The Offshore Wind Energy Environment in the U.S.A. by Chris Nunalee, North Carolina State University

It is no secret that the economic state of modern America, like the rest of the world, is intricate and fragile, especially when it comes to the supply and demand of electrical energy. Considering that cheap and convenient fuel sources are finite, and that their depletion rate is increasing due to rises in population and industrialization, it necessarily follows that the price of energy becomes more expensive. To many, this predicament threatens the long-term sustainability of conventional power production methods such as burning fossil fuels.

Within the realm of U.S. wind energy, offshore areas possess enormous value (See Figure 1), as they typically have abundant power potential, a result of low surface friction and high mean wind speeds, and are located close to high energy consumption regions (e.g., New York, Philadelphia, Boston, Los Angeles, Chicago). In addition, the lack of construction constraints for projects such as houses, water pipelines, roads, and power lines allows for the construction of offshore wind farms on a much larger scale than onshore wind farms. In addition, the transportation logistics associated with using ships versus trucks supports the construction of larger, more powerful wind farms. Nevertheless, the current status of offshore wind power production (WPP) in the U.S. does not reflect the promise of these advantages. In fact, the current capacity of operational offshore WPP in the U.S. is zero megawatts! In contrast, it cannot be said that the U.S. lacks substantial onshore WPP; over the last decade, the U.S. has been the global leader in annual WPP (i.e., 60 GW in 2012), only recently losing that title to China (GWEC, 2012). In addition, the notion of offshore WPP is neither a new or fictional concept. In Europe, the first offshore wind farm (Vindeby) was constructed over twenty years ago offshore of Denmark; today there are over 50 offshore wind farms
hosted by more than 10 countries. This totals to approximately 5,415 MW of global offshore WPP out of a combined onshore and offshore capacity of 282,500 MW in 2012 (up approximately 33% from 2011 [GWECE, 2012]). If the U.S. is one of the most industrialized nations in the world and has one of the top ten longest coastlines in the world, then why is its offshore WPP portfolio so weak?

While the efficiency and profitability of offshore wind energy projects have grown significantly over the past two decades, there are a number of important barriers that continue to limit its progress. These barriers can be separated into two primary categories, technical and social; collectively, these barriers act to discourage many American developers from capitalizing on offshore wind power potential in their home country. To speculate about which suite of barriers is most disabling for offshore wind energy development in the U.S. is a touchy subject and can often be project-dependent. However, a brief survey of some of the most common challenges provides insight into overall industry trends.

With regard to technical challenges, constructing a WPP infrastructure offshore presents a relatively complex engineering task, as one might expect. In fact, the cost of construction per kilowatt of installed offshore wind power can be twice or more than that of onshore wind power (IRENA, 2012). One of the most important pieces of equipment currently needed to erect offshore wind turbines is a large vessel that has the ability to rise vertically out of the water in order to stabilize the working environment. These vessels are expensive to build, and the current global fleet lacks any U.S. members (Douglas-Westwood, 2013). At the same time, the ships’ crews need calm wind conditions for construction, which can be rare in locations sought out for their high mean wind speeds. Also, in U.S. east coast waters, frequent hurricane activity draws concerns from developers and turbine manufacturers, as standard turbine components are not designed to endure the atmospheric and oceanic forces harbored by tropical cyclones (IEC, 2009). However, the International Electrotechnical Commission is currently revising its design requirements for wind turbines, and there is discussion around introducing a “class-T” wind turbine capable of withstanding tropical cyclones.

In addition, offshore wind farm sites are limited to locations where the water depth is relatively shallow (on the order of tens of meters); this is because turbine foundations are not capable of supporting heights greater than this and also because floating turbine structures have not yet been fully tested and adopted by the ocean engineering community.

Figure 1. United States estimated onshore and offshore wind power classifications. Source: National Renewable Energy Laboratory.
Nevertheless, a number of experimental floating turbines have been installed in multiple countries such as Norway, Portugal, Japan, and most recently off the coast of Maine (DOE, 2013). At the same time, floating turbines amplify another problem, and that is that every offshore turbine must be connected to the utility scale power grid. Typically, each turbine is connected to a local power substation through underwater cabling, and then power is sent from that substation to the land-based grid through large underwater power cables. Of course, this method of grid connection requires extensive planning and material cost, not to mention potential maintenance headaches down the road.

All of the above-mentioned technical challenges are primarily independent of the shortcomings of the wind resource estimation process. The tasks of identifying offshore territories with attractive wind resources, and then designing wind farm attributes capable of exploiting these resources safely, hinges on accurate characterization of local wind climatology. Such characterizations ideally employ long-term (>2 years), high-frequency (<10 minute) wind velocity time series from multiple heights within the wind turbine rotor plane from platforms similar to that shown in Figure 3. Such datasets are rare over land, let alone over the ocean, where tall meteorological masts are nearly unheard of in the U.S. However, the Department of Energy’s proactive involvement in establishing a number of demonstration projects along the Atlantic and Pacific seabords and in the Great Lakes region is aimed at addressing this problem (DOE, 2012). In the meantime, many developers are exploring the use of numerical weather prediction models and wind extrapolation techniques in conjunction with buoy data to overcome climatological uncertainty. However, such techniques naturally bring with them their own practical uncertainty in estimated power production capacity. Another source of uncertainty stems from a lack of understanding of how the turbulent footprint (i.e., wake) of one turbine effects the power generation of another downstream; this is a major component of wind farm layout design. Empirical wake loss models designed for onshore wind farms are known to demonstrate bias in certain offshore circumstances (e.g., low turbulence, stable stratification), while at the same time intelligent wind turbine array configurations have been shown to yield performance increases up to 33% offshore (Archer et al. 2013). Both of these forms of power production uncertainty are leveraged by banks and investors to deny initial sponsorship of potential wind farms.

This opens the door to the other side of the story, which involves social dilemmas ranging from community aesthetics to military interference. One of the most interesting of the social barriers in the U.S. involves a policy originating from 1920 known as the "Jones Act" which, broadly speaking, prevents non-American merchant vessels from engaging in commerce between two U.S. ports. Wind turbine foundations are considered ports; therefore, the rare Jack-Up vessels previously discussed must be American flagships to install them (NREL, 2010). Currently there are no such vessels in the U.S., and practical and economic constraints of the American shipbuilding industry...
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limits the development of such a fleet (Douglas-Westwood, 2013). In addition, many coastal communities mount strong protests against the construction of offshore wind farms, which they fear will compromise the natural beauty of their coastline (see Cape Spin video documentary). In fact, visual impact analysis has become an increasingly important component of the offshore wind farm planning and permitting process. On the other hand, some communities encourage the installment of offshore structures for artificial reef formation that they claim can strengthen local ecosystems. Still, speculation that such structures can negatively alter bio-systems has been used as ammunition for protestors as well. Also, federal permitting regulations require that proposed offshore wind farm sites respect vital military training zones and national sea shore boundaries. Cumulatively, these issues force potential stakeholders to question whether offshore wind power in the U.S. will be profitable, worth the risk, or worth the effort, given the infancy of industry.

All in all, even though an offshore wind energy infrastructure has yet to materialize in the U.S. that is not to say that no progress is being made. Industrial awareness of the success of the European market is growing in the U.S., and many proposals for development have been submitted. In addition, Google has expressed interest in funding a large underwater power cable paralleling the Mid-Atlantic States, which could be used by multiple wind farms to easily tie into the onshore electricity grid. Finally, vast scientific research and development projects, some of which NCAR has contributed to, have helped to reduce the level of uncertainty associated with offshore wind farm development in the U.S. by bridging knowledge from previously disconnected communities. With the announcement of the Department of Energy’s goal to have 20% of U.S. electricity generation coming from wind by 2030 (DOE, 2008), the next few decades are sure to be an exciting and progressive period for offshore wind energy in the U.S.

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References


Figure 2. FINO1 offshore meteorological-tower in the North Sea. Image Source: BMU/ Christoph Edelhoff, Germany.