Offshore Renewable Resources - The Case for Improving the Cost-of-Energy

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ABSTRACT

Electricity produced from wind is secure, clean, and renewable, and has the potential to transform the U.S. energy portfolio. The U.S. wind resources are massively abundant and traverse great swaths of land and sea. When evaluating cost effectiveness of energy sources, the Cost-of-Energy (COE) plays a major role. COE is defined as production facility's total costs (C) divided by the amount of energy produced (E). It is clear that COE improvements require reduction in C accompanied by an increase in E. Shallow-offshore wind energy is feasible only in waters less than 50 meters deep and is expensive to produce. Wind and wave harvesting in deeper water presents formidable engineering and logistical challenges, however it also holds the promise of the most cost-effective offshore energy generation. HighSeasWind is developing a revolutionary floating offshore wind and hydrokinetic energy system that will lead to a new era of record-low COE.

***Keywords**:* cost-of-energy, renewable, wind turbine, floating, offshore

1 OFFSHORE WIND ENERGY

The U.S. has an abundance of wind and wave offshore resources suitable for industrial-scale power generation; the best resources are in deep waters. For example: California has 56.5 Gigawatts (GW) of wind resources with wind speeds above 8.0 meters per second (m/s) within 3-12 nautical miles (nm) offshore where waters are deeper than 60 meters (m) [7], Maine at similar distances and water depths has 33.2 GW, and Massachusetts has 9.7 GW. Offshore wind resource is characterized by strong winds, low turbulence, and proximity to major load centers.

In 2008, the U.S. Department of Energy established a goal of "20% Wind Energy by 2030" [1] (The Report). The Report calls for the installation of 300 GW of wind power generating capacity with 54 GW generated offshore. Total utility-scale wind capacity installed in the U.S. through September 2010 reached 36.6 GW [8], all of which is on land, mostly in the Great Plains. However, the main demand centers in the U.S. are located along coastal lines, where 78% of all electricity is consumed [1] and available land is scarce. Offshore energy generation is a viable alternative to on-shore wind energy. The Report identifies 400 GW of available offshore resources that can be fed into the existing transmission grid, which translates into a potential market total of \$800B–\$1200B for offshore generated power in the U.S. alone.

Shallow-offshore wind energy production requires construction of turbine foundations on the sea floor. This is feasible only in waters less than 50m deep. Due to shore-line proximity it often encounters fierce local opposition. Wind and wave harvesting in deeper water is expected to be less controversial, but present formidable engineering and logistical challenges. Nevertheless, the abundance of energy resources, the proximity to the centers of consumption, and the minimal interference with other human activities make deep-sea energy development very attractive. Floating wind turbines, modeled after floating oil platforms, are generally regarded to be the technological solution for energy generation in deep water [4-6].

Essentially all existing offshore wind turbine concepts, fixed-bottom, and floating, such as spar-buoy-mounted, barge-mounted, tension-leg platform (TLP) [6] suffer from inadequate manufacturability, maintainability and survivability. Existing offshore, as well as land-based, methods require extensive on-site assembly. The foundation must be constructed on location, massive components and hoisting equipment delivered and assembled piece by piece [2]. The process is time consuming and very expensive. It contributes 25-40% to the cost of constructing a wind farm [1, 2]. Consequently, the cost of energy produced from wind in shallow water is high, in deep water it is projected to be prohibitive. Shallow-offshore wind farms became quite common in Europe, but no energy producing plant in deep water exists anywhere around the world.

2 COST OF ENERGY

Cost-of-Energy (COE) is defined as

$$COE = \frac{C}{E}$$

where C denotes production facility's total costs and E is the total amount of energy produced. COE averaged over the life time of a production plant is also known as Levelized Cost of Energy (LCOE). COE improvement is about rising energy production E amid falling expenses C.

Europe has held the lead in offshore wind; cost data and cost analysis collected there over the years provide the basis for the discussion that follows. European countries have installed 2.3 GW of capacity, mostly in shallow waters less than 30 meters deep [7]. These shallow-water turbines are installed on foundations built on the sea floor. Estimated average capital investment for an offshore fixed-bottom wind project in 2010 totaled $4,250 per kilowatt (kW) [7].

Fig.-1 depicts life-cycle cost breakdown for a typical shallow-water wind project [7].

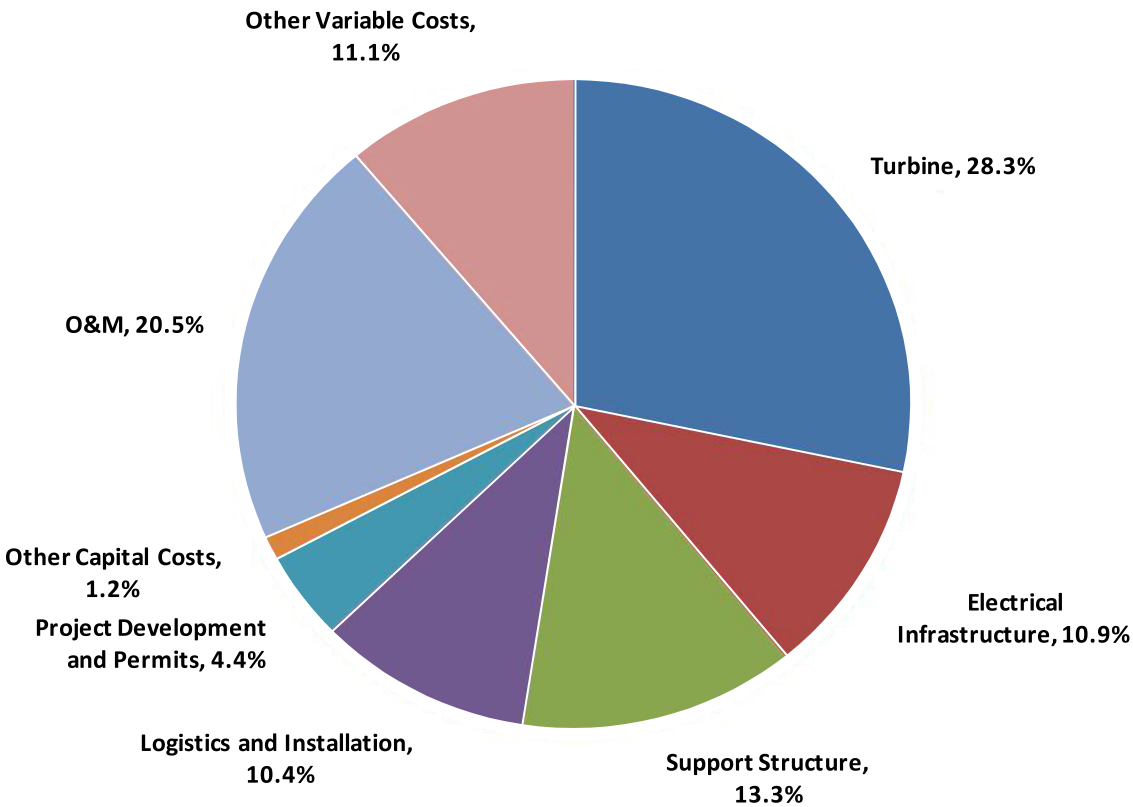

Fig-1. Estimated life-cycle cost breakdown for a typical baseline offshore wind project. *Source*: (7)

Turbine cost represents only 28.3% of the total life-cycle costs for an average fixed-bottom offshore wind plant. Over 44% of the cost is attributed to the Support Structure, Logistics & Installation and Operation & Maintenance (O&M). The high costs of all three items have a common cause – accessibility to the turbine operating site. Simply stated, it is difficult and expensive to work in open waters. Removing the need for labor at sea can significantly improve the COE. Accordingly, floating wind turbines, when designed properly and completely assembled on land, have the ability to drastically change the existing COE paradigm, especially as it relates to the current labor-intensive installation and O&M practices at sea.

3 HighSeasWind Energy System

The core priority of HighSeasWind has been to devise technologies and methods that reduce the cost of energy generated in deep waters by reducing costs while increasing energy production. Our efforts have resulted in the HighSeasWind floating platform concept that represents a significant change from current designs of offshore wind turbines, both floating and fixed-bottom. Unlike other designs, the HighSeasWind floating concept eliminates the need for at sea construction by assembling on land in a shipyard [Fig-2]. Our invention streamlines turbine manufacturing, deployment - [Fig-3], maintenance, and weather-protection practices. This approach dramatically reduces cost. Inclusion of a wave converter on the same platform provides for an increased energy production at a minimal marginal expense. Mooring and laying of power cables are the only construction activities performed at sea. For significant repairs the system transitions into the horizontal orientation and is towed back to shore.

HighSeasWind calculated the levelized cost of energy generated by the HighSeasWind system over a 20 year expected life time. The LCOE for the HighSeasWind system is 6.6 ¢/kWh (cent per kilowatt-hour) when equipped with a wave converter, and 7.6 ¢/kWh without it – both in waters deeper than 50m. Conventional shallow-water LCOE calculated utilizing the same modeling tool is 11.7 ¢/kWh for water depths of 40-50m and 8.9 ¢/kWh at 20-30m depth. The advantage of the HighSeasWind system is a 43.6% LCOE reduction (HighSeasWind system with a wave converter vs. conventional shallow-water turbine, at a water depth of 50m). Without the wave converter in the same setting the HighSeasWind floating turbine in comparison to a conventional turbine has 35% lower LCOE.

This analysis does not take into account one-time expenditures for port upgrades, staging areas, specialized fleet and personnel development. Also not accounted for are additional COE cuts that become possible due to amenability of the HighSeasWind land-based production techniques to economies-of-scale.

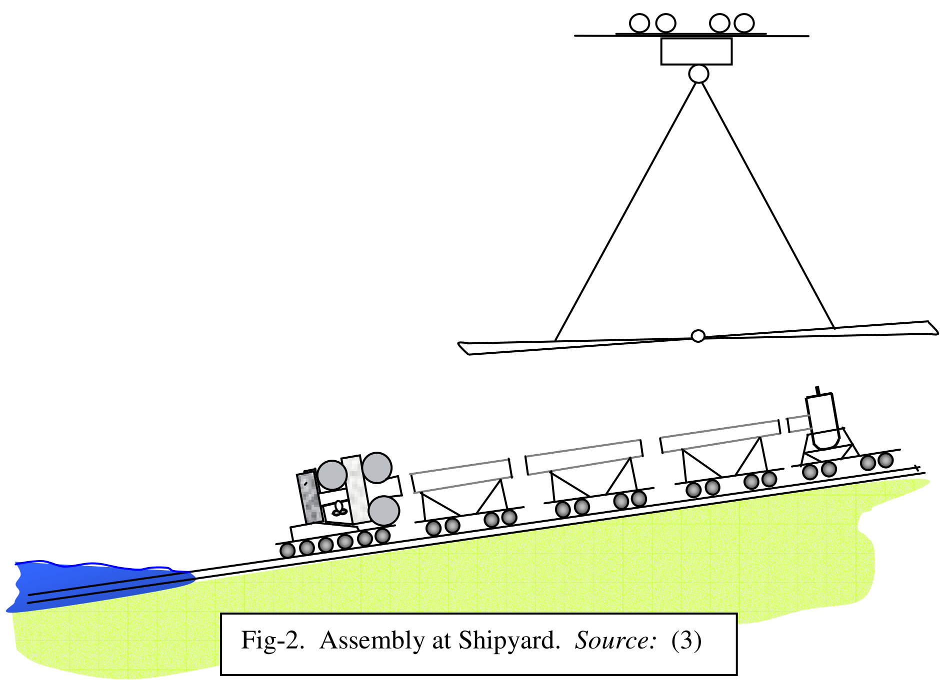

Fig-2. Assembly at Shipyard. *Source:* (3)

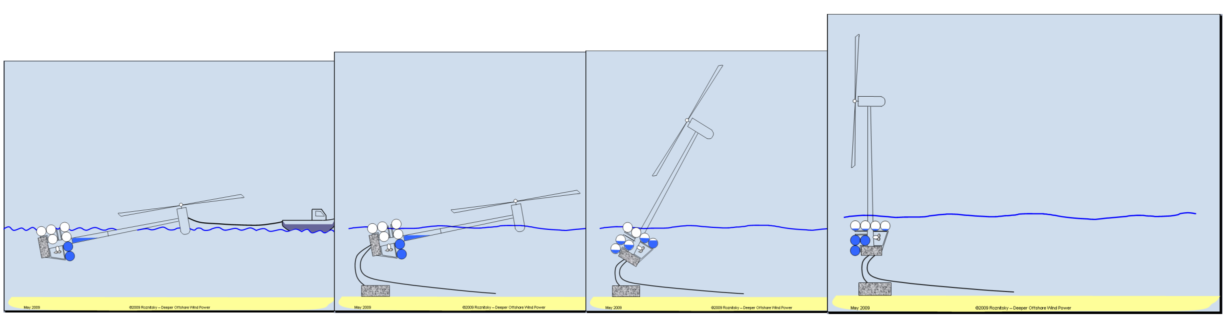

Fig-3. Turbine Deployment. *Source:* (3)

4 CONCLUSION

Floating offshore energy production, as represented here by the HighSeasWind floating energy system, can achieve 43.6% LCOE reduction in comparison to a fixed-bottom wind turbine installed nearby in waters 40-50 meters deep. The savings are due to unique HighSeasWind system characteristics:

- Manufacturing of the energy system in its entirety on land
- Ease and speed of deployment
- High quality efficient maintenance on land
- Effective protection in severe weather
- Minimal environmental impact
- Ease of decommissioning
- Inclusion of a hydrokinetic energy producing modality on the same platform and increase in energy generation - at a minimal marginal cost.

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