Offshore Wind Assessment for the Southeastern United States

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Executive Summary

This report provides an assessment of the current state of potential offshore wind generation in the southeastern United States. Analysis in this report aims to provide input to our client, Southern Company, on expanding their renewable generation portfolio.

While offshore wind has begun to thrive in the European Union, the United States, with significantly larger areas of available land, has largely avoided offshore installations in favor of cheaper onshore farms. However, there is significant offshore wind potential in the coastal areas of the U.S. including the southeast where our client, Southern Company, operates. Numerous considerations including endangered wildlife, limited policy incentives, and widespread stakeholder impacts have kept offshore wind from becoming practical in the U.S. Emerging new technologies, more consistent operation, and careful planning and siting may allow a utility with a large customer base and significant influence like Southern Company to overcome the financial hurdles involved in construction and installation of wind farms. Limited federal and state policies within Southern Company's service region, however, remain a significant challenge and will likely keep offshore wind as an unfavorable source of renewable energy for the foreseeable future.

The first section of this report provides significant background on current turbine and platform technology, an overview of relevant state and federal policies for the development of offshore wind, and a history of offshore exploration. Additionally, this section includes discussion of the few projects that have been approved in the United States and potential impacts for offshore energy development if the Clean Power Plan were approved.

We then lay out some basic methods for this report that help describe our levelized cost of electricity (LCOE) model along with the specific areas of focus for each portion of our literature review. We then dive into the results of our LCOE calculations including cost estimates for each facet of offshore wind generation: capital costs, operations and maintenance, and transmission. The results of those calculations are given below, as we attempt to estimate the costs of an OSW investment in Southern Company's service area.

Table 1 OSW levelized cost of electricity estimates

OSW LCOE Estimate Year 2015	
Annual Energy Production, MWh	837091.58
Capital Costs, $/MWh	63.22
Operating Costs, $/MWh	28.30
Transmission Costs, $/MWh	67.00
LCOE, $/MWh	158.50

The final section brings our literature review findings together with our LCOE results to discuss the current state of offshore wind and its relevance to the states in which Southern Company operates. A focus on potential LCOE cost savings in the vein of improving the economics of OSW is given along with the primary findings and recommendations from this report:

- The creation of the Bureau of Ocean and Energy Management's Smart from the Start program has streamlined the offshore energy exploration leasing process.
- Wind turbines are growing taller with greater blade diameter and capturing more wind power more often than their earlier, smaller counterparts.
- Marine spatial planning can help minimize the destruction of critical habitat through intelligent development and construction of offshore wind farms.
- Approval of the Clean Power Plan will push states in Southern Company's service area to invest in significant energy efficiency improvements and renewable installations.
- The levelized cost of electricity for wind is still more than twice that of traditional fuels and even other renewables like onshore wind and solar photovoltaic.
- Southern Company, as a regulated utility, should look for more cost-effective alternatives to add to their renewable portfolio.

1. Introduction

Ocean energy, specifically ocean winds, may be the next frontier for renewable energy in the United States. While onshore wind has been expanding in the U.S, offshore wind (OSW) has yet to become established in our waters; but the tide seems to be changing. Most recently, Deepwater Wind in New Shoreham, Rhode Island has begun construction on the country's first OSW farm. This development is an important step forward towards achieving a clean energy future. Expanding the renewable portfolio for the U.S. will help meet the clean energy goals and help keep our planet's warming below 2°C. The United Nations Framework Convention on Climate Change (UNFCCC) has set this target for all member countries. Reaching 2 ℃ would spell out accelerated climate impacts including changes to species migration patterns, increased melting rate of ice sheets, more frequent extreme weather events, and community displacement due to rising sea levels and temperatures (United Nations, 2015). OSW is one promising mitigation option, but it is important to understand associated costs and limitations.

Southern Company is an Atlanta based electric utility that serves 4.4 million customers in the southeastern states of Georgia, Alabama, Florida and Mississippi (Southern Company, 2016). With a combined installed capacity of 46 GW, Southern Company is one of the largest utilities in the US (Southern Company, 2016). While renewables are not a large portion of the current capacity (in 2014, about 20% of Southern Company's generation mix was from renewable sources), they are a growing resource that is being explored (Southern Company, n.d.). Wind, solar, biomass, and hydroelectric power are just a few of the resources Southern Company is interested in expanding. Wind, in particular, is a major interest for our client. Currently, Southern Company purchases wind energy from Oklahoma and Texas through power purchase agreements (PPAs) because the company does not own wind assets. With onshore wind resources already available to Southern Company, assessing the potential for OSW is the next step for the company in building their renewable profile.

The main objective of this project is to assess the feasibility of an OSW farm installation in the waters off the coast of North Carolina, South Carolina and Georgia. To properly assess the viability for an OSW farm in the waters of the southeastern United States, it is important to evaluate the technology, policies and economics associated with OSW. This comprehensive viability report for OSW specifically details the wind potential, technology resources, regulatory pathways and barriers, and expected costs. This report will also serve as an update and expansion of the previous wind power potential study by Southern Company that was conducted nine years ago by Georgia Tech (Southern Company & Georgia Tech, 2007). This study focused on the southeastern states, and our new plan intends to study examples of installations outside the U.S., as domestic growth in OSW has been slow. Regardless, it is our objective to answer the questions: "Is an OSW farm technologically, economically and politically realistic in the southeastern United States?" and "Where is the optimal wind farm location?" We ultimately expect this report to serve as a guide for Southern Company in understanding the potential for OSW development in the Southeastern U.S.

2. Background

2.1. Technology

The 2007 Georgia Tech report has provided a detailed wind turbine layout which includes all the important pieces such as nacelle, rotor blade, generator and gearbox (Southern Company & Georgia Tech, 2007). The technology section in this report will not give redundant explanations on turbine structure but rather focus on the turbine mechanical technology improvements from 2003 up until now.

The Georgia Tech report also investigated three OSW turbine manufacturers: Siemens, Vestas and General Electric (GE). These three companies were chosen because, at that time, they were the only OSW turbine manufacturers in the market. After twelve years of development, there are currently more than ten OSW turbine providers, each with multiple offshore products. By the end of 2015, the leading offshore manufacturer in Europe is Siemens, which ranks first in both 2015 annual installed capacity (63.5% market share) and cumulative number of wind turbines connected to the grid (2059 turbines in total) (European Wind Energy Association (EWEA), 2016). MHI Vestas, Senvion, Adwen and BARD are the other top OSW turbine suppliers who provided turbine-to-grid connected wind farms. In the United States, five 6MW OSW turbines in Block Island Deepwater Wind Farm were provided by GE Renewable, which had acquired Alstom's power unit. In this section, detailed data of offshore turbines from these six vendors will be provided and analyzed.

The U.S. first OSW farm - located in Block Island, Rhode Island - began construction in July, 2015 (Energy Information Administration (EIA), 2015b). The Block Island Wind Farm is designed with 30 MW generation capacity, coming online in 2016. Compared to the U.S., European OSW turbine technology has improved steadily since the first commercial OSW farm was launched in Denmark (South Baltic Programme, n.d.). In this section many examples and data from Western Europe will be used.

Compared to onshore wind turbines, OSW turbines are exposed to greater potential for corrosion of rotor blades, hubs and foundations. As more than half of U.S. OSW resources are located in deep waters (water depth greater than 20-50m), the OSW farms will have high maintenance costs and component replacement fees (Sarah Laskow, 2011). Thus, OSW turbines must be designed carefully to ensure more robust components, stable systems, and reliable performance.

2.1.1. Foundation platforms

The design and engineering parameters of an OSW turbine are determined by site-specific conditions, such as wave and tidal conditions, seabed geology, and water depth (Bureau of Ocean Energy Management (BOEM), n.d.-e). Currently in the market there are five major types of foundations: monopile, tripod, jacket, tripile and gravity based. The mechanical layout of these foundations can be found in Figure 1 below.

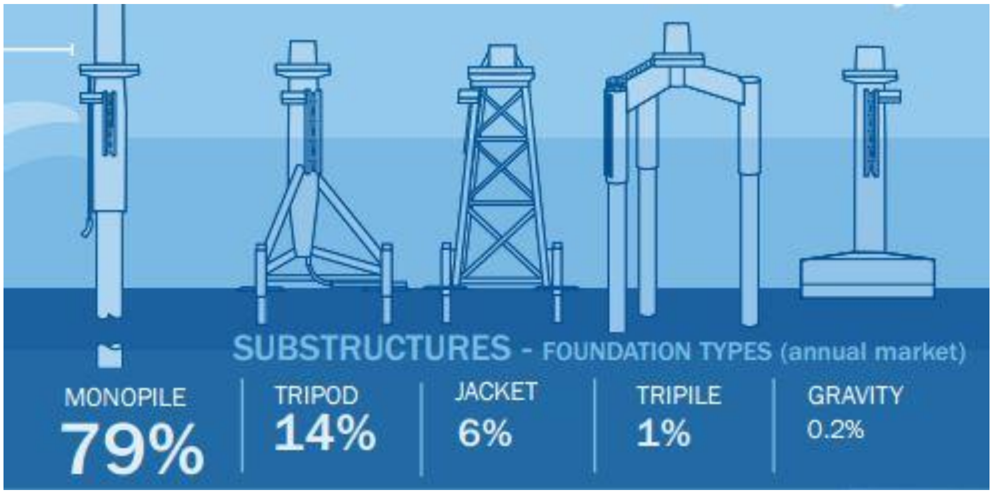

Figure 1 European offshore platform structure types and market share in 2014. (European Wind Energy Association (EWEA), 2015)

Monopile:

The monopile is currently the dominant foundation used in European offshore wind farms (European Wind Energy Association (EWEA), 2015). Monopiles are favored by the offshore wind industry because of their reliability and simplicity to fabricate and install (European Wind Energy Association (EWEA), 2015). The monopile consists of a single steel tower which typically has a diameter ranging from 2.5 – 6.0 meters and a vessel thickness of as much as 1.5 meters (Sanjeev Malhotra, 2011). During the installation process, monopiles are either driven into the seabed or drilled into rock, depending on site specific subsurface condition.

There are multiple reasons contributing to the popularity of monopiles in European OSW farms. First of all, the water depths in most active farms in UK, Germany and France are in the range of 30-40 meters, which is the perfect site condition for monopiles (Wind Energy Update, 2015). The abundance in monopile manufacturers also plays an important role.

Apart from the advantages of being easy to construct and install, the monopile also has several disadvantages. It requires extra scour protection around the pile to prevent grout from crumbling, especially in cold weather. Once the problem happens, it will be expensive for the remedial action during maintenance (Worldwind Technology, 2013). The use of monopiles is also constrained by water depth and turbine size. The diameter of the pile needs to increase with the increase of turbine weight so that it can resist hydrodynamic forces from the water. Thus a 5-6 MW turbine will be the upper limit for the largest monopile (Worldwind Technology, 2013). Because the monopile is driven/hammered into the ground, the construction noise may interfere with marine mammal's normal living patterns and may result in habitat alternation (Bergström et al., 2014). This acoustic disturbance is often a concern during wind farm planning and sometimes it will pose restrictions on farm construction.

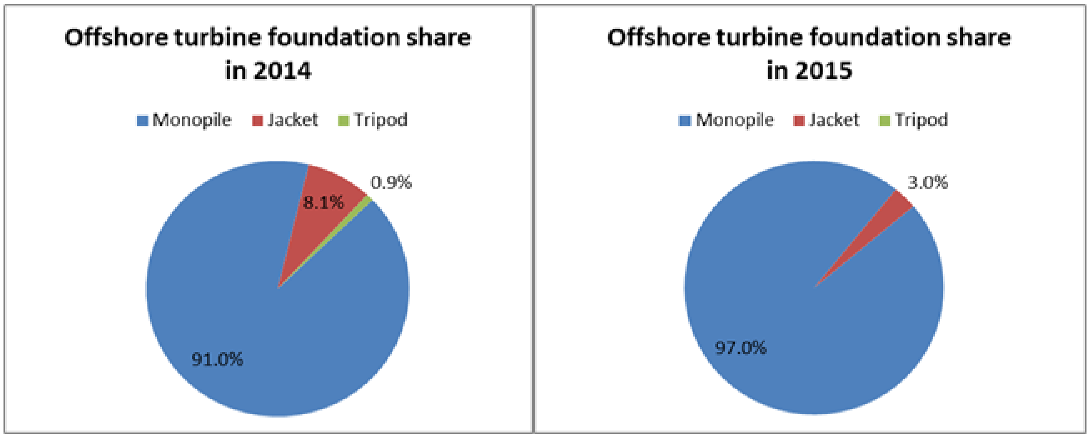

Figure 2 European offshore turbine foundation share in 2014 and 2015. (European Wind Energy Association (EWEA), 2015) (European Wind Energy Association (EWEA), 2016)

Jacket:

As ocean depth increases, the wind farm industry mostly prefers jacket foundations. Jackets can handle mid-to-deep waters with depths between 25-60 meters, and they may also be used as the support for offshore substations (Kaiser & Snyder, 2012). The surface area that is in contact with the water is smaller compared to the monopile, leading to lower wave loads (4coffshore Ltd, 2013). However, jacket foundations require high construction and maintenance costs and have a difficult transportation process.

The jacket substructure can have different forms with variable footing options. Currently, most jacket foundations used for offshore turbines have four legs, compared with the three-leg jackets used for oil and gas exploration (Kok Hon Chew, E. Y. K. Ng, & Kang Tai, 2014). A twisted three-leg jacket foundation was recently designed which is easier to manufacture than conventional jacket foundations. The innovative jacket has three twisted legs around a central pile. This kind of substructure will be applied to offshore sites of Dominion Virginia Power and Fishermen's Energy along the coast of New Jersey (Office of Energy Efficiency & Renewable Energy, 2014).

Tripod:

Like the monopile and jacket, a tripod is also attached to the subsurface using piles. Three steel legs are connected to a central shaft while being driven into the seabed. Compared to the monopile, tripods are heavier and more expensive, and they can be used in water up to 35 meters deep (Miceli, 2012).

Gravity Based:

Gravity based foundations are also used in shallow water. They are precast concrete structures that are ballasted with sand, gravel or stones to add weight that helps resist wind and hydrodynamic forces. Due to their simple structure but heavy weight, gravity based foundations are cheaper to manufacture but more expensive to install than monopiles (Worldwind Technology, 2013).

Floating Turbine:

Currently, most offshore turbines have foundations that extend to the ground, which limits the location of these turbines to coastal areas where water is less than 60 meters (Sanz Martinez, Natarajan, &

Henriksen, 2013). To extend the wind farm into deeper waters where wind resources are superior, the OSW industry is trying to figure out how to put turbines further from the coast while reducing the associated costs. The U.S. Department of Energy called floating turbines “a substantial departure from the proven OSW turbines that exist today”, due to their ability to extend wind energy extraction to areas with deeper waters (Sarah Laskow, 2011). In wind-abundant areas where water is too deep, traditional foundations with bulky piles are neither practical nor economical (Office of Energy Efficiency & Renewable Energy, n.d.). Development is currently focused on innovative floating platforms for use in deep waters, although it may still be a long way before this technology becomes economically feasible. The three types of possible floating turbines include spar-buoy, tension leg platform, and semi-submersible.

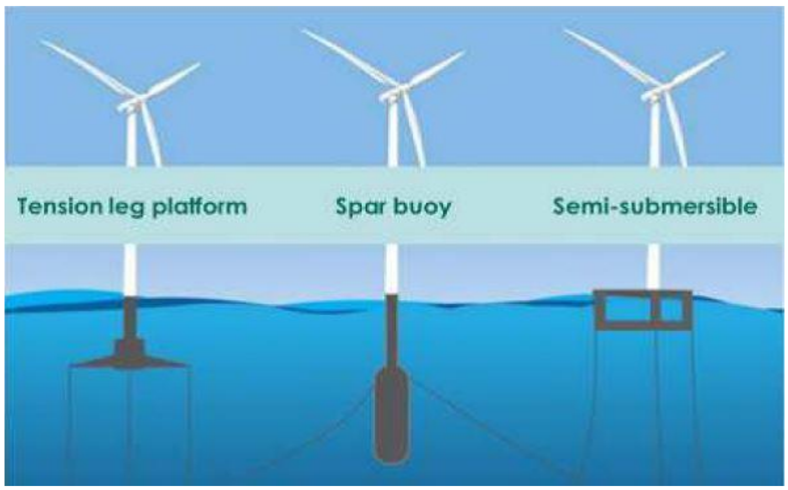

Figure 3 Three types of floating turbine platform concepts. (Briggs, 2014)

The spar buoy turbine is built upon the concept of gravity, which is also known as a deep draught caisson vessel (Charles R Briggs, 2014). The idea is to put the platform’s center of gravity under the center of buoyancy so that the turbine can float, like a spar. In order to meet the mechanical requirement, the platform has to be very long and thus the type of platform cannot be used in water less than 120m deep (Dominique Roddier & Joshua Weinstein, 2011). The spar structure has to be protected carefully during the installation process.

Semi-submersible platforms have a wide surface and float like a ship. This kind of structure is most commonly a floating structure and is often used by offshore petroleum exploration. Mooring lines and anchors are applied to prevent random moving. Compared with spar-buoy, a semi-submersible structure requires less construction material and can be assembled and repaired onshore (Office of Energy Efficiency & Renewable Energy, 2014). Thus it significantly reduces the capital costs for specialized vessels and maintenance cost for offshore transporting.

A tension leg platform (TLP) is moored to the subsurface using stiff cables or tethers, which are known as tendons. The stability of the TLP is dependent upon various parameters such as the amount of buoyancy, turbine and tendon coupling, seabed condition, and tidal fluctuation. Therefore, the application of TLP is restrained and can only be used in deep water areas where the current and tide are relatively mild.

2.1.2. Offshore vendors and their products

In 2013 and 2014, Siemens (1,278MW, 86.2%) was the top OSW turbine supplier in Europe in terms of annual installations, while MHI Vestas (141 MW, 9.5%) was the second largest turbine supplier (European Wind Energy Association (EWEA), 2015). Areva (45 MW, 3%) and Senvion (12.3 MW, 0.8%) are the other turbine manufacturers who had turbines connected in full-scale wind farms during 2014 (European Wind Energy Association (EWEA), 2015). Samsung also connected one prototype offshore turbine to the grid in the United Kingdom (7 MW, 0.5%). The 2014 market share can be found in the pie chart below (European Wind Energy Association (EWEA), 2015). One year later in 2015, the annual installation capacity of Siemens has increased from 1,278MW to 1816.4MW, but the market share decreased to 62.2% (European Wind Energy Association (EWEA), 2016). This is due to the increased grid connection of turbines provided from other suppliers – Adwen installed 440MW in 2015, Vestas installed 391.5 and the total for Senvion is 270.6MW (European Wind Energy Association (EWEA), 2016). Comparing the two years' performances, Siemens takes the lead in OSW turbines, with generation ranging from 3.6MW to 7.0MW. Wind turbine technical data from those six OSW turbine vendors are collected and presented in Table 2. The Siemens 3.6MW turbine is the most widely used offshore turbine in European wind farms, so we use 3.6MW as our turbine capacity assumption in Levelized Cost of Electricity (LCOE) calculations.

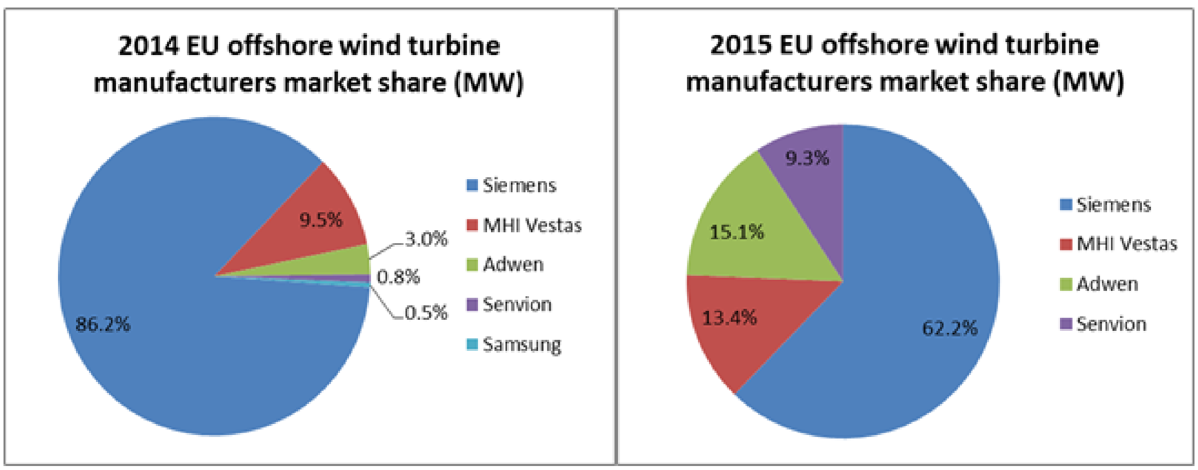

Figure 4 Pie charts of European OSW turbine vendors' market share in 2014 and 2015. (European Wind Energy Association (EWEA), 2015) (European Wind Energy Association (EWEA), 2016)

Table 2 Specifications of wind turbines by major manufacturers

	Type	Size	Tower height	Rotor diameter
GE /Alstom	Haliade 150	6.0MW	100m	150m
Siemens	SWT-3.6-120	3.6MW	90m or site-specific	120m
	SWT-4.0-120	4.0MW		

	SWT-4.0-130	4.0MW	Site-specific	130m
	SWT-6.0-154	6.0MW	Site-specific	154m
	SWT-7.0-154	7.0MW	Site-specific	
Vestas	V164-8.0	8.0MW	NA	164m
	V112-3.30	3.3MW	NA	112m
Adwen /Areva	AD 5-135	5.0MW	NA	135m
	AD 5-132	5.0MW	Site-specific	128m/132m
	AD 8-180*	8.0MW	Hub height 90m	180m
Senvion	6.2M126	6.15MW	Hub height 95/96.5m	126m
	6.2M152	6.15MW	Hub height 97-100m	152m
Samsung	S7.0-171	7.0MW	NA	171.2m

Based on the statistics from the European Wind Energy Association, the average OSW farm in 2014 was located in water 22.4m deep, with an average distance to shore of 32.9 km (European Wind Energy Association (EWEA), 2015). In the year 2015, there were 754 OSW farms under construction, with an average size of 337.9MW (European Wind Energy Association (EWEA), 2016). The average water depth was 27.2 meters and the average distance to shore as 43.3km (European Wind Energy Association (EWEA), 2016). This gives us evidence that average water depths and distances from shore are likely to increase.

In the United States, Alstom, part of which was consolidated into General Electric (GE), provided five Hialide-150 OSW turbines for the 30-MW Block Island Wind Farm.

2.2. Policy and Regulation

Understanding the policy implications associated with the implementation of an OSW farm is a complex but integral component of this report. This complexity stems from the planning and evaluation of policies, regulations, and many environmental factors. We will address several topics relating to policy. First, we will detail the specifics of the leasing and permitting process before presenting a current state of the industry where we review and assess the progression of OSW today in 2016. This assessment will explore the findings of the 2007 Georgia Institute of Technology report and determine whether these findings are still relevant today. It will also explain the history of the Production Tax Credit (PTC) and

the successes and failures of the OSW projects started in the U.S. Next, we discuss the specific policies and regulations that pose potential barriers to the success of offshore projects before finally discussing the key policies and agencies involved in offshore permitting.

2.2.1. Clean Power Plan

On August 3, 2015, the Clean Power Plan (CPP) was jointly announced by President Obama and the Environmental Protection Agency (EPA), which nationally aims to reduce carbon dioxide emissions by) on August 3, 2015 (Environmental Protection Agency (EPA), 2016). To meet the target that 30% from the power sector by 2030 and puts forward strong but achievable state-based carbon emissions targets for individual power plants (Environmental Protection Agency (EPA), 2016). The Supreme Court stayed the implementation of the CPP pending further review as of February 9, 2016; but the EPA announced that it will provide support for states still perusing carbon power sector reduction goals.

Based on the current energy mix of individual states, emission reduction goals are tailored to each state; states also have flexibility in how to achieve the plan including: first, increasing investments in energy efficiency programs to improve the heat rates of existing coal plants; second, switching to cleaner natural gas, increasing NGCC portion of energy mix; third, relying more on renewable generations that have low or zero-carbon emissions, such as wind and solar energy. This plan, enforcing each state to do their best to reduce carbon emissions, is essential to the development of renewable energy. OSW, a zero emissions producing renewable technology, could certainly benefit from this plan potentially leading to an increase in attention and investment especially in states with rich coastal wind resources (Southern Environmental Law Center, 2016).

CPP in North Carolina

The goals established in the CPP by EPA are expressed in two ways: rate-based and mass-based. States are allowed to choose their preference. For example, in North Carolina, 1,136 lb CO_2/ MWh is the goal for 2030. You can see that a 32.1% emission rate reduction (537lbs CO_2/MWh) is required compared with base year 2012 by 2030 (Energywire, n.d.).

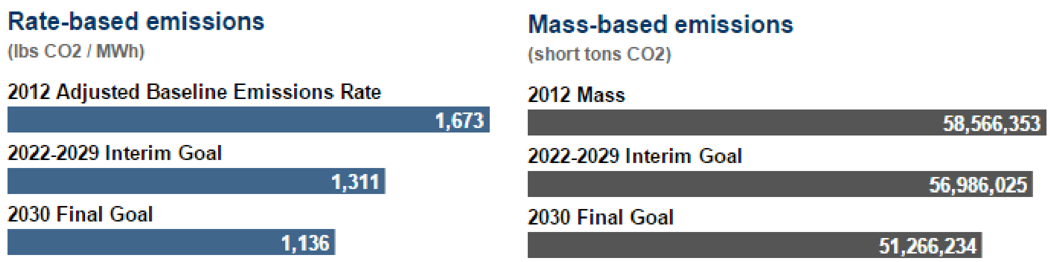

Figure 5 North Carolina CPP goals by 2030 (Energywire, n.d.)

CPP in Georgia

Table 3 below demonstrates the interim and final CPP requirements in Georgia (Environmental Protection Agency (EPA), n.d.). By 2030, the rate-based goal is 1,049 lbCO_2/MWh.

Table 3 Georgia interim and final CPP requirements by 2030 (Environmental Protection Agency (EPA), n.d.)

Georgia's Interim (2022-2029) and Final Goals (2030)

GEORGIA			
	CO_2 Rate (lbs/Net MWh)	CO_2 Emissions (short tons)	
2012 Historic [1]	1,600	62,851,752	
2020 Projections (without CPP)	1,135	61,305,697	
	Rate-based Goal	Mass-based Goal (annual average CO_2 emissions in short tons)	Mass Goal (Existing) & New Source Complement
Interim Period 2022-2029	1,198	50,926,084	51,603,368
Interim Step 1 Period 2022-2024 [2]	1,290	54,257,931	54,535,858
Interim Step 2 Period 2025-2027 [3]	1,173	49,855,082	50,792,677
Interim Step 3 Period 2028-2029 [4]	1,094	47,534,817	48,420,669
Final Goal 2030 and Beyond	1,049	46,346,846	46,944,404

2.2.2. OSW Permitting and Leasing Process

Before addressing the policies and regulations that affect OSW development, we will provide an overview of the permitting and leasing process. While BOEM is the primary facilitator of permitting and leasing activities, there are a number of other parties that are involved in these decisions. The Intergovernmental Task Force, created by BOEM, is responsible for conducting assessments that gather data and information regarding OSW developments (Bureau of Ocean Energy Management (BOEM), 2015). This task force serves to inform BOEM's decisions, and resolve any foreseen conflicts (Bureau of Ocean Energy Management (BOEM), 2015). In conjunction with this group, there are also a variety of other stakeholders that can become involved in the permitting and leasing process. Most likely dependent on state and location, some examples of stakeholders include residents, ocean front business owners, environmental groups, and government organizations. These groups are able to voice their opinions during public forums held in the early stages of this process.

The permitting and leasing process itself can be broken down into 4 stages: planning and analysis, leasing, site assessment, and construction and operations (Bureau of Ocean Energy Management (BOEM), 2015). During the planning and analysis stage, potential development areas or wind energy areas (WEAs) are identified and an Environmental Assessment for Lease Issuance and Site Assessment Activities is conducted. In the next phase of leasing, a commercial wind energy lease is issued. Before this can happen BOEM determines whether a competitive interest exists. Under the Outer Continental Shelf Lands Act (OCSLA), BOEM must competitively issue leases (Bureau of Ocean Energy Management (BOEM), n.d.-b). The lease however, does not allow development activities, but rather allows the lessee to construct a plan for development that must then be approved by BOEM (Bureau of Ocean Energy Management (BOEM), 2015). In the site assessment phase, the lessee submits their site assessment plan (SAP) for further surveys or studies on the lease area to BOEM for approval, modification or rejection (Bureau of Ocean Energy Management (BOEM), 2015). Finally, if approved, the lessee enters the construction and operation phase where they formulate a Construction and Operations Plan (COP) with instructions on how they intend to develop the site (Bureau of Ocean Energy Management (BOEM), 2015). Before approving or disapproving the COP, BOEM conducts environmental and technical reviews to assure minimum impact and maximum potential (Bureau of Ocean Energy Management (BOEM), 2015). If all is approved, the wind project moves forward and begins construction.

2.2.3. History of Lease Issuing by BOEM

The Obama Administration is responsible for launching a sequence of initiatives to develop both on and off shore renewable energy. As of today, BOEM has issued 9 commercial wind energy leases in the federal waters of the Atlantic Ocean (Table 4). There were a total of 7 competitive lease sales with 2 offshore Rhode Island-Massachusetts, 2 offshore Massachusetts, 2 offshore Maryland, and 1 offshore Virginia (U.S. Department of the Interior, 2015b). Two non-competitive leases were also issued for Cape Wind another farm off the coast of Delaware. Another two competitive lease sales off the New Jersey coast are receiving public comments and are under review by BOEM and Department of Justice (U.S. Department of the Interior, 2015b). The bidding was held on November 9, 2015 by BOEM (U.S. Department of the Interior, 2015b). These 9 lease sales have gained a combined $15.7+ million in revenue, comprising more than one million acres on the OCS (U.S. Department of the Interior, 2015b).

The first competitive lease sale was made on July 31, 2013 for a WEA in Rhode Island/Massachusetts WEA (Bureau of Ocean Energy Management (BOEM), n.d.-b). The area was bided as two leases: The North Lease Area (Lease OCS-A0486) and the South Lease Area (Lease OCS-A0487), 97,500 acres and 67,250 acres respectively (Bureau of Ocean Energy Management (BOEM), n.d.-b). Before the lease sale, "BOEM published a 'Call for Information and Nominations for Commercial Leasing for Wind Power on the OCS Offshore Rhode Island and Massachusetts' in the Federal Register (under Docket ID: BOEM-2011-0049)" between August 18, 2011 and October 3, 2011 to collect public comment, conduct the environmental assessment (EA) and determine the competitive interest (Bureau of Ocean Energy Management (BOEM), n.d.-b).

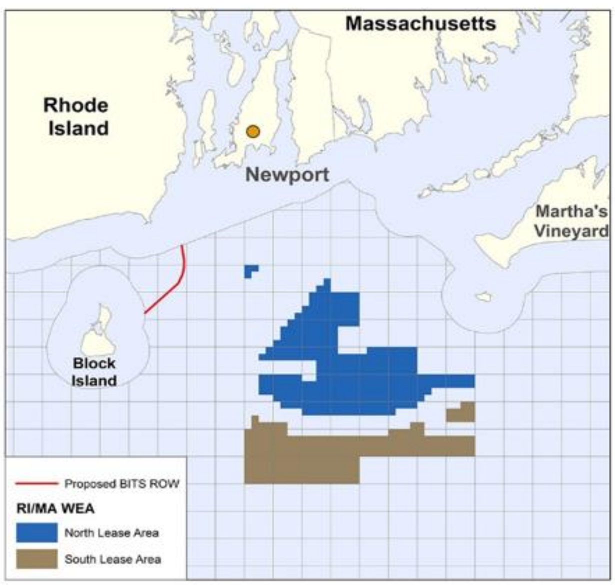

Figure 6 Lease Areas Offshore Rhode Island and Massachusetts (Bureau of Ocean Energy Management (BOEM), n.d.-b)

Table 4 History of OCS leases issued by BOEM (Bureau of Ocean Energy Management (BOEM), n.d.-f)

Number	Owner	Location	Status	Lease Area

1	Cape Wind Associates, LLC	Offshore Rhode Island/Massachusetts	Effective 10/6/2010 but was suspended by at the request of CWA on 2/26/2015.	OCS-A 0478
2	Bluewater Wind Delaware, LLC	Delaware	Lease was executed on 11/16/2012	OCS-A 0482
3	Virginia Electric and Power Company (operating as Dominion Virginia Power)	Virginia	Effective 11/1/2013	OCS-A 0483
4	Deepwater Wind New England, LLC.	Massachusetts	Effective 9/12/2013 but DWW has requested 2 term extensions and are waiting on approval from BOEM.	OCS-A 0486 (North)
5	Deepwater Wind New England, LLC.	Offshore Rhode Island/Massachusetts	Effective 9/12/2013 but DWW informed BOEM they will not conduct site assessment activities for this lease.	OCS-A 0487 (South)
6	US Wind Inc.	Maryland	Effective 12/1/2014	OCS-A 0489
7	US Wind Inc.	Maryland	Effective 12/1/2014	OCS-A 0490
8	Commonwealth of Virginia's Department of Mines, Minerals and Energy	Virginia	3/24/2015	OCS-A 0497
9	RES America Developments Inc.	New Jersey	Lease went into effect on 3/1/2016	OCS-A 0498 (South)
10	US Wind Inc.	New Jersey	Lease went into effect on 3/1/2016	OCS-A 0499 (North)
11	DONG Energy Massachusetts (U.S.) LLC.	Massachusetts	Effective 5/27/2015	OCS-A 0500
12	Offshore MW LLC	Massachusetts	Effective 3/23/2015	OCS-A 0501
13	Florida Atlantic University Board of Trustees	Florida	Interim lease policy effective on 6/1/2014	Within three OCS blocks in Proposed Lease Area 1
14	Southern Company	Georgia	Application in Process	3 to 11 nautical miles off the coast of Tybee Island

2.2.4. OSW off the Southeast Coast

North Carolina

In North Carolina, three Wind Energy Area Identifications were announced by BOEM on August 11, 2014 (See Figure 6). Similar to the procedure in Rhode Island/Massachusetts, the OCS Lands Act requested that BOEM publish a "Call for Information and Nominations" in the Federal Register (under

Docket ID: BOEM-2012-0088) where there was a 45-day period for public comments to determine competitive interest on Dec. 13, 2012. Additionally, BOEM made a motion to make an Environmental Assessment report which was done on December 13, 2012 (under Docket ID: BOEM-2012-0090). One year later, North Carolina requested BOEM allow additional comments from the public input and BOEM reopened the comment period for this call (Bureau of Ocean Energy Management (BOEM), 2016a). Potential environmental and socioeconomic impacts were taken into consideration at this time. BOEM also published a Visual Assessment of commercial wind leasing sites off the North Carolina OCS to simulate the visual impacts together with OSW. The WEAs are identified in Figure 6, which totals approximately 307,590 acres, including the Kitty Hawk Wind Energy Area, the Wilmington West Wind Area and the Wilmington East Wind Energy Area (U.S. Department of the Interior, 2015a).

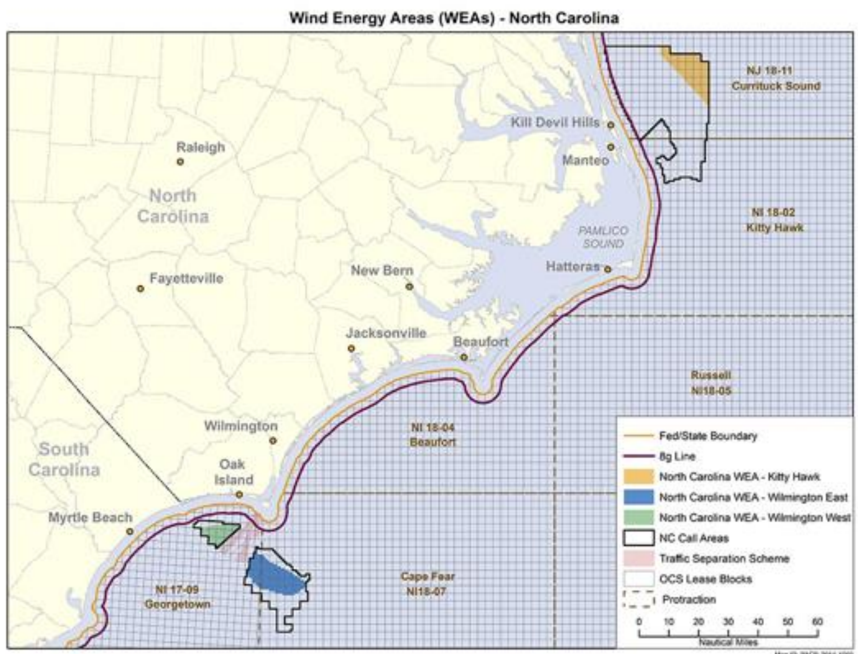

Figure 7 North Carolina Energy Areas (Bureau of Ocean Energy Management (BOEM), 2016a)

Georgia

As for Georgia, Southern Company submitted an Interim Policy lease application in April 2011 to replace a meteorological tower and collect wind data. In 2012, Southern Company submitted two addendums to provide additional information including field site impact, construction and decommissioning in response to BOEM's request for clarification (Bureau of Ocean Energy Management (BOEM), n.d.-c). BOEM published a NOI to prepare an EA for public comments to identify the WEA and problems associated with the data collection lease (Bureau of Ocean Energy Management (BOEM), n.d.-c).

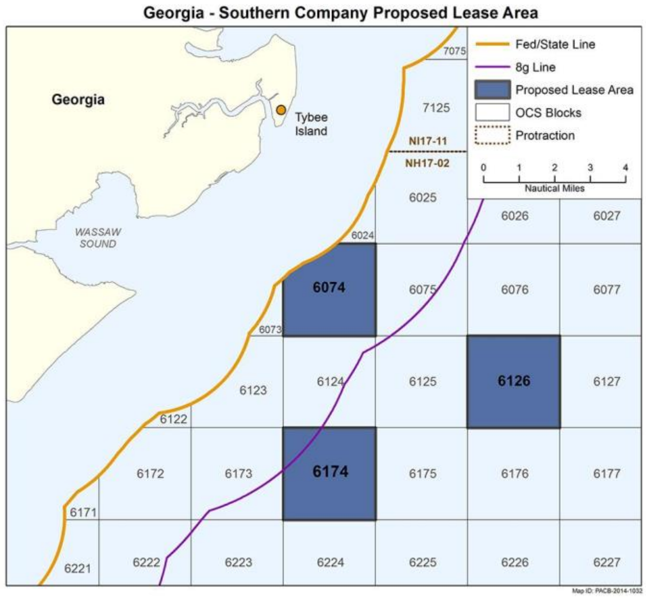

Figure 8 Proposed Georgia Lease Areas (Bureau of Ocean Energy Management (BOEM), n.d.-c)

As for Georgia, Southern Company submitted an Interim Policy lease application in April, 2011 in order to erect a meteorological tower for wind data collection. In 2012, Southern Company submitted two addendums to provide additional information including field site impact, construction and decommissioning in response to BOEM's request for clarification (Bureau of Ocean Energy Management (BOEM), n.d.-c). BOEM published a NOI calling for an EA that could be used for public comments to identify the WEA and problems associated with the data collection lease (Bureau of Ocean Energy Management (BOEM), n.d.-c).

2.2.5. Current state of the OSW industry in the United States

We now delve into the current state of policy and regulations since the 2007 Georgia Tech report (Southern Company & Georgia Tech, 2007). Today, the MMS is known as BOEM, the Production Tax Credit (PTC) was renewed in December 2015, Deep Water Wind (DWW) passed regulatory hurdles and is currently constructing an OSW farm, and Cape Wind construction has been suspended.

MMS to BOEM

On October 1, 2011, MMS was reorganized into two independent organizations: The Bureau of Ocean Energy Management (BOEM) and The Bureau of Safety and Environmental Enforcement (BSEE). BOEM is in charge of "managing [the] development of the nation's offshore resources in an environmentally and economically responsible way (Bureau of Ocean Energy Management (BOEM), 2016b)." Some of BOEM's duties are "issuing leases, plan administration, environmental studies, National Environmental Policy Act (NEPA) analysis, resource evaluation, economic analysis and the Renewable Energy Program (Bureau of Ocean Energy Management (BOEM), 2016b)". BOEM also has the power to grant commercial OSW energy leases to interested parties that intend to develop these renewable resources (Bureau of Ocean Energy Management (BOEM), 2016b). While BSEE focuses on enforcing safety and environmental regulations they also permit "offshore explorations and coordinate inspections, offshore regulatory programs, oil spill response, and newly formed training and environmental compliance functions" (U.S. Department of the Interior, 2011b).

This change is beneficial for OSW developers because three independent agencies were created with clear missions and goals that were put in place to minimize organizational conflicts (Bureau of Ocean Energy Management (BOEM), 2010). Prior to this restructuring, lease grants were slow and difficult to obtain. The Cape Wind project is evidence of this, taking 9 years since originally filing an application to receive an initial permit. Since the instatement of BOEM, the offshore lease process has become more streamlined and has a direct path to approval thanks to the "Smart from the Start" program. This program uses interagency cooperation, reduces and changes the Environmental Assessment and SAP process, while identifying the WEA with the lowest impact and highest potential (Farquhar, 2011). These changes, together allow for a more efficient and timely process in issuing leases. The DWW farm is evidence of this because permitting for the project began in 2012 and was fully permitted by 2014.

PTC renewal

The renewal of the federal PTC in 2015 was long awaited after the last PTC expired in December of 2014. The Consolidated Appropriations Act of 2016 renewed the PTC until December 2019 with a gradual phase-down for wind facilities that begin construction after December 2016 (NC Clean Energy Technology Center, 2015). For example, facilities beginning construction in 2017 face a 20% reduced PTC, while construction beginning in 2018 faces a 40% reduction (NC Clean Energy Technology Center, 2015). The current PTC is $0.023/kWh for wind facilities (NC Clean Energy Technology Center, 2015).

The PTC is responsible for ushering wind farm development that has resulted in various economic benefits (Union of Concerned Scientists, n.d.). Onshore wind electricity generation has increased by 40% between 2012-2014, and "wind capacity has [almost] quadrupled [and become] an average investment of $15 billion" per year (Union of Concerned Scientists, n.d.). With these measurable benefits, the PTC is a large incentive for more OSW ventures. The PTC has been a major driver of wind farm development resulting in various economic benefits (Union of Concerned Scientists, n.d.). Onshore wind electricity generation has increased by 40% between 2012-2014, and wind capacity has almost quadrupled to an average investment of $15 billion per year (Union of Concerned Scientists, n.d.). With these measurable benefits, the PTC is a large incentive for more offshore wind ventures.

Deepwater Water Wind (DWW) Farm

The status of OSW installments in the US is currently in its preliminary stage. DWW in New Shoreham (Block Island), Rhode Island is in the midst of constructing the first OSW farm in the U.S.

The DWW farm will consist of 5 turbines with a 6MW capacity for a total output of 30MW that will be sold to National Grid in the form of a power purchase agreement (PPA). This farm is operating under a federal investment tax credit (ITC) that will provide up to 30% of the upfront costs of development. While the project had early barriers to acceptance, both the Rhode Island Department of Environmental Management and U.S. Army Corps of Engineers, granted approval that was in accord with the Clean Water Act, state water quality regulations, and the Rivers and Harbors Act. The USACE and the U.S. Fish and Wildlife Service have also agreed that construction and operation of the farm are not likely to adversely affect terrestrial and marine protected species. This was the result of DWW working to minimize impacts on marine habitats by selecting construction techniques and equipment that minimized disturbances (U.S. Army Corps of Engineers, n.d.). Developers also minimized adverse impacts to fish and invertebrate species by situating the project to avoid direct impacts to important habitats (U.S. Army

Corps of Engineers, n.d.). This project is in the midst of construction, but is slated to begin operations in the fourth quarter of 2016 (Deepwater Wind, 2015).

DWW is paving the way for more OSW farms to begin construction and operations in U.S. waters. Unlike Cape Wind, DWW has the potential to be our nation's first operational OSW farm. The pathways taken by DWW developers will help facilitate future OSW development in the U.S. Understanding these pathways and following their example will only make for a stronger OSW future in this country.

Continued success for the DWW farm can be attributed to the Ocean Special Area Management Plan (Ocean SAMP), a Rhode Island State Development plan that supports and encourages offshore energy development (Kuffner, 2015b). This plan has been credited with saving the DWW farm years in permitting according to RI Governor Gina Raimondo. DWW was also proactive in resolving conflicts with other marine users and residents of Block Island while in the planning process. The Ocean SAMP allowed for fishermen, and others with conflicting interests to meet with planners and state regulators before construction activities began (Kuffner, 2015b). Meetings continue to occur during the construction process and are expected to continue after construction is complete (Kuffner, 2015b). This open communication system has proved successful so far to the efforts of DWW and all parties involved.

Financing was another important pathway to a relatively smooth construction process for DWW. Financing came after DWW secured necessary permits to begin construction. $290 million worth of financing was secured by DWW from the "Societe Generale of Paris, France and KeyBank National Association, of Cleveland, Ohio" and is further supported by D.E. Shaw and SunEdison (Kuffner, 2015a). DWW also maintains a contract with National Grid where costs for electricity are expected to be more than double the current rates for Rhode Island residents (Kuffner, 2015c). Juxtaposed with Cape Winds financing issues, DWWs small size might have been a determining factor in how quickly full financing was attained (Kuffner, 2015a).

Cape Wind

BOEM granted the first lease to build and operate an OSW farm in 2010 in Horseshoe Shoal, but Cape Wind Associates was granted a two year suspension of operations by BOEM in 2015 due to project finance issues (Bureau of Ocean Energy Management (BOEM), n.d.-a). Operations were slated to begin again in 2017, but in early 2015 National Grid and Northeast Utilities (now Eversource Energy) opted to indefinitely suspend their contracts to purchase power from Cape Wind (Abel, 2015). Furthermore, the developer was suspended by ISO New England from partaking in New England's electricity market following the developers' decision to terminate contracts to buy land and facilities needed for farm operations (Abel, 2015).

While it seems the Cape Wind development process is constantly delayed by regulatory and voluntary means, this project has come a long way since filing a permit application back in 2001. This project has possibly hurdled the most regulatory cases, and has been presented with the biggest opposition due to the environmental sensitivity of the Cape region. As difficult as OSW permitting is, the location of Horseshoe Shoal is potentially one of the most difficult locations to obtain a permit for. Despite these difficulties and an almost 15-year battle, Cape Wind is a lesson in perseverance for any utility companies contemplating OSW development.

With the long and tumultuous history that is Cape Wind, we can find several lessons that might be valuable to future OSW ventures. Finances and endless litigation are two hurdles that have been never ending for this project. Since 2001, there have been 32 cases filed against Cape Wind by environmental

activists, town governments, and other opposition groups. Out of 32 cases, 26 rulings were in favor of Cape Wind, 5 were withdrawn by the plaintiffs, and 1 initial ruling against Cape Wind has was temporary and is now moot (Cape Wind, 2014). Despite this backlash, Cape Wind has responded to each case and undergone the necessary procedures, despite being set back years. BOEMs new "Smart from the Start" program may satisfy the opposition or at the very least work through these issues in stakeholder engagement meetings. These meetings could provide a valuable arena where concerned groups can gather, discuss, and debate issues. This format may eliminate the number of cases brought against the project that stall development.

When compared to financing, one may believe litigation to be trivial in terms of setbacks. Financing a project like Cape Wind has been difficult and ongoing in the 15 years Cape Wind has been on the scene. Throughout the history of this project, the developer has faced an inability to secure financing. Over the years, Cape Wind was granted finances and loans from the Department of Energy, Massachusetts Clean Energy Center, the Danish Export Credit Agency and other foreign financial companies. Despite claims of complete financing, Cape Wind neglected to make payments on contracts with ISO New England and the Quonset Development Corporation on a lease causing much of their funding and contracts to fall through (Abel, 2015). ISO New England informed FERC that Cape Wind was suspended from operating in the electrical market soon after (Abel, 2015). Cape Wind further failed to begin construction by the contracted date, and choose not to extend contract deadlines, leading utility companies to terminate their contracts (O'Sullivan, 2015). With the project seemingly imploded in 2015 by financial struggles, we can use these struggles as lessons to secure all necessary finances before moving forward with a project. The Cape Wind project is a lesson in the importance of financing and how it is integral to such a large operation. Size of project, permit attainment and legal issues can affect financing and ultimately the feasibility of a project. It is likely that an offshore farm in the SE would also face similar hurdles, depending on chosen location.

South Carolina Palmetto Wind Project

The Palmetto Wind Project in South Carolina is currently undergoing assessment to determine if there is a potential OSW resource for the state-owned utility, Santee Cooper (Laporte & Alber, 2011). In 2010 the Southern Alliance for Clean Energy held a public forum to gauge the public and stakeholder interests associated with this project (Laporte & Alber, 2011). The Palmetto Wind Project in South Carolina is currently undergoing assessment to determine if there is a potential offshore wind resource for Santee Cooper, a state-owned electric and water utility (Laporte & Alber, 2011). In 2010 a public forum was held by the Southern Alliance for Clean Energy to gauge public and stakeholder interests (Laporte & Alber, 2011).

2.2.6. Policy for OSW Farm Construction

The GT 2007 report listed several sets of policies they believed to be important in assessing the feasibility of OSW off the coast of Georgia. Further analysis was done to assess whether these policies were pertinent to construction today in 2016. A brief description of the policies mentioned in the GT report can be found in the tables below.

Federal Policies and Governing Authorities

Federal governing authorities are important to consider in the event the offshore farm is built in federal waters. It is important to note that there are many regulatory authorities that require proper

permitting before planning and construction activities commence. Many federal policies require proper permitting, public comment periods, and final approvals from the appropriate governing agencies. Any of these considerations can provide push back that can delay OSW development.

The Federal legislative authorities and their required permits can be difficult to obtain as witnessed in the Cape Wind case which faced legal strife. Since 2011, BOEM has been the lead agency on alternative uses and leasing rights of the OCS according to the OCSLA. Other federal policies have remained stable in their authorities, provisions and permit requirements.

Georgia Policies and Governing Authorities

After a closer examination of the GA state policies, it appears that the Protection of Tidewaters Acts and the GA Oil and Gas Deep Drilling Act are inconsequential to an OSW project in Georgia waters. The Oil and Gas Drilling Act is pertinent to oil and gas development which is not a focus here. This act is void of provisions for renewable technologies which we are addressing in this report. The Protection of Tidewaters Act also seems irrelevant to this situation because it involves vessels used for habitation and refuge, something superfluous to OSW. However, the GA Coastal Management Act, Shore Protection Act, and Endangered Wildlife Act of 1973 may detail important guidelines that need to be adhered to if the choice is made to build OSW off the Georgia coast. Some of these policies are only relevant to Georgia due to the GT report's focus. For example the Heritage Trust Act of 1975 can be interpreted as a protecting policy for shipwrecks, reefs, and other types of natural and historical attraction off the coast. It is important to consider these policies when drafting applications for an offshore lease permit.

Table 5 Federal Policies taken from Southeast and Mid-Atlantic Regional Wind Summit (Ram, 2005)

Legislative Authority	Major Program/Permit	Lead Agencies
Energy Policy Act of 2005 amended OCSLA	Designated by BOEM as lead authority for alternative uses of the OCS. Jurisdiction over leasing rights for minerals production	BOEM (previously MMS)
Federal Power Act	License issued for electric power generation or interconnection on or on navigable waters	FERC
Rivers and Harbors Act-Section 10	Controls all work and construction on structures in U.S. navigable waters (≤ 200 nm) under OCSLA	U.S. Army Corps of Engineers (District Office)
National Environmental Policy Act (NEPA)	Mandates environmental assessment reports be created for all federal activities that could impact the value of the environment.	U.S. Army Corps of Engineers (District), Council on Environmental Quality
Coastal Zone Management Act (CZMA)	Gives jurisdictional rights for states to assess any actions that may impact state coastal resources	State Coastal Zone Management Agencies
Navigation and Navigable Waters	Requires a navigation aid permit (states vessels should be marked and lighted)	U.S. Coast Guard
Navigational Hazard to Air Traffic	Identifies airspace safe uses upon the commencement of construction activities.	U.S Federal Aviation Administration (regional administrator)
Migratory Bird Act	Prohibits that there shall be no “taking” or injuring of birds	Fish and Wildlife Service Migratory

		Bird Conservation Commission
National Historic Preservation Act	Consultation to protect historical sites and resources – places, properties, shipwrecks.	Department of the Interior (State Historic Preservation Offices)
Magnuson-Stevens Fishery Conservation and Management Act	Maintains and regulates fish stocks to a 200mi zone and defines "essential fish habitat" areas	National Marine Fisheries Service (Commerce)
National Marine Sanctuary Act (Title III)	Defines protection areas	National Ocean Service (within NOAA)
Endangered Species Act	Offers discussion around actions posing dangers to threatened and endangered species or habitats that have been modified.	Fish and Wildlife Service (Interior) National Marine Fisheries Service
Clean Water Act	Manages U.S. pollutant discharge into waterways	U.S. EPA
Marine Mammal Protection Act	Forbids or "strictly limits" any direct or indirect taking or aggravation of mammals	Fish and Wildlife Fisheries Service
Submerged Lands Act	States looking to develop on public lands or natural resources held in trusts by the government must be approved and granted a title	BOEM (previously MMS)
Estuary Protection Act	Protects estuarine habitats	Fish and Wildlife Service

Table 6 Georgia Policies (Marx, n.d.)

Legislative Authority	Major Program/Permit	Lead Agencies	Permitting
Georgia Coastal Management Act	Allows the GA Department of Natural Resources (DNR) to produce an implementation plans; spend, accept, and grant funds; grant the Governor rights to accept coastal management plans and to submit such plans to the federal government for authorization.	DNR Local Resources Division	
Shore Protection Act	Protects sands, sandbars, dunes, shoals, and beaches. Only temporary structures with permits are allowed to undergo construction activities. Establishes the Shore Protection Committee.	DNR Coastal Resources Division	Permit from DNR
Endangered Wildlife Act (1973)	Purpose is to identify/protect animals facing potential extinction. Provides authority to DNR board to issue regulations for protection of protected species.	DNR Wildlife Resources Division	
Ground Use Water Act	Provides authority to establish regulations and permit requirements for withdrawal, drilling, and water conservation plans.	DNR Environmental Protection Division	Requires Permit
GA Oil and Gas Deep Drilling Act	Provides protection to underground water supplies and environmentally sensitive areas afflicted by oil and gas drilling.	DNR Environmental Protection Division	No
Protection of Tidewaters Act	Requires permit for vessels used for habitation and not transportation within the tidewaters of the state	DNR Law Enforcement Section	Requires Permit

GA Environmental Policy Act	Necessitates an Environmental Effects Report for gov't actions that may adversely impact the integrity of the environment	State Attorney General's Office	Similar to EIS under NEPA for federal projects
Heritage Trust Act of 1975	Strives to protect areas in GA with either historical, recreational or natural value.	DNR	
GA Water Quality Control Act	Establishes regulatory requirements for water quality and quantity, permits for discharges into surface and subsurface waters.	DNR Environmental Protection Division	Requires Permit
GA Boat Safety Act	Establishes 1000 ft boating safety zones on Jekyll, Tybee, St. Simons, and Sea Islands.	DNR & GA Bureau of Investigation	
Game and Fish Code	Designates Wildlife Resources Division to operate Wildlife Management Areas, to register aquaculture activities, and to protect wildlife resources. Establishes hunting, trapping and fishing laws.	DNR Wildlife Resources Division	
Coastal Marshlands Protection Act	Works to protect tidal wetlands. Permits needed for activities requiring filling and dredging	DNR Coastal Resources Division	Permits needed for activities or structures in coastal marsh areas.

South Carolina Policies and Governing Authorities

OSW would need to undergo scrutiny with several governing authorities and policies before becoming a reality in South Carolina. The SC Public Service Commission (SCPSC) has regulatory control over wind projects in state waters while the South Carolina Department of Health and Environmental Control (SCDHEC) would be liable for ensuring projects are consistent with the SC Coastal Wetlands and Tidelands Act and the Critical Area Regulations (South Carolina Ocean Planning Work Group, 2012). The South Carolina Estuarine & Coastal Assessment Program, South Carolina State Historic Preservation Office, South Carolina Department of Natural Resources, and SCDHEC are some major SC agencies that would become involved in the SC OSW process.

North Carolina Policies and Governing Authorities

For the possibility of OSW to become a reality in North Carolina, there are several state policies and permits that need to be reviewed and obtained. Some notable policies include the North Carolina Environmental Policy Act (NCEPA), the Coastal Area Management Act (CAMA), the North Carolina Archives and History Act, the Carolina Public Utilities Act, and the North Carolina Dredge and Fill Act. Under CAMA, permits are required and issued by the Coastal Resources Commission for development that is located in an area of concern (North Carolina General Assembly, n.d.-b). In the event CAMA handles the offshore permitting from the state level, the developer would need to file a request with the Department of Environmental and Natural Resources (DENR) (North Carolina General Assembly, n.d.-a). The application under CAMA would likely cover any dredging and filling permits, and water quality permitting (North Carolina General Assembly, n.d.-b). The NC Cultural Resource Department in conjunction with the NC Archives and History Act, similar to the Georgia Heritage Trust Act, has the function of preserving and protecting the state's coastal history including shipwrecks and other underwater archaeological artifacts (North Carolina General Assembly, n.d.-b). Special permitting may be required if OSW development occurs in the vicinity of these areas. The NCEPA, by law, gives towns the

right to require environmental impact statements unless one has already been filed with the state (North Carolina General Assembly, n.d.-a). Along with these state policies, the same federal policies mentioned above are important to the regulation and permitting process in NC.

2.2.7. Other Notable Policies and Initiatives

In addition to the existing major federal/states policies and regulations, there are some updates of new policies and initiatives that are directly related to the management and exploration of ocean resources, with a specification of OSW.

The National Ocean Policy

The National Ocean Policy (NOP) and the National Ocean Council (75 FR 43023) was established by Executive Order 13547 in July 2010 to ensure the safety and sustainability of the ocean, coasts and the Great Lakes (U.S. Department of the Interior, 2011a). The NOP states, in part, that the U.S. will protect, maintain, and restore the "health and biological diversity" of these areas and use "the best available science to inform decisions so as to promote the wellbeing, prosperity, and security of present and future generations (Executive Order 13547)" (The White House, 2010). In 2012, the National Ocean Council released the NOP Implementation Plan, which specified the Federal agencies roles in translating the NOP into action, supporting local choices, and providing scientific research information and was open for public comment (The White House, 2014).

The NOP also calls for the creation of "a framework for coastal and marine spatial planning (CMSP)" (Bureau of Ocean Energy Management (BOEM), n.d.-d). CMSP is an ecosystem-based spatial planning process used to increase scientific understanding of ocean and coastal ecosystems. It is a method developed from the bottom up to improve collaboration and coordination among all coastal and ocean interests, informing and guiding decision-making that affects economic, environmental, security and social interests.

CMSP is critical in ensuring the compatibility of OSW generation to minimize the potential water use conflicts so as to achieve socio-economic benefits. A recently conducted assessment of the proposed South Atlantic Regional Planning Areas including Georgia, Florida, North Carolina, and South Carolina used CMSP to compile baseline information on wind speeds, marine traffic, and locations of artificial reefs and vital fish habitat with the OCS and federal waters (The White House, 2009). In May 2011, Rhode Island Sea Grant expanded the utilization of CMSP to offshore renewable energy siting and uses it to efficiently and effectively resolve political conflicts with stakeholders, reduce environmental impacts and increase offshore energy production certainty for investors and regulators (Laporte & Alber, 2011). More on the benefits and use of CMSP will be discussed later.

OSW Planning Initiatives

Department of Interior Secretary, Ken Salazar, announced the OCS renewable energy initiative to streamline the processes for commercial wind generation legal work, identify and concretely study the Wind Energy Areas (WEA) and process OCS energy transmission line proposals (U.S. Department of the Interior, 2011a). This specification focuses on collaborative efforts to facilitate all aspects of OSW development including funding, site evaluation, permitting, and designation of potential wind energy areas or zones (Farquhar, 2011).

Funded by US DOE and managed by the Southern Alliance for Clean Energy, the Southeastern Ocean-based Renewable Energy Infrastructure Project is coordinated and monitored by the Georgia Environmental Finance Authority team. This team works to provide an evaluation of infrastructure requirements for WEAs, using time-series data, gathered from sites along SE Coast. Currently, there are several ongoing OSW plans at the Federal, State, local and regional levels (Laporte & Alber, 2011).

Georgia Wind Working Group

Formed in 2005, the Georgia Wind Working Group is a coalition of representatives comprised of utilities, wind developers, government agencies, and institutions. The group is comprised of several agencies including Georgia Institute of Technology's Strategic Energy Institute, the Georgia Environmental Finance Authority, and the Southern Alliance for Clean Energy. This Group works to promote offshore renewable energy through stakeholder partnerships, site evaluations, and public education.

North Carolina OSW Jobs and Economic Development, NCSB 747

North Carolina legislators put forth an aggressive piece of OSW legislation in May, 2011. This novel legislation aimed to include a targeted installation of OSW energy with a capacity of 5000 MW by 2030. It further listed requirements for state utilities to sign a 2,500 MW long-term OSW contract for 7-10 years.

2.2.8. Important Regulatory Considerations

Stakeholders

Stakeholders play an important role and can have a large influence on decisions regarding OSW. OSW stakeholders come in many forms and can include various government organizations, environmental organizations, coastal alliances, and wealthy residents. Stakeholders have many opportunities to voice their opinions on related OSW projects via task force meetings. BOEM is responsible for hosting these meetings for states with renewable energy task forces. SE states with these task forces include NC, SC, and FL. These task forces provide a means for stakeholders to make informed decisions. BOEM and other agencies attend these meetings to present finding of OSW related studies. While these studies can be useful for strategic decision making, stakeholders can choose to ignore this information and make decisions based on their own interests. This makes related studies very important in order to convince stakeholders to choose a course of action based on scientific data. Marine Spatial Planning (MSP) is a valuable tool for making these types of decisions.

Marine Spatial Planning

Marine spatial planning is critical for a wind developer. MSP takes multiple factors into consideration for the siting of a wind farm. Defined, MSP is a "public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process" (UNESCO Marine Spatial Planning Initiative, 2016). MSP is particularly helpful in identifying barriers that make an area unfavorable for wind farm operations. Electricity markets, locations surrounding military areas, shipping lane locations, fishing grounds, endangered species migratory paths and ecologically rich regions can pose as barriers to OSW development, but MSP can help model these constraints and provide useful

information that allows for the smooth integration of wind into the marine environment (European Wind Energy Association (EWEA), 2012).

While the Southeast has favorable coastal wind resources, it is not exempt from these constraints. These barriers make areas of this coastline unfavorable for wind farm operations. In particular, there are large restrictions off the GA coast. To see all the barriers that exist, Georgia Tech recently released a marine spatial planning tool in February 2016 that models various restrictions. The proposed wind farm locations off the Georgia coast in the Georgia Tech report are in an area that experiences OSW speeds of 7.63 m/s with water depths ranging from 10-15m according to the online geospatial tool. These areas should be reevaluated based on constraints we discovered while using the tool related to North Atlantic Right Whale calving, bird migration, military operations, and shipping routes. When considering a new electrical venture, it is important to consider the transmission network capacity limits and the current electricity market in the potential area of development. Transmission lines may not be able to fully support the power generated from the farm and greater transmission lines signal greater line losses. This constraint must be considered in site assessment plans. Finding a market where the generated power can be sold is also vital. This means constructing a wind farm near large demand centers and cities where the power needs to be transmitted a short distance. The Tybee Island farm location near Savannah is logical because Savannah is a large demand center for electrical power due to the population size. Savannah is also one of the busiest ports in the U.S, meaning maritime traffic in this area is highly concentrated (Piperato, 2014). Furthermore, military operations require air space that cannot be impeded by turbines. FAA regulations can further restrict turbine height. Bird migration is another important restriction for deciding where to place an OSW farm. Finally, one of the most important restrictions has to do with a species on the brink of extinction, the North Atlantic Right Whale.

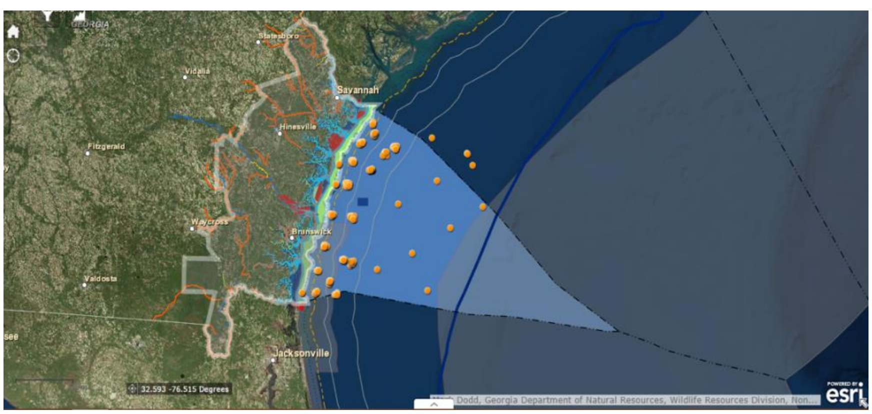

Figure 9 North Atlantic Right Whale Habitat (light blue triangle) and Critical Marine Habitat (light gray) (Georgia Tech, 2016)

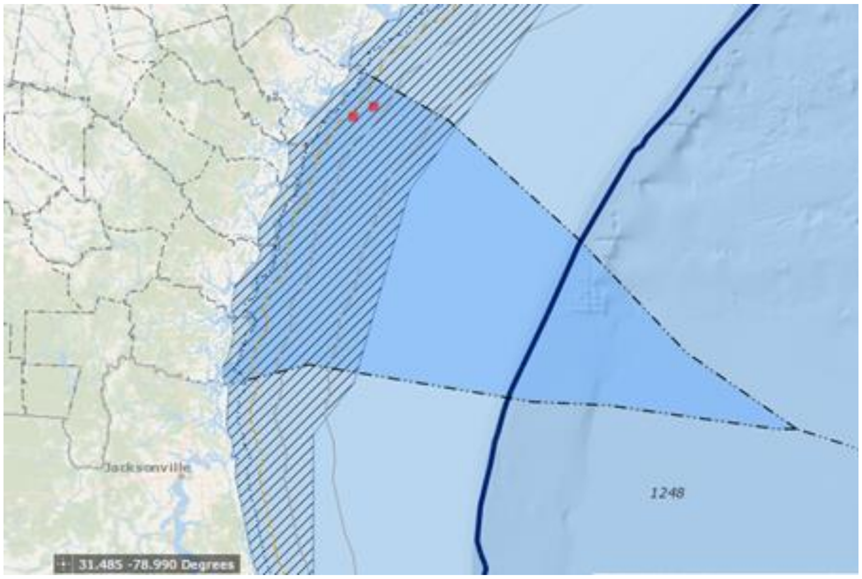

Figure 10 GT wind planning sites/ BOEM wind planning areas (red boxes) juxtaposed with the critical NARW habitat (striped region) and NARW Habitat (light blue triangle) (Georgia Tech, 2016)

Environmental Impacts and Regulations

Environmental regulations exist to protect the integrity of the marine environment. Several of these policies could impact the development of an OSW farm in the SE and anywhere in the U.S. The implications of some of these policies, in relation to wind development in the SE, are discussed in table 7.

Table 7 Environmental Policy Considerations. (American Wind Energy Association (AWEA), 2013)

Policy name	Description
Endangered Species Act 1973	Developer must work conjointly with NMFS and USFWS to minimize threats that may consequently "take" a species.
Marine Mammal Protection Act 1972	Works to prevent a "taking" of mammals
Magnuson-Stevens Fishery Convention and Management Act	Protects habitats of federally managed fish species by collaborating with NMFS on precautions to take to avoid the adverse effects associated with any proposed activities.
National Environmental Policy Act 1969	Requires environmental assessment that provides analysis on OCS activities and subsequent environmental hazards.
Rivers and Harbors Act 1899	Activities and modification in a navigable waterway must be accepted and permitted by the USACOE.
National Marine Sanctuaries Act	States that projects cannot be built in a designated marine sanctuary and must be reviewed if they are expected to impact nearby sanctuaries.

Clean Water Act	Requires a dredge and fill permit from USACOE that is mandatory for the erection of OSW, and for buried transmission lines.
Migratory Bird Treaty Act 1918	States that effects on these birds are "avoided, minimized, and mitigated" if possible.
Estuary Protection Act	Project developers must give consideration to the estuarine impacts associated with the use and development of areas that can impact these waterways.

The Endangered Species Act requires agencies to work with the U.S. Fish and Wildlife Service and NOAA NMFS when engaging in activities that can "take" a species classified as endangered or threatened via the interaction with the endangered species' habitat (American Wind Energy Association (AWEA), 2013). If a taking event is expected, the wind project producer must acquire "an Incidental Take Permit" and simultaneously file a "Habitat Conservation Plan" as explained in ESA 1973 (American Wind Energy Association (AWEA), 2013). The Marine Mammal Protection Act is similar to the ESA, but focuses primarily on the protection of mammals. Under the MMPA, OSW developers need to "apply for a Letter of Authorization or Incidental Harassment Authorization" that identifies any prospective species afflicted (American Wind Energy Association (AWEA), 2013). These reports are often written in conjunction with appropriate government agencies that have detailed data on species movement and habitat. This enables comprehensive analysis that minimizes the impacts associated with marine development activities.

As an ecologically rich region, the southeastern U.S. is sensitive to this type of marine development. In particular, this region bears witness to the migration and calving of the North Atlantic Right Whale, one of the most endangered mammals in the world. The migratory path of the NARW follows the coast down to the southeast where the whales stop to calve in the Fall/Winter months. As a result, there is a proposed critical habitat area for the NARW that extends from Cape Fear, NC down to Northern Florida. This proposed habitat area, could restrict OSW activities to further distances from shore, or to northern regions of the southeast. Noise associated with wind farm construction (pile driving, boat traffic, etc.) can interfere with mammal sounds which are important for NARW mating (Cleary & Halpin, 2016). A decision on this habitat designation is expected to be made in early 2016 (Cleary & Halpin, 2016).

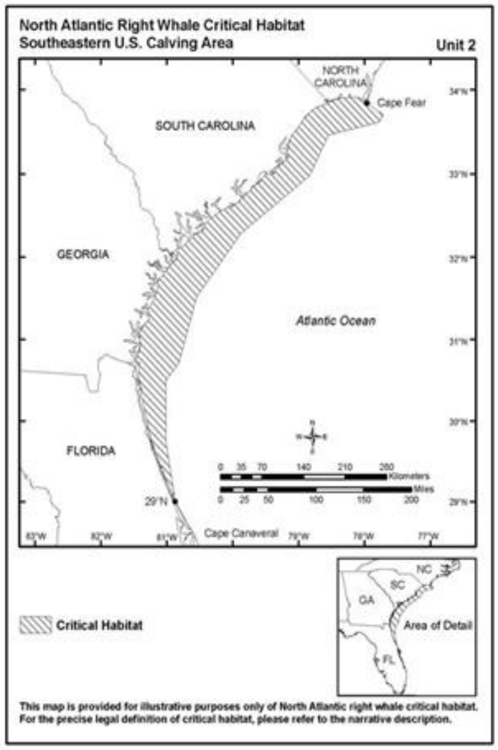

Figure 11 North Atlantic Right Whale Critical Habitat Zone (National Oceanic and Atmospheric Administration (NOAA), 2016)

The DWW project went through these ESA and MMPA permitting processes with the help of several Northeastern conservation organizations. In doing so, they hatched a plan to minimize the construction impacts on the NARWs found in the region. Restrictions on noise producing activities and reduced speed limits for boat traffic are some examples of the protective measures taken for the construction of the DWW farm (Deepwater Wind, 2014). These types of protective measures and others are needed in the southeast, in the event of wind farm construction, to ensure the safety of the NARW and other critical marine species. It is critical to consider the timing of development activities in order to minimize adverse impacts (Cleary & Halpin, 2016). In doing so, OSW will coexist in harmony with the marine environment.

2.3. Economics

2.3.1. Financing Structures in Europe

The European Union (EU) has used a number of innovative financing structures to fund developments in OSW. As one of the more costly renewable energy options, favorable policies including mandated renewable energy goals have kept potential financiers interested. With the higher incurred risk, investors that aren't the power producers themselves are typically looking for return on equity (ROI) in excess of 10% (Figure 11) *(Sims, 2013)*.

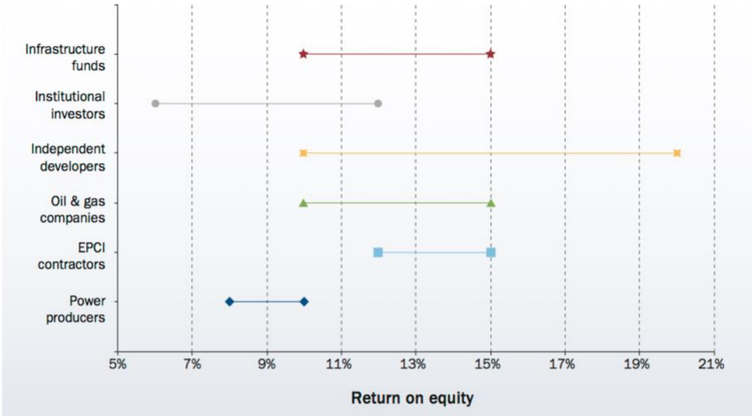

Figure 12 Required return on equity (Sims, 2013)

With a typical 3:1 debt to equity ratio, OSW requires significant access to debt capital for projects requiring external funding (European Wind Energy Association (EWEA), 2013). Compared to other alternative technologies, it involves higher investment risk and is less attractive to debt and equity providers (Figure 12). In the U.S., while Southern Company could apply to build an OSW farm, the relevant state Public Utility Commissions would need to arrange financing for the project. Due to the security of this funding and the project, required ROI would be nearly zero. Southern would still have to factor this cost into their rate base for customers, which would eliminate the need for debt capital, but it would run counter to their stated goal of providing "cost-effective renewable energy" solutions (Southern Company, 2013).

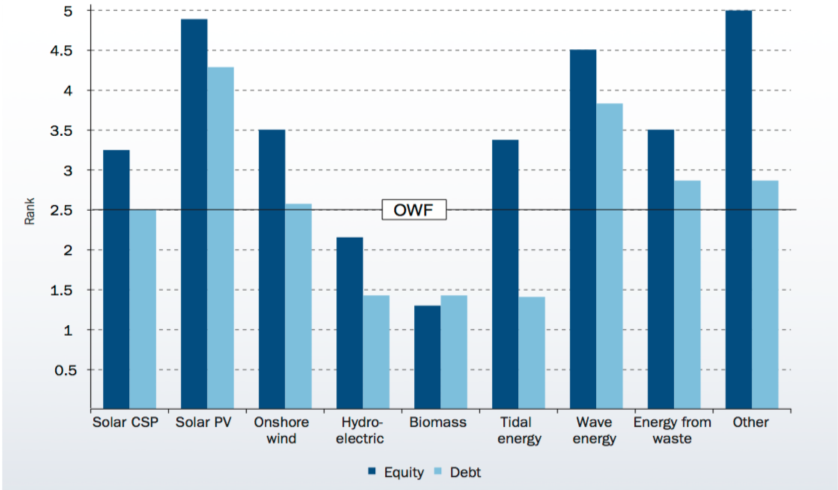

Figure 13 Debt to equity ratios for renewables (European Wind Energy Association (EWEA), 2013)

Aversion to the risks of investing in OSW will inevitably decrease as technology improves and more projects are approved, but kick-starting that process in the U.S. may prove to be difficult.

2.3.2. U.S. Economics in the Face of Changing Policy

The Clean Power Plan (CPP) could offer some new incentive and place a bit of urgency on new renewable energy developments, specifically in states with high emissions reduction targets like North Carolina, South Carolina, and Georgia. For the South Atlantic coastal states, OSW could present itself as

a potential option to create a large renewable generating capacity that can make a significant green portfolio for Southern Company in the face of escalating demand. New project financing structures and bidding scenarios can streamline development planning and pave the way for more of these projects to go forward at once.

The pricing and bidding structures used for creating and approving these projects are slow and outdated. It was built to maximize revenue for a given number of projects in the short term rather than speed-up the process of getting projects developed and onto the grid (Firestone et al., 2015). In the U.S., developers were typically responsible for getting these renewable projects off the ground, but a new model would promote competitive pricing and put the onus on the states to invest in these projects, including OSW (Figure 13). With significant policy pressure from the CPP, states could become more amenable to a streamlined model, but this would be true of all renewables.

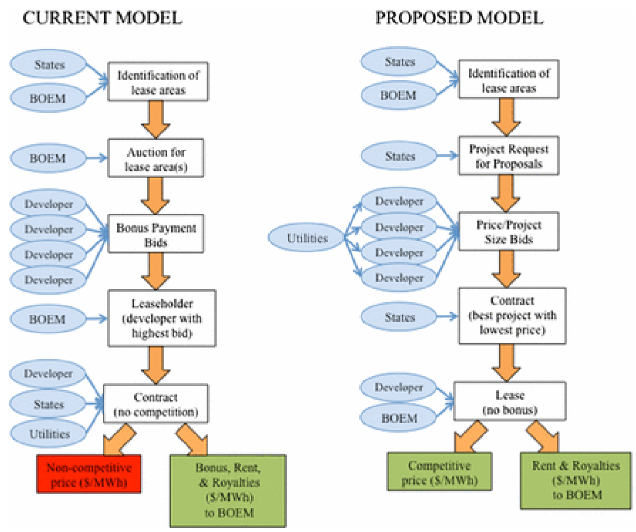

Figure 14 Bidding strategy paradigm shift proposed by National Academy of Sciences (Firestone et al., 2015)

Applying an EU model to U.S. policy won't happen overnight, but a utility provider could work with state public utility commissions to institute this new model that would help states in their customer base comply with the CPP.

2.3.3. Project Economics in the U.S.

With third-party OSW projects limited to 80 MW under the Public Utility Regulatory Policies Act (PURPA) (Cornell University Law School, n.d.), the southeastern U.S. remains a high-risk, low-reward market for potential developers. Additionally, there is a lot of room left for expansion of onshore wind at significantly lower costs than offshore throughout the U.S. (Figure 14) (U.S. Department of Energy, 2015).

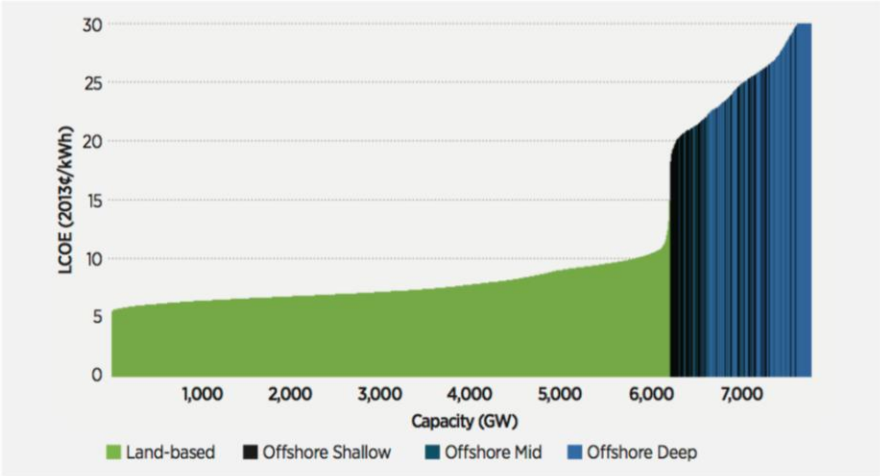

Figure 15 LCOE for onshore vs. OSW (Source: DOE, 2015)

Short of significant financial incentives specifically for OSW, it's difficult for an investor owned utility or public utility company to justify the very high installation costs and incurred debt for OSW projects.

3. Methodology

3.1. Technology

The 2007 Georgia Tech report provided a detailed wind turbine machine layout which includes all the important pieces such as nacelle, rotor blade, generator and gearbox. Thus the technology section in this report does not provide redundant explanations on turbine structure, but rather focuses on the turbine mechanical technology improvement from 2003 up until now. Wind turbine data from six major turbine manufacturers is collected, including detailed specifications on hub height, generator size and rotor blade length.

3.2. Policy and Regulation

A closer examination of major regulatory changes, including changes to government agencies, organizations and federal and state level policies in relation to renewable energy was conducted. We further provided elaboration on the policies and regulations listed in the 2007 Georgia Tech Report and commented on their relevance today. Most of this analysis was done by conducting an extensive literature review and reaching out to experts in the field of marine studies.

This regulatory analysis provides Southern Company with the basic tools to further assess the incentive or limitations of OSW technology. It also serves to highlight any financial cost reduction potential when paired with our levelized cost of electricity analysis.

3.3. Economics and Financing

A variety of lenders, a less restrictive, and great policy incentives have allowed for more opportunities to construct wind farms and subsequently produce wind in the EU, but the U.S. and the Southeast in particular are limited by PURPA and third-party sales restrictions. A literature review was done of European case studies and reports aimed at linking EU results to a potential U.S. OSW market.

Since the 2007 Georgia Tech Report, the U.S. hasn’t made nearly as much progress in OSW as compared to the E.U., so comparisons are made between the two markets in order to inform our LCOE calculations and the decisions of Southern Company. Updates on the cost of offshore vs. onshore wind are given, as well.

3.4. Levelized Cost of Electricity (LCOE) Methodology

The levelized cost of electricity (LCOE) is an economic measure of the total financial requirements for power generating units over its operating terms. It represents minimum return to recover all the expenses, including capital expenditures, transmission costs and variable costs such as fuel costs, operations and maintenance (O&M) costs. To get the LCOE, we added up all the fixed and variable expenses using the NREL data, scaled them down to our proposed OSW farm size and divided the total costs by the annual electricity generation. It could provide Southern Company a comparison of the costs across different technology, especially with onshore wind generation.

4. LCOE Results

4.1. OSW LCOE

For our proposed OSW farm, there are several underlined assumptions concerning the wind farm size, location, timing of construction and operations, etc. To start with, we determined the wind farm overall capacity to be 300 MW, which is a variable input of our LCOE model and subject to change based on our client's need. Using the Siemens OSW turbine, which is the most widely used one in Europe and has a turbine rating power of 3.6 MW, we got the number of turbines needed in our OSW farm as 84. Timing is an important assumption in our model, since the estimated OSW LCOE could lower by 39% from the fiscal year 2011 to 2020 (The Crown Estate, 2012).

4.1.1. Key Assumptions

Table 8 Key Assumptions adopted for the LCOE Calculation (*Model Inputs)

DCF Model Inputs (Kempton, Pimenta, Veron, & Colle, 2010)		**Wind Farm Assumptions** (Green, Bowen, Fingersh, & Wan, 2007)	
Capacity Factor, %	31.6	Years of Development	2015 - 2020
Inflation, %	2	Commissioning Year	2020
Discount Rate, %	10	Operation Terms, yr	20
Depreciation Term	MACRS	Wind turbine rating, MW	3.6
Depreciation Years	5	Number of turbines	84
Policy Inputs		Rotor diameter, m	120
PTC, $/MWh	22 (Levitt, Kempton, Smith, Musial, & Firestone, 2011)	Distance between turbines, m	630
PTC Escalation, %	1.5	Distance between rows, m	630
PTC Terms, yr	5	Cable length between turbines and between rows, m	630
Decommissioning, % of Capital	3	Substation distance to shore, km	20
Tax Rate, %	40	Length of onshore transmission, km	15

PTC is the inflation-indexed Production Tax Credit adjusted in 2010 dollars, which is worth $22/MWh. All wind power generation in the United States benefits from a 5-year Modified Accelerated Cost-Recovery System (MACRS). The US DOE has two loan guarantee programs: Section 1705 (expired in 2011) and Section 1703. Under Section 1703, a loan is provided to innovative technologies that reduces or sequesters anthropogenic emissions of greenhouse gases (Chadbourne, 2014). This includes wind generation loans which are provided by the Federal Financing Bank at low rates, with an additional 15% subsidy fee to cover the risk of default (Levitt et al., 2011).

4.1.2. OSW Generation Output

Assuming an OSW turbine nameplate capacity of 3.6 megawatts (European average) and a farm size of 300 MW, we figure a farm of 84 turbines in a hypothetical wind farm off the Southeast Coast. The annual electricity output can then be calculated as:

$$Annual\ Electricity\ Output = Nameplate\ Capacity \times Capacity\ Factor \times 8760 hrs/yr$$

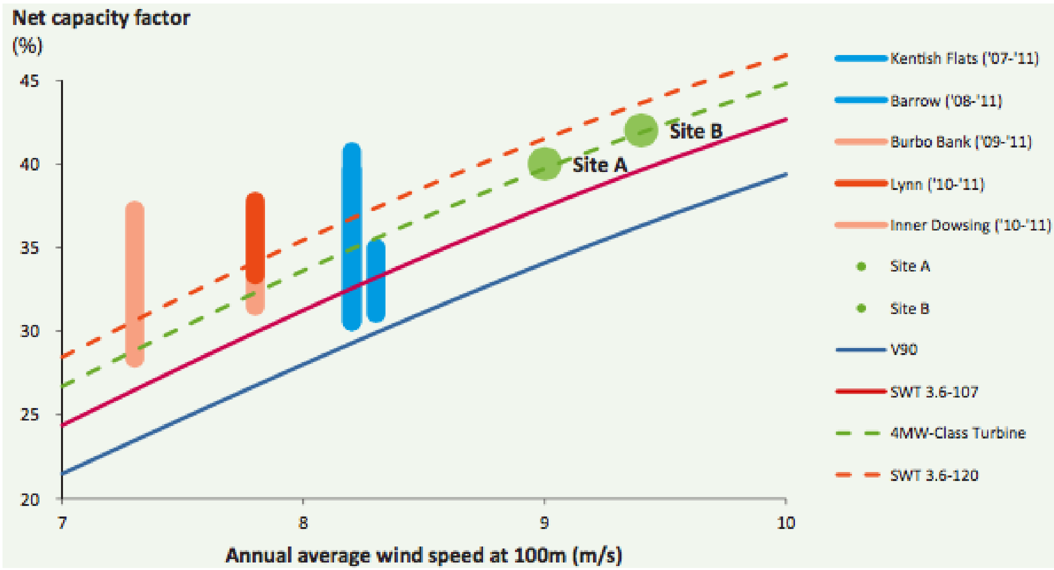

Figure 16 Net Capacity Factor with Respect to Annual Average Wind Speed at 100m (The Crown Estate, 2012)

One of the key challenges faced by the simulation of OSW generation is the variability and uncertainty of the wind resource. Figure 15 shows the relationship between gross capacity factors and annual average wind speed for commercial UK wind farms using the V90 or the SWT3.6-107 turbine.

The wind speed data off the Southeast Coast in the US is demonstrated in Table 9. The annual average gross OSW capacity factor off the Southeast Coast is around 38% (Kempton et al., 2010).

Table 9 Overview of Seasonal and Yearly Mean Wind Speed, Mean Power Generation(MW), and Capacity Factor (CF) (Kempton et al., 2010)

Season	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Mean	N
Wind speed ($m\ s^{-1}$)													
Spring	6.81	7.45	7.79	7.14	8.72	9.5	8.59	7.85	8.51	8.59	7.94	8.08	6918
Summer	5.12	5.61	6.03	7.34	7.23	7.73	6.98	6.78	7.38	7.06	6.13	6.67	5709
Autumn	7.77	7.93	8.43	7.85	7.93	8.25	7.45	8.5	8.46	8.95	8.89	8.22	7350
Winter	7.62	7.68	8.04	7.12	9.29	10.16	8.72	9.33	9.38	9.83	11.03	8.93	5957
Yearly	6.9	7.23	7.64	7.38	8.3	8.91	7.94	8.14	8.44	8.64	8.52	8.00	25934
Turbine power (MW)													
Spring	1.42	1.63	1.78	1.48	2.18	2.56	2.22	1.82	2.09	2.12	1.89	1.93	6918
Summer	0.64	0.77	0.95	1.51	1.52	1.81	1.43	1.34	1.57	1.41	1.10	1.28	5709
Autumn	1.74	1.80	2.06	1.79	1.83	1.97	1.65	2.11	2.09	2.31	2.31	1.97	7350
Winter	1.68	1.72	1.90	1.54	2.45	2.81	2.24	2.46	2.46	2.63	3.09	2.27	5957
Yearly	1.40	1.51	1.70	1.59	2.00	2.29	1.89	1.94	2.06	2.13	2.11	1.87	25934
Capacity Factor (CF)													
Spring	0.28	0.33	0.36	0.30	0.44	0.51	0.44	0.36	0.42	0.42	0.38	0.39	6918
Summer	0.13	0.15	0.19	0.30	0.30	0.36	0.29	0.27	0.31	0.28	0.22	0.25	5709
Autumn	0.35	0.36	0.41	0.36	0.37	0.39	0.33	0.42	0.42	0.46	0.46	0.39	7350
Winter	0.34	0.34	0.38	0.31	0.49	0.56	0.45	0.49	0.49	0.53	0.62	0.45	5957
Yearly	0.28	0.30	0.34	0.32	0.40	0.46	0.38	0.39	0.41	0.43	0.42	0.38	25934

In addition to the year-around wind variability, there are average losses include 6.20% wind-farm shut-down time for maintenance, 7.00% aerodynamic array losses (wake effects), 1.80% electrical array losses and 3.00% of other losses (Levitt et al., 2011). After factoring these additional losses, we found the average net capacity factor to be 31.6%, which is close to Levitt's estimates of capacity factor (27% - 30%) off the Southeast Coast. Therefore, annual electricity output is calculated to be around 837,000 MWh/ yr for our proposed offshore wind farm (Levitt et al., 2011).

4.1.3. Baseline Capital Cost Estimates

Turbine parts, labor, grid connection, construction of buildings to aid in farm construction and project consultancy costs all encompass the capital costs of offshore wind (International Renewable Energy Agency (IEA), 2012). Capital costs of OSW are typically around twice the cost of onshore projects due to extreme conditions in the oceanic environment according to Douglas-Westwood (Westwood, 2010). Using the "observed industry ranges for LCOE inputs" from NREL, the baseline and most likely scenario would have a capital cost of $4,343/kW and a total capital cost of around $1.3 billion.

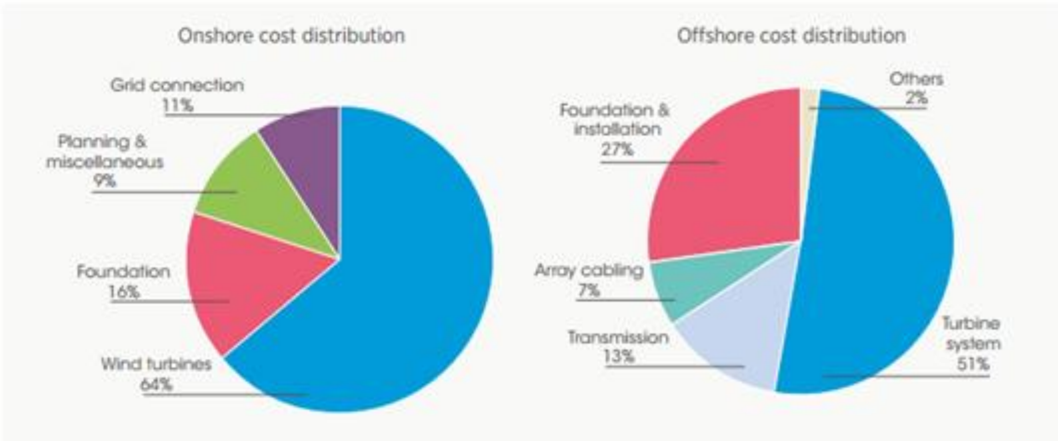

Figure 17 Comparison of cost distributions for onshore wind vs. OSW (International Renewable Energy Agency (IEA), 2012)

4.1.4. Baseline O&M Estimates

According to the National Renewable Energy Lab's 2013 OSW Report, the baseline installation, operation, and maintenance (IO&M) costs of onshore are approximately ⅓ that of OSW energy costs in U.S. When installation is excluded, O&M averages 12% of the total cost of a wind farm. This yields an average O&M cost of 2.83 ¢ per kWh (Maples, Saur, Hand, van de Pietermen, & Obdam, 2013). With a total baseline LCOE of 23.3 ¢ per kWh, OSW well exceeds a typical grid price for electricity, even before it hits the wholesale and retail markets.

Table 10 Baseline LCOE costs for Atlantic Coast (Maples et al., 2013)

	($/kW)	($/kWh)
Turbine Capital Cost	1800	0.0650
Development	*118*	*0.0043*
Port and Staging	*26*	*0.0009*
Support Structure	*800*	*0.0289*
Electrical Infrastructure	*498*	*0.0180*
Installation Vessels	*1240*	*0.0448*
Balance of Station	2682	0.0969
Insurance	*90*	*0.0033*
Decommissioning	*471*	*0.0170*
Contingency	*448*	*0.0162*
Soft Costs	1009	0.0364
Overnight Capital Cost (OCC)	5491	0.1983
Construction Financing	*165*	*0.0060*
Installed Capital Cost (ICC)	5656	0.2043
O&M ($/kW/yr)	784	0.0283
Net Annual Energy Production (AEP) (MWh/MW/yr)	3267	
Fixed Charge Rate (FCR)	11.8%	
Levelized Cost of Energy ($/kWh)	**0.233**	

As seen in the above table, O&M is evaluated on an annual average basis which is then expressed as a cost of $784 per installed capacity ($/kW). This value is then levelized to a total O&M cost of $.0283/kWh.

O&M Cost Scenarios

Overall, variations in O&M can have a significant effect on LCOE, especially when compared to grid prices for conventional fuels or even onshore wind. The average O&M cost of $.0283/kWh for U.S. offshore is significantly greater than the approximately $.01/kWh for onshore (International Renewable Energy Agency (IEA), 2012). Weather conditions around offshore installations, distance to shore, and technical components of turbines can have a significant impact on variable aspects of O&M. Investing in barges to transport large replacement parts, having on-site parts storage and helicopter access, and advanced performance monitoring systems are all additional installations that can improve turbine availability and lower overall O&M. Lack of cost savings investments can raise O&M up to 4.44 ¢per kWh in the worst case scenario, which assumes poor weather conditions and no additional installations. The lowest possible LCOE O&M cost for a wind installation is 1.80 ¢per kWh, which includes investment in each of the installations mentioned above. However, it is important to keep in mind that while these investments offer cost savings in the category of O&M, the additional capital costs would raise the LCOE above the baseline scenario (Maples et al., 2013). The NREL put together a more elegant comparison with their baseline scenario compared to a preferred strategy including better turbine service operations and advanced condition monitoring (Table 11) (Maples et al., 2013).

Table 11 Preferred vs. Baseline LCOE scenario for O&M (Maples et al., 2013)

	Baseline	Preferred	Impact
AEP (MWh/MW/yr)	3267	3648	+11.7%
Availability (%)	84.5	93.3	+10.4%
O&M ($/kWh)	0.0283	0.0248	-12.4%
Ports & Staging ($/kW)	26	79	+304%
Installation Vessels ($/kW)	1240	1055	-15%
LCOE ($/kWh)	**0.233**	**0.200**	**-14%**

With these improvements in the functionality and availability of a wind installation, O&M costs fall slightly, but production rises significantly enough to cause a 14% decrease in total LCOE. While this doesn’t begin to approach grid parity, this makes it clear that technological advancements can lower the O&M and increase the productivity of a wind installation.

4.1.5. OSW Transmission Costs

Offshore transmission costs consist of the expense of offshore and onshore substations, and transformers and cables. Based on the assumptions listed above, we assume the distance to shore is 20 km and thus the length from the offshore substation to the onshore substation is 20 km. It is also assumed that the turbine-to-turbine distance is 630m. For electricity transmission, the energy loss along cables is typically 1.2%, with an ideal scenario of 0.9% (Green et al., 2007). The baseline and preferred scenario analysis listed below are both based on case studies by National Renewable Energy Laboratory (NREL).

Table 12 Baseline vs. preferred scenarios for transmission costs. (Green et al., 2007)

	Baseline	Preferred
Substation and transformer ($M)	69.89	69.89
Onshore substation and transformer	29.37	29.37
Offshore substation w/Transformers	40.52	40.52
Cable ($M)	104.73	99.51
Onshore cables	5.59	5.59
Offshore cables	9.46	8.31
Cable collection and shipping	82.85	78.78
Cable installation	6.83	6.83
Total	174.620	169.400
Annual electricity generation (MWh)	2628000	2628000
Losses	1.20%	0.90%
Net electricity production	2596464	2604348

4.1.6. OSW LCOE Results

The LCOE we estimated is around $158.50/MWh. According to the EIA, the LCOE of offshore wind for a farm build by 2020 is $168.6/MWh (Energy Information Administration (EIA), 2015a).

Table 13 LCOE Parameters and Final Estimate

OSW LCOE Estimate Year 2015	
Annual Energy Production, MWh	837091.58
Capital Costs, $/MWh	63.22
Operating Costs, $/MWh	28.30
Transmission Costs, $/MWh	67.00
LCOE, $/MWh	158.50

4.2. Sensitivity Analysis of Capacity Factor

For a typical US OSW farm, doubling the Capacity Factor could lower the LCOE by nearly half. As indicated in Figure 17, if we assume a 10% cost of capital, inflation-adjusted to 2010 dollars, the LCOE is 0.19$/KWh when the net capacity factor is 31.6% for a 3.5MW-size OSW farm in 2015. If the capacity factor improves to 50%, LCOE would decrease to 0.15$/KWh. According to International Renewable Energy Agency, compared to onshore wind generation, the high O&M costs add to the high LCOE of OSW generation, which indicates that better operational strategies and optimized supply chain management can significantly improve the OSW generation economics and reduce its LCOE (International Renewable Energy Agency (IEA), 2012). As we calculated for our proposed OSW farm in

Figure 17, an increase of capacity factor from 27% to 35% could lower the LCOE from $ 0.168/KWh to $ 0.152/KWh.

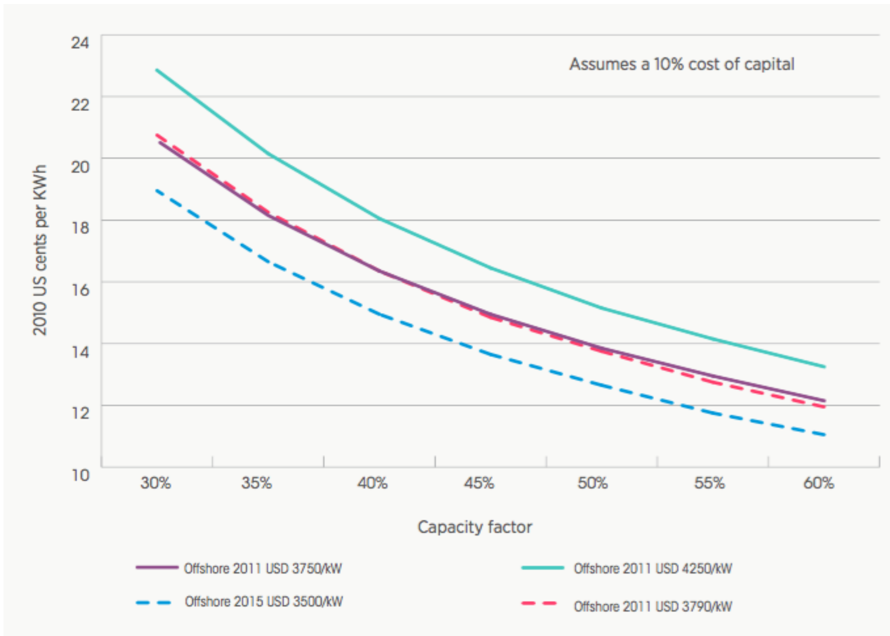

Figure 18 The LCOE of Wind For Typical North American OSW Farms (International Renewable Energy Agency (IEA), 2012)

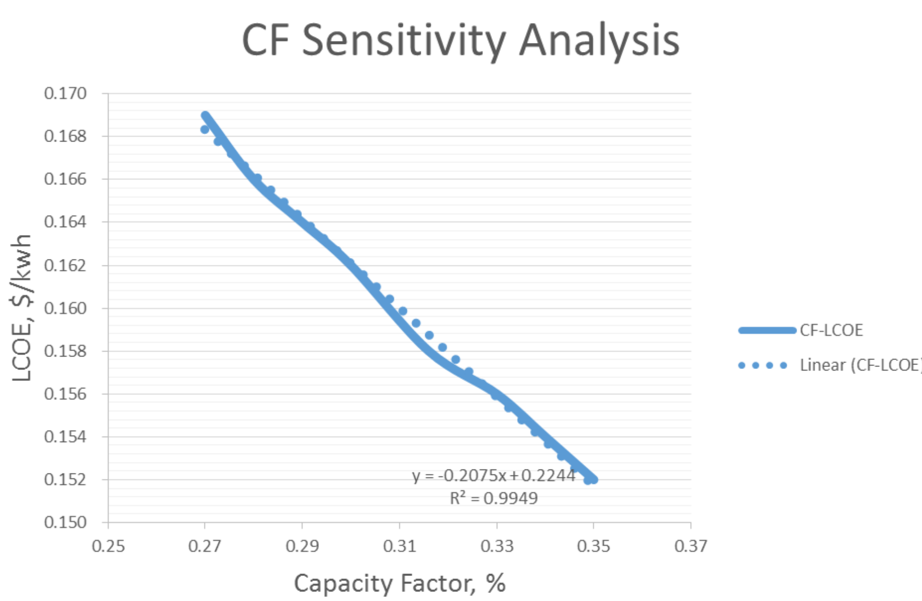

Figure 19 Capacity Factor (CF) Sensitivity Analysis for Proposed OSW Farm

5. Conclusion and Discussions

5.1. Fundamental Recommendations

From a technological perspective, OSW is mature for shallow waters (depth range of 0- 30 meters). Turbine hubs are getting taller and blades are increasing in size, while floating turbines are still mostly in the demonstration stage. Currently, the US doesn't have a complete monopile supply chain, but jacket setups could be used as a viable substitute for progressively deeper waters.

The Clean Power Plan may put significant pressure on states to bolster their renewable portfolios, but there are more favorable alternatives to OSW. As of April 2016, though there are several existing federal and state policies aimed at developing renewable energy, more favorable policies specific to OSW are needed for this energy to become a viable option for Southern Company. Furthermore, marine spatial planning is a beneficial tool that allows for offshore resource management and planning. It could prove useful to Southern Company by providing early conflict resolution for potential hindrances to construction.

The pure economics of OSW are not favorable in the US market, especially compared to onshore wind generation. The LCOE of onshore wind is currently one-third to half that predicted for OSW in the U.S., making onshore wind much more cost-efficient. Of course, this is dependent on several factors including wind farm size, distance to shore, and time of construction and operation.

5.2. Technology improvement trends

Offshore turbines are moving towards bigger size, including higher hubs and longer blades. From an LCOE perspective, larger-capacity turbines will generate electricity at a lower cost per kWh and taller turbines will have more consistent wind generation. Larger OSW projects can be operated at lower cost with innovative services such as remote diagnostics (Font, 2016). In terms of power generation, the amount of power that a turbine extracts from wind is proportional to the area of rotor blades, that is, to the square of the rotor diameter. Thus turbine manufacturers are pushing offshore turbines with greater capacity. In contrast, the size of onshore wind turbine is often limited by transportation because the turbine parts have to be constrained by the size of road and bridges.

Figure 19 below is a wind turbine size prediction made by a CompositesWorld report in 2009. In this report, it predicted that the 8-10MW offshore wind turbine would be technically and economically feasible in 2015, and the 20MW offshore turbine will be applied by 2020 (Red, 2009). This prediction matches the current situations – both Vestas and Adwen provide 8MW offshore turbine models. If the offshore turbine capacity would reach 20MW by 2020, the turbine will weigh 60.5 tons and has a rotor diameter of 500 meters.

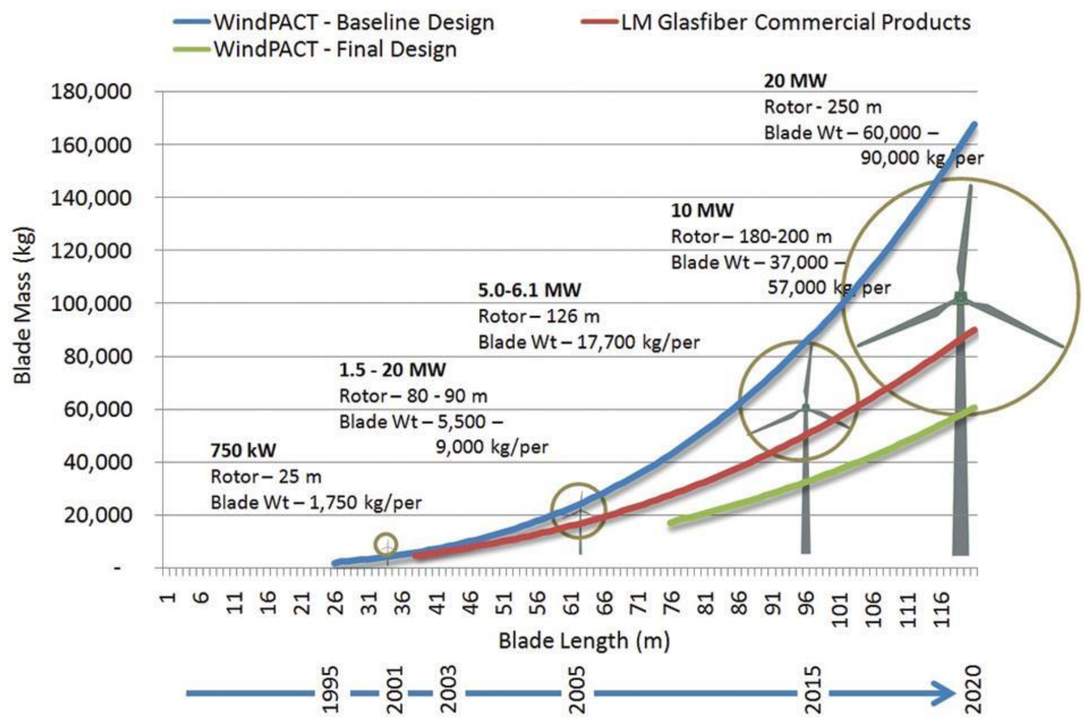

Figure 20 Wind turbine size predictions by 2020. (Red, 2009)

Clipper, a U.S. turbine manufacturer, once designed the biggest wind turbine in United States. In 2010, it planned to build a 10 MW turbine, but these plans were ultimately scrapped due to financial concerns within a parent company. Despite the setback, it's clear that the U.S. wind industry is working to provide bigger turbines and trying to gain market share from European offshore turbine providers.

From a turbine efficiency perspective, rotor blade technology will continue evolving to equip better fluid dynamic efficiency in order to improve turbine efficiency. Since offshore turbines are normally located far from the shore and require high maintenance costs, major players in the wind industry are also looking into ways to increase turbine availability and minimize downtime.

Due to the lack of a U.S. monopile manufacturing industry, U.S. offshore wind industry may favor other foundations such as jacket structure, which is suitable to use from 20-60m deep waters (Red, 2009). Currently the wind industry is in the demonstration stage of developing floating turbine. There will also be more advanced technologies of floating turbines in the near future. Figure 20 shows clear evidence that the floating turbine trend matches the trend of larger turbines (Marcacci, 2013). Moving turbines from close-shore areas to deep waters can extract greater wind energy while solving the problem of potential view shed litigations. Floating platforms can also reduce transportation burden of moving bulky steel vessels into deep sea.

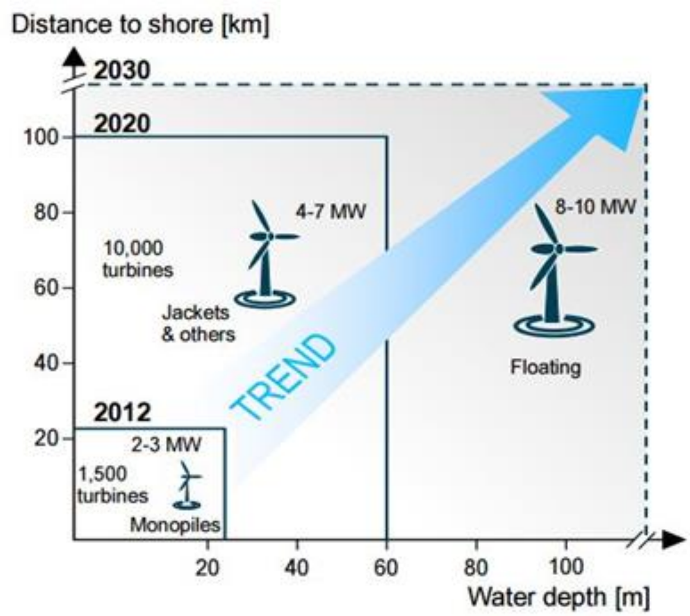

Figure 21 Trend of OSW turbine distance to shore. (Marcacci, 2013)

5.3. Policies and Regulations Discussions

Leasing OCS property has become more streamlined since the Smart from the Start program was instated by BOEM. This program has allowed for a quicker leasing process that fosters interagency cooperation and simplifies the environmental assessment and SAP process. The changes to the OSW frontier since the GT 2007 report have shaped the future of OSW. From the failures of the Cape Wind project, to the successes of the DWW farm, to the change in authority from MMS to BOEM, the world has witnessed changes on all fronts that will impact the future of OSW. The success and failure of the other OSW project will especially provide insight and instruction on how to plan and construct these future farms. There are many different governing authorities in each state that impact OSC prospects. State agencies can either show support or opposition for a proposed project. Cape Wind has shown us that one town government can be in support of OSW, while another can be starkly against such a project.

Stakeholders play an important role and can have a large impact on the decision to implement an OSW farm. Engaging stakeholders in public forums and meetings with developers can allow for open communication that makes for smoother operations. Marine spatial planning is a useful tool to aid in decisions regarding OSW farms. It can highlight any constraints that would limit development or require permitting. Environmental concerns are necessary to consider when developing offshore energies. One of the most important concerns specific to the southeast region is the North Atlantic Right Whale.

Policy incentives which may affect costs and taxation of OSW farm based on different financial structures will be discussed in the next section.

5.4. LCOE Reduction Potential

Assuming the accelerated 5-year MACRS tax benefits, Levitt et al. modeled four policy incentives for the Production Tax Credit (PTC), the Investment Tax Credit (ITC), the Cash Grant in Lieu

of ITC (Cash Grant) and the DOE Section 1703 Loan Guarantee Program (LGP). They also combined the study with four financial scenarios. The breakeven price details and sensitivity analysis are demonstrated in Table 14 and Figure 21. For corporate financial structure, PTC could lower the LCOE by approximately 8% to 12%. While facing a 20% reduced PTC in 2017 means the earlier starter of OSW construction certainly will get a lower breakeven price at an earlier coming year (Levitt et al., 2011).

Table 14 Breakeven Price by Financial Structures and Policies (Levitt et al., 2011)

Financial Structure	Cost Scenario	PTC		ITC or cash grant		No policy
		No LGP	*LGP*	*No LGP*	*LGP*	*No LGP*
Corporate	FOAK	$243	–	$205	–	$265
	GA	166	–	146	–	189
	BRV	78	–	75	–	98
Tax Equity	FOAK	$406	–	$334	–	–
	GA	290	–	245	–	–
	BRV	155	–	142	–	–
Project	FOAK	$241	$235	$220	$213	$268
	GA	164	164	158	156	192
	BRV	64	86	75	85	90
Government owned	FOAK	–	–	–	–	$160
	GA	–	–	–	–	117
	BRV	–	–	–	–	78

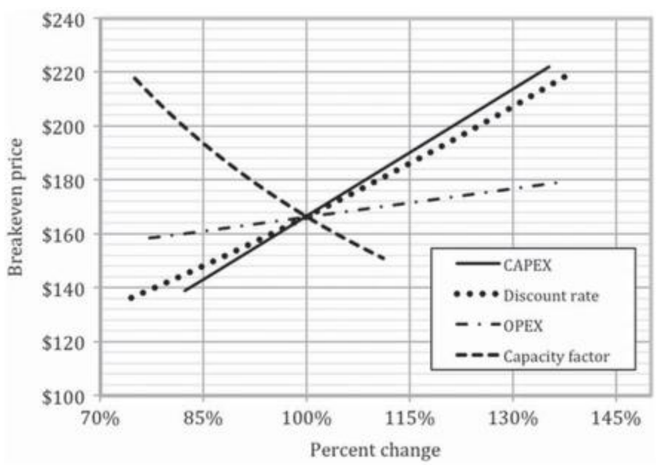

Figure 22 Sensitivity Analysis (Source: Levitt, 2011)

There can be some minor cost savings for O&M that may add to the overall installation costs but can bring down the total LCOE including improved crew transfer, larger transport vessels, helicopter access, and better system monitoring. Greater quantities of basic turbine maintenance workboats can allow larger crews to service a wind farm at a single time, reducing overall down time for an offshore system. Larger vessels can be purchased that allow for transfer of parts over 2 tons and minimize the effect of storm conditions. One highly advanced solution is to have advanced condition based-monitoring to provide quicker and more accurate recognition of turbine component malfunction. This, coupled with on-site spare part storage and helicopter access to avoid storm delays, can significantly improve the

availability of a system and improve the LCOE through lower variable O&M and increased productivity (Maples et al., 2013).

However, it is important to be cautious in this respect, as the capital and installation costs of these tools can often overwhelm the intended cost savings when calculating overall LCOE. While a balance is possible and a 14% cost savings in overall LCOE is possible just through O&M investment, the most optimistic NREL scenario doesn't begin to approach the $.01/kWh O&M variable costs of onshore wind in the U.S.

5.5. Economics and the Clean Power Plan

OSW is not an attractive investment for external financiers in Europe, but Southern Company may face additional political pressure from the CPP. While the CPP is currently stayed, likely pending the outcome of the 2016 Presidential Election and the resultant Supreme Court confirmation, enactment of this law would put a heavy burden on certain states to reduce their emissions. The three states targeted in this study all have individual targets well above the national average of 30%; in fact, South Carolina will require more than a 50% emissions reduction by 2030 through the CPP. These ambitious targets will facilitate significant energy efficiency and renewable investments for each affected state.

However, given the high LCOE of OSW discussed previously, especially in relation to other more attractive renewables, it is unlikely that an OSW farm would be a preferable or even secondary choice. Due to the economies of scale inherent for wind farms, the LCOE may far exceed that calculated by our model due to restrictions on the size of third-party purchases if Southern Company were to look in that direction. Perhaps, in the future, the CPP will open up the OSW market and precipitate a price drop similar to that seen in solar PV over the past decade, but the current economics offshore simply don't offer any cost-effective solutions in the United States.

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