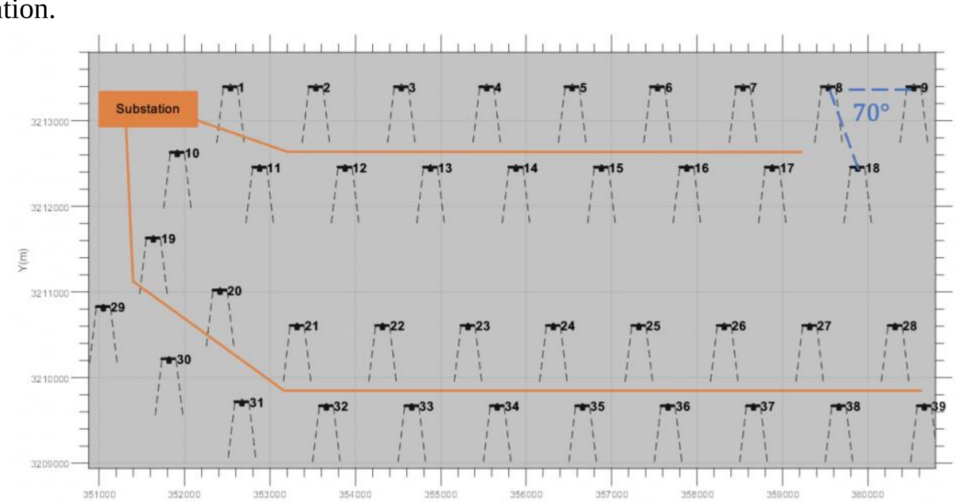

Figure 3. Major transmission lines within the layout are routed through the middle of each section to the substation located in the northwest corner. The optimal angle between turbines can be demonstrated by turbine 9, turbine 8, and turbine 18, which form a 70° angle with each other.

This layout has wake effect losses of 6.39% and mean wake affected wind speeds 3% lower than the mean free wind speed, as calculated with the Bastankhah wake model. With an installed capacity of 370.5 MWh, the net electrical output of the HSWET offshore wind farm is **1,297,735 MWh** at a net capacity factor of **40.0%,** as calculated by SAM. These calculations also consider unavailability, turbine performance, electrical, and environmental losses.

1.2 Transmission Plan

The coast of Texas offers many opportunities for energy transmission connection. With the Renewable Portfolio Standards (RPS), Texas is focusing on the development of transmission lines to assist with increased wind farm development. Demand in the ERCOT energy market continues to increase, with even greater desire for green energy as companies seek to reduce their carbon footprints. Connecting to the energy grid in Galveston is, therefore, promising, and ensures a market for generated electricity within the Galveston and greater Houston area.[16]

HSWET's wind farm will use underwater high voltage alternating current (HVAC) transmission cables, which is economically viable under 50 km. Cables will run from the turbines to a substation, which will regulate voltage and current, in the northwest corner of the lease blocks. From the offshore substation, HVAC cables will travel 40.2 km to the shore near 7 Mile Road, Galveston, TX, as shown in **Figure 4A.**[17] Here, an onshore substation transformer will bring the nominal voltage up to 138 kV, prior to connecting to the ERCOT network.[18] Onshore AC transmission lines will run along 7 Mile Road and connect with the overhead electric bulk transmission and control power grid at the intersection of 7 Mile Rd and Stewart Rd, as in **Figure 4B**. The final interconnection plan will need to be approved by ERCOT prior to implementation.[19]

Interconnection with the EROCT power grid nearest to shore is financially favorable due to the high material and installation costs of underwater cables. However, HSWET recognizes that this location is further from large energy demand and may limit the viability of future projects in the area.[20] HSWET anticipates that Texas's RPS will continue to develop transmission lines to meet increasing renewable energy demand, reducing the likelihood of these consequences.

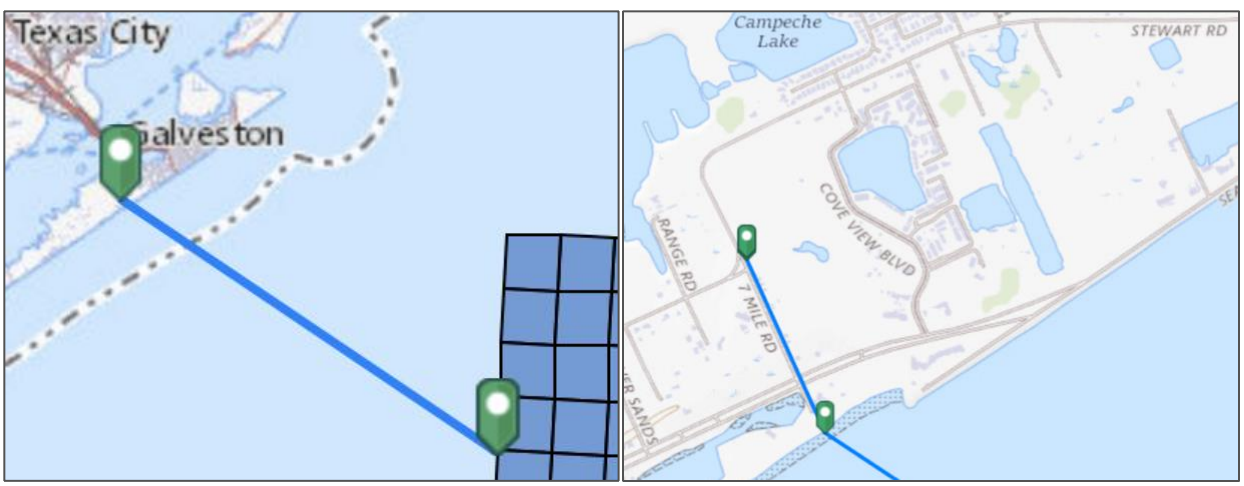

Figure 4A-B. Transmission trajectory from the northwest corner of lease block 236 to the shore near 7 Mile Road, Galveston, TX. Onshore connection point to connection with the ERCOT grid at 7 Mile Rd and Stewart Rd.

1.3 Environmental Analysis

To minimize harm to the environment caused by this project, HSWET considered risks to sensitive species in the Galveston coastal region and mitigation strategies to reduce impacts. Many species of songbirds, protected under the Migratory Bird Treaty, pass through the Trans-Gulf route. There are also migratory aquatic species, including a variety of sharks and other coastal pelagic species. Threatened fish in the area include the opossum pipefish and the smalltooth sawfish. Additionally, the Kemp's Ridley and Loggerhead Sea turtles have nesting sites along the Galveston coast, and both turtles are endangered and protected under the Endangered Species Act.

To create a mitigation strategy, HSWET has identified three habitats to protect: the aerial habitat, the pelagic habitat, and the benthic habitat.[21] In addition to monitoring species abundance in the leasing area during both construction and O&M, HSWET will use mitigation strategies commonly found on European offshore wind farms.

The aerial habitat is prone to three risks: displacement from otherwise suitable ocean habitats, direct mortality from collision with the turbine blades, and the barrier effect, in which birds make energetically costly detours to avoid flying through obstacles such as the planned wind installation. Many strategies to prevent collision risk are available because they can be implemented at onshore wind farms. HSWET plans to feather turbine blades as well as paint the turbine base and blade tips for increased visibility. Flashing blue lights of low intensity will be installed for nocturnal species. The project will also use curtailment during times of seasonally high abundance of migratory species. While this reduces the annual energy production of the wind farm, well-time curtailment can limit these energy losses to 1%.[22]

Impacts to species in the pelagic habitat include displacement due to disturbance created by operational turbine noise, changes in oceanographic processes, or attraction to the lease area due to the artificial reef effect. There is also risk of direct injury or mortality from impulsive pile-driving noise during construction. Pile driving during foundation installation creates the most noise and can lead to hearing damage, masking of calls, or spatial displacement as animals move out of the area to avoid the noise.[23] To reduce harm from noise to underwater creatures while respecting benthic habitats, it is necessary to select an adequate foundation. HSWET selected a jacket foundation due to its smaller footprint, durability, and potential for enhanced artificial reef effects (see **1.1 Wind Farm Design**). In addition, HSWET will implement soft starts during construction, by beginning construction slowly ramping up the noise. Proceeding in this manner will avoid startling marine populations and give them time to move away from the area. Construction will also be timed to avoid of high species abundance during migration periods.

The benthic habitat shares the same potential impacts as the pelagic habitat does. Additionally, benthic species could suffer from changes in populations or community structure due to disturbance of sediments from construction activities or scour around foundations, as well as behavioral disruptions caused by electromagnetic fields from cables. Providing scour protection to each turbine not only protects the benthic habitat but also increases the stability of the foundation by preventing erosion of the surrounding sediment due to hydrodynamic forces.[24] Common scour protection uses boulders placed around the base of the foundation. However, the chosen jacket foundation is less well-suited in locations with many boulders. Therefore, HSWET will install anchored polypropylene fronds around the base of the foundations. The fronds are buoyant and project into the ambient current resulting in localized drag and reduced current velocities, which causes sediment to fall out of suspension and accumulate and compact around the fronds.[25] The fronts resemble sargassum seaweed, which is common to the coasts of Texas.[26]

The installation of the foundation to the seafloor provides a hard substrate that benthic fouling species can cling to, providing them a stable, protective habitat. This phenomenon is known as the artificial reef effect. This also promotes the stepping-stone effect, where non-indigenous invasive species also find protection, harming native species. While sensitive fish species can benefit from the wind farm, care must be taken to ensure that ships moving to and from the area do not carry any invasive species. Artificial reefs are often used to promote increased biodiversity; however, any accumulation of fouling organisms will increase the hydrostatic drag. The selected scour protection will establish a reduced habitat availability because the surfaces give less space for colonization compared to the area they cover.[27] At the same time, they may have a positive artificial reef effect since they create new habitat and thus increase the carrying capacity of an area and its ecological functioning.

Finally, to mitigate the adverse effects of electromagnetic fields, HSWET plans to bury transmission cables one to two meters deep. This will ensure that the fields are emitted farther away from the sea floor.

Most of HSWET's environmental mitigation strategies are factored into net capital costs. Altered construction timing increases the required construction timeline, with mild increases to construction costs. Turbine curtailment reduces the annual energy production based on non-operational hours. Furthermore, HSWET will undergo the BOEM environmental permitting process to ensure that the site has been properly assessed. HSWET will complete the required Construction and Operations Plan and Environmental Impact Statement as well as the associated monitoring. This process is anticipated to take approximately four years.[28]

1.4 Site Development and O&M

Ports used for offshore wind farms have specific infrastructure needs. This includes heavy-duty wharves made from iron/concrete capable of withstanding the weight of turbine components, such as a stationary tower rack holding at least four completed towers, each weighing around 750 tons. Large, heavy components like turbine blades, foundations, and nacelles need lay-down areas for staging and assembly that can withstand their weight and size. Ports with manufacturing facilities near marshaling areas will improve the efficiency of transporting parts.

Offshore wind farms also require unique vessels for surveying, installation, and O&M. For wind turbine installation, HSWET plans to use Charybdis, which Dominion Energy Virginia expects to be completed by December 2023. Charybdis can transport many turbines and provides a stable work platform on the sea. For cable laying, the Isaac Newton from Jan De Nul will be used. Isaac Newton can install up to 10,700 t of cable. For O&M, HSWET intends to use the service operation vessel T60-18 from Royal IHC, which is fully integrated with a motion compensated gangway, a motion compensated crane, and a daughter craft with step-less boat landing for effective operations.

The construction process will start with the arrival of components into the Port of Galveston, which was chosen due to its proximity to the project and its minimum depth of 45 feet, ensuring that any Wind Turbine Installation Vessel has access to the port and terminal facilities. The blades of the V164-9.5 MW will either be sourced from the Isle of Wight, UK or Nakskov, Denmark, and the nacelles will be sourced from Lindø, Denmark. The towers will be sourced from the CS Wind manufacturing facility in Pueblo, Colorado, which was recently purchased from Vestas in 2021.[29] This is feasible due to the ongoing positive relation between the two companies that accompanied the purchase of the plant. To construct the towers, Dominion Energy's *Charybdis* (which comes online in 2023 and will be available for use starting in 2025) will be leased and used to construct the towers. The *Charybdis* will be used as it is the first Jones Act compliant WTIV in the United States, providing the proposed project with an efficient source of transportation and installation. If the *Charybdis* or another Jones Act compliant WTIV vessel is not used, then the components will need to be barged out to the project area where they can be assembled by a non-Jones Act compliant vessel.

Due to the prevalence of hurricanes and the increased risk of damage at the proposed project location, Inward Battered Guide Structures (IBGS), otherwise known as twisted jacket foundations (See **1.2 Wind Farm Design**), will be used to provide additional support and stability to the wind turbines. An additional benefit of this choice of foundation is that due to its use of three piles driven into the ground rather than a single monopile, smaller hydraulic/vibratory hammers can be used to install the piles. The installation process doesn't require offshore welding or underwater work as the structural elements can be fully assembled before being transported to the installation site on a barge.[30] Moreover, the reduction in weight and compact size for IBGS versus monopiles mean that smaller installation vessels can be used instead of the *Charybdis*.[31] At the intersection of the seafloor and the bottom of the jacket, HSWET will install anchored polypropylene fronds. These fronds are set in concrete in mats that are laid around the foundation and secured to the seabed using diver-deployed anchors.

While assembling the structure of the wind turbines above the water line, an artist's rendering of the *Charybdis* show that for wind turbines of the size of the V164-9.5 MW, the components of the turbines will be moved to the installation site in individual pieces on the deck of the *Charybdis*, and each tower will be assembled from the foundation up, starting from the towers to the installation of the nacelle, to the attachment of the wind turbine blades.[32] The *Charybdis* has the additional benefit of using "legs" that extend down to the ocean floor to stabilize itself during the construction process, providing a secure platform which will help increase installation efficiency.[33]

Due to the distance from shore, an installation of an offshore substation is also necessary. The offshore substation, like the turbines, will be installed on a IBGS foundation to mitigate storm and hurricanes risk. This offshore substation will be used to step up the voltage that is received from the turbines (66 kV) to the connection voltage (100-220kv).[34] Underwater cables will also connect each turbine to the offshore substation and will be run down a leg of each IBGS foundation to protect the cables. Once on the ocean floor, all cables will be buried approximately 1.0-2.0 meters beneath the seabed, using a remotely operated vehicle (ROV) guided from a nearby cable installation vessel.[35]

HSWET will submit an Operations and Construction Plan to BOEM which may take three years to be approved. Construction will commence thereafter and take two to three years to complete.[36]

2.0 Capital Expenditures

Developing an initial capital cost is a complicated procedure involving several components such as the cost of turbines, transportation to and from the site (including leasing sophisticated vessels for installation and space/time at the port for use), construction, and lease blocks. Due to the numerous factors and the fact that, as a university organization, HSWET does not have access to confidential information from private companies, most of the SAM model's inputs are general assumptions from industry mentors and default model values, with the remaining from publicly available sources. When everything came together, HSWET calculated that the project's **total capital cost is $1.05 billion**.

An offshore wind project, especially of commercial size and in the Gulf of Mexico, where wind speeds are lower and the industry in the US is nascent, is only financially viable if the Investment Tax Credit (ITC) is accessed. This means such the project would have to be permitted and ready for installation before the end of 2025 when the ITC expires, or the ITC would have to be extended. Because the environmental analysis and permitting process through the BOEM would take three to four years, installation would be complete by the end of 2024, or 2025 at the latest, assuming start date upon submission by HSWET in August 2021.

HSWET found that the two main components affecting the net capital cost are the turbine cost and the balance of system cost. Elements affecting the turbine cost include distance from manufacturer to location, cost of labor, and cost of resources, among other factors. One major element worth accounting for is the size of the turbine. When faced with the option of having more "smaller" turbines or fewer "larger" turbines, HSWET elected to go with the middle. The logic is that with each turbine comes a new foundation, nacelle, hub, crane pic, and transmission line, not to mention the additional ships (or lease time per ship) and workers needed for construction. However, we elected to not go with the largest end due to constraints on shipping and US wind industry capacity for offshore construction.

While the SAM model has its own estimation-of-turbine-costs calculation, significant research into industry standards for offshore per MW costs of turbines and confirmation from a couple of industry mentors working in onshore wind development and offshore wind deal banking yielded a figure of $1MM per MW, or $9.5MM per V164 turbine. Making this assumption is a large reason why the project costs around what the industry would expect at just over $1 billion.

Another element that heavily affects our net capital cost is balance of system (BOS) costs. The BOS cost considers all direct construction costs excluding the cost of the turbines. Using NREL's LandBOSSE modeling software and citing research from Lazard's Levelized Cost of Energy Offshore Wind report**,** HSWET determined BOS CapEx to be **$1,780/MW**. Listed on the table below is the project's use of funds table.

Table 3. Use of Funds

Use of Funds Table				
Cost Type	Subtype	$	$/kW	% breakdown
Development and Financing		$23,280,235	$62.83	2.21%
Turbine				
	Nacelle	$160,749,494	$433.87	15.26%
	Rotor	$82,165,534	$221.77	7.80%
	Tower	$27,809,873	$75.06	2.64%
	Other turbine	$110,607,450	$298.54	10.50%
	Total	$381,332,352	$1,029.24	36.20%
Balance of system				
	Turbine foundation	$120,298,770	$324.69	11.42%
	Cables	$84,272,343	$227.46	8.00%
	Offshore substation	$51,300,789	$138.46	4.87%
	Other balance of system	$55,093,044	$148.70	5.23%
	Offshore cable installation	$111,239,493	$300.24	10.56%
	Foundation installation	$46,349,789	$125.10	4.40%
	Turbine installation	$20,014,681	$54.02	1.90%
	Other installation	$160,222,792	$432.45	15.21%
	Total	$337,826,755	$1,751.12	61.59%
Total		**$1,053,404,288**	**$3,872.43**	**100%**

An important subset of these costs, especially for offshore wind projects, are the cost of ship rental fees for installation and transmission cables to hook the farm up to the grid onshore. *Charybdis* rental fees are a maximum of $500,000 per day based on the standard $250,000 per day for non-US-made vessels),The ship would likely be used for about one day per turbine, or about 39 days for the installation of all of the turbines, yielding rental fees of maximum $20 million.

In terms of transmission cables, after weighing the different options, such as hooking up to existing nearby oil rigs' pipeline and cable infrastructure or wiring oversea cables with towers, HSWET decided on laying its own undersea cables. Because the farm is 40.2 km from the grid interconnection point on the barrier island of Galveston, AC/DC conversion is not necessary (as it only becomes viable for transmission lines over 50km long), saving immensely on capital costs.

Finally, the financing cost accounts for costs such as bank and legal fees and legal fees involved in contract negotiations. This accounts for the smallest amount of the capital cost.

2.1 Financing Plan

HSWET, as the developer of the project, has secured financing for the project. The capital cost of the project is $1.05B. The offshore project will be financed by tax equity, sponsor equity, and back leveraged debt. The capital stack of the project is listed in the table below:

Table 4. Capital Stack

Capital Stack Summary		
Funding Type	$ Amount	% Breakdown
Debt	563,404,288	53.48%
Tax equity	290,000,000	27.53%
Sponsor equity	200,000,000	18.99%
Total	$1,053,404,288	100.00%

The project's financing is structured as a partnership-flip with back leveraged debt. JP Morgan, a bank with significant enough tax liabilities to honor advance funding commitments, is sponsoring the tax equity financing, and HSBC, a large European bank with significant experience financing offshore wind in Europe, is providing the back-leveraged debt.

The sponsor equity is being provided by our PPA offtaker, Exxon Mobil. The company showed interest in the project due to increasing pressure from legislators and from the public to divest from oil and gas.

After contract negotiations, JP Morgan and HSWET settled on a 99/1 tax flip and 15/5 cash flip. The tax equity sponsor, JP Morgan, will be assuming 99% of the project's tax benefits, and 15% of the project's income until Year 6, when it fully absorbs the tax credits and deductions available to it. At that point, the partnership will flip, and JP Morgan will assume only 5% of the project's income and tax benefits. Before the flip year, HSWET will only be assuming 1% of the project's tax benefits, and 85% of the income. After the flip, HSWET will be taking on 95% of the project's income and tax benefits.
The back-leveraged debt is structured to take advantage of favorable refinancing. The initial loan is a mini perm with a seven-year tenor with an interest rate of 4.194%. The mini-perm is priced 200 basis points above the benchmark 10-year SOFR swap rate, which is in line with current industry rates. At the end of the seven years, HSWET will pursue favorable refinancing of the back-levered debt to lower interest rate expenses using the project's proven history of reliable cash flow. HSWET anticipates being able to achieve an average interest rate of 3.5% across all of its loans during the project's 25-year lifespan.

2.2 Power Purchase Agreement

After doing extensive research into the deregulated wholesale market of Texas, HSWET concluded that a power purchase agreement (PPA) would be integral to an economically viable offshore wind project. Project revenue stability is crucial to securing low-cost financing (especially debt financing), and a fixed PPA price would help guard against fluctuations in the floating wholesale prices.

Therefore, HSWET will be signing an as-generated bus bar PPA with Exxon Mobil Corporation. ExxonMobil is headquartered in Irving, Texas, and has a market cap of $371.14 billion.[37] S&P Global Ratings rated ExxonMobil an AA-, or strongly investment-grade,[38] with a stock price of $87.83 as of April 14th, 2022.[39] The PPA will specify a price of **$60.85/MWh** for 15 years with a 3.3% escalation rate to cover O&M cost escalation, and an optional 5- or 10-year contract extension at a renegotiated PPA price. This gives HSWET the possibility of selling on the ERCOT merchant market using its proven cash flows and production up to that point to maintain its strong debt contracts (and favorable interest rates). These figures for the PPA are based on the SAM model, and our financial models that indicate that the selected price is the minimum feasible price given DSCR, tax equity IRR, and sponsor equity IRR. Our price was approved by industry mentors working on project financing in the region. This agreement also includes the sale of the Renewable Energy Credit (REC) of $0.90 per MW of energy produced to ExxonMobil.

As many oil majors have pledged to become net-zero companies, ExxonMobil faces significant external pressures to reduce emissions. The company has laid out its 2025 emission reduction plans to decrease its upstream greenhouse gas intensity by 15 to 20 percent compared to 2016 levels. This is accompanied by a 35 to 45 per cent reduction in flaring intensity.[40] In 2021, Chairman and CEO Darren Woods reported that ExxonMobil will be investing over $15 billion on lower greenhouse gas emission initiatives over the next six years.[41] In the same year, ExxonMobil signed a 12-year power-purchase agreement with Ørsted's subsidiary, Lincoln Clean Energy, for 500 megawatts (MW) of wind and solar power in the Permian Basin.[42] Major oil and gas (O&G) companies like Total, BP, and Royal Dutch Shell have invested in offshore wind, and ExxonMobil's competitor, Chevron, has become the first major US O&G firm to invest in offshore wind by purchasing Ocergy, Inc. in 2021.[43] HSWET believes there is significant opportunity and feasibility for a partnership with ExxonMobil. An agreement would help ExxonMobil reach and diversify its environmental targets and Renewable Portfolio Standards, as well as achieve positive publicity following backlash from activists and investors.

With the busbar agreement, ExxonMobil will purchase the generated power at the same location, or node, that HSWET puts it on the grid. This will eliminate basis risk because there will be no difference in prices based on distance. ExxonMobil's energy center is situated immediately nearby in the Houston area, making this a viable PPA.

2.3 Market Conditions

ERCOT administers financial settlements in the competitive wholesale bulk-power market. Since we are financed completely through PPA to minimize risk in our revenue stream, it is important to consider spot and future pricing in the wholesale market to ensure the profitability of our project as an intermittent generator. HSWET's PPA is physical and not virtual because of the proximity to ExxonMobil's HQ in Houston, which makes it more attractive than Exxon signing a VPPA with some onshore project that faces freeze risks like the ERCOT disaster last February.

Average price for electricity on ERCOT since this time four years ago (April 17, 2018) is $62.08, making HSWET's PPA price of $60.85/MW competitive. This timeframe was constructed in Excel using price curve data to encapsulate a significant portion of pre-COVID data without going too far back where electricity prices would be drastically different due to different technologies, energy resources, and policies). Further, such a PPA deal provides a strong hedge for firms against the risk of fluctuating power prices, which only go down as far as the high teens (and hit an absolute minimum of -$56.39/MW) but will rise to thousands of dollars per MW in emergencies and extreme circumstances, hitting a maximum of $10,101.26/MW and frequently surpassing $1,000/MW over the period. Firms looking to protect their electricity costs against the vast potential for price spikes would be looking for such a deal in the market.

Long-length PPAs are also becoming rare, though they still exist, due to the rate of technological innovation. The LCOE of the most cutting-edge turbine produced in 2022 may be far higher than the LCOE of a turbine produced five or 10 years later. Thus, if a corporate offtaker locks itself into a 10+ year PPA, they could end up overpaying for their power as over time power gets cheaper to produce. However, analysis of ERCOT price data from 2018 until 2022 shows no significant trend in price changes. Traditional "as generated" contracts with local offtakers are also becoming rarer, though they also still exist, because offtakers are opposed to onboarding the risk of committing to pay a predetermined price for all the power the wind farm produces. Offtakers could be hurt if the market price of power is lower than the predetermined PPA price/MWh since the offtaker would still be forced to pay the power producer the agreed upon PPA price even though they could get cheaper power from the market. This risk is typically mitigated by a "fixed contract" where the offtaker is only obligated to pay the PPA price for a fixed amount of power that the contract specifies. However, for simplicity reasons (and more stable revenue streams for more secure financing), HSWET is assuming that it will use an as generated contract.[44]

2.4 Incentives and Depreciation

Anticipating that our project's commercial operations date (COD) is in 2022, this project qualifies for the Business Energy Investment Tax Credit (ITC). This one-time credit is based on the dollar amount of the investment and will be earned at the COD. If offshore construction commences by the end of 2025, HSWET is eligible for a **30% tax credit**.[45] The existence of ITC will allow this project to maintain profitability at the current calculated cost, incentivizing the investment in renewable energy in the area of Galveston. This project is ineligible for the Renewable Energy Production Tax Credit (PTC), a capacity-based incentive that was phased out for projects beginning construction in 2022 and later. Federal regulations allow us to claim 100% 5-year MACRS depreciation on the project.[46]

In Texas, there are several regional incentives for wind farms, one of which is the franchise tax deduction. Texas' franchise tax is generally equivalent to a corporate tax, and wind projects are eligible for a 100% deduction on taxable capital. HSWET plans on claiming this deduction, effectively setting the project's state corporate tax rate to zero. In addition, wind projects in Texas often receive production-based incentives. On average, wind projects in Texas receive a subsidy of 0.00183 $/kWh.[47] These incentives make development on Texas' coast and transfer of power to ERCOT cheaper and easier for our project, decreasing tax liability and increasing profitability.

2.5 O&M Costs

As a developer, HSWET would hire an O&M contractor to provide labor, day-to-day operations, and ensure that our plant delivers to its listed capacity. HSWET would have a fixed-price contract with a clause that requires the O&M contractor to pay the developer a fee for every day that the plant is unable to deliver up to its capacity.

The total operating costs calculated by the SAM model is **25.9M** for year 1 and increases to **83.5M** by year 25. The annual escalation rate is 5%. We selected an aggressive escalation rate due to current concerns around inflationary pressures on labor and supply chain costs.

The major factors that drive O&M costs for offshore wind are the number of turbines to be serviced, the distance between the project and maintenance facilities, and the midocean climate at the project site. In a recent report released by BOEM, a site with near-identical coordinates to HSWET's proposed wind farm was analyzed. This area has an average significant wavelength of 0.88 m and an average wind speed at 10-m elevation of 6.12 m/s. The conceptual NREL wind farm consisted of one hundred 6-MW turbines for a total 600MW capacity. For a jacket bottom-fixed foundation, total O&M costs corresponding to our proposed distance to the O&M port were about $85 million/yr. By scaling down the capacity and number of turbines, HSWET calculates that total annual O&M costs for its project would be $25.9 million/yr. A separate report released by NREL supports this claim. It projected that offshore wind OpEx amounted to $70-80/kWh.

2.6 Risks

Table 5. Risk Analysis

Risk Summary		
Danger Rank	Risks	Details
1	Political	Disruptions from changes or expiration in legislation affecting access to tax incentives
2	Weather	Unreliable weather data, unpredictable wind resource, and incliment weather conditions.
3	Financing	Changing interest rates on construction loans.
4	Construction and Supply Chain	Delays and cost overruns to CapEx and OpEx from supply chain disruptions.

Political Risk:
The most dangerous risk HSWET is anticipating is political risk. Specifically, fluctuations in federal and state policy create significant potential downsides in access to incentives. First, if the project is delayed beyond a COD of December 31, 2025, our ITC eligibility is phased out. Currently, the Build Back Better Act introduced by the Biden administration would extend ITC for projects that begin construction before the end of 2026 and be phased down over the following two years. However, the bill's success is reliant on its passage through both houses of congress and enactment by the sitting president. Since the bill is nearly entirely supported by lawmakers from the Democratic Party, a Republican victory in the 2022 midterm would likely put an end to the bill's potential for passage. Worse still, a Republican majority might pass ITC cuts or an early phase-out, increasing apprehension on availability of both the tax credit and resulting tax equity investments.

Weather Risk:
The risk from weather is two-fold. Inaccurate wind resource data, and unpredictable weather. Either can significantly impact revenue, and therefore investor returns. HSWET has spared no expense to ensure it obtained the highest quality weather data available. In addition, HSWET conducted a 20-year P50/P75/P90 analysis to determine the impact of weather variability on the financial soundness of the project.

Table 6. 20 Year P50/P90 Projections

20 Year P50/P90 projections			
Scenario	Annual electricity to grid (mWh)	Sponsor 25 yr IRR	Tax Equity IRR
P50	1,297,735	9.92%	7.64%
P75	1,167,962	6.89%	5.82%
P90	1,038,188	3.81%	3.86%

P75 analysis indicates in the extremely improbable event that average wind resource is 10% less than estimated during the first 20 years of the project, sponsor equity and tax equity investor returns would remain intact, at **5.64**% and **6.09%** respectively. Even in the face of uncertain weather, the project is assured to be financially robust.

A second risk related to weather is hurricanes. The Gulf of Mexico is home to significant hurricane activity from June to November. While the project is insured against damage caused by hurricanes, a particularly difficult hurricane season can produce larger than expected insured losses which forces insurance providers to tighten coverage. HSWET, anticipating uncovered damage costs, has taken the measure of setting aside 1% of annual revenue into a reserve account earmarked for damage repair. This preventative measure ensures that investor returns are protected against harsh hurricanes.

Finally, it's necessary to analyze the risk of cold weather freezes for the project because of the ERCOT disaster in February 2021. Fortunately, the lowest average temperature in HSWET's selected lease blocks is 8º Celsius and the V164 turbines can function down to -15º Celsius in their standard operating temperature range.

Financing Risk:
Financing risk inherent in rising inflation and the potential increase in interest rates. The 12-month inflation rate has risen by 6.2 percentage points between February 2021 and February 2022, from 1.7% to 7.9%, and the Federal Reserve has indicated that interest rates are soon to rise to curtail it. If interest rates continue to rise in attempts to curtail inflation, the returns to both the project's developers and investors will be adversely affected. Investor returns are highly sensitive to the interest rates, therefore financing risk is a genuine concern for the project. HSWET currently projects that the average interest rate across the initial mini-perm construction loan and subsequent refinanced loan is 3.5%. HSWET conducted stress tests to demonstrate the effect that higher loan interest rates have on investor returns and debt-service-coverage-ratio (DSCR), a common metric used by bankers to determine the risk of a project.

Table 7. Interest Rate Stress Test

Interest Rate Stress Test				
Scenario	Interest Rate	Minimum DSCR	Sponsor 25 yr IRR	Tax Equity IRR
Base Case Scenario	3.5%	1.45	9.94%	7.65%
Scenario 1	4.0%	1.4	9.39%	7.27
Scenario 2	4.5%	1.32	8.39%	7.16%
Scenario 3	5.0%	1.26	7.71%	6.74%

Analysis indicates that HSWET's construction loans can endure a 50-basis point increase on its interest rates before its DSCR becomes unfinanceable. Wind project loans with a DSCR below 1.4 are deemed "too risky" and therefore very difficult to finance.

Construction and Supply Chain Risk
HSWET secured construction insurance to protect its investors from unexpected construction costs. Construction insurance applies to the project from the time that components arrive in the harbor to the commission of the wind turbine and will cost HSWET $12.2M. This covers damages that could occur during assembly in the harbor or while being assembled onsite by the wind turbine installation vessel (WTIV). HSWET has secured operation insurance with Munich RE, a major European insurance company with deep experience in insuring European offshore wind turbines. HSWET is covered against unexpected O&M costs, costs arising from supply chain disruptions and delays, and ruinous guarantee obligations forced by unexpected project downtime. This insurance is particularly important because the project's selected turbines, the Vestas V164-9.5 M, have many different components that are produced between production facilities spread between the UK and Denmark. Munich RE's insurance ensures that the project's finances are protected against international shipping delays.

3.0 Optimization

The first set of parameters that HSWET sought to optimize were the site design elements. The wind farm size and location were limited by the physical constraints faced in the auction area off the coast of Galveston, including shipping lanes and oil pipelines. Given the relatively uniform wind speeds and geotechnical conditions in the lease area, HSWET opted to remain close to shore and in shallower waters to reduce transmission, shipping, and repair/maintenance costs.

HSWET then began optimizing the wind farm design within blocks 235, 236, 260, and 261. Layouts and sizes requiring all four lease blocks were considered "large" while those only in lease blocks 235 and 236 were classified as "small." The small layouts reduced the energy losses and capital costs, so these were selected for further optimization. Based on European examples, simple parallelogram layouts were first tested to find the optimal angle between turbines to reduce Bastankhah model wake effects.[48] Using these angles, the rows of turbines were flared out to further reduce wake effect losses along the Y-axis.[49] Through subsequent iterations minimizing wake losses, the energy yield of turbines 10 through 18 were improved by 3% when moving from a parallelogram to a flared layout. Along the X-axis, turbines experience fewer wake losses and were, therefore, kept at three rotor diameters apart to reduce the cost of transmission cabling. While a larger flare between rows would reduce wake effects further, turbines in the final layout are grouped into two sections to reduce transmission cabling, construction, and O&M costs. The optimal angles from the parallelogram trials are preserved in each of the two sections.

With these considerations in place, we then sought to further optimize our finances, looking for areas in which costs could be reduced using different equipment and new, justifiable assumptions. With multiple iterations of the System Advisor Model and our parameters, we were able to reduce capital costs from $1.3 billion to $1.05 billion and PPA price from about $160/MW to $60.85/MW, given a wind farm size of 370 MW using 39 Vestas V-164 - 9.5MW turbines and the 30% ITC. Additionally, HSWET found vastly optimized O&M procedures due to the farm's proximity to the Galveston coast which significantly reduced costs, while also analyzing multiple wake effect models for the farm to maximize capacity factor and thus net annual energy production for PPA revenue. Simultaneously, HSWET worked to maximize and maintain our returns to the investor, as well as a positive NPV, to ensure that the project was not only financially viable but also attractive to undertake for the investors. HSWET built its own financial model in addition to SAM to further optimize these figures. HSWET faced an NPV and IRR to the tax equity investor of about -$130,000,000 and 1.9%, respectively, before iterating through the model and adjusting the PPA, including adding the sale of RECs to the contract, as well as the other parameters discussed above, to reach about $156,000,000 and 7.65%.

3.1 Bid Amount

With all of these considerations in mind, HSWET is willing to bid **$57,600,000** [less than total CapEx, probably the total figure minus cost of all turbines, installation, and any balance of system costs that aren't leasing/property itself]. This was derived from the size of HSWET's lease area of two blocks at about 9 square miles per block, or 11,520 acres total, and the BOEM's requirement of a minimum bonus bid of $25 per acre for its lease off the coast of Galveston.[50] With an NPV of over $150 million in income from the project, there was ample room to increase the bid amount without affecting investors' returns. Had HSWET bid the minimum, the bid amount would have been $288,000 - leaving the project NPV untouched - but also unlikely to win the auction. Therefore, HSWET went with a safe bid of $5,000 per acre, compared to the rate range of $6,000-$10,700 per acre off the coast of New York and New Jersey in 2016.

This bid amount also comes from an Offshore Wind NEF report which discusses average lease prices for offshore wind in the US, but focuses primarily on the Atlantic Coast where wind speeds are higher and water depths are greater, making floating turbines also an option. Therefore, HSWET can justify cheaper prices as the Gulf of Mexico is an unproven, lower potential, risky new area to develop in, which helps our capital costs and still makes a cheaper bid than the other areas competitive and likely successful. This price ensures that HSWET can maintain the same returns to its stakeholders and overall yield a financially viable and attractive project that will generate profit, while also remaining competitive with other potential bidders in such a lease auction.

References

[1] "Wind Prospector." The Wind Prospector, National Renewable Energy Laboratory, 2021, maps.nrel.gov/wind-prospector/.
[2] Bathymetric Data Viewer, NOAA, 2021, www.ncei.noaa.gov/maps/bathymetry/.
[3] "Coastal Ecosystem Maps." National Centers for Environmental Information, National Oceanic and Atmospheric Administration, NOAA, 2021, www.ncei.noaa.gov/maps/coastal-ecosystems/viewer.htm.
[4] "Shipping Fairways in the Gulf of Mexico, from Boem." Shipping Fairways in the Gulf of Mexico, from BOEM - CKAN, BOEM, NESDIS, NOAA, U.S. Department of Commerce, 4 Dec. 2020, catalog.data.gov/dataset/shipping-fairways-in-the-gulf-of-mexico-from-boem.
[5] Office, U.S. Government Accountability Office. "Oil Spills in the Wake of Hurricane Ida Highlight Need for Better Federal Oversight of Offshore Oil and Gas Pipelines." U.S. GAO, 14 Dec. 2021, www.gao.gov/blog/oil-spills-wake-hurricane-ida-highlight-need-better-federal-oversight-offshore-oil-and-gas-pipelines.
[6] "Atlantic Area." United States Coast Guard (USCG) Atlantic Area, U.S. Department of Homeland Security, www.atlanticarea.uscg.mil/Our-Organization/District-8/District-Units/Sector-Houston-Galveston/.
[7] "Submerged Lands Act." BOEM, 1953, www.boem.gov/sites/default/files/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Leasing/Outer_Continental_Shelf/Lands_Act_History/submerged.pdf.
[8] "V164-9.5 MW™." Vestas US, Vestas, us.vestas.com/en-us/products/offshore/V164-9-5-MW.
[9] "MHI Vestas Offshore V164/9500 - Manufacturers and Turbines - Online Access - The Wind Power." The Wind Power: Wind Energy Market Intelligence, The Wind Power, www.thewindpower.net/turbine_en_1476_mhi-vestas-offshore_v164-9500.php.
[10] Allen, Michael C, and Matthew Campo. Ecological Monitoring and Mitigation Policies and Practices at Offshore Wind Installations in the United States and Europe. Rutgers University, NJ Climate Change Alliance, Aug. 2020, njadapt.rutgers.edu/images/OSW_Ecological_Monitoring_Report_1.pdf.
[11] Gartman, Victoria, et al. "Mitigation Measures for Wildlife in Wind Energy Development, Consolidating the State of Knowledge — Part 1: Planning and Siting, Construction." Journal of Environmental Assessment Policy and Management, vol. 18, no. 03, 2016, p. 1650013., doi:10.1142/s1464333216500137.
[12] Horwath, Sarah, and Jason Hassrick. "Comparison of Environmental Effects from Different Offshore Wind Turbine Foundations." U.S. Department of the Interior Bureau of Ocean Energy Management Office of Renewable Energy Programs, BOEM, Aug. 2021, www.boem.gov/sites/default/files/documents/environment/Comparison-Environmental-Effects-Different-OWT-Foundations-2021.pdf.
[13] Ibid.
[14] Hartman, Liz. "Wind Turbines in Extreme Weather: Solutions for Hurricane Resiliency." Energy.gov, Office of Energy Efficiency and Renewable Energy, 23 Jan. 2018, www.energy.gov/eere/articles/wind-turbines-extreme-weather-solutions-hurricane-resiliency.
[15] Mittal, Prateek, et al. "A Novel Hybrid Optimization Methodology to Optimize the Total Number and Placement of Wind Turbines." Renewable Energy, vol. 86, 2016, pp. 133–147., doi:10.1016/j.renene.2015.07.100.

[16] Daniel, John, et al. National Offshore Wind Energy Grid Interconnection Study Executive Summary. Department of Energy , July 2014, www.energy.gov/sites/prod/files/2014/08/f18/NOWEGIS%20Executive%20Summary.pdf.

[17] Wright, Sally, et al. "TRANSMISSION OPTIONS FOR OFFSHORE WIND FARMS IN THE UNITED STATES." Renewable Energy Research Lab, citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.495.7227&rep=rep1&type=pdf.

[18] "Electric Power Transmission Lines." Homeland Infrastructure Foundation-Level Data (HIFLD), hifld-geoplatform.opendata.arcgis.com/datasets/electric-power-transmission-lines/explore?location=29.326644%2C-94.882889%2C13.30.

[19] "Resource Integration." ERCOT, ERCOT, www.ercot.com/services/rq/integration.

[20] Gifford, Sheyna, et al. "Connecting Offshore Wind Energy to Onshore Users." Now. Powered by Northrop Grumman, Sept. 2020, now.northropgrumman.com/connecting-offshore-wind-energy-to-onshore-users/.

[21] Allen, Michael C, and Matthew Campo. Ecological Monitoring and Mitigation Policies and Practices at Offshore Wind Installations in the United States and Europe. Rutgers University, NJ Climate Change Alliance, Aug. 2020, njadapt.rutgers.edu/images/OSW_Ecological_Monitoring_Report_1.pdf.

[22] "Smart Wind Turbine Curtailments Cut Wildlife Energy Losses to 1%." Reuters Events, Reuters Events: Renewables, 9 Oct. 2019, www.reutersevents.com/renewables/wind-energy-update/smart-wind-turbine-curtailments-cut-wildlife-energy-losses-1.

[23] Bailey, Helen, et al. "Assessing Environmental Impacts of Offshore Wind Farms: Lessons Learned and Recommendations for the Future - Aquatic Biosystems." BioMed Central, BioMed Central, 14 Sept. 2014, aquaticbiosystems.biomedcentral.com/articles/10.1186/2046-9063-10-8.

[24] Langhamer, Olivia. "Artificial Reef Effect in Relation to Offshore Renewable Energy Conversion: State of the Art." The Scientific World Journal, vol. 2012, Dec. 2012, pp. 1–8., doi:10.1100/2012/386713.

[25] Review of Reef Effects of Offshore Wind Farm Structures and Potential for Enhancement and Mitigation. Berr Department for Business Enterprise and Regulatory Reform, Jan. 2008, tethys.pnnl.gov/sites/default/files/publications/Potential_for_Enhancement_and_Mitigation.pdf.

[26] Randall, Keith. "Texas Coast Dodges Seaweed This Summer." Texas A&M Today, 12 June 2019, today.tamu.edu/2015/08/20/texas-coast-dodges-seaweed-this-summer/#:~:text=Port%20Aransas%2C%20Corpus%20Christi%2C%20Padre,many%20tons%20of%20the%20sargassum.

[27] Review of Reef Effects of Offshore Wind Farm Structures and Potential for Enhancement and Mitigation. Berr Department for Business Enterprise and Regulatory Reform, Jan. 2008, tethys.pnnl.gov/sites/default/files/publications/Potential_for_Enhancement_and_Mitigation.pdf.

[28] Kerschner, Seth, and Brittany Curcuru. "Environmental Laws and Regulations Affecting US Offshore Wind." White & Case LLP, 25 June 2021, www.whitecase.com/publications/insight/fast-forward-us-offshore-wind/environmental-laws.

[29] Harmon, Tracy. "CS Wind Takes over Vestas Wind Tower Factory in Pueblo; Pledges More Jobs." Pueblo Chieftain, The Pueblo Chieftain, 17 Aug. 2021, www.chieftain.com/story/business/2021/08/17/cs-wind-takes-over-worlds-largest-wind-tower-factory-pueblo/8157385002/.

[30] Dvorak, Paul. "Meet Keystone Engineering's Twisted Jacket, an Offshore Wind-Turbine Foundation." Windpower Engineering & Development, 14 June 2018, www.windpowerengineering.com/meet-keystone-engineerings-twisted-jacket-an-offshore-wind-turbine-foundation/.

[31] Ibid.

[32] McGowan, Elizabeth, and Energy News Network March 8 Elizabeth McGowan. "Turbine-Installing Ship Is Dominion's Big Bet on Offshore Wind." Energy News Network, 10 Mar. 2022, energynews.us/2022/03/08/giant-turbine-installing-ship-is-dominion-energys-500m-bet-on-u-s-offshore-wind/.

[33] Ibid.

[34] 2019 Offshore Wind Handbook - K&L Gates. K&L Gates, Oct. 2019, files.klgates.com/files/uploads/documents/2019_offshore_wind_handbook.pdf.
[35] Asgarpour, M. “Assembly, Transportation, Installation and Commissioning of Offshore Wind Farms.” Offshore Wind Farms, 2016, pp. 527–541., doi:10.1016/b978-0-08-100779-2.00017-9.
[36] “Vineyard Wind 1.” Bureau of Ocean Energy Management, www.boem.gov/vineyard-wind.
[37] “Exxon Mobil Corp (XOM) Stock Price & News.” Google Finance, Google, www.google.com/finance/quote/XOM:NYSE?sa=X&ved=2ahUKEwjuhuzqk5n3AhWymOAKHVe3B9QQ3ecFegQIFxAg.
[38] S&P Global Ratings Affirms Exxon Mobil at "Aa-" (Foreign Currency Lt Credit Rating); Outlook Negative, cbonds.com/news/1470959/.
[39] “Exxon Mobil Corporation (XOM) Stock Price, News, Quote & History.” Yahoo! Finance, Yahoo!, 25 Apr. 2022, finance.yahoo.com/quote/XOM/?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAIPhF5HSmOHNZe6QyDsW9-V3-VKKXj9w8VwyEuwqnl-lhjOaGbT9pelMQmRm91APT9tkypRdj3CTZqqVsp8te2uSHjcpEPb8wIcNLOA0amBrJ5XRJ2pdcssEQ3RpJGVdKmhfoD-h5MSagqFbYnsmVpCRlTYumgRi4ua6XwUjgHPS.
[40] Kulovic, Nermina. “ExxonMobil Curbs Spending Plans, Reveals Path to Lower-Carbon Future.” Offshore Energy, 3 Mar. 2021, www.offshore-energy.biz/exxonmobil-curbs-spending-plans-reveals-path-to-lower-carbon-future/.
[41] Darren W. Woods Chairman and Chief Executive Officer, et al. “Why We're Investing $15 Billion in a Lower-Carbon Future.” ExxonMobil, corporate.exxonmobil.com/News/Newsroom/News-releases/2021/1109_Why-we-are-investing-15-billion-in-a-lower-carbon-future.
[42] Addison, Velda. “ExxonMobil Turns to Solar, Wind for Power in Permian.” Hart Energy, www.hartenergy.com/exclusives/exxonmobil-turns-solar-wind-power-permian-31640.
[43] Larson, Aaron. “Chevron Joins Growing List of Oil and Gas Companies Investing in Offshore Wind.” POWER, 22 Apr. 2021, www.powermag.com/chevron-joins-growing-list-of-oil-and-gas-companies-investing-in-offshore-wind/.
[44] Wilson, Adam. “Watershed February Freeze Upends Booming ERCOT Wind Hedge Market.” S&P Global Market Intelligence, S&P Global, 11 Mar. 2021, pages.marketintelligence.spglobal.com/ERCOT-wind-hedge-market-ws.html.
[45] Advancing the Growth of the U.S. Wind Industry: Federal Incentives, Funding, and Partnership Opportunities. US Department of Energy, June 2021
[46] “The Power of Nature – Taxation of Wind Power 2020.” KPMG US, KPMG, 3 Nov. 2021, www.kpmg.us/insights/2021/taxation-of-wind-power.html.
[47] “The Full Cost of Electricity (FCe-) The History and Evolution of the U.S. Electricity Industry.” Internet Archive, The University of Texas at Austin Energy Institute, July 2016
[48] Yong, Zhang, and Qian Shengli. A Practical Optimization for Offshore Wind Farm Layout. Renowind Energy Technology and Dx Wind Technologies, windeurope.org/summit2016/conference/allfiles2/571_WindEurope2016presentation.pdf.
[49] Hansen, Kurt. “Simulation of Wake Effects between Two Wind Farms - Eera-DTOC.” EERA DTOC, DTU Wind Energy, www.eera-dtoc.eu/wp-content/uploads/files/Simulation-of-wake-effects-between-two-wind-farms.pdf.
[50] United States, Congress, Bureau of Ocean Energy Management. *Proposed Western Planning Area Lease Sale 218, December 2011*, 2011, https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/Regional-Leasing/Gulf-of-Mexico-Region/Lease-Sales/218/nos_w218p_lt.pdf.