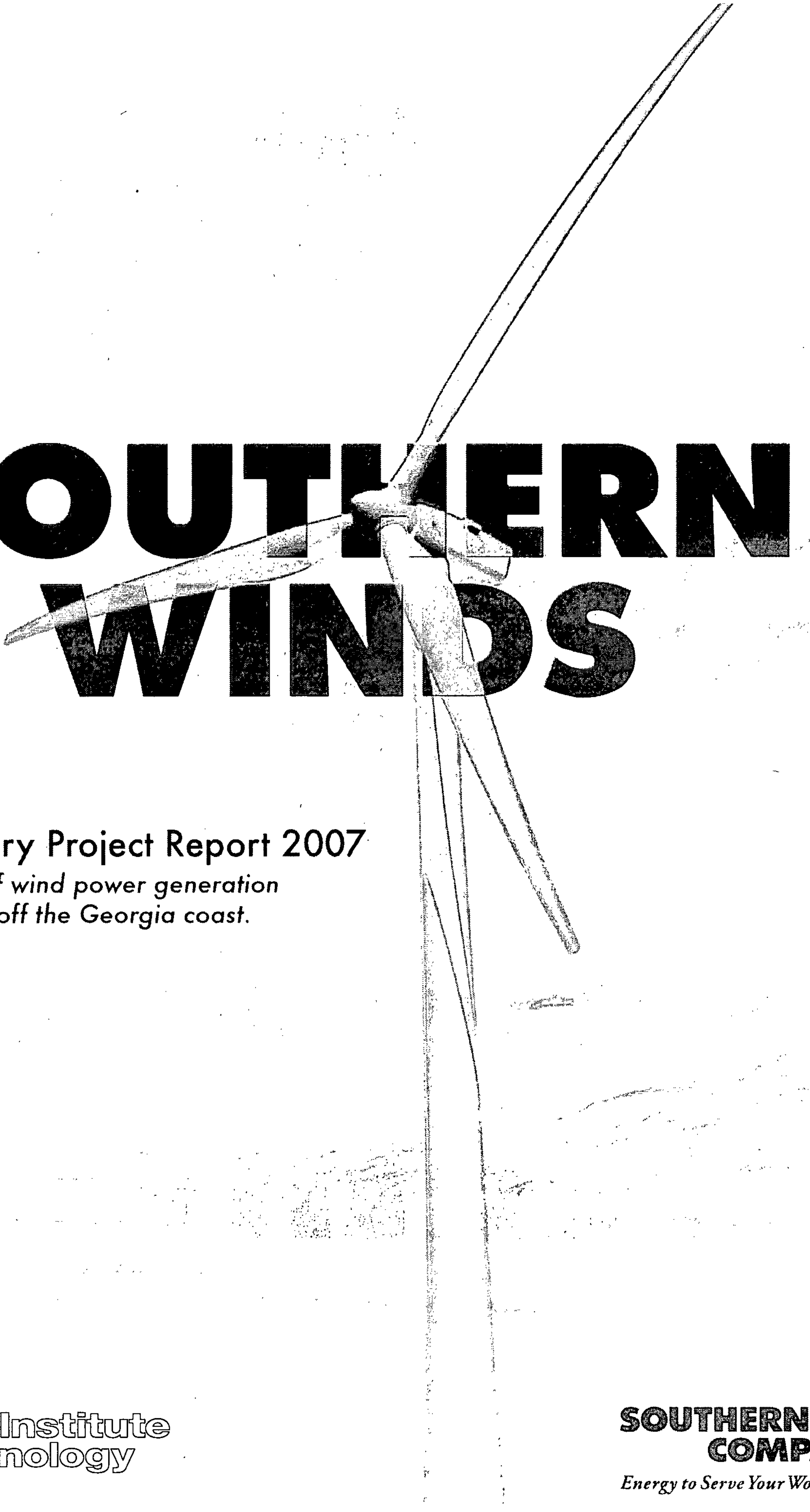
SOUTHERN WINDS



Summary Project Report 2007

A study of wind power generation potential off the Georgia coast.

Georgia Institute of Technology

SOUTHERN COMPANY
Energy to Serve Your World®

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1 Executive Summary

Traditionally it has been assumed a fact that there is "no wind resource" in the southeastern U.S. except for small isolated areas, such as mountain ridges in Tennessee and North Carolina. Indeed, the only onshore wind farm built in the Southeast to date is located on one of these mountain ridge locations.

In 2004, a research team from the Georgia Institute of Technology's Strategic Energy Institute (SEI) began an examination of the wind data available from a Navy platform via the South Atlantic Bight Synoptic Offshore Observational Network (SABSOON) located off the Georgia coast and concluded that there is a "Class 4" wind regime in coastal Georgia waters which may provide enough energy to power an offshore wind farm. A "Class 4" wind has wind speeds that range from 15.7 – 16.8 mph or 7.0 – 7.5 m/s. In 2005, SEI and Southern Company decided to work together to determine the technical and economic feasibility of locating an offshore wind farm in this area.

The project included a more detailed review of wind data, siting options and issues, regulatory issues, and the technology. An economic analysis was also conducted as a part of this project. This report is a summary of the findings from this project.

In general, it was concluded at the end of this project that:

- Despite the large amount of historical wind resource data available, more data in the exact location of a proposed wind farm would be required. Wind turbine vendors prefer wind data collected within the footprint of the selected site and at heights comparable to the hub height of an offshore wind turbine prior to providing wind turbine costs.

- As authorized in the Energy Policy Act of 2005 (EPAct), the Department of Interior Minerals Management Service (MMS) has jurisdiction over alternative energy-related projects on the outer continental shelf, including wind power developments. MMS has been authorized to complete a rulemaking process outlining the permitting requirements for such projects. Until these regulations are finalized, only limited activities toward the development of an offshore wind farm in federal waters can be conducted. The permitting process is anticipated to be complete by fall of 2008.

- There are currently only three equipment vendors in the marketplace manufacturing offshore wind turbines. Much of the manufacturing is taking place in Europe and due to the high demand for such turbines most of the manufacturers are "sold out" until 2008.

- The current commercially available offshore wind turbines are not built to withstand major hurricanes above a Category 3 or a 1-minute sustained wind speed of 124 mph.

- Coastal Georgia waters include large areas with good wind resources in shallow water that have the potential for wind farm development. Also, much of the coastline includes undeveloped areas with close proximity to potential landfall sites for transmission grid access.

- The available wind data indicates that a wind farm located offshore in Georgia would likely have an adequate wind speed to support a project, although offshore project costs run approximately 50% – 100% higher than land based systems. Based on today's prices for wind turbines, a commercial size 50 MW to 160 MW offshore wind farm could produce electricity at 12.9 to 8.2 cents/kWh respectively, assuming a 20-year life and regulatory incentives such as a federal production tax credit (PTC) with accelerated depreciation similar to those currently available. A smaller or larger commercial wind farm would increase or decrease, respectively, the cost per kWh because of the economies of scale. Also, the development costs would need to be taken into consideration. The size of an offshore wind farm would not be a significant factor in the overall development costs, but because the permitting process is currently unknown, these costs cannot be fully realized until MMS has outlined the requirements for permitting.

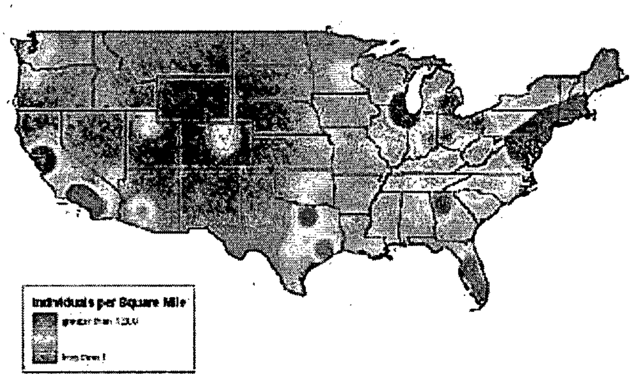
- The benefits to a wind project include the following:
  - Free fuel for the duration of the project with no impacts from increasing fuel prices.
  - Renewable energy credits and/or potential reduced costs from carbon credits/avoided taxes.
  - Significant benefit in public relations, showing Southern Company to have a "proactive" stance with regard to renewable energy.
  - Potential for the creation of a new industry and new job opportunities within Southern Company's service territory.

2 Project Background

Offshore wind power has seen significant maturation in Europe during the 15 years since the first development project was located off the coast of Vindeby, Denmark. The Kyoto Protocol, national initiatives by European Union (EU) countries, and lack of land space for further onshore farms have encouraged the development of the offshore wind industry in Europe. In contrast, the United States market for wind power has been focused solely on land-based facilities, because the U.S. drivers for offshore wind projects have not been as strong as in Europe.

One of the main reasons for exploring the potential for offshore wind development in the U.S. is that the major load centers, as shown in Figure 2.1, are located near the oceans and Great Lakes. Also, windy land is not often found near the load centers. Few people want to live where it is windy, so therefore, current onshore wind farms are usually located far from major load centers in the U.S., and in its present configuration, the grid is not set up for long interstate electric transmission. Some regions of the U.S. have had support from the federal and state governments in the establishment of wind farms, especially land-based, through the passage of Renewable Portfolio Standards (22 states) and the Federal Production Tax Credit (currently expiring 12/2008). Another significant driver of wind power development has been the high cost of electricity in some regions of the country such as the Northeast and in some western states.

Figure 2.1: Major Load Centers in the U.S.[1]



Traditionally, it has been assumed that there is "no wind" in the southeastern U.S. However, after analyzing the offshore data collected from equipment on U.S. Navy platforms located approximately 40 miles off the coast near Savannah, researchers at the Georgia Institute of Technology Strategic Energy Institute (SEI) have found a "Class 4" wind resource off the Georgia coast. A "Class 4" wind has winds speeds ranging from 15.7 – 16.8 mph or 7.0 – 7.5 m/s. Though this wind resource is not as strong in comparison to the winds available in certain offshore areas of Europe and the northeastern U.S., which are primarily "Class 6" or above or 17.9+ mph or 8.0+ m/s, the Georgia resource has been found to be similar to the resource available in the location of at least one European offshore wind farm.

The program under which these analyses were conducted, InfinitEnergy: A Coastal Georgia Partnership for Innovation, was developed and supported by the National Science Foundation's (NSF) Partnerships for Innovation (PFI) Program (Grant No. 0332613).[2] A critical component of this PFI grant was performing strategic technology assessments on alternative energy options to determine the potential for implementation. Upon the preliminary analysis of wind data obtained for the region offshore of Georgia, it was determined that the wind resource merited further research on the feasibility of locating an offshore wind farm in the area.

SEI approached Southern Company to determine its interest in jointly pursuing a more in-depth study into the feasibility of building and operating a wind farm off the coast of Georgia. Georgia Tech and Southern Company signed a contract in June 2005 to conduct a joint feasibility study for one year. This project has been referred to as *Southern Winds*.

This document serves as a summary version of the final report produced as a result of the *Southern Winds* study to determine the overall feasibility of building a wind farm off the Georgia coast. The full final report contains additional information on the wind resource data, analyses conducted using the data, wind turbine technology, and possible regulatory issues.

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[1] *Musial, W., National Renewable Energy Lab, presentation.*

[2] *Grant No. 0332613, any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

3 Wind Resource

Skidaway Institute of Oceanography (SkIO), a research unit of the University System of Georgia located 16 miles southeast of Savannah, has been recording meteorological data off the coast of Georgia since June 1999. There are eight platforms spanning the Georgia coast, covering a 69 mile x 30 mile [111 km x 48 km] area or an area of roughly 2,100 square miles [5,400 km^2] on the outer continental shelf located directly off the Georgia coast. Originally, these platforms had been built by the Navy to monitor tactical aircrew training.

In 1999 Skidaway received funding from the National Oceanographic Partnership Program (NOPP) to implement the South Atlantic Bight Synoptic Offshore Observational Network (SABSOON) using the network of existing fixed platforms.[3] Three of these eight platforms, R2, M2R6, and R8, were equipped as a part of SABSOON to gather meteorological and oceanographic data at 6-minute intervals. The data from one of these towers (R2) was used by SEI in its data analysis. Data from the other two towers equipped (M2R6 and R8) was studied but not used in this feasibility study because these towers were located beyond 60 miles from shore. An example of these platforms has been shown in Figure 3.1.

Figure 3.1: SABSOON Tower[4]

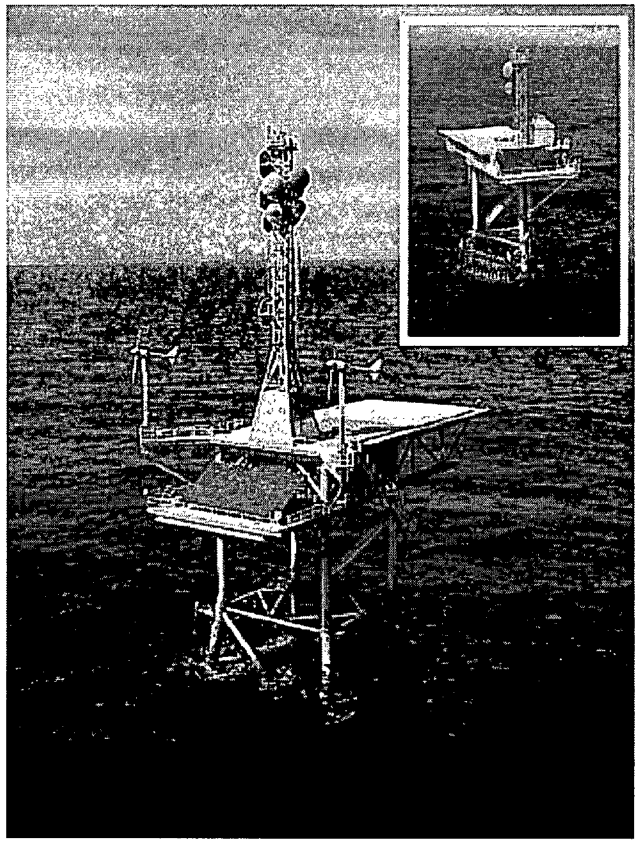


Table 3.1: Summary of *Southern Winds* Wind Data Sources

Location	Anemometer Height ft [m]	Distance from Shore mi [km]	Water Depth ft [km]	Data Time Coverage	Coordinates
SABSOON - R2	164 [50]	37 [60]	85 [26]	6/99 - present	31.375 N, 80.567 W
SABSOON - R8	112 [34]	65 [105]	164 [50]	6/03 - present	31.6266 N, 79.9216 W
SABSOON - M2R6	164 [50]	55 [88]	98 [30]	8/04 - present	31.5334 N, 80.2334 W
Savannah Light Tower	108 [32.9]	10 [16]	<66 [20]	5/95 - 11/96	31.95 N, 80.68 W
Gray's Reef Buoy	16 [5]	17 [28]	59 [18]	1988-1990 1990-1992 1997 - present	30.6997 N, 81.100 W 30.7308 N, 81.080 W 31.4022 N, 80.871 W
St. Augustine Buoy	16 [5]	37 [60]	125 [38]	6/02 - present	30.0 N, 80.6 W

[2] *Grant No. 0332613, any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

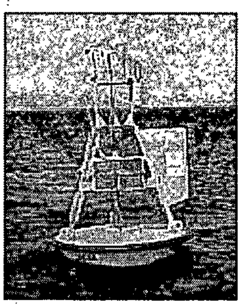
[3] *Skidaway Institute of Oceanography, SABSOON: http://www.skio.peachnet.edu/research/sabsoon/.*

[4] *Skidaway Institute of Oceanography, SABSOON, http://www.skio.peachnet.edu/research/sabsoon/images/M2_R8.jpg.*

Figure 3.2:
Savannah Light Tower[5]

Another valuable resource for offshore wind data for this study was the former Savannah Light Tower (SLT), as shown in Figure 3.2. This tower had been equipped to take hourly wind data at 108 ft [32.9 m] above the ocean surface from 1985 until the tower was destroyed by a freighter in 1996. This site was approximately 10 miles [16 km] from shore and very close to Tybee Island, which is near one of the sites considered for placement of a potential wind farm.

Figure 3.3:
Gray's Reef Buoy[6]



To illustrate the geographical variation of the wind resources along the coast of the southern part of Georgia, two additional sources of data were evaluated. Both sources were collected from five-meter high buoys. One buoy (GR), shown in Figure 3.3, was in the Gray's Reef Marine Sanctuary and located about 17 miles [24 km] off the middle of the Georgia coastline. This location provided hourly data for the time periods 1988-1992 and 1997-present. The second buoy (StA) was located due south of R2 near St. Augustine, Florida. This site provided hourly data for the years 2002-present

The wind data collected at all of the wind data sources had anomalies that were removed before the analysis was conducted. There were also time periods over which no data recordings occurred. Corrections were made to account for the missing data, and these corrections have been documented.

Figure 3.4 shows the locations of these wind data sources, and Table 3.1 lists the specifics for these data sources.

As shown in Table 3.1, the data from the available data sources was collected at varying heights, and thus, not directly comparable. Because the data from R2 was collected at 164 ft [50 m] above the ocean's surface, this data most closely resembled the wind speeds that would be found at the typical hub heights (approximately 230+ ft [70+ m]) of current commercially available offshore wind turbines. In order to determine the geographic variation in the wind resource, the wind speeds measured at SLT and the buoys were extrapolated using the power law model to wind speeds at a height of 164 ft [50 m] or the height of the R2 tower anemometer. The power law model has been generally used to estimate the wind speed at a specific height by taking into account the wind shear or the amount of turbulence caused by surface conditions such as ocean waves. An estimated power law exponent of 0.1 was used for extrapolation.

Even though the SLT data was extrapolated to represent data collected at a height of 164 ft [50 m] using a wind shear model, a direct chronological comparison was not possible because the time periods of data collection at SLT and R2 did not overlap.

3.A Wind Speeds and Directions

The wind speeds measured at each data location were averaged by month and by year to show seasonal and annual variation, respectively. Averages for the annual and monthly wind speeds were calculated by summing up all of the wind speed recordings and dividing by the total number of recordings for each year and month, respectively.

Figure 3.5 shows the average wind speeds by month for R2. As shown by the figure, the strongest wind velocities (8+ m/s) are associated with the winter months, December through March, and with the peak tropical storm season, September (8.30 m/s). The summer has the lowest wind speeds with the minimum average calculated for August (5.88 m/s). The overall annual average wind speed, 7.36 m/s, is noted by the dotted line in Figure 3.5. The annual averages are fairly consistent with a low in 1999 of 7.01 m/s and a peak in 2004 of 7.73 m/s. The standard deviation shown is +/- 0.268 m/s.

[5] *National Renewable Energy Laboratory, Publication # 40045, http://www.nrel.gov/wind/pdfs/40045.pdf*

[6] *National Data Buoy Center, Station 41008, http://www.ndbc.noaa.gov/station_page.php?station=41008.*

Figure 3.4: Locations of Data Sources for the *Southern Winds* Data Collection and Analysis

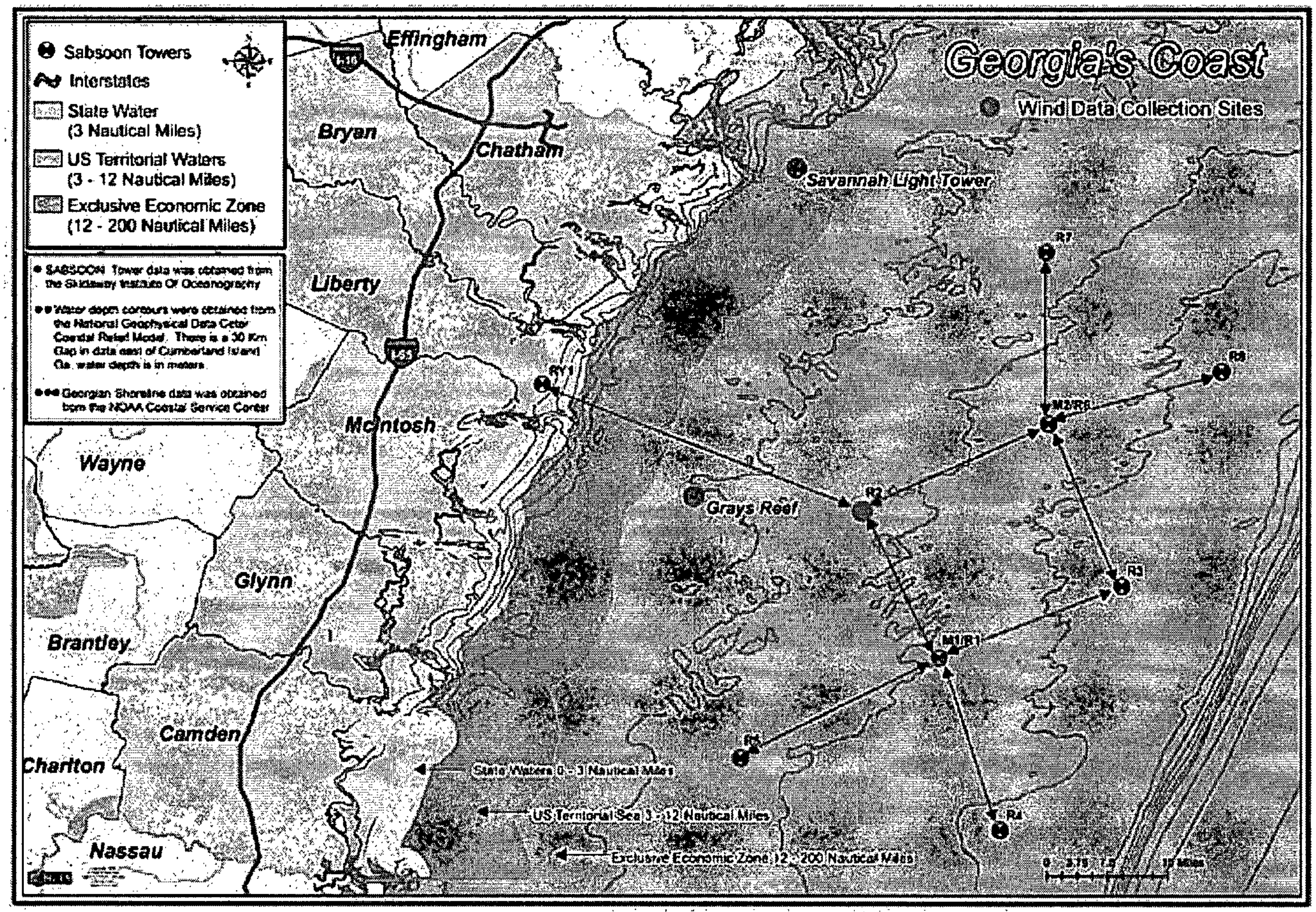


Figure 3.6 and Figure 3.7 show the monthly average and annual average wind speeds, respectively, calculated for the all of data sources extrapolated to a height of 164 ft (50 m). The bars on Figures 3.5 and 3.7 show a confidence level of ±1%. Table 3.2 shows the annual average wind speeds for all of the data sources at both their data collection heights and their extrapolated values for 50-m height. These show that both the monthly averages and the annual averages for each data location are fairly consistent with the R2 trends.

Figure 3.5: R2 Monthly Average Wind Speed at a Height of 164 ft [50 m]

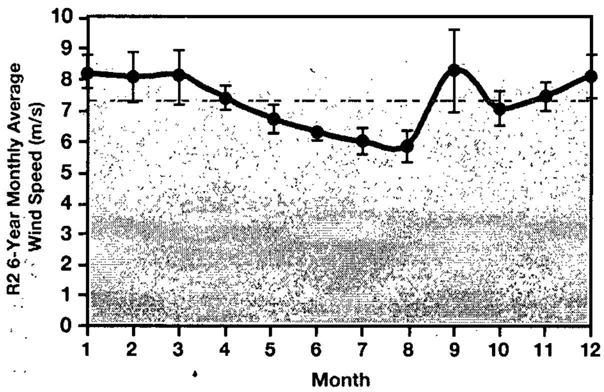


Figure 3.6: Monthly Average Wind Speeds by Data Source at a Height of 164 ft [50 m]

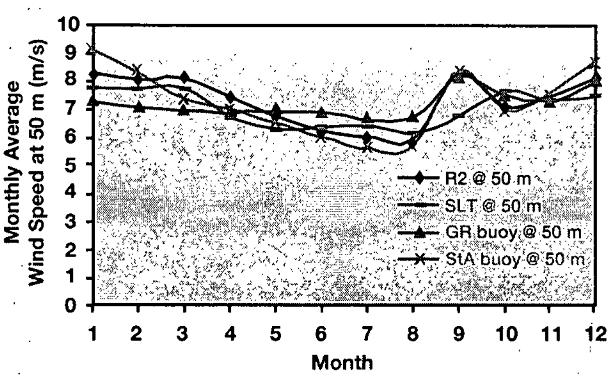
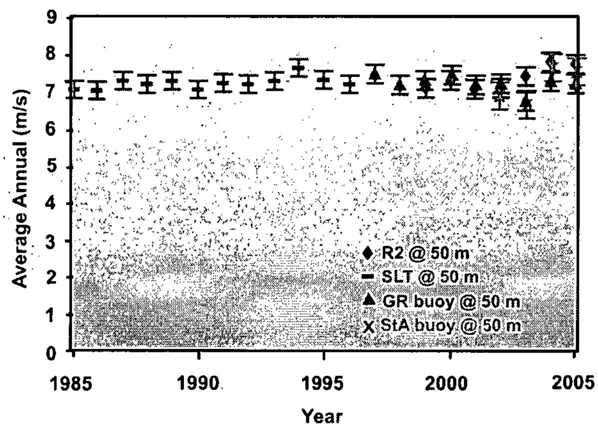


Table 3.2: Summary of the Overall Average Wind Speeds

Location	Height (m)	Wind Speed (m/s)	Extrapolated Wind Speed at 50m (m/s)
R2	50	7.36	7.36
SLT	32.9	6.73	7.02
GR	5	5.79	7.29
StA	5	5.66	7.12

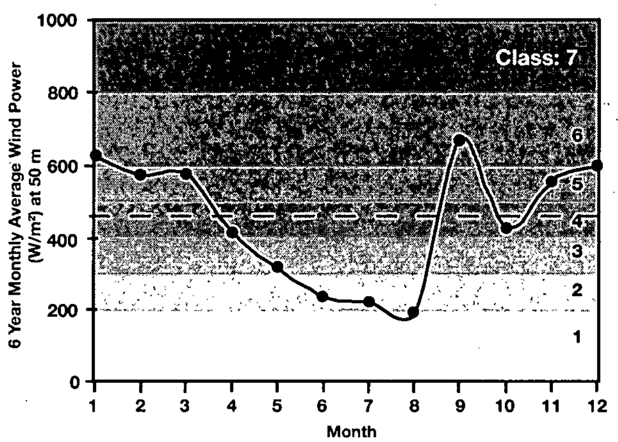
Figure 3.7: Annual Average Wind Speeds at a Height of 164 ft [50 m]



In determining a site's wind power resource, it is standard to calculate the average annual power density. The power density is then used to classify the resource into wind power classes. A filter had been used to remove wind speeds above a specified limit in calculating average power densities. The National Renewable Energy Laboratory (NREL) has recommended this limit should be 25 m/s, which is the typical cut-out speed for wind turbines. Using this limit in the filter, 0.063% of the R2 data had been excluded before the analysis. By restricting the wind power densities to occurrences below this limit, a more realistic value of the wind resource is obtained. Figure 3.8 shows the average monthly power density and its respective wind class determined from the R2 data. There is a significant seasonal variation in wind power density, with the strongest in the fall and winter months and the weakest in the summer months. The dotted line on the chart represents an average annual power density of 460 W/m^2. The area above the dotted line indicates a "good" Class 4 or better wind. This is based on the wind power density classes used by NREL.[8]

[8] *National Renewable Energy Laboratory, Wind, Dynamic Maps, GIS Data, and Analysis Tools, Classes of Wind Power Density at 10 m and 50 m, http://www.nrel.gov/gis/wind.html*

Figure 3.8: R2 Monthly Average Wind Power Density



The direction from which the wind blew was recorded on R2, SLT, and GR over the same time period as the wind speeds. The dominant wind directions were from the northeast and south by southwest with secondary effects from the northwest and west. However, the wind power density was the strongest from the northeast and northwest with secondary effects from the south by southwest. The 13-year average wind direction frequencies and power densities by direction from GR buoy data showed that winds from the northeast provided the most power, even though the most prevalent wind direction was from the south. This agreed with the results found from the SLT data except that most of the winds came from both the northeast and the south.

Figure 3.9: R2 6-Year Average Wind Speeds by Hour of the Day (EST) at a Height of 164 ft [50 m]

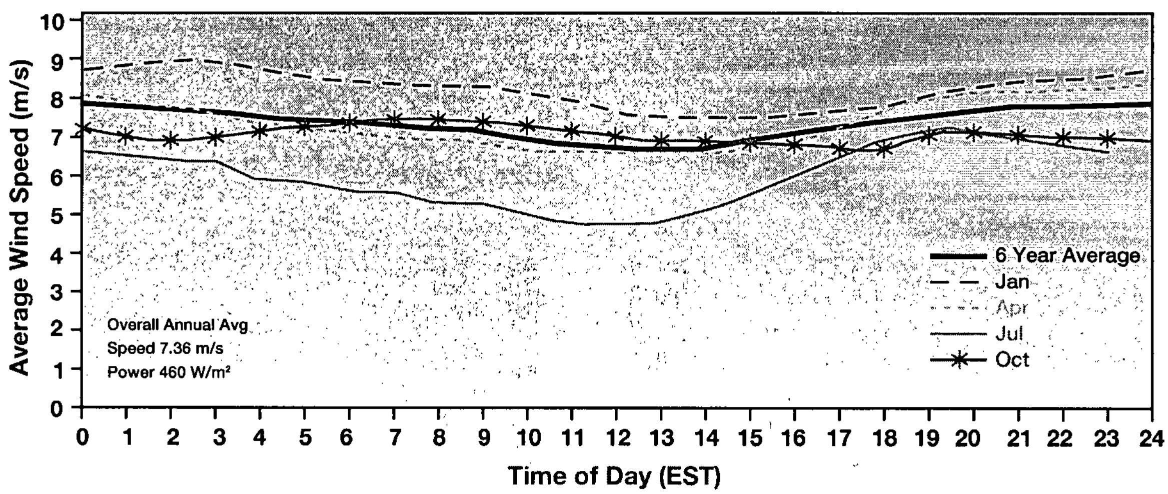
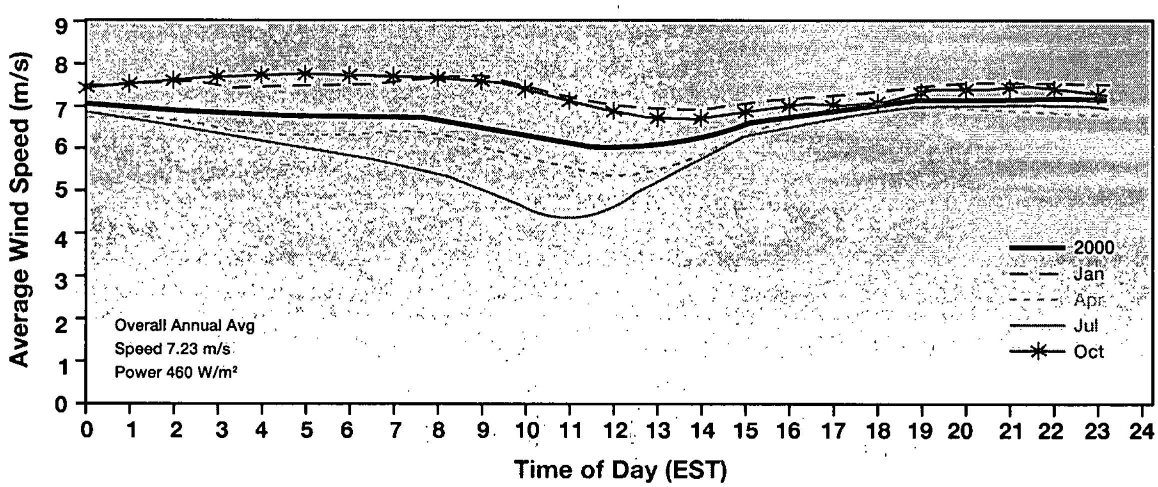


Figure 3.10: SLT 11-Year Average Wind Speeds by Hour of the Day (EST) at a Height of 108 ft [32.9 m]



The wind speed varied with the time of day as shown in Figure 3.9 and Figure 3.10 for R2 and SLT, respectively. For R2, the wind speeds decreased throughout the morning, with the minimum occurring between 12–2 p.m., and the wind speeds increased throughout the evening until approximately midnight. This trend was found to be fairly consistent during the different seasons. As found from earlier analyses, the summer months experienced lower wind speeds while the winter months had higher wind speeds. The spring and fall months experienced wind speeds generally closer to the annual average wind speeds.

For SLT, however, the minimum occurred slightly earlier than for R2. It occurred between approximately 11 a.m. and 1 p.m. Also, the averages from mid-afternoon through early morning were found to be less influenced by seasons. During the morning hours, the fall and winter months experienced higher than average wind speeds, while the spring and summer months had lower than average wind speeds.

3.B Wind Power

The average wind speed measured at a site is a poor indicator of the wind resource. Wind power is a more accurate measure. Wind power is generated when the wind turbine captures the wind and converts the wind's kinetic energy into electricity. Wind power can be calculated using the following equation.

$$P = \tfrac{1}{2}\rho V^3$$

where ρ is air density (approximately 1.2 kg/m^3), P is wind power, and V is wind speed. This equation shows that wind power is proportional to the cube of the wind speed.

Using the average wind speed in the wind power calculation above ignores how the wind speed varies throughout the year. For example, a calculation of the wind power produced for a year with a fixed average speed of 7 m/s gives a wind power of 205.8 W/m^2. This assumes that the wind blows constantly at that speed throughout the entire year. However, because of the cubic relationship of wind speed with power, it is necessary to incorporate the annual wind speed distribution or actual wind speed data to get a more realistic approximation of the wind power at a location. The wind blowing at speeds higher than the average speed over a time period will generate considerably more power than winds blowing at lower than average speeds over a time period. In fact, by adding up the wind power calculated for each data point throughout the year and taking the average, the resultant wind power is approximately twice (~400 W/m^2) the wind power calculated using just the average wind speed.[9]

Wind power is generated when the wind turbine captures the wind and converts the wind's kinetic energy into mechanical energy or shaft energy from which electricity is generated through a generator. Not all of the wind's kinetic energy is able to be used by the turbine. If all of the kinetic energy is extracted from the wind by the turbine, the air moving through the turbine will come to a standstill behind the turbine and the air would not flow away from the turbine. However, the air moves away from the turbine at a lower wind speed, so only a portion of the kinetic energy from the wind is captured and is converted to mechanical energy or shaft energy. Betz's Law estimates that the maximum amount of energy extracted from the wind and converted to shaft power is 59% of the energy flowing into the turbine.[10] Most modern turbines approach 40% – 45% conversion.

In order to calculate different wind turbine power outputs, wind data measured at the actual hub height of the wind turbine must be used with the turbine vendor's power curves. However, actual wind speed data at this height was not available; therefore, the power law model was used to extrapolate the wind speeds measured at the different heights up to 262 ft [80 m] to allow for estimations of power outputs from specific wind turbines.

In addition, the power curves from selected wind turbines were digitized from vendor brochures. The turbines selected were the GE 3.6sl MW machine, the Siemens 2.3 MW Mk II machine, and the Vestas V90 2.0 MW

[9] *Danish Wind Energy Association, Wind Energy Reference Manual, Part 1: Wind Energy Concepts, http://www.windpower.org/en/stat/unitsw.htm#anchor1345942, Accessed 10-4-06.*

[10] *Ackermann, T. ed. Wind Power in Power Systems, Wiley, West Sussex, England 2005. p. 527.*

Table 3.3: Wind Turbine Specifications

Vestas V90-2.0 MW	Siemens 2.3 MW MkII	GE 3.6sl MW
• Hub height: 80 m • Rotor Diameter: 90 m • Swept Area: 6362 m² • Operating wind velocities: 3.5-25 m/s • Nominal wind speed: 11.5 m/s	• Hub height: 80 m • Rotor Diameter: 93 m • Swept Area: 6793 m² • Operating wind velocities: 4-25 m/s • Nominal wind speed: 13-14 m/s	• Hub height: 80 m • Rotor Diameter: 104 m • Swept Area: 8495 m² • Operating wind velocities: 3.5-27 m/s • Nominal wind speed: 14 m/s

Figure 3.11: R2 Total Annual Electrical Energy Output Using Three Different Wind Turbine Power Curves

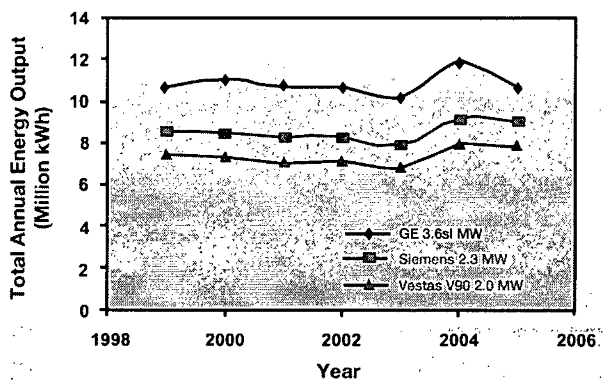
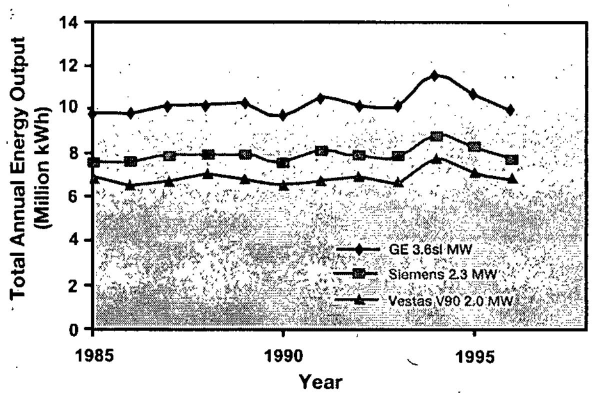


Figure 3.12: SLT Total Annual Electrical Energy Output Using Three Different Wind Turbine Power Curves



machine. Each of these machines has been marinized (weatherized to protect against the marine environment) to be able to withstand the offshore environment. The turbine specifications for these models have been shown in Table 3.3. This information was obtained from the specific turbine manufacturers.[11,12,13] This list does not include all machine options, but shows a range of sizes, technologies and vendors.

Only the wind data measured at R2 and SLT was used to calculate the energy outputs for the three selected machines. These stations were the closest to shore with the highest positioned anemometers, and thus, the results of the energy output analysis had less extrapolation error.

Figure 3.11 and Figure 3.12 show the calculated annual energy output for the selected turbines using R2 and SLT data, respectively.

The resulting overall annual averaged capacity factors (kWh_{actual} per year / kWh_{max} per year) using R2 data and SLT data for the three selected turbines are shown in Table 3.4.

These results alone do not provide enough information to select an optimum turbine with respect to the wind resource. Economic models are needed to maximize power output and minimize cost.

[11] *National Data Buoy Center, Station 41008, http://www.ndbc.noaa.gov/station_page.php?station=41008.*

[12] *Siemens Power Generation, http://www.powergeneration.siemens.com/en/windpower/index.cfm.*

[13] *GE Wind, www.gewind.com.*

Table 3.4: Average Ideal Annual Capacity Factors

Turbine	R2 Average Ideal Annual Capacity Factor	SLT Average Ideal Annual Capacity Factor
GE 3.6 MW	34%	33%
Vestas 2.0 MW	42%	39%
Siemens 2.3 MW	42%	40%

3.C Site-Specific Data

To obtain accurate, site-specific wind data, a meteorological tower should be installed at the selected site. Often for land-based applications the meteorological tower is installed in the exact location where a wind turbine will be placed. Once enough data has been collected, the meteorological tower is taken down, and a wind turbine is installed in the same location, possibly using the same foundation. This may not be the case for offshore applications. The cost for purchasing, installing, and maintaining an offshore wind meteorological tower will be high. Because of these high costs, an offshore meteorological tower may be installed at a site in the selected area where it will be used to determine if the wind resource is good enough for wind farm installation prior to project development. It also will remain there after project construction to monitor the performance of the wind farm.

In general, the installed meteorological tower needs to be as tall as the anticipated wind turbine hub height and must have anemometers located at three or more different heights so that the wind shear can be determined. The wind data needs to be collected for at least one year and preferably for three years. Only after this data has been obtained will the wind turbine manufacturers give "ballpark" capital and installation costs for constructing an offshore wind farm.

The Energy Policy Act of 2005 has given U.S. Department of Interior Minerals Management Service (MMS) authority over alternative energy activities on the outer continental shelf (OCS). This includes the placement of meteorological towers on the OCS to collect data needed for determining the potential for offshore wind power generation. During discussions, MMS has stated that placement of a meteorological tower in a selected site would resemble "staking a claim" and thus has put a moratorium on the placement of any energy-related structures in federal waters until the rulemaking has been completed. It is anticipated that the rulemaking will be completed by fall of 2008. However, MMS encourages discussions with agency representatives during the early stages of project planning.

4 Siting

Determining the location, size and footprint, or siting, of power plants has often been a controversial subject. Even back in the days of Thomas Edison, it did not take long for communities and property owners to voice concern about the placement of power plants near residential areas. The siting of wind farms has been no less controversial and has received a significant amount of media coverage, both pro and con, in recent years.

Coastal Georgia waters and the adjacent offshore regions are located in the South Atlantic Bight, as shown in Figure 4.1. A bight is defined as a long, gradual bend or recess in the coastline that forms a large, open bay. This loosely describes the coastal ocean between North Carolina and Florida. It has up to an 87-mile [140 km] wide continental shelf[14] and approximately 3,100 square miles [8,000 km^2] of open water less than 66 ft [20 m] deep (100 miles [160 km] coastline by 31 miles [50 km] out from shore). Beyond this area, there is an open area of water with a depth of up to 98 ft [30 m] that spans an additional 1,900 square miles [4,900 km^2].

In addition, as shown in Figure 4.1, the Georgia coast is dominated by a series of barrier islands, many of which contain salt water marshes. Many of these barrier islands are protected areas, and some are almost totally uninhabited. The areas of greatest population concentration include Wilmington and Tybee Islands in the north at the mouth of the Savannah River, and St. Simons and Jekyll Islands to the south, just north of Florida. The islands with more inhabitants tend to have sandy beaches and are more resort-like in nature. Some of the coastal islands are National Wildlife Refuges, including Wassaw Island, Blackbeard Island, and Wolf Island. Cumberland Island is maintained by the National Park Service and is designated the Cumberland Island National Seashore. The lack of coastal habitation could be a benefit from the perspective of development of a wind farm, since the potential for viewshed objections might be reduced.

The *Southern Winds* project was initially conceived as a "demonstration" project that would be a nominal 10 MW wind farm consisting of 3 – 5 wind turbines in the 2.0 MW – 3.6 MW size range. While this size project could still be developed as a stepping stone to a larger project, the project team, during the course of this study, decided to look at larger wind farms that would improve the economics by using the economies of scale.

In the United Kingdom there have been several projects constructed in the 60 MW range (Scroby Sands, Kentish Flats etc.) and in Denmark two projects have been constructed in the 160 MW range (Nysted and Horns Rev). These two size ranges have thus been considered as potential build out scenarios for a demonstration project.

4.A Potential Wind Farm Locations

The first step in determining potential locations for an offshore wind farm was to select the best landfall sites for the offshore wind farm transmission line. In August 2005, a team composed of both Georgia Tech and Southern Company personnel traveled along the Georgia coast evaluating the coastal Georgia Power substations. Each substation was examined according to its geographic characteristics, substation configuration, and landfall options. The initial consideration was a substation's proximity to the ocean. Any site located further than six miles from the coastline was eliminated from consideration because of additional transmission costs that would be incurred. The substations visited are shown in Figure 4.1.

After the results were compiled, all of the visited substations were ranked according to their potential with regard to supporting an offshore wind facility. It was determined that all of the visited substations would require some additional infrastructure. The Jekyll Island and Tybee Island Georgia Power substations were considered the best options.

In addition to the Georgia Power substation review, a review of the Georgia Transmission Corporation (GTC) coastal substations was conducted. However, all of these substations were located further than six miles from the coastline and thus, were not considered as economically viable options.

After the landfall review, a separate review was conducted of the obstacles such as natural reefs, shipwrecks, flight

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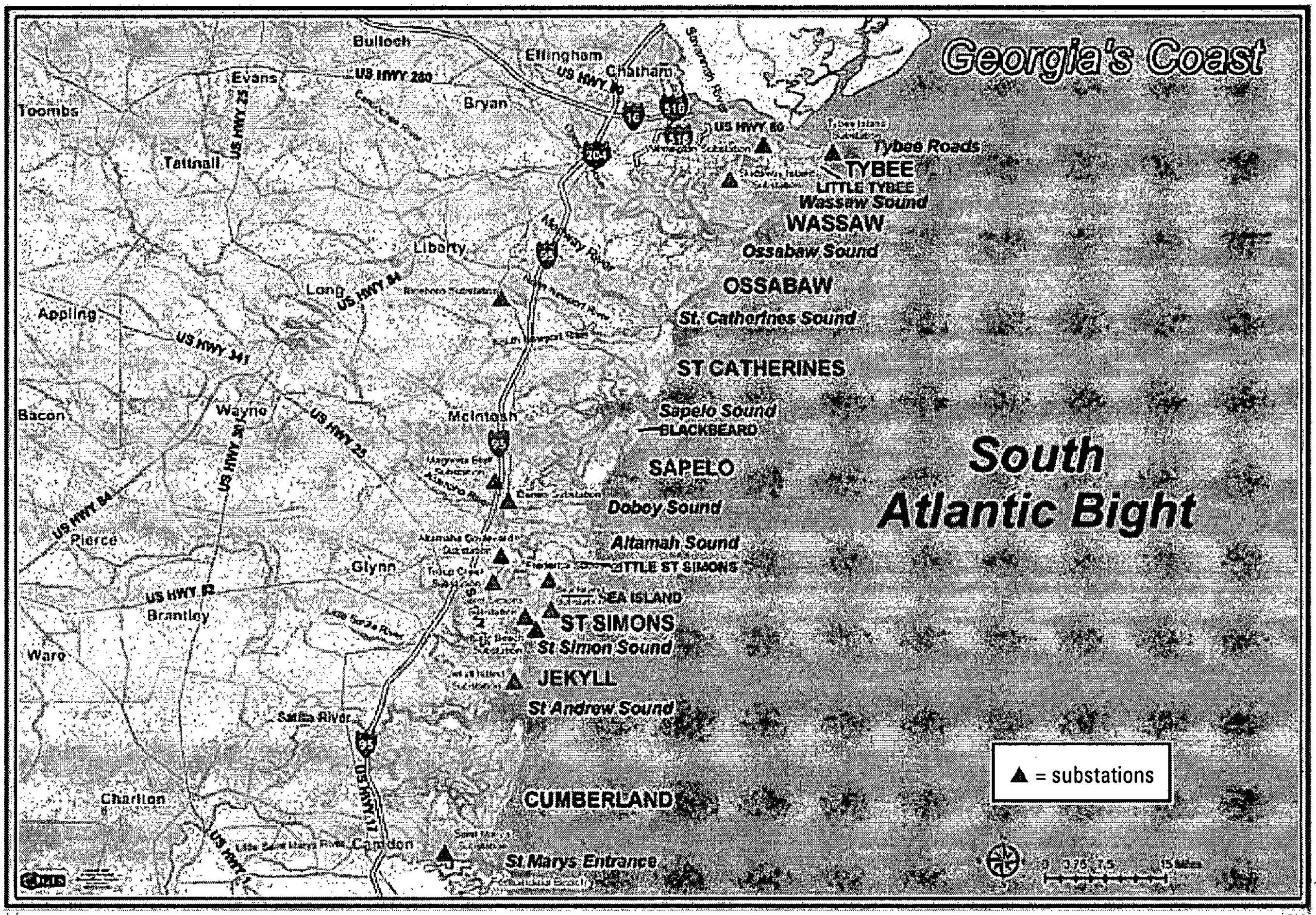
[14] *Shepard, Andrew N. "South Atlantic Bight: Bitten by Worsening Problems." NOAA National Undersea Research Center. July 12, 2005: http://oceanexplorer.noaa.gov/explorations/islands01/background/bight/bight.html.*

Figure 4.1: Map of Georgia Coast



paths, and shipping lanes that would potentially impact wind farm placement on the outer continental shelf near each of the two landfall sites deemed the best options for transmission interconnection. Three potential wind farm footprints were identified in the waters adjacent to each of the two landfall sites (refer to Figure 4.2). These potential footprints were sized so that 80 turbines, each with a 295 ft (90 m) rotor diameter, could be positioned in the selected areas with a spacing of eight times the rotor diameter, or 2,363 ft (720 m). This wind farm size and spacing were selected based on the size and spacing used at Horns Rev, an offshore wind farm in Denmark.

4.B Geology

Data collection and analysis would be required to provide information on the location of buried channels which could impact tower footing installation, to provide existing geotechnical information to support footing installation and to identify areas where the seafloor sediments are significantly mobile. For the *Southern Winds* study, existing data was identified and interpreted to characterize seabed structure and stability in the selected areas. Some of this data existed in grey literature reports, whereas other portions of the data were in a raw data format and required interpretation. This was only a preliminary survey prior to the initiation of new data collection for the eventual site. In this survey, existing data was examined to identify what data gaps and geologic hazards existed.

In general, the Georgia coast consists mainly of marine sediments of variable sands, silts, and clays of varying ages and consistencies, overtopped at localized positions by more recent soft alluvial and/or deltaic soils from rivers that enter into the Atlantic Ocean. Information concerning seabed surface and subsurface structure are contained in original sidescan and subbottom surveys of the area. All the raw data from these surveys is archived at the Georgia Southern Applied Coastal Research Laboratory and at the Skidaway Institute of Oceanography (SkIO). There exist two sources of sidescan data that portray the surficial character of the seabed: paper records collected by Dr. Jim Henry over the past 30 years and digital data collected by Dr. Clark Alexander in the last decade.[15]

4.C Wave Conditions

SkIO completed a report on the wave and weather characteristics of the coastal Georgia region using available offshore data as a part of the *Southern Winds* project. In general, SkIO found that the ocean and atmospheric conditions in the study area are influenced by the Gulf Stream, tides, river discharge, wind stress, and air-sea fluxes of heat and moisture from the Gulf Stream. One example found was that river discharge to coastal waters during spring has an embedded weak flow to the south, which is significant in the central South Atlantic Bight (SAB) and can lead to a low salinity zone along the coast. This embedded southward flow easily reverses by prevailing winds from the southwest in spring and summer and is reinforced by northeast winds in autumn.

It is not uncommon to see anomalies in normal water temperatures in the SAB. Intrusions of Gulf Stream waters on the SAB outer continental shelf associated with the meandering of the Stream are common during all seasons. However, detection of these intrusions in the mid-shelf is rare.[16] In the spring of 2003, several of these intrusions were detected as far inshore as the mid-shelf at the SABSOON towers off Georgia and South Carolina (in depths less than 40 m). Although there is no data linking this cold water event to wind conditions in the region during this time period, the occurrence of these intrusions should be noted for possible future review.

Data on wave heights and currents was obtained from observations at two NOAA National Data Buoy Center (NDBC) stations (SLT and GR).[17] The NDBC stations had complete sets of meteorological data plus wave data and air and sea temperature data. To provide information on currents, the NDBC station data was supplemented with older observations from SLT and a current meter station near St. Simons. Information on the locations of these sites and the time periods covered by the data summaries have been tabulated in Table 4.1.

[15] *Raw data from these sources archived at the Georgia Southern Applied Coastal Reseasrch Laboratory and at the Skidaway Institute of Oceanography.*

[16] *Aretxabaleta, A., Edwards, C., Seim, H., Nelson, J., Characterizing Spring and Summer Gulf Stream Water Intrusions in the Mid-Shelf of the South Atlantic Bight, Gordon Research Conference, Coastal Ocean Circulation, New London, NH, 2005. http://seacoos.org/Research%20and%20Technology/Folder.Publications/WaterIntrusion.*

[17] *National Data Buoy Center, http://www.ndbc.noaa.gov.*

Figure 4.2: Proposed Wind Farm Sites

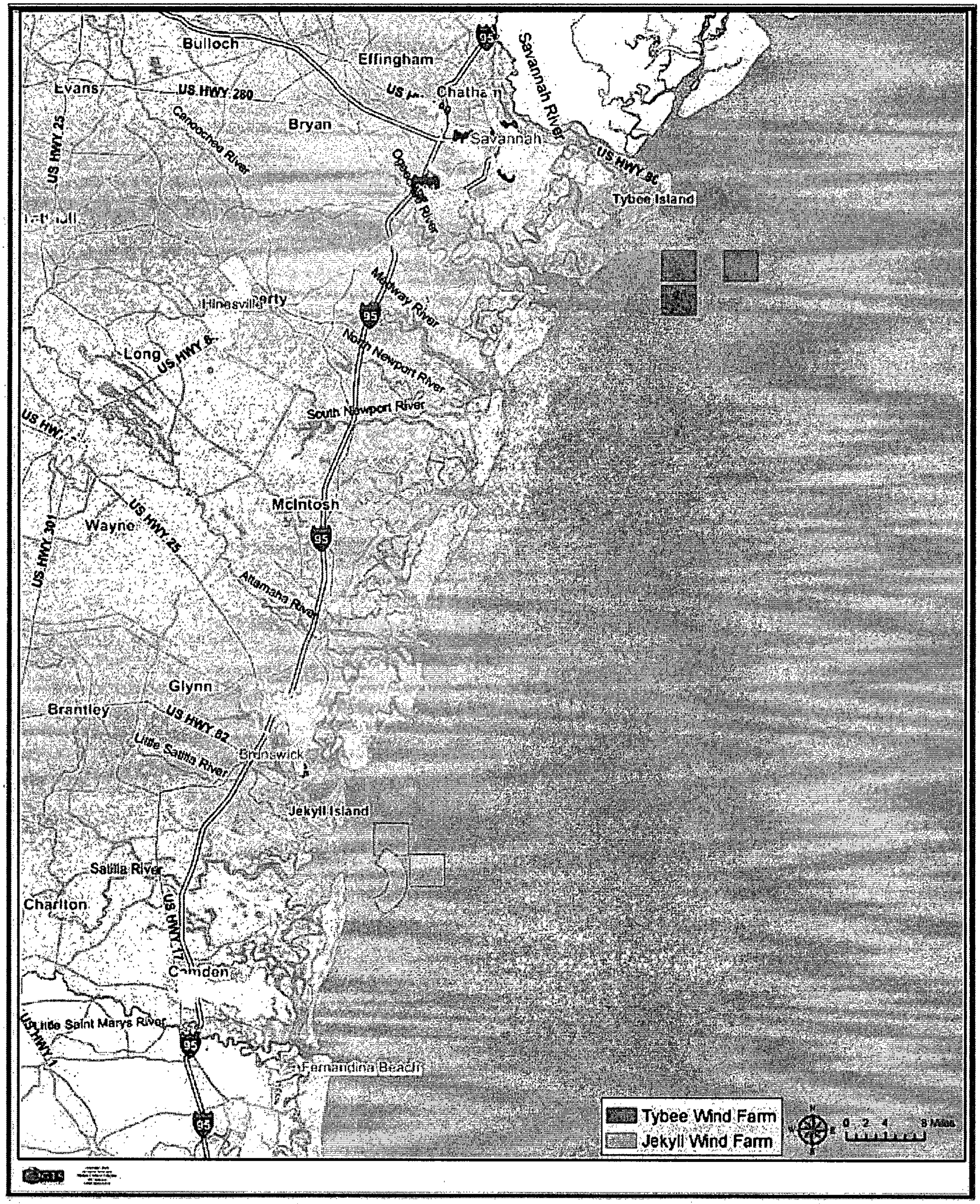


Table 4.1: Data Sources Used

Site	Station	Latitude (N)	Longitude (W)	Depth	Time Period
NORTH SITE					
Winds/waves	SLT	31°57.0'	80°40.8'	16 m	Nov 1985 - Oct 1996
Currents	SLT	31°57.0'	80°40.8'	16 m	Feb - May 1977
Water levels	Ft. Pulaski	32°02.0'	80°54.1'	N/A	Jul 1935 - Dec 2005
SOUTH SITE					
Winds/waves	GR	31°24.1'	80°52.2'	18 m	Jan 1988 - Dec 2005
Currents	FREEF	31°05.9'	81°12.5'	14 m	May - Dec 1985
Water levels	St. Simons	31°07.9'	81°23.8'	N/A	Jul 1999 - Dec 2005

Table 4.2: Summary of Water Levels (m) at the North and South Sites

Parameter	North Site Fort Pulaski, GA	South Site St. Simons Island, GA
Highest Observed Water Level	3.32 (15 Oct 1947)	2.92 (22 Jul 2001)
Mean Higher High Water (MHHW)	2.29	2.19
Mean High Water (MHW)	2.17	2.07
North American Vertical Datum (1988)	1.24	1.28
Mean Sea Level (MSL)	1.17	1.08
Mean Tide Level (MTL)	1.12	1.07
Mean Low Water (MLW)	0.07	0.06
Mean Lower Low Water (MLLW)	0.00	0.00
Lowest Observed Water Level	-1.40 (20 Mar 1936)	-0.86 (8 Mar 2005)
Mean Tide Range	2.11	2.01
Mean Spring Tide Range	2.45	2.35

Water levels and other auxiliary parameters are compared between the sites in Table 4.2. Tidal data is based on a 19-year series (Jan 1983 - Dec 2001) at Fort Pulaski and a 2-year series (Jul 1999 - Jun 2001) at St. Simons. Water levels are based on data from coastal tide gauges at Fort Pulaski and St. Simons.[18] It is assumed that the highest storm surge is included in the highest observed water level at the two sites. Elevations are referenced to Mean Lower Low Water (MLLW).

[18] *National Ocean Service, Fort Pulaski Tide Data, http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8670870%20Fort%20Pulaski,%20GA&type=Tide%20Data.*

5 Environmental and Regulatory

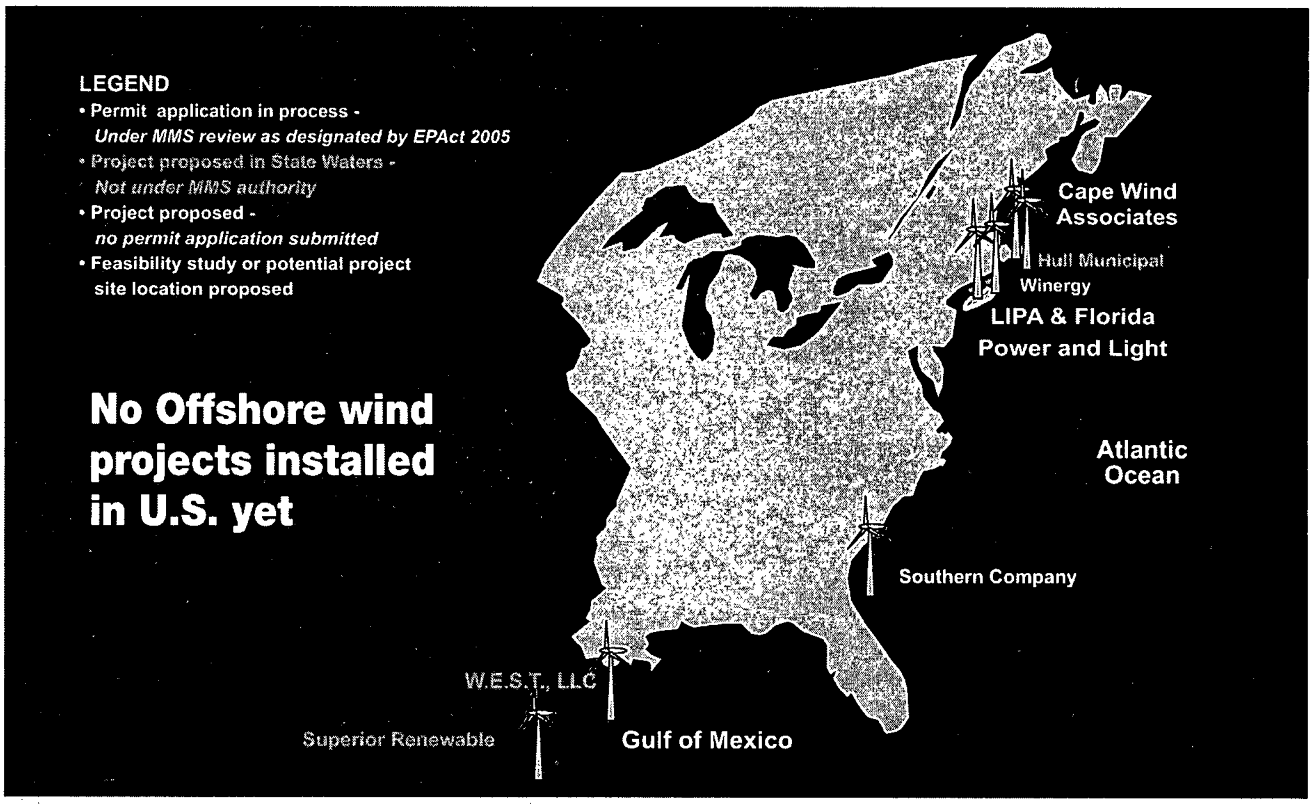
There are currently several offshore developments proposed in the U.S, as shown by Figure 5.1. However, as discussed previously, the Department of the Interior Minerals Management Service (MMS) has been given the authority to regulate alternative energy activities on the outer continental shelf by the Energy Policy Act of 2005 (EPAct). MMS is in the process of developing their rulemaking and does not anticipate its completion until fall of 2008. Until that time, no alternative energy-related activities can occur on the outer continental shelf.

Two proposed projects, Cape Wind and LIPA, were grandfathered under EPAct. These projects had started the permitting process with the U.S. Army Corps of Engineers (USACE) before EPAct was enacted. Also, two Texas offshore wind projects have been proposed. These projects would not fall under MMS authority because they would be located in state waters. State waters in Texas and the panhandle of Florida are unique in that they extend nine nautical miles from the coastline instead of three nautical miles as in all other coastal states.

The Cape Wind project proposed by Energy Management, Inc. (EMI) would consist of 130 large 3.6 MW wind turbine generators located at Horseshoe Shoal in Nantucket Sound in Massachusetts. These turbines would produce up to 450 MW of electricity. The overall size of the wind facility would be approximately 26 square miles [62 km^2]. Electricity would be brought ashore by a cable into Hyannis and interconnected to the utility grid.

EMI embarked on a permitting process with the USACE in the 2000 – 2001 timeframe. On January 30, 2002

Figure 5.1: U.S. Offshore Wind Projects Proposed[19]



[19] *Figure courtesy of Walt Musial, NREL.*

the USACE published a Notice of Intent in the Federal Register for the "Preparation of an Environmental Impact Statement (EIS)" for the proposed Cape Wind Project. The Cape Wind Draft Environmental Impact Statement (EIS) was extensive and represented approximately a $25 million investment.[20]

This project has gained significant attention in New England and polarized many citizens and stakeholder groups into camps for and against the project. Cape Wind has answered all questions and concerns that arose during the public hearing process. However, the entire permit process has been currently slowed by the transition in authority from USACE to MMS.

In 2003 the Long Island Power Authority (LIPA) selected Florida Power and Light (FPL) Energy to install a 140 MW wind facility off the south shore of Long Island, New York, near Jones Beach. The project is conceived to have a nominal capacity of 140 MW consisting of forty 3.6 MW turbines. The nearest turbines to shore would be approximately 3.6 miles [5.8 km] south of Jones Beach. Studies have shown that the average wind speed in this area is 18.5 – 19 mph [8.3 – 8.5 m/s][21] and that the water depth is 40 – 60 feet [12 – 18 m].

FPL Energy submitted an application for the wind farm to USACE on April 26, 2005. Several public meetings and a public comment period were held. Comments have been received, and LIPA/FPL provided USACE a response to the comments on December 5, 2005. As in the case of the Cape Wind project, the LIPA project has been required to restart the permitting process due to the transitions of authority to MMS. A draft EIS from MMS for the LIPA project was scheduled for release in the second quarter of 2007.

5.A Environmental

Georgia's coastal waters are home to a number of unique animals and plant species, some of which have been listed as endangered, threatened, rare, and, otherwise, species of interest. For the purposes of this project, the project team compiled a list of those species currently identified by the Georgia Department of Natural Resources under each category. This information provided a broad baseline summary of species that might be impacted by some aspect of an offshore wind facility. The summary included those species that may be found onshore where potential transmission access may affect habitat during construction and/or follow-up maintenance or those marine or avian species with habitats or migratory pathways that might intersect with potential wind farm site footprints or routes for construction and/or maintenance vehicles. Once a location has been formally identified for potential wind power development, many of the identified species would be removed from the list because of insignificant or no impact on habitat. The current list was designed to address all potentially impacted species along the entire Georgia coastal region in order to make the best case, environmentally sound decisions prior to siting an offshore wind facility.

One specific environmental consideration is that this coastline and its adjacent waters provide one of the primary corridors for many migratory birds.[22] Some potential impediments to migratory birds from an offshore wind farm include collision risk and the possibility of habitat loss. These factors must be incorporated into future environmental assessments.

Another migration of particular interest is that of the North Atlantic right whale. These whales travel along the entire Atlantic coastline. They travel to the waters adjacent to the Georgia-Florida coast for calving in the fall and winter and travel along the Atlantic seaboard to the north Atlantic region for the remainder of the year. Because Georgia's coastal waters are home to the North Atlantic right whale calving grounds, any potential wind farm located in these waters will need to adhere to a construction schedule that does not overlap the calving season between December and March.

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[20] *Conversation with Craig Olmsted, Cape Wind.*

[21] *Long Island's Offshore Wind Energy Development Potential: Phase 2 Siting Assessment.*

[22] *United States Geological Survey, Migration of Birds – Patterns of Migration, http://www.npwrc.usgs.gov/resource/birds/migratio/patterns.htm Accessed 9-15-06.*

In the fall of 2006, a multi-year study, *Danish Offshore Wind: Key Environmental Issues,* was published with a positive evaluation from the International Advisory Panel on Marine Ecology. The study examined the research findings of the Danish environmental monitoring program at two large scale offshore wind farms both pre- and post-construction.[23]

5.B Regulatory

Because the offshore wind industry is new to the U.S. and current regulatory issues are undefined, it is important to understand the basic jurisdictional boundaries and oversight issues that are defined for existing activities in coastal waters. The jurisdictional areas that will be affected by a potential offshore wind farm can be identified in two ways: "by whether they are navigable and by their distance from the shore (usually defined as the mean high tide line). The activities include permanent structures and various effects related to the operation of the projects.[24]" The bodies of water that define U.S. (and Georgia) coastal waters are

- State Waters – Waters extending from shoreline to three nautical miles seaward
- U.S. Territorial Sea – Waters extending from the shoreline seaward to twelve nautical miles (overlap with both state and federal waters)
- Federal Waters – Waters extending from three-mile to two hundred-mile economic exclusive zone boundary

While Europe has expanded its wind industry to offshore locations, the U.S. has proceeded cautiously by providing general guidelines in the form of an overview of federal regulations and a list of governing agencies that would be involved in permits and approvals. While MMS proceeds with the scoping process to provide a consensus on federal regulatory and jurisdictional authority, potential projects are navigating the offshore wind development process with the assistance of legal input and policy guidance based on other offshore industries. Each proposed project must work through significant multi-jurisdictional issues at federal, state, and local levels. The following lists identify governing authorities at the federal and state levels, but until such time that MMS has developed a comprehensive regulatory regime, this information and analysis should serve only as a guide.

FEDERAL GOVERNING AUTHORITIES

Rivers and Harbors Act, Section 10
National Environmental Policy Act (NEPA)
Coastal Zone Management Act
Navigation and Navigable Waters
Navigational Hazard to Air Traffic
Migratory Bird Treaty Act
National Historic Preservation Act
Magnuson-Stevens Fishery Conservation & Management Act
National Marine Sanctuary Act (Title III)
Endangered Species Act
Marine Mammal Protection Act
Submerged Lands Act
Outer Continental Shelf (OCS) Lands Act
Clean Water Act
Estuary Protection Act

Federal Agencies Involved in Offshore Wind Farm Permitting

Because of the overlapping jurisdictions both in geographical location and policy application, numerous federal, state, and local agencies will need to participate in a coordinated manner during the process of permitting an offshore wind facility. Below is a list of federal agencies that will be involved in some aspect of the process based on currently required mandates. It is important to note that this list may be subject to change as a result of the MMS rule-making process scheduled for completion by fall of 2008.

Minerals Management Service (lead agency)
U.S. Army Corps of Engineers
Council on Environmental Quality
National Ocean and Atmospheric Administration
U.S. Coast Guard
U.S. Federal Aviation Administration (Regional Administrator)
Fish and Wildlife Service
Migratory Bird Conservation Commission
Department of the Interior
National Marine Fisheries Service
U.S. Environmental Protection Agency

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[23] *DONG Energy, Vattenfall, Danish Energy Authority, and Danish Forest and Nature Agency, Danish Offshore Wind Key Environmental Issues, http://www.ens.dk/graphics/Publikationer/Havvindmoeller/havvindmoellebog_nov_2006_skrm.pdf.*

[24] *Renewable Energy Policy Project, Coastal North Carolina Wind Resource Assessment Project, http://www.repp.org/articles/static/1/binaries/REPP_Offshore_Wind_Approval.pdf (accessed 8-8-06).*

GEORGIA GOVERNING AUTHORITIES

Georgia's coastal region has a unique ecosystem that is home to many rare, threatened and endangered species. It is imperative that any proposed energy generating facility meet a rigorously scrutinized review of impacts prior to development. The Georgia Coastal Management Program addresses issues related to balancing economic development with the natural resources of Georgia's coastal region. The program is administered by the Georgia Department of Natural Resources (DNR), Coastal Resources Division (CRD) and covers an 11 county region in southeast Georgia. Multiple agencies coordinate activities via the CRD under the authority of the Coastal Management Act. This network ensures that all appropriate state laws are addressed in parallel to issues of national concern under Federal Consistency regulations. As noted on the Georgia DNR Web site, there are 33 state laws that fall under the auspices of federal consistency regulations.[25] The acts that are most likely to be triggered with the development of an offshore wind farm include the following;

State of Georgia Primary Governing Authorities

Georgia Coastal Management Act
Coastal Marshlands Protection Act
Shore Protection Act
Georgia Environmental Policy Act
Endangered Wildlife Act of 1973
Game and Fish Code
Georgia Boat Safety Act
Georgia Oil & Gas Deep Drilling Act
Georgia Water Quality Control Act
Groundwater Use Act
Heritage Trust Act of 1975
Protection of Tidewaters Act

Additional legislation has been identified as a part of the Coastal Management Program framework and has been noted in the primary project report. Although it does not deal directly with ocean and coastal management, some aspect of the legislation may be pertinent to a potential offshore wind farm.[26]

State and Local Agencies Involved in Offshore Wind Farm Permitting

Georgia Department of Natural Resources (DNR)

- Coastal Resources Division
- Environmental Protection Division
- Historic Preservation Division
- Parks, Recreation, and Historic Sites Division
- Wildlife Resources Division

Other State and/or Local Agencies

- Department of Community Affairs
- Human Resources
- Georgia Department of Transportation
- Georgia Forestry Commission*
- Georgia Ports Authority
- Jekyll Island Authority*
- Office of the Secretary of State
- Public Service Commission
- Local City and/or County Commissions*

* *may have oversight subject to project footprint and landfall site location*

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[25] *http://www.gadnr.org/.*

[26] *Georgia Department of Natural Resources, Coastal Resources Division Website, "State Laws Under Federal Consistency." http://crd.dnr.state.ga.us/content/displaycontent.asp?txtDocument=100 (accessed 8-8-06).*

6 Technology

6.A Wind Turbine Technology

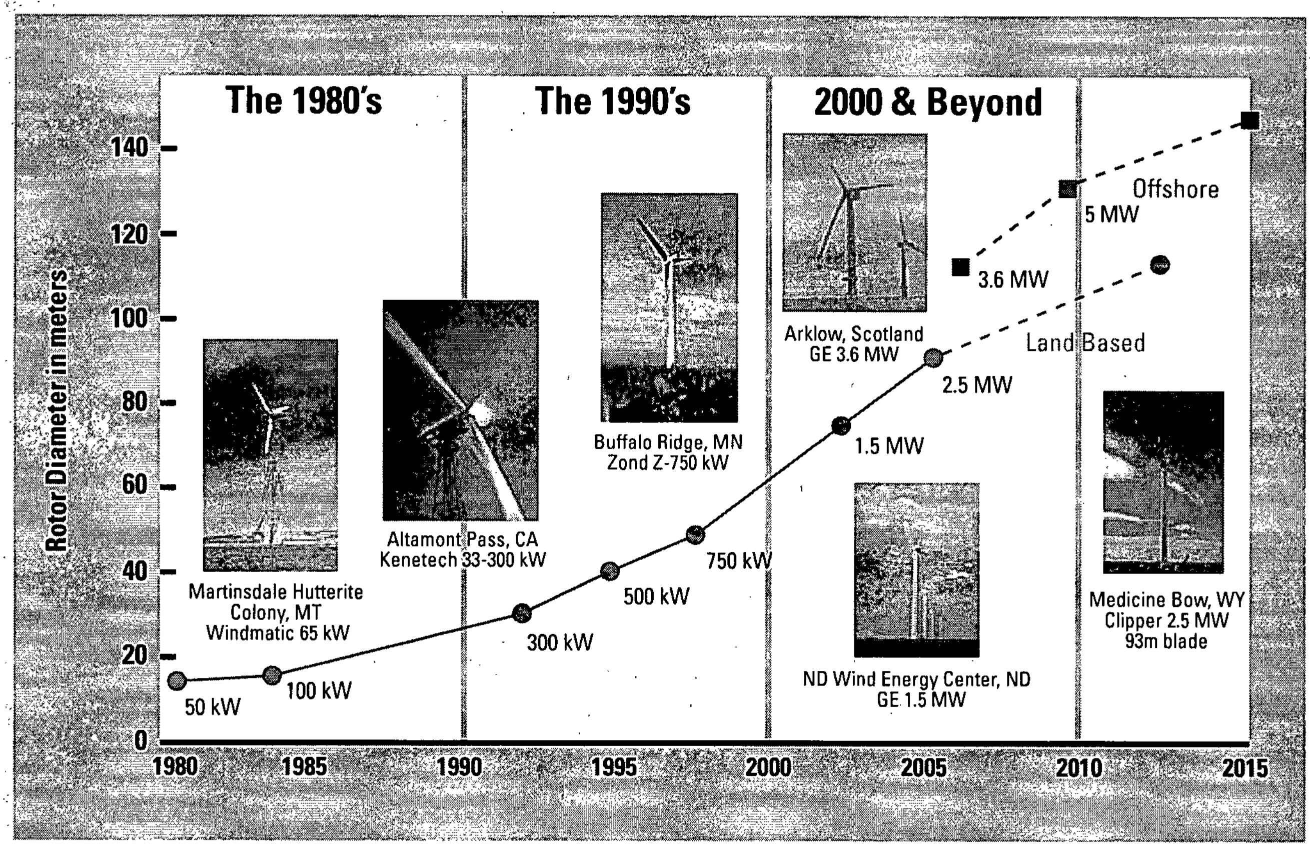
The first "modern" wind farm was located in California in 1981. This resulted because of the incentives put in place by the California Energy Commission. These "modern" wind farms consisted of wind machines that produced 50-100 kW. Over time these machines have evolved into much larger machines as shown in Figure 6.1.

A typical wind turbine machine layout is shown in Figure 6.2. The nacelle is the case of the turbine and contains all of the key components, including the gearbox and generator.

The rotor blades capture the energy from the wind and cause the rotor hub to rotate and deliver power to the generator. It operates in a similar manner as an airplane propeller. The lift experienced on the rotor blade increases with the pitch of the blade up to the point of stall. The blades twist with increasing radius to keep a constant angle of attack. The pitch of the rotor blades changes to extract the most power possible from the prevailing wind, or the blades can be "feathered" to actually stop the rotor rotation. The relatively low speed (12 – 20 rpm) rotor is "geared up" through the main gearbox to reach the high speed required for the generator. This speed will depend on the characteristics of the particular machine and the characteristics of the interconnected electrical grid (50 hertz or 60 hertz). It typically may be 1,800 rpm in U.S. applications.

Turbine generator sizes currently range from 1.5 – 5 MW. In theory, the rotor size can be optimized for a given generator size based on the wind resource. This allows the power output to be maximized and the cost to be minimized. Alternatively, the generator size could be

Figure 6.1: Evolution of Wind Technology[27]



[27] *National Renewable Energy Laboratory, Wind Energy Update, http://www.eere.energy.gov/windandhydro/windpoweringamerica/docs/wpa_update. ppt#442.*

optimized for a given rotor size. It should be noted that the rotor/generator configuration with the highest capacity factor may not be the most economical choice. Also, the type and number of commercially available turbines limits this optimization. A wind developer can only install what the turbine vendors can provide.

This section of the wind turbine historically has been the most troublesome. Gearbox failures have been frequent in many applications. From a maintenance standpoint, it is important to monitor the quality of lubricating oil to detect bearing and gear metal deposits early to be able to determine the presence of any potential gearbox problems.

Figure 6.3 is a more basic schematic drawing of a nacelle. It shows that the rotor hub of the nacelle connects the rotor blades to the low speed shaft.

The gearbox transfers torque from the low speed shaft coming from the rotor hub to the high speed shaft. An induction or asynchronous electrical generator is typically used because the power output can vary greatly in a short period of time.

The electronic controller continuously monitors the wind conditions and the turbine and controls the yaw and pitch mechanisms using the hydraulic system. The controller also stops the turbine in the case of a malfunction, sending an alarm message to the control station.
The anemometer measures the wind speed while the wind vane measures the direction from which the wind is blowing. This information is used to operate the yaw and pitch mechanisms and stops the turbine when the wind is lower or higher than the allowed operating wind speed range. The operating range varies from manufacturer to manufacturer and includes "cut in" and "cut out" speeds.

The yaw mechanism uses electric motors to rotate the nacelle around the tower axis to keep the blades facing into the wind. The yaw is controlled by the electronic controller which receives data from the wind vane.

The cooling unit contains an electrical fan which cools the generator and radiator for cooling the oil in the gearbox.

The actual size of the Megawatt Class wind turbines and their swept areas are large, especially compared to earlier machines. Earlier machines had very small swept areas but had high rpm which made them very noticeable to the public. This aspect is clearly shown in Figure 6.4 and Figure 6.5.

Figure 6.2: Wind Turbine Layout

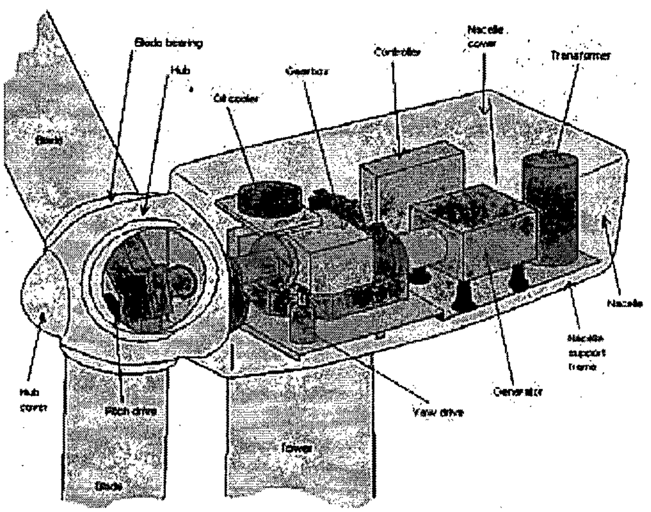


Figure 6.3: Wind Turbine Nacelle

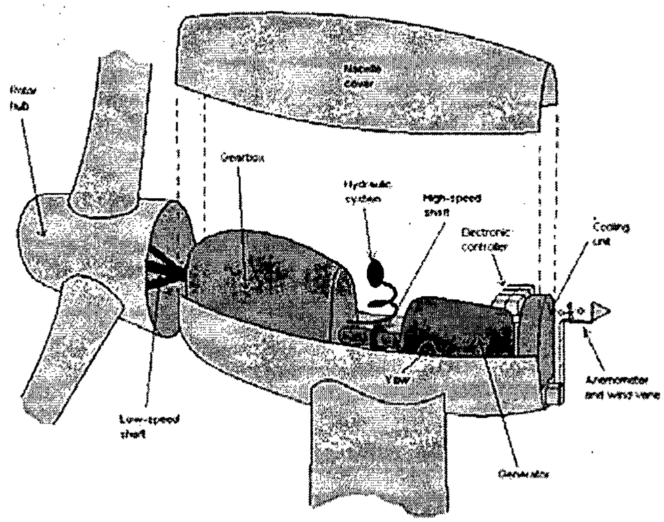
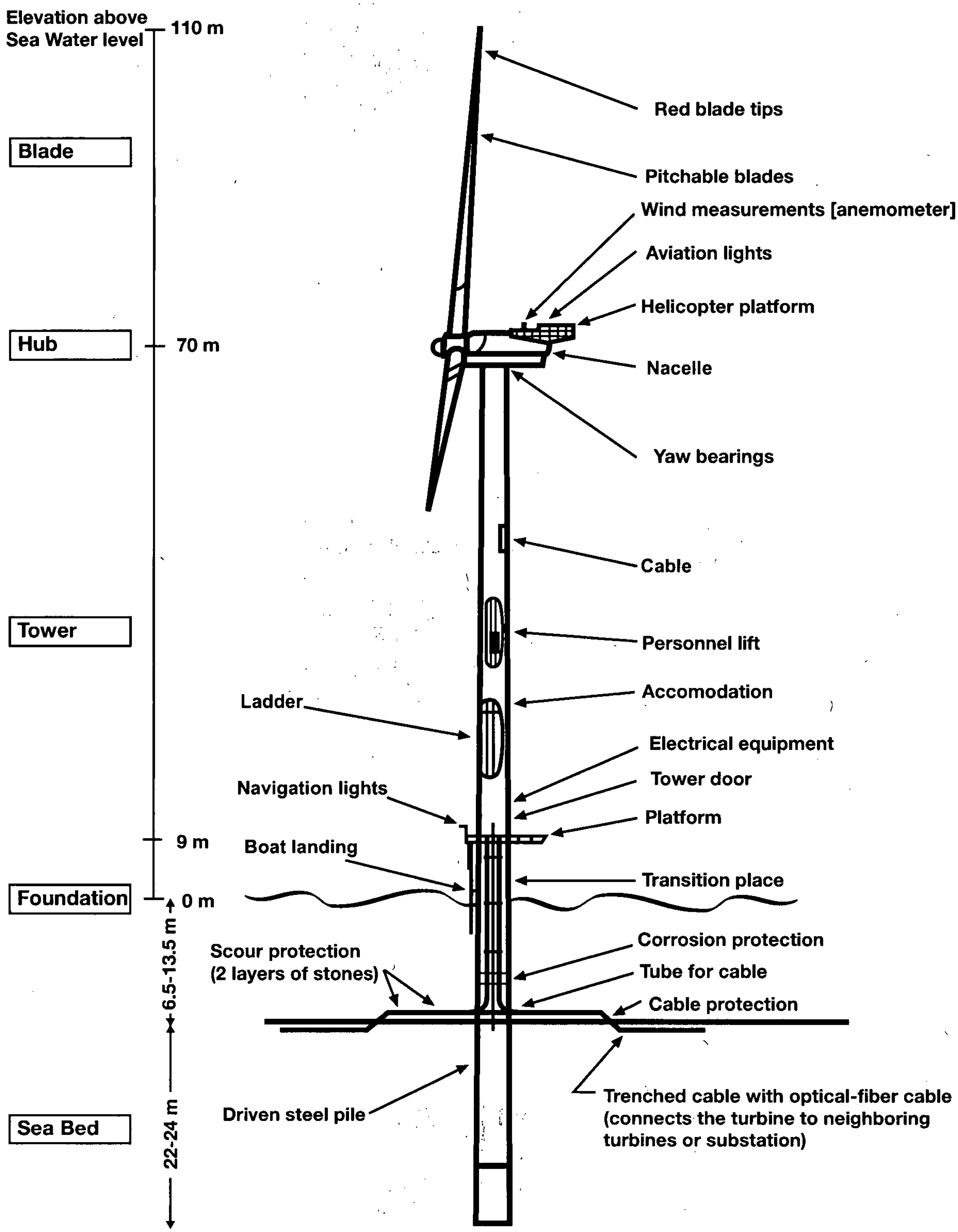


Figure 6.4: Horns Rev Offshore Wind Turbine Schematic



6.B Offshore Wind Vendors

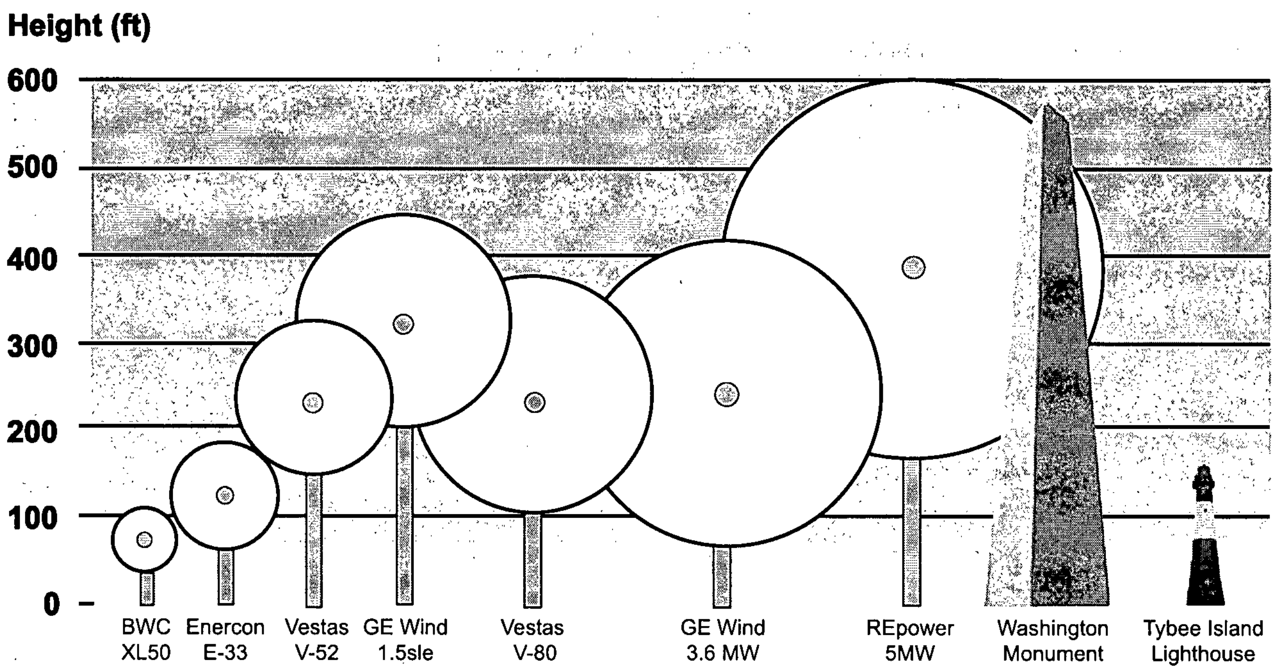
Information was collected from three equipment vendors: Siemens (Bonus), Vestas, and General Electric (GE). These vendors were asked to make presentations on their products. At the time of data collection, these were only three turbine vendors with products available for offshore applications. The other turbine vendors had not yet taken necessary steps to "weatherize" their products to protect them against salt spray and the other harsh aspects of offshore locations.

A review was conducted during the study of the various wind turbine designs with regard to appropriateness for the wind regime, projected capital cost, projected operating and maintenance cost, history of component failures, ease of construction, etc.

Costs for all wind turbine equipment have been going up recently because of the increase in demand and the increase in steel and copper prices. In fact, the price of steel for some of the critical components has doubled over the past two years. Figure 6.6 shows NREL's guidelines on offshore component costs.

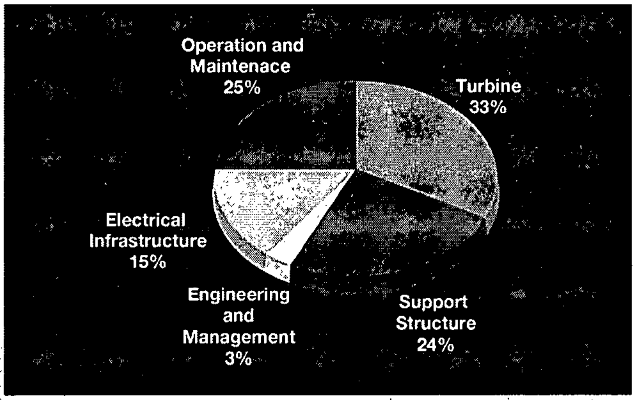
As discussed, the vendors with offshore products have in addition to taken special steps to "marinize" their offshore machines, have developed methods for access to these turbines for maintenance. Because of weather conditions, the turbines at existing wind farm locations can only be accessed by sea 60% - 70% of the time. The vendors have designed and built special boats that allow them to dock next to the turbines and reduce problems gaining access

Figure 6.5: Wind Turbine Size



Capacity	50 kW	330 kW	850 kW	1500 kW	2000 kW	3600 kW	5000 kW		
Rotor diameter	46 ft (14 m)	110 ft (33 m)	171 ft (52 m)	253 ft (77 m)	265 ft (80 m)	341 ft (104 m)	413 ft (126 m)		
Tower height	82 ft (25 m)	144 ft (44 m)	243 ft (74 m)	328 ft (100 m)	230 ft (80m)	243 ft (104m)	394 ft (120 m)	558 ft (170 m)	151 ft (47 m)

Figure 6.6: Offshore Wind Electricity Cost Components[28]



to the turbines from the ocean. However, these special boats cannot overcome access problems associated with "rough" seas. In this situation, wave conditions make personnel access too dangerous. Some turbines have platforms on top of the nacelle that allow helicopter drops for personnel and equipment.

The real time cost data was unobtainable from the vendors. Because of the constrained wind turbine market at this time and the recent rise in the costs of raw materials, especially copper and steel, the vendors contacted would not provide any cost information on their machines without a complete project specification being presented from a developer. This situation has made it difficult to put "real" cost data in the financial models being used to look at the feasibility for an offshore wind farm in Georgia. An estimated cost curve was developed using cost data from the recent European offshore wind farms (developed since 2003). The curve was adjusted to current pricing using a cost number provided by a vendor of $2,700/kW for a 100 MW wind facility. This was a substantial premium above the cost for an onshore project and a substantially higher cost that was reported more than three years ago.

6.C Foundation Systems

Based on studies completed by the Skidaway Institute of Oceanography and the Georgia Tech School of Civil and Environmental Engineering, it was determined that six different foundation systems can be considered as foundation options for the proposed offshore wind turbines. These have been listed below.

1. Large diameter driven open-ended steel pipe (most common used to date).
2. Drilled shaft foundations (used extensively along I-95 for bridge support).
3. Gravity platform, similar to those used for offshore oil platforms.
4. Multi-pod arrangement (e.g., tripod or quad-pod).
5. Suction anchors (new for deep water offshore oil production).
6. Floating foundations using anchored moorings to keep the wind turbines in place.

The most appropriate foundation system will depend upon the actual site-specific stratigraphy and the results from the data collection of geotechnical and geophysical parameters at a particular location. For general loading, consideration must be given to the following: (a) dead loads; (b) wave loading; and (c) wind loading. Components of loading include axial, lateral, moment, and torsion.[29] Depending on the specific situation, additional considerations must be made towards seismic earthquake loading, ship and/or barge impact, scour, snow and ice loading as well as transient loads due to shutdown.[30]

Based on the limited geotechnical information currently available for the proposed offshore wind farm sites, the use of large diameter driven steel open-ended pipe appears to be the best choice for foundation support of the wind turbine towers. The driving will require the mobilization of specialized installation equipment, because these size pilings are not normally utilized along the U.S. eastern coast. Large diesel hammers may be found in the Houston, Texas, area for the driving of the large pipe piles in offshore environments. Driven piles up to 6 ft (2 m) in diameter and to embedded depths of 100 - 150 ft (30 - 45 m) are not uncommon. For very large piles with 10 - 15 ft (3- 4.5 m) diameters, it may be necessary to mobilize special hammer systems from Europe.

[28] *Conversation with Walt Musial, NREL.*

[29] *Lesny, K. and Wieman, J. Design aspects of monopiles in German offshore wind farms. Frontiers in Offshore Geotechnics (Proc. ISFOG, Perth), Taylor & Francis Group, London: 2005. pp.383-390.*

[30] *Senders, M. (2005). Tripods with suction caissons in sand under rapid loading. Frontiers in Offshore Geotechnics (Proc. ISFOG, Perth), Taylor & Francis Group, London: pp. 397-404.*

6.D Wind Integration on the Utility Grid[31]

With most forms of electricity production, the primary fuel is "dispatchable." This means that the fuel can be converted to electrical energy at a rate which is controlled by the operator. Controlling electricity production is important because it allows the electric utility industry to adjust power output to meet demand as it fluctuates throughout the day. Wind power is not dispatchable. Wind is an intermittent resource. It does not blow consistently and it is hard to predict when it will blow. An operator cannot adjust the speed of the wind when more electricity is needed.

Traditional power plants generally fall into one of two categories: base load plants and "peaking" plants. Base load plants provide a steady supply of power that is at, or less than, the lowest demand on the system. Peaking plants fluctuate or adjust output to meet the load that is not met by the base load plants. Due to the non-dispatchable nature of the resource, wind farms do not fit well into either category. It is impossible for a wind farm to provide a steady supply of power, and it is impossible for them to provide extra power "on demand." One advantage of wind farms, however, is that the energy resource is free. Once a plant is built, its operating costs are very low and are more-or-less limited to maintenance. Because of this, the objective of a wind facility is to always capture as much energy as possible. Other power plants, particularly peaking plants, can adjust output to match demand.

Capacity factor is defined as energy produced during a given period (usually a year) divided by the amount that would have been produced if the equipment was driven at capacity the entire time. When purchasing electric generating equipment, it is often desirable to select devices that will operate at a high capacity factor. This is driven by economics. Equipment represents a significant investment, and there is considerable incentive not to purchase more machinery capacity than is absolutely necessary.

Utilities have traditionally avoided relying on intermittent resources such as wind power because of the risks such as large blackouts resulting from not having adequate capacity or generation to meet the demand on their systems. Therefore the question can be raised: "Can wind power replace part of the (conventional) capacity in a (power) system[32]?" Many wind power experts feel that it can despite these issues. In fact, some consider wind power to offer a capacity credit.[33,34,35] The capacity credit of wind power refers to the capability of a wind power plant to increase the reliability of a power system by increasing the availability of more capacity on the system.

To determine the ability of wind power to replace conventional generation, an examination of the wind power potential production during the system's peak load events and during each day should be made using at least several years of data.[36,37] If this examination shows that wind power is consistently available during the peak load times of the power system and/or shows a diurnal pattern of wind power production that matches the daily peak loads for a particular season, wind power can be used to replace part of the conventional capacity in a power system. For example, during the summer, the daily peak loads occur in the afternoon and early evening hours, and during the winter the daily peak loads occur in the early morning hours.

A limited review of the data was conducted looking at the Georgia offshore locations. As shown in Figure 3.9 and Figure 3.10 for the R2 and SLT locations respectively, there is a pronounced increase in average wind speeds in the afternoon hours during the summer months. Meanwhile in the winter months, the average wind speeds are generally constant through the morning hours. A more detailed data analysis would be required to determine the potential of wind power's capacity credit in the region off the Georgia coast.

Another advantage of including wind power in the generation mix of a power system is fuel source diversity. Wind

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[31] *Martin, Kirk. Site Specific Optimization of Rotor/Generator Sizing of Wind Turbines. Georgia Institute of Technology MS Thesis, August 2006.*

[32] *Ackermann, T. ed. Wind Power in Power Systems, Wiley, West Sussex, England 2005. p. 162.*

[33] *Ackermann, T. ed. Wind Power in Power Systems, Wiley, West Sussex, England 2005. Chapters 8.4.3, 9.2.2, 9.3.1.*

[34] *Munksgaard, J., Pedersen, M.R., Pederson, J.R. 1995. Economic Value of Wind Power, Report 1, Amternes of Kommunernes Forskningsinstitut (AKF) Copenhagen (in Danish).*

[35] *van Wijk, A. 1990. Wind Energy and Electricity Production, PhD Thesis, Utrecht University, Utrecht, The Netherlands.*

[36] *Giebel, G. 2001. On the Benefits of Distributed Generation of Wind Energy in Europe, VDI Verlag, Dusseldorf, available at http://www.drgiebel.de/.thesis.htm, Accessed 10-12-06.*

[37] *Milligan, M. 2000. Modeling Utility-scale Wind Power Plants. Part 2: Capacity Credit, Wind Energy, 2000, 3, 167-206.*

power provides a generation option for the power system that is independent of a fuel cost and transportation fees. It also provides an energy generation option that does not emit any greenhouse gases.

Wind's variability and uncertainty and the performance of the turbines themselves have caused concern among utilities with respect to wind's potential and effects on the electrical system's operation and reliability and the ability to forecast wind's impact on the system. Standards have and are being established so that wind integration does not affect electrical system's operation and reliability. The North American Electric Reliability Council (NERC) and its eight Regional Reliability Organizations, which includes the Southeastern Electric Reliability Council (SERC), have been given authority by U.S. Federal Energy/Regulatory Commission (FERC) under the Energy Policy Act of 2005 (EPAct) to set up standards for adding new generation such as wind power generation and the construction or modifications of the transmission and distribution components of the grid necessary to accommodate the generation. Included in these standards are studies that have and are being conducted to examine the response of a wind turbine and a wind farm to recover from disruptions such as a gust of wind and its effects on the electrical system. Computer models are being developed to help complete these studies and to predict the system's behavior.[38]

Formal rules and regulations have begun to be set up in portions of the U.S. for wind generation. FERC has included in its "Standardization of Generator Interconnection Agreements and Procedures for Large Generators" (Order 2003 and subsequent revisions) provisions specifically addressing interconnection issues for wind generation with an aggregate total capacity greater than 20 MW. The order focuses on issues such as low-voltage ride through capability, reactive support capability, and communication.[38]

[38] *Smith, C. Demeo, E., and Smith, S., Integrating Wind Generation Into Utility Systems. North American Windpower, September 2006, Volume 3, Number 8. pp 12 -18.*

7 Other Considerations

Wind resources, technological challenges, and geographical parameters are only some of the many aspects that must be considered in order to determine if a site is appropriate for an offshore wind facility. Multiple issues need to be examined prior to site selection to avoid potential roadblocks from local communities, other interested parties, and to ensure compliance with legislative authorities. The following sections represent some of the considerations that have been identified by the Europeans in their offshore wind siting experience and by the Cape Wind and Long Island Wind Park developers in their initial U.S. permitting process work.

7.A Viewsheds

The ability to see a wind farm from shore could be a significant constraint in the ability to permit and locate the facility. Perhaps the least controversial location from a viewshed standpoint would be the placement of the wind farm far enough offshore where it could not be seen from land. Thus, any landowners or other stakeholder concerns about views could be mitigated. This approach, however, might have significant negative financial impacts due to the high cost of running cable from the offshore wind farm to the coastline and to the additional costs associated with maintaining a wind farm so far off shore. A compromise would need to be made taking into account all of these important parameters when locating an offshore wind facility.

To better understand the visual impact of wind farms off the coast of Georgia, photo-simulation studies were conducted using the potential wind farm footprints identified in Section 4.A. Figure 7.1 to Figure 7.6 have been included to illustrate the results of these studies. These figures illustrated the results from the simulations of a "demonstration" wind farm which would consist of only five turbines. The photo-simulation studies consisted of two tasks: photography in the field and post-production assembly of images using Adobe PhotoShop®, and computer-design applications within the AutoDesk® family: AutoCAD® and 3D Studio VIZ. The results were felt to reasonably depict completed wind farms using Vestas V90 2.0 MW turbines with an 80 m hub height as observed from selected shore locations.

7.B Noise and Vibrations

The noise level generated during the construction of monopiles, which would be pile driven into the ocean bottom, would create a substantial and unavoidable short term impact. Though there would be some impact, studies have shown that noise levels would still be below 180 dBL at a distance of 500 meters, which is the threshold set by the National Marine Fisheries Service (NMFS) to prevent injury or harassment to marine mammals, sea turtles and fish. Based on simulated modeling, potential acoustical impacts on fish and marine mammal populations were deemed to be minimal.

In Europe, there have been some tactics used to scare marine animals away from sites before pile driving begins, such as the release of air jets and the creation of other objectionable low level noise before the pile driving is started.

In *Danish Offshore Wind: Key Environmental Issues*, observation data showed some effects on fish behavior related to the cable running between turbines and to shore. The primary change in behavior was an avoidance or attraction to the cable route, depending on species, but the observations noted that these behaviors did not correlate to the strength of the magnetic fields.[39]

7.C Air and Climate

Currently, the only existing offshore wind farms have been located in areas with cold water and predominantly cool weather climates. The South Atlantic Bight experiences a mild climate with both significantly higher water and air temperatures throughout the year. Lightning strikes are also very common in this region of U.S. coastal waters, especially during the summer months. The effect of lightning on a potential wind farm located in this region must be considered and mitigated.

Although the Georgia coast has not been hit by a major hurricane in over 100 years, as shown in Figure 7.7, the possibility of such an occurrence must be factored into the site selection process for an offshore project. At present, the highest wind speed turbine for which manufacturers have certified turbine survival is a 10-minute sustained wind speed of 111 mph. This equates to a 1-minute sustained wind speed of 124 mph, which is a "Category 3" hurricane on the Saffir-Simpson scale.

[39] *DONG Energy, Vattenfall, Danish Energy Authority, and Danish Forest and Nature Agency, Danish Offshore Wind Key Environmental Issues, http://www.ens.dk/graphics/Publikationer/Havvindmoeller/havvindmoellebog_nov_2006_skrm.pdf, p. 13.*

Figure 7.1: Photo-Simulation, Northern Wind Farm Location, 6.8 miles Southeast of Tybee Island

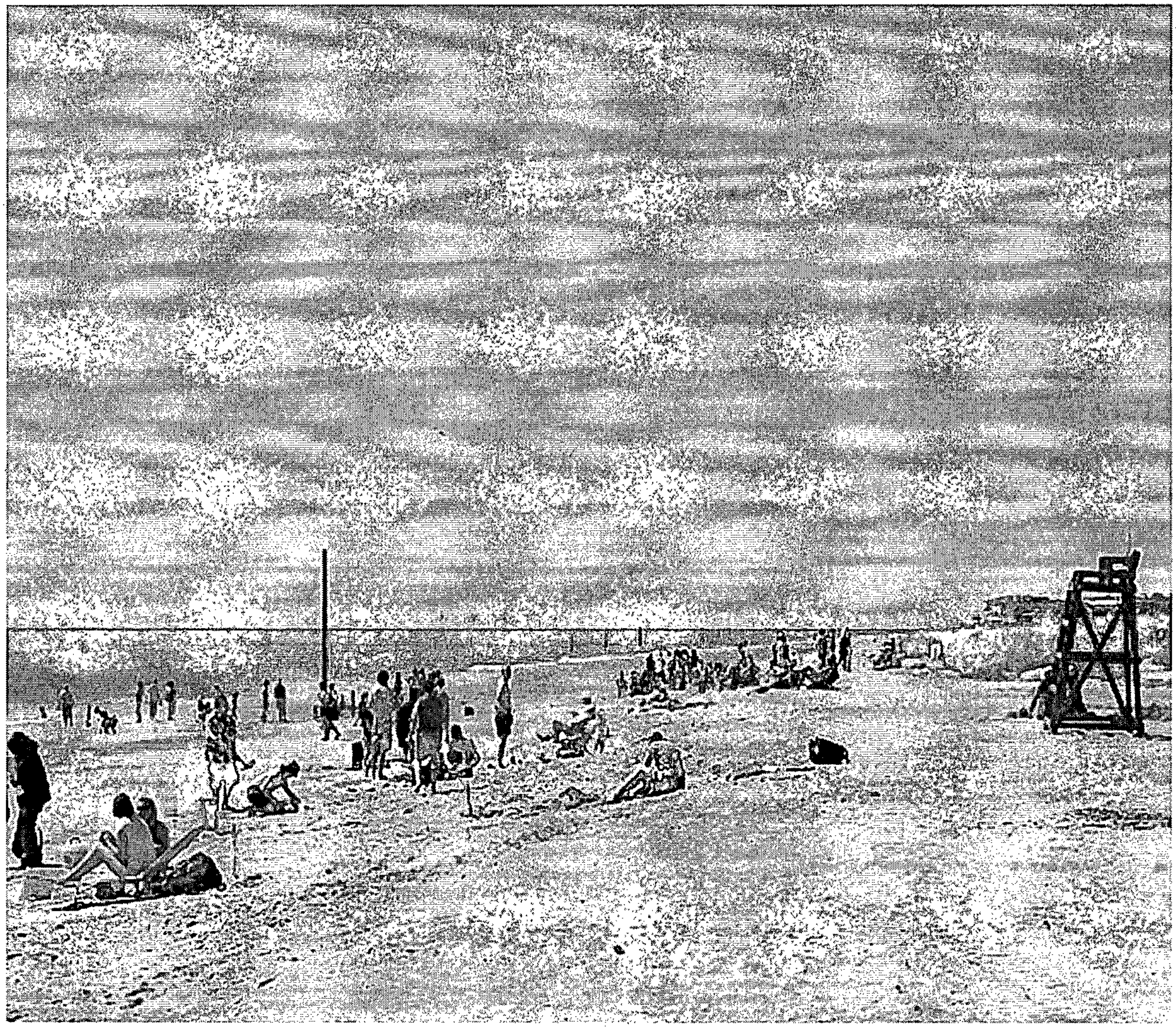


Figure 7.2: Photo-Simulation, Southeastern Wind Farm Location, 10.4 miles Southeast of Tybee Island

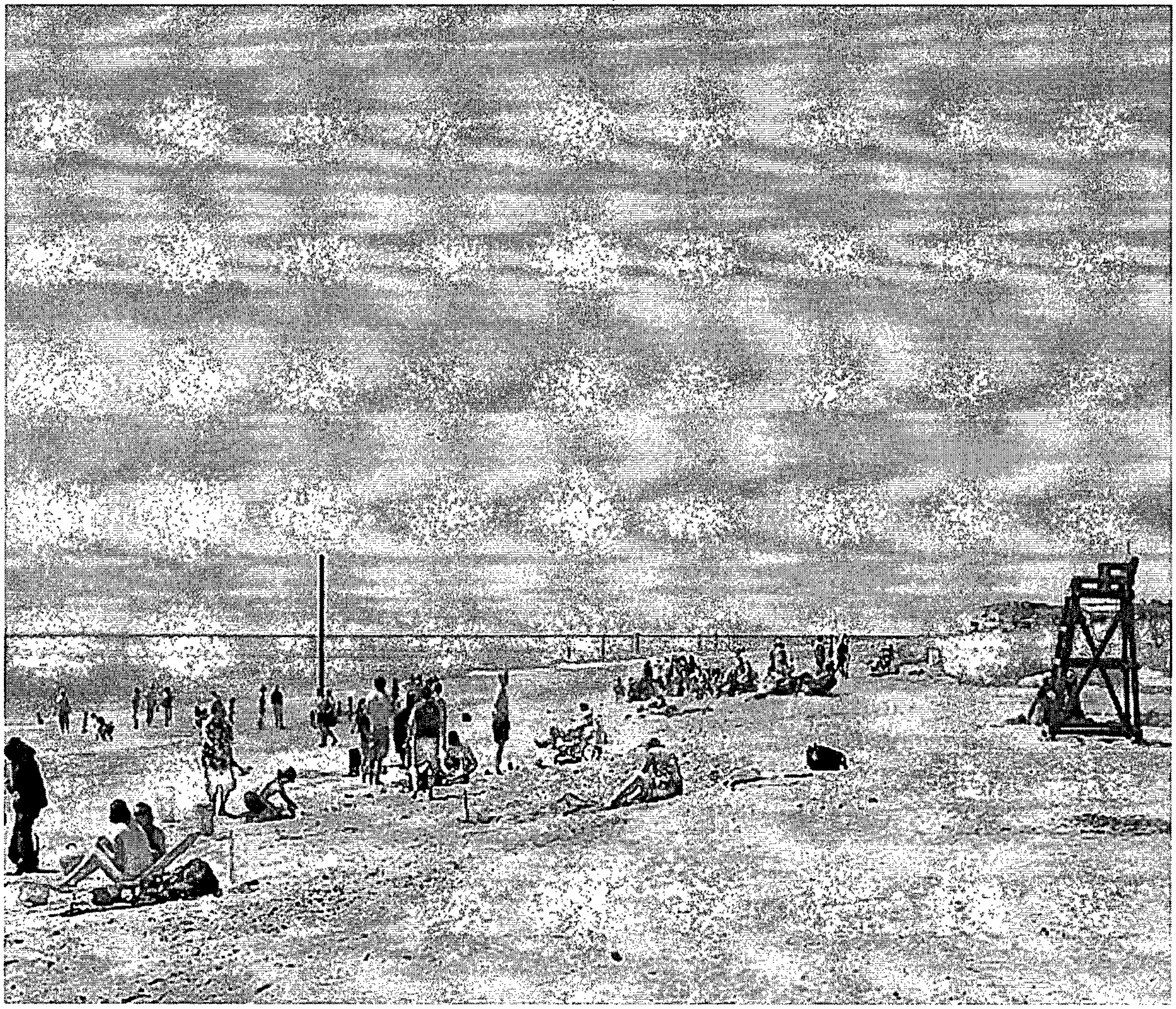


Figure 7.3: Photo-Simulation, Eastern Wind Farm Location, 10.2 miles South-Southeast of Tybee Island

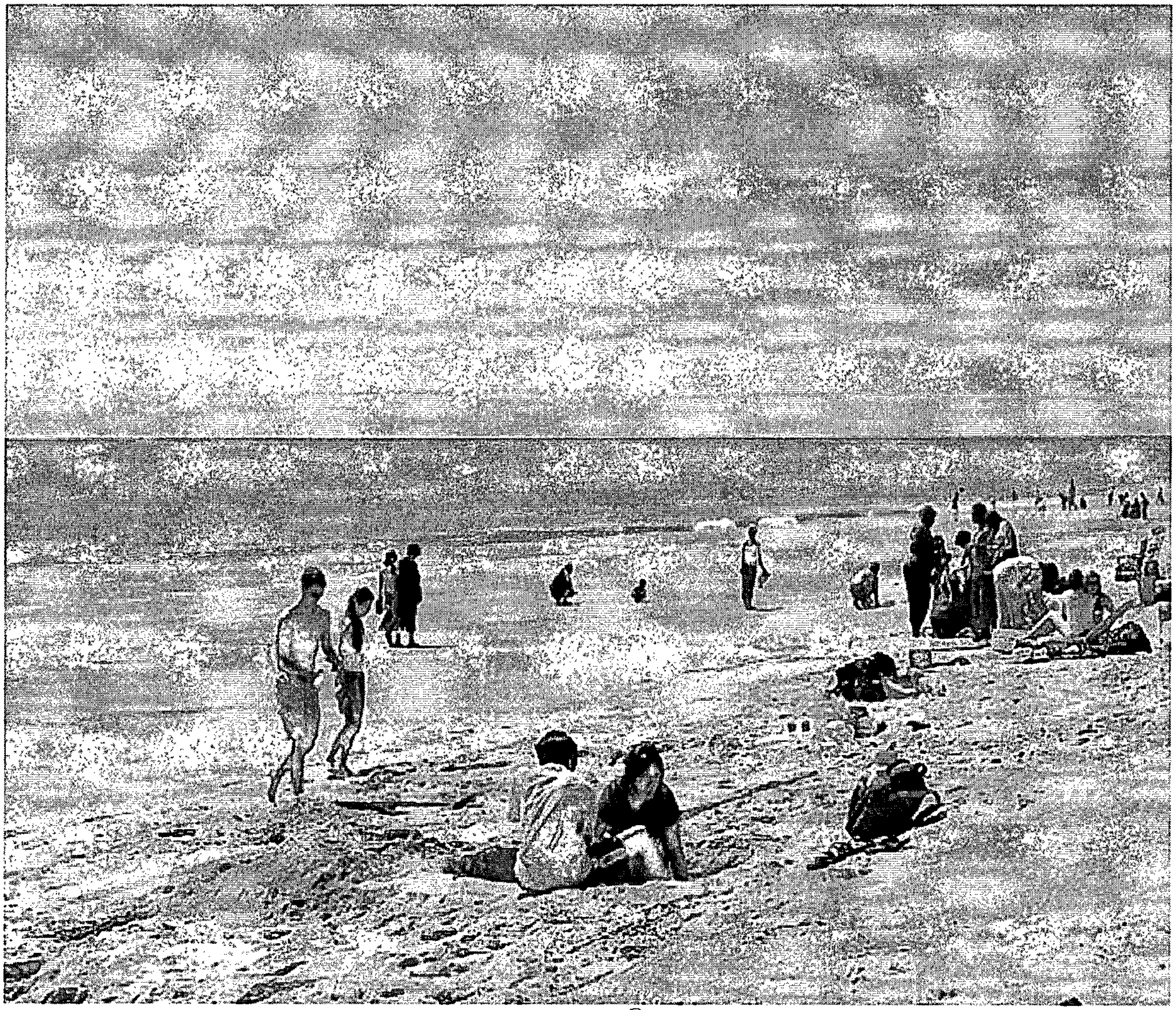


Figure 7.4: Photo-Simulation, Eastern Wind Farm Location, 4.1 miles East of Jekyll Island

Figure 7.5: Photo-Simulation, Far Eastern Wind Farm Location, 8.4 miles East of Jekyll Island

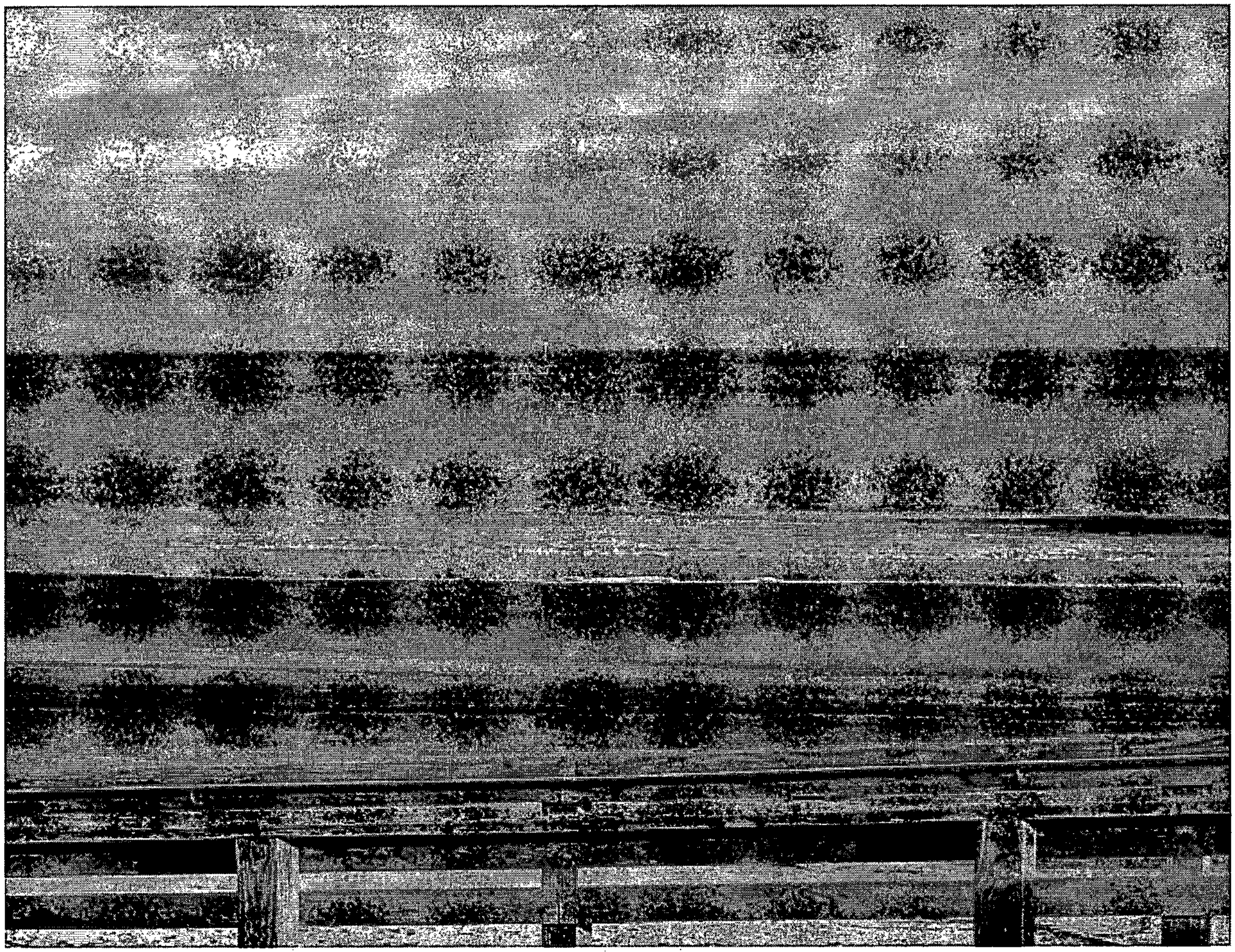


Figure 7.6: Photo-Simulation, Arcing Wind Farm Location, 9.4 miles Southeast of Jekyll Island

New developments in hurricane survivability from the equipment vendors and research organizations are being made and need to be monitored continually. Insurability also needs to be established, and the risks of a total loss should be considered.

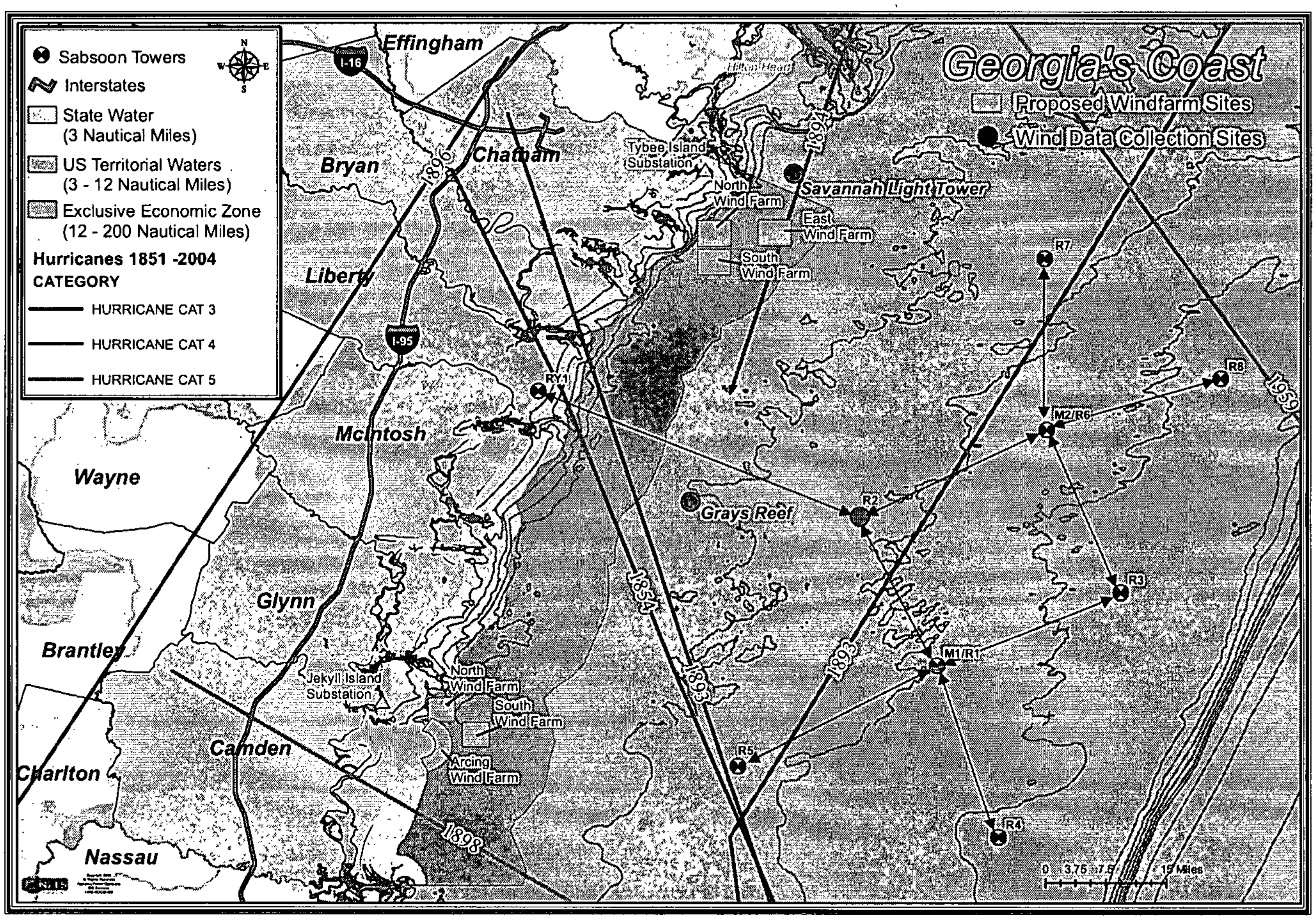
7.D Competing Uses

Georgia's coastal waters are home to significant commercial and recreational activity. Shrimp trawling, sport fishing, reef diving, sailing, and many other activities share this region and must be considered during both the construction, maintenance, and operating phases of an offshore wind development.

In Europe, each country individually handles public access to the area in the vicinity of the offshore wind farms differently. For example, in the UK and Ireland, the public is allowed access to the areas around some of the wind farms, while in Denmark the public is not permitted access.

During the course of this study, several meetings were held with sport fishers, saltwater fishing guides, and personnel with the Georgia Department of Natural Resources (DNR) who were concerned with commercial fishing activities off the Georgia coast. These groups and individuals have been generally in favor of the placement of the wind turbines offshore as they will act as fish attractants much like artificial reefs[40]. The commercial fishing interest was concerned about the offshore cabling because of shrimp trawling activities.

Figure 7.7: Major Hurricanes in Offshore Georgia Region Since 1854



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[40] *Conversation with Kathy Knowlton of DNR – April 3, 2006.*

8 Project Economics

Before the economics for an offshore wind farm were estimated, the electrical output from three different commercially available marinized wind turbines - GE 3.6sl MW machine, Siemens 2.3 MW MkII machine, and Vestas V90 2.0 MW machine - were calculated and compared. The electrical output estimates were made using digitized power curves and the Savannah Light Tower (SLT) data extrapolated to 80 m using the wind shear power law model. The results have been shown in Table 8.1.

Table 8.1: Estimated Annual Ideal Electrical Output by Machine using SLT Data

Turbine	Estimated Ideal Annual Electrical Output (kWh/yr/machine)
Vestas V90 2.0 MW	6,826,000
Siemens 2.3 MW MkII	7,996,000
GE 3.6sl MW	10,304,000

8.A Cost Model

Very little cost information for offshore wind farms was available from the vendors. One data point of $2,700/kW in-service cost for a 100 MW wind farm built today was given by a vendor during a conversation.[41] Therefore, in order to better represent the economies of scale, the recent European offshore wind experience was assessed.

The European offshore wind farms developed since 2003 with publicly available cost data have been tabulated in Table 8.2. The costs reported in euros or British pounds were converted to U.S. dollars using the currency conversion factors from the year of their contract.[42] These costs were then inflated by 3% per year to 2006 U.S. dollars. The resulting offshore wind farm costs per kW were shown versus farm size in Figure 8.1 with the additional data point, $2,700/kW, obtained from the vendor.[41] A power law curve fit has been shown to fit fairly well for this data set.

The European data points (in 2006 U.S. dollars) shown in Figure 8.1 were increased by 25% in order to incorporate the "$2,700/kW for 100 MW wind farm" number obtained from a vendor and to account for the recent increases in turbine price. Turbine prices have been recently increasing because of constraints on supplies of steel, copper, and carbon fiber and because of the extremely high demand for wind turbines which currently exceeds near-term manufacturing capacity. The results from this adjustment have been shown with the cost curve fit in Figure 8.2. The 25% multiplier used was determined by calculating that the "$2,700/kW for a 100 MW wind farm" represents an approximate 25% increase in offshore wind farm costs.

Even though the Arklow expansion project (520 MW) was listed in Table 8.2, it was not used in the curve fit. The size of this project was significantly larger than the other projects listed in Table 8.2, and large inaccuracies would probably result from extrapolating the calculated curve fit beyond the point of 166 MW. However, it should be noted that the cost curve begins to flatten between 165.6 MW ($2,179.1/kW) and 520 MW ($2,164.7/kW).

Also, no economy of scale on individual machine sizes has been included in this curve fit. Additional vendor cost information for a product line would be needed to determine a wind turbine economy of scale. Information would also be needed on the difference in cost for foundations. Since the larger capacity turbine is larger in physical size, it would require a larger foundation. However, a wind farm made up of larger capacity turbines would require fewer turbines, and thus, fewer foundations, for the same total farm size than a farm with smaller capacity turbines. This added information would improve the overall offshore wind farm economy of scale.

The resulting curve fit equation shown in Figure 8.2 is of a power law type:

$$\$\text{Cost/kW} = 14460 \times \text{Size}^{-0.3702}$$

This equation was used to analyze the levelized busbar cost or the cost to generate electricity before it enters the transmission grid for a 50 MW, 100 MW, and 160 MW wind farm as discussed in Section 8.C.

8.B Wind Turbine Comparisons

Using the ideal annual electricity production estimated from the SLT data and the three different turbines shown

[41] *Conversation with Vendor, September 2006.*

[42] *Currency Exchange Rates, http://www.x-rates.com.*

Table 8.2: Recent European Experience Offshore Wind Farm Economics

Name	Completed Year	Contract Year	Farm Size	Cost				2006 $	Machine Size	Depth	Distance	Avg Wind Speed
			MW	mill euro	mill British pound	mill $[43]	$/kW	$/kW	MW	m	km	m/s
Horns Rev[44]	2003	2002	160	270		256.5	1603.1	1804.3	2	6 – 12	14 – 20	9.2
North Hoyle[45]	2003	2002	60		80	120	2000.0	2251.0	2	10 – 20	6	
Scroby Sands[46]	2003	2003	60		66.8	123.58	2059.7	2318.2	2	4 – 8	2.3	7.5
Nysted/ Rodsand[44]	2003	2003	165.6	270		256.5	1548.9	1743.3	2.3	5 – 9.5	10	9.1
Barrow-in-Furness[44,47]	2004 - 2005	2004	90	145	100+	185	2055.6	2180.7	3	21 – 23	7	9
Kentish Flats[48]	2005	2004	90		105	194.3	2158.3	2223.1	3	5	8.5	8.7
Egmond[49]	2006	2005	108	200		250	2314.8	2314.8	3	16 – 22	10	
Beatrice (Moray Firth)[50]	under const.	2006	10	41		52.1	5210.2	5210.2	5	40	5.5 – 9.5	
Arklow, expansion[44]	2003 - 2007	2006	520	630		800.1	1538.7	1731.8	3.6	2 – 5	10	

Figure 8.1: European Experience Offshore Wind Farm Costs ($2006)

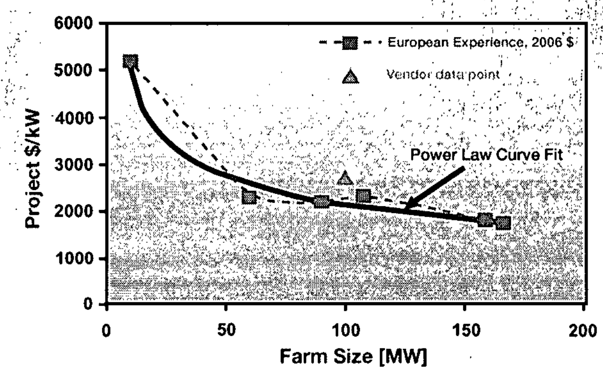
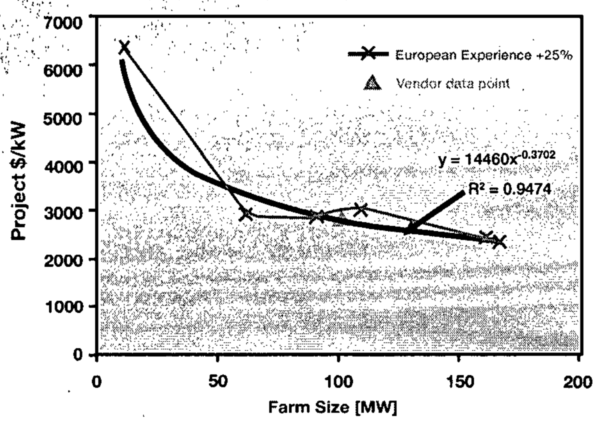


Figure 8.2: European Experience Offshore Wind Farm Costs + 25% Cost Increase ($2006)



[43] *Currency Exchange Rates, http://www.x-rates.com.*

[44] *Offshore Wind Energy Europe, Windfarms, http://www.offshorewindenergy.org.*

[45] *NPower Renewables, North Hoyle, Site Statistics, http://www.natwindpower.co.uk/northhoyle/statistics.asp.*

[46] *Scroby Sands Annual Report, 2005.*

[47] *BO Wind, Press Releases, http://www.bowind.co.uk/press030506.htm.*

[48] *Vattenfall, Kentish Flats, http://www.kentishflats.co.uk/page.dsp?area=1414.*

[49] *Nordzee Wind, Egmond, aan Zee, Project, http://www.noordzeewind.nl/.*

[50] *Beatrice Wind Farm Demonstration Project, http://www.beatricewind.co.uk/home/default.asp.*

in Table 8.1, the ideal annual capacity factors can be calculated by dividing the expected ideal annual turbine energy output (kWh) by the total turbine capacity times the number of hours in a year. Table 8.3 summarizes these ideal capacity factors.

Table 8.3: Estimated Ideal Annual Capacity Factors

Machine	Estimated Ideal Annual Capacity Factor (%)
Vestas V90 2.0 MW	39
Siemens 2.3 MW MkII	40
GE 3.6sl MW	33

Adjustments to the ideal capacity factor based on several assumptions need to be made in order to make a more realistic cost estimate. These adjustments have been summarized in Table 8.4.

Table 8.4: Adjustments to Ideal Capacity Factor

Assumption	% Reduction in Ideal Energy Output
Wake effect	95.0
Electrical Efficiency	97.0
Availability	94.0
Icing & Blade Fouling	98.0
High Wind Hysteresis	99.7
Substation Maintenance	99.8

The net annual capacity factors were calculated by taking the ideal annual capacity factors and correcting them using the adjustments shown in Table 8.4. The results are shown in Table 8.5.

Table 8.5: Estimated Net Annual Capacity Factors

Machine	Estimated Ideal Annual Capacity Factor (%)
Vestas V90 2.0 MW	33
Siemens 2.3 MW MkII	34
GE 3.6sl MW	28

The best net capacity factor shown in Table 8.5 is 34%. This is the number used in the levelized busbar analysis as shown in Section 8.C.

8.C Levelized Busbar Modeling Assumptions

A Southern Company model incorporating publicly available data[53,54] was used to estimate the levelized busbar costs for an offshore wind farm. The term "levelized busbar cost" indicated the cost to generate electricity before it enters the transmission grid.

The following assumptions were made during modeling the levelized busbar costs:

- Financing structure assumptions
  - Generic regulated utility capital structure
  - 55% debt, 45% equity
  - ROE = 13.5%, cost of debt = 7.5%
  - Tax rate = 40%
  - Standard revenue requirement methodology for capital cost recovery over economic life of asset
  - 20 year economic life
  - 5-yr tax life (accelerated depreciation per MACRS 5-yr schedule)
  - 2.02 ¢/kWh Production Tax Credit (PTC) levelized over 30-yr life[55]
  - 33.5% capacity factor assumed
  - Costs calculated are considered in-service costs
- Capital and O&M costs constant for all technologies
- 50, 100, and 160 MW wind farm size
- 12-month construction schedule
- 2007 in-service date

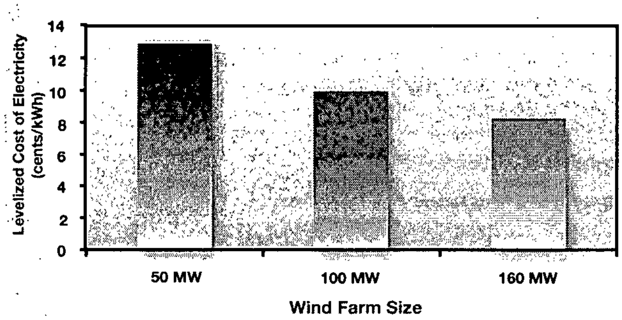
The resulting levelized busbar costs using these assumptions along with the cost curve developed in Section 8.A for 50, 100, and 160 MW wind farms have been shown in Figure 8.3. As shown in this figure, there is an "economy of scale" which makes a larger wind farm more economical. This concept, previously discussed in Section 8.A, was the impetus for using the European experience to determine an appropriate curve to depict the wind farm size economic scaling. Also, the levelized busbar costs shown in Figure 8.3 include an approximate 25% increase in cost over the European data to account for recent increases in turbine costs.

[53] *Assumptions for EIA Annual Energy Outlook 2006, Table 38 and p. 85-86.*

[54] *Recurring capital estimates based on rounded internal data (no data in EIA for recurring capital since it is such a small component of busbar cost).*

[55] *Assumed 1.9 cent/kWh PTC (2005$) grossed up to pre-tax value based on 40% assumed federal tax rate, PTC escalated at 1.9% annually over 10 years of PTC applicability.*

Figure 8.3: Levelized Busbar Costs for Various Wind Farm Sizes (with PTC)



In addition to the levelized busbar costs, one consideration needs to be made for the development costs incurred for an offshore wind project. The busbar costs represented in the above calculations do not include the costs required to develop the project. The Cape Wind project as previously described has incurred costs of $25M for the development of their project and their project has not been built to date. However, this project is the first one of its kind in the U.S. and, thus, the anticipated development costs would be expected to be higher than for the "nth plant". Based on a conversation with a developer, it is anticipated that the development costs for an "nth plant" of any size would be approximately $15M.[56] The actual cost will depend on the issues that might arise such as avian and "not in my backyard" issues as the project is being developed. If issues such as these become significant, the developmental costs may increase significantly.

[56] *Confidential source.*

9 Conclusions

After extensive study of the many technical, financial, environmental, and public issues related to the potential for development of an offshore wind farm in coastal Georgia waters, several conclusions can be drawn. This section outlines some of the conclusions based on the work performed during the *Southern Winds* project period from July 2005 to March 2007.

9.A The Wind Resource

Traditionally, it has been assumed a fact that there is "no wind resource" in the southeastern U.S. except for small isolated areas, such as mountain ridges in Tennessee and North Carolina. The only onshore wind farm built in the Southeast to date is located on one of these mountain ridge locations. In 2004, a research team from the Georgia Institute of Technology's Strategic Energy Institute (SEI) began an examination of the wind data available via SABSOON located on a Navy platform off the Georgia coast and based on this, concluded that there is a "Class 4" wind regime off the Georgia coast which may provide enough energy to power an offshore wind farm. In 2005, SEI and Southern Company decided to work together to determine the technical and economic feasibility of locating an offshore wind farm in this area.

While the strength of the wind regime off the coast of Georgia is not as high as in the other locations being considered for offshore wind development in the eastern U.S. (e.g. Cape Wind and Jones Beach, New York), the actual breadth of the Georgia data available was better than at these other locations. The Georgia data came from three different offshore locations collected over a 20-year span. An important point to note is that at least one of the wind farms built in Europe (Scroby Sands in England) has a wind resource just slightly higher in magnitude than that found off the Georgia coast. However, British utilities and developers in Europe have different motivations and or regulatory incentives due to participation in ratification of the Kyoto Protocol, which help improve wind farm economics. If similar incentives and regulatory requirements develop for U.S. energy markets, the Georgia offshore wind resource represents one of the best opportunities available for harnessing large scale wind energy in the Southeast.

9.B Ongoing Data Needs

Despite the historical wind resource data available, the wind turbine vendors prefer to have wind data collected within the footprint of the selected site and at heights comparable to the hub height of an offshore wind turbine. The project team, thus, recommends that if the project goes forward, the next step should be the placement of a meteorological data collection system offshore in the actual site selected for the wind farm. However, the team recognizes the inability to currently place structures offshore in federal waters until the regulatory rulemaking process has been completed by the Minerals Management Service (MMS).

9.C Project Permitting

The original intent of SEI was to have a permitting package essentially completed at the end of this project to present to the U.S. Army Corps of Engineers (USACE) for a "10 MW demonstration" wind farm. A "10 MW demonstration" wind farm was believed to have been small enough not to require a full Environmental Impact Study (EIS). However, during the course of this project, the Energy Policy Act of 2005 was passed which gave MMS the governing authority rather than USACE over offshore wind development. This change in authority ruled out the possibility of a submitting a permitting package for a "10 MW demonstration" wind farm at the conclusion of the *Southern Winds* project, because MMS has placed a moratorium on any activities offshore until their rulemaking has been completed, which they anticipate to be finalized by the fall of 2008.

The project team recommends that Southern Company should continue engagement in the MMS regulatory rulemaking process, with the continued assistance from Georgia Tech if appropriate. If the decision is made to go ahead with a "demonstration" wind farm or a "full scale" commercial wind farm, Southern Company should prepare for a comprehensive permitting process that is likely to be required by MMS. With regard to biological issues (avian, aquatic and sea bed), relevant studies can require a significant amount of time and expense and as such, should be undertaken as soon as feasible, if the project appears to have forward momentum.

9.D Equipment Availability

During the course of this project the project team learned that there are a number of equipment vendors in the marketplace manufacturing large (greater than 1 MW) wind turbines considered "state of the art." Much of the manufacturing is taking place in Europe, and most of the manufacturers are "sold out" until 2008. The equipment vendors have expressed a lack of confidence in the long-term viability of the wind production tax credit (PTC) program in the U.S. and in the uncertainty as to the timeframe for permitting of offshore wind farms under an as yet to be developed MMS permitting process and regulatory scheme. These issues have caused the equipment vendors to limit their manufacturing capabilities in the U.S.

General Electric, Siemens, and Vestas are currently the only equipment vendors who offer offshore wind turbines. Clipper Wind may be offering an offshore product in the future, and it is likely that this machine will be built in the U.S. Developments in wind turbine technologies need to be monitored.

Globally, equipment vendors are taking similar approaches to the current high market demand. Vendors are screening projects to gauge whether or not the projects are likely to succeed, by predetermining on their own if the site is a good fit for their equipment. This approach can be taken in a seller's market but is subject to change over time.

9.E Offshore Conditions and Foundations

Studies performed with the support of the Skidaway Institute of Oceanography and the Georgia Tech Civil Engineering School indicate that monopile foundations similar to those used in many of the offshore locations in Europe would be appropriate in an installation located off the coast of Georgia. However, none of these foundations have been constructed in U.S. waters. If foundations are constructed in the near future, specialized marine construction equipment and seagoing vessels provided by contractors in Europe or Asia might have to be used, although many of the construction firms used to build the offshore drilling platforms in the Gulf of Mexico may also be able to adapt their equipment for these projects.

9.F Georgia Weather Conditions

The increased frequency of major hurricanes in the southeastern U.S. is a major potential concern to the developers of offshore wind farms. At present, the highest wind speed turbine manufacturers have certified turbine survival for is a 10-minute sustained wind speed of 111 mph. This equates to a 1-minute sustained wind speed of 124 mph, which is a "Category 3" hurricane on the Saffir-Simpson scale. However, hurricane and severe storm activity needs to be planned for in any offshore project. Insurability needs to be established, and the risks of a total loss should be considered. New developments in hurricane survivability from the equipment vendors and research organizations need to be monitored continually.

Lightning, another weather phenomenon particularly severe in the Southeast, must be considered in wind turbine design. Any chosen vendor design must be examined closely to determine its success in handling lightning strikes.

9.G Project Location

The project team has identified two regions off the coast of Georgia which appear to offer feasible sites for wind farms – either for demonstration or for "full scale." These regions are southeast of Tybee Island and east of Jekyll Island. The Tybee Island location has been determined to be more suitable because of a slightly better wind resource and preferable substrate conditions on the ocean floor.

9.H Regulatory Issues

With interest in developing wind generation, long term extension of the federal wind production tax credit (PTC) should be supported, as well as the possibility of additional incentives that could be put in place for renewable energy in the State of Georgia. In addition, discussions should be started with the Georgia Public Service Commission about cost recovery in the rate base for wind generation feasibility evaluations, early site permitting, and development planning.

9.I Stakeholder Involvement

No widespread release of information on a potential offshore wind farm in the Georgia coastal area has been made to the general public or to other stakeholders. A careful roadmap for sharing of this information with the general public should be developed if Southern Company chooses to go ahead with an offshore wind project. The project team has learned much from the other projects being planned in the U.S. While the Cape Wind project may eventually be permitted and built, the progress might have come much easier if the public announcements had taken place in a phased approach and if a "demonstration" rather than a "full-scale" project was recommended. Several turbines could have been installed initially as a "proof of concept" project, rather than announcing an entire project consisting of 170 wind turbines. It was likely that consensus could have been built more quickly and more positively with that approach. The Long Island Power Authority/FPL project has taken a more collaborative approach with stakeholders and might be a better model for a Georgia project.

The project team has had a number of meetings and informal discussions with the Georgia Department of Natural Resources, commercial and private fishermen, and other interested parties, and the majority of their comments have been positive. It is recommended that discussions continue with state and local agencies and other stakeholders to ensure accurate dissemination of information if a project moves forward.

9.J Project Economics

There are very few locations in the Southeast where the average wind speed is adequate to support the construction of an onshore wind farm on an economic basis. Available wind data indicates that a wind farm located offshore in Georgia would likely have an adequate wind speed to support the project, but the high costs associated with offshore technology, construction, and maintenance would drive the costs up by 50% – 100%. Based on today's prices for wind turbines, a commercial size 50 MW to 160 MW offshore wind farm could produce electricity at 12.9 to 8.2 cents/kWh respectively, assuming a 20-year life and regulatory incentives such as a federal production tax credit (PTC) with accelerated depreciation similar to those currently available. A smaller or larger commercial wind farm would increase or decrease, respectively, the cost per kWh because of the economics of scale. Also, the development costs would need to be taken into consideration. The size of an offshore wind farm would not be a significant factor in the overall development costs of an offshore wind farm, but because of the unknown permitting process these costs cannot be fully understood until MMS has completed their rule-making process.

In the Southeast, the real opportunities for renewable projects are limited. The only other type of renewable projects equal to or less in cost than wind are biomass and landfill methane gas electric generation projects.

However, there are benefits to a wind project which include the following:

- Free fuel for the duration of the project with no impacts from increasing fuel prices.
- Renewable energy credits and/or potential reduced carbon tax costs.
- Tremendous benefit in public relations, showing Southern Company to have a "pro-active" stance with regard to renewables.
- Potential for the creation of a new industry and new job opportunities within Southern Company's service territory.

10 Recommendations

It is recommended that Southern Company continue to pursue the potential development of wind energy resources off the coast of Georgia. The next step should be to remain active in the offshore rule making process currently being developed by the MMS. Once the MMS completes the rulemaking process and begins to allow structures to be built on the continental shelf, the team recommends that Southern Company attempt to secure rights from the MMS for future wind energy development in the most promising area or areas of the study. If Southern Company is successful in acquiring these rights and wind energy technology is continuing its move toward economic viability, then the company should consider the erection of an offshore meteorological tower near Tybee Island to measure the wind speeds and directions and to collect other required data.

If analysis of the meteorological data shows the resource to be technically viable (i.e., at least Class 4) the project team recommends that Southern Company consider the construction of a small (10 MW) "demonstration" wind farm, possibly as a joint project with a vendor, the Department of Energy and other federal and state agencies. The erection of a small demonstration farm would allow ongoing data collection and would establish a better database for operation and maintenance issues.

If the concerns about the costs and insurability of offshore wind have been sufficiently resolved by the time the necessary wind resource data has been acquired and analyzed, then this demonstration project phase might be bypassed in favor of an effort to move forward with the development of a commercial-scale wind farm.

Both Georgia Tech and Southern Company found this study to have been productive. Georgia Tech personnel have learned more about the details and the technology issues involved in a wind project, and Southern Company personnel have become involved with a new generation option and have formed a good basis to look at renewable energy from a more informed standpoint in the future. The project team recommends that an ongoing relationship be promoted between Southern Company and Georgia Tech SEI.

GLOSSARY

A

ADIZ – Air Defense Intercept Zone: serves as a national defense boundary for air traffic and is administered by the U.S. and Canada.

B

C

CZMA – Coastal Zone Management Act.

Capacity factor – ratio of the energy produced over a given period of time to the energy that could have been generated at the equipment's full capacity over the same period of time.

Cooper marl – layer of stiff clay (North Carolina).

Cut in speed – wind speed at which the turbine begins to produce power.

Cut out speed – wind speed at which the turbine may be shut down to protect the rotor.

D

E

EIS – Environmental Impact Statement: document under NEPA stating environmental impacts of an action affecting the quality of human environment.

Estuarine – Formed in an estuary.

Estuarine area – (from Coastal Marshland Protection Act) All tidally influenced waters, marshes, and marshlands lying within a tide-elevation range from 5.6 feet above mean high-tide level and below.

F

FHWA – Federal Highway Administration.

FPL – Florida Power & Light Energy Company, selected to install a wind farm off the south coast of Long Island.

G

GDOT – Georgia Department of Transportation.

GTC – Georgia Transmission Corporation.

Green Tags – also known as Renewable Energy Credits or Tradable Renewable Certificates that represent environmental benefits associated with generating electricity from renewable energy sources.

Grey literature – literature (often of a scientific or technical nature) that is not available through the usual bibliographic sources such as databases or indexes. It can be both in print and, increasingly, electronic formats. Grey literature is produced by government agencies, universities, corporations, research centers, associations and societies, and professional organizations.

H

Hub height – height of wind turbine axis above water or land.

I

Isobath – an imaginary line or one drawn on a map connecting all points of equal depth below the surface of a body of water.

J

K

L

LIOWI – Long Island Offshore Wind Initiative: educational and public outreach forum for the wind power generation project off the coast of Long Island.

LIPA – Long Island Power Authority.

M

Marginal sea – a part of ocean partially enclosed by land such as islands, archipelagos, or peninsulas. Marginal seas are different from mediterranean seas because they have ocean currents caused by ocean winds. The waters between some of Georgia's barrier islands are considered marginal seas.

Marinize – Weatherized to protect against the offshore environment.

MMS – Minerals Management Service: Lead federal agency for offshore wind farm permitting.

MOA – military operations areas.

Miocene marl – unconsolidated limestone in soil-like consistency with partial to full cementation in localized areas (Georgia).

N

NEPA - National Environmental Policy Act.

NHPA – National Historic Preservation Act.

NIMBY – Not In My Back Yard: phenomenon in which residents say a development is inappropriate for their local area.

NMFS – National Marine Fisheries Service.

NMSA – National Marine Sanctuary Act.

NREL – National Renewable Energy Laboratory: Golden, Colorado.

NSF – National Science Foundation: U.S. agency supporting research and education in non-medical fields of science and engineering.

Nacelle – Enclosure for wind turbine mechanical components.

Nautical mile – 1.1 statute miles.

O

OCSLA – Outer Continental Shelf Lands Act.

OPEC – Organization of the Petroleum Exporting Countries: Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela; headquarters Vienna, Austria.

Outer Continental Shelf – submerged lands, subsoil, and seabed between the U.S. and Federal seaward jurisdiction.

P

PFI – Partnerships for Innovation: program developed by NSF involving technology assessments on alternative energy options to determine potential for implementation.

Pitch mechanism – turns rotor blades of a wind turbine into and out of the wind.

Power curve – graphical representation of the relationship between a wind turbine's power output and wind speed.

Q

R

RHA – Rivers and Harbors Act.

Rotor Diameter – diameter of swept circle of wind turbine rotor blades.

S

SABSOON – South Atlantic Bight Synoptic Offshore Observational Network.

SEI – Strategic Energy Institute.

SLT – Savannah Light Tower: entrance to Savannah River ship channel (destroyed 1996).

South Atlantic Bight – U.S. coastal ocean from North Carolina to the east coast of Florida.

Squirrel cage – a type of induction machine that uses copper bars in order to generate electrical power.

Stator – the stationary part of an electric motor.

T

U

USACE/USACOE – US Army Corps of Engineers: formerly lead agency for offshore permitting.

V

Viewshed – an area of land, water, and other environmental elements that is visible from a fixed point.

W

Weibull curve – a frequency diagram that is used to approximate the variation of wind speed over time.

Wind farm – a collection of wind turbines in the same location.

Wind rose – a-map symbol showing, for a given locality or area, the frequency and strength of the wind from various directions.

Wind shear – the change in wind speed or direction with height.

Wound rotor – a type of induction machine that is comprised of a set of coils used to generate electrical power.

X

Y

Yaw mechanism – turns the wind turbine rotor against the wind.

Z