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Cost Reductions for Offshore Wind: Signs of Progress, Expectations for More

Berkeley Lab study suggests that further cost improvements are on the horizon

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The barriers to offshore wind are formidable. Yet, after many years of delays and cost increases, there are signs of progress. Offshore wind bids coming out of Europe suggest that steep cost reductions are at hand; the most recent of those bids, for a 350 MW near-shore project off the coast of Denmark, came in at a record-low of just $67 per MWh. These and other developments hold promise for further cost reductions in the years and decades ahead.

Research by Berkeley Lab offers insight into possible future trends for this emerging technology. Specifically, a new study published in *Nature Energy* summarizes a global survey of 163 of the world's foremost wind energy experts to gain insight into the possible magnitude and sources of future wind energy cost reductions. It represents the largest-ever 'expert elicitation' survey on an energy technology, and was led by Berkeley Lab, NREL, University of Massachusetts, and participants in the IEA Wind Technology Collaboration Programme Task 26.

Formidable Barriers to Growth

Foremost among the barriers to offshore wind in the United States is its cost. With low natural gas prices, increasingly attractive solar prices, and inexpensive land-based wind, the competition is fierce. And, with power purchase agreements for offshore wind in the United States historically coming in at around $200 per MWh, it's simply been hard to justify the expense.

Historical trends demonstrate an initial decline in costs for the first European offshore wind installations in the 1990s, but then a steep increase in the 2000s. Instead of following the predictable pattern of progressively lower costs as deployment increases, as seen in everything from solar panels to cell phones, the opposite pattern occurred. In part this was due to the very real challenges of installing and operating wind projects at sea. It was also a result of placing turbines into deeper waters, farther from shore, requiring better offshore technologies and imposing higher costs.

Cost Reductions on the Horizon

This history notwithstanding, the *Nature Energy* article shows that global wind experts anticipate significant future cost reductions for offshore wind (Figure 1). Under the 'best-guess' (median) scenario, experts anticipate an average 30% reduction in the levelized cost of energy (LCOE) for fixed-bottom

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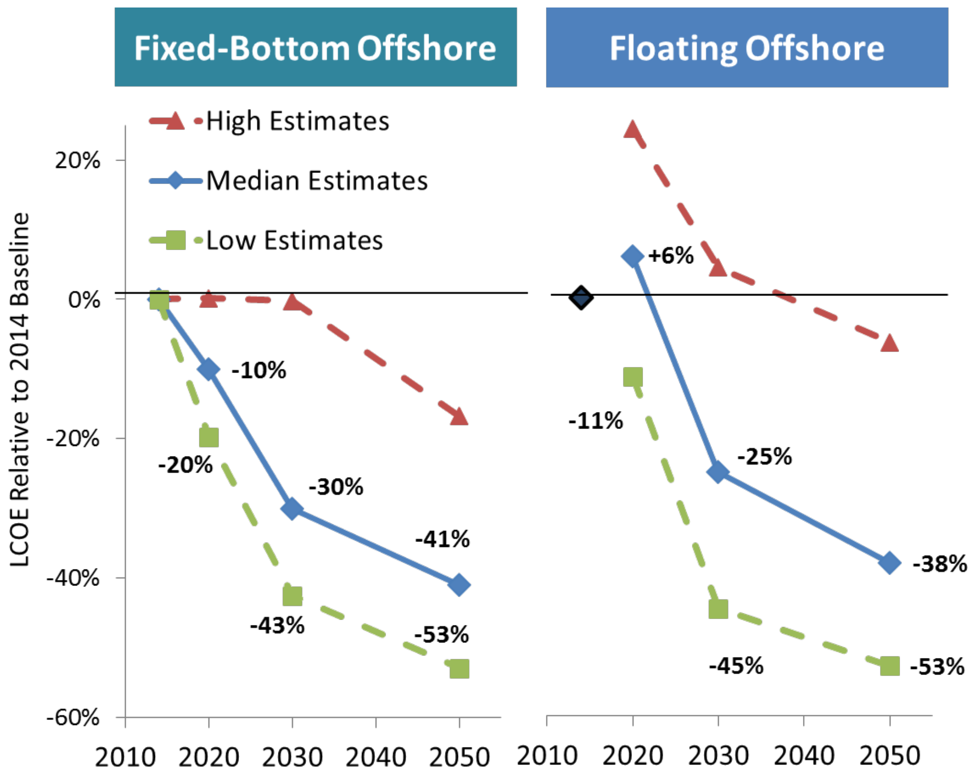
offshore wind by 2030 (relative to a median-expert baseline value of $169/MWh for projects installed in 2014), with costs falling by 41% by 2050. The cost of floating offshore wind, now in early commercialization, is expected to be 25% lower by 2030 and 38% lower by 2050, relative to the same 2014 fixed-bottom baseline. Floating offshore wind is forecast to come down in cost faster than fixed-bottom, with costs converging over time.

Costs could be even lower: respondents predict a 10% chance that reductions will be more than 40% by 2030 and more than 50% by 2050. On the other hand, respondents also note a 10% chance that costs will remain relatively high to 2050.



Note: Floating offshore costs are compared to the 2014 fixed-bottom baseline

Figure 1. Estimated Range in Offshore Wind LCOE Reduction for Typical Projects

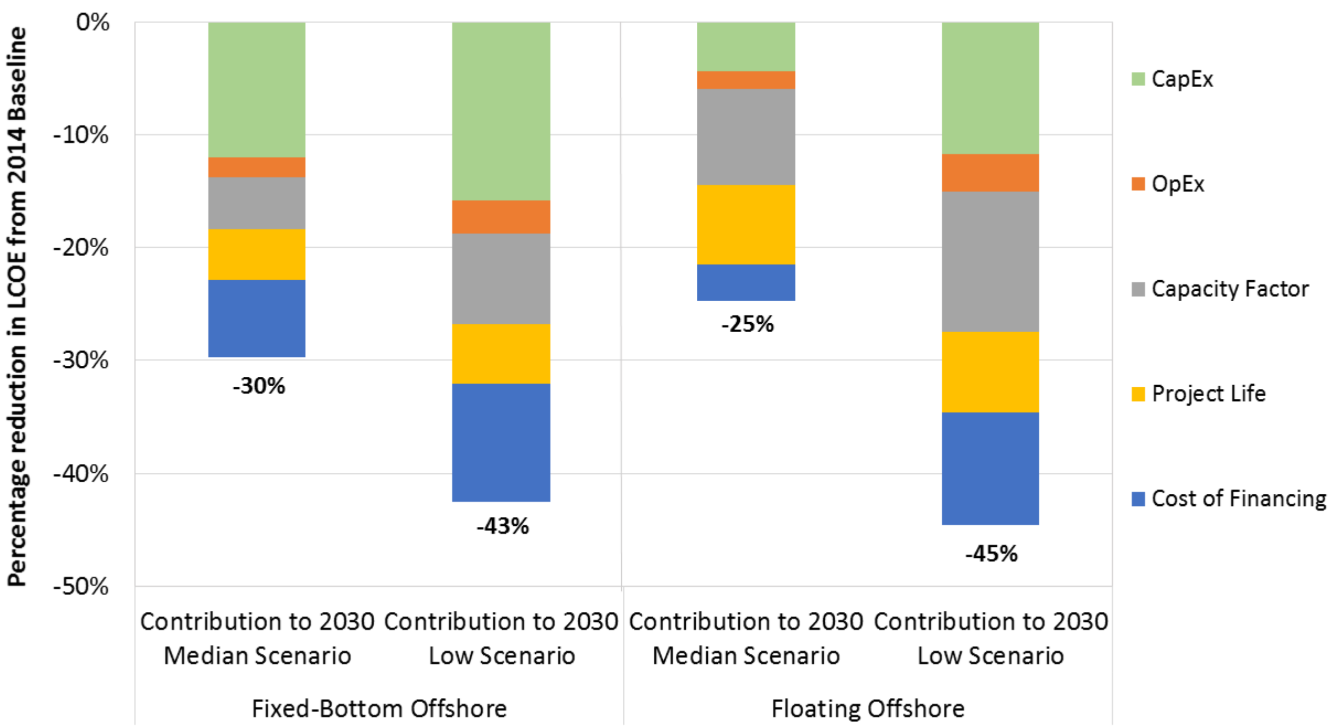
Drivers for Lower Costs

So what will lower costs? Most importantly, turbine size: bigger generators, taller towers, and longer blades. Offshore projects in planning today expect to use turbines in the 6-8 MW range. The expert survey suggests further growth, to an average of 11 MW by 2030, featuring 125 meter towers and 190 meter rotor diameters.

Turbines of this scale will economize on the significant substructure and installation costs that otherwise bedevil offshore wind power installations. A report by BVG Associates shows the positive impact of turbine size on not only up-front capital costs (CapEx), but also operating expenditures (OpEx) and capacity factors; BVG estimates a possible 18% reduction in LCOE between 2014 and 2030 based on turbine size alone.

Other factors also contribute to lower costs. For fixed-bottom offshore wind, the experts point to better designs for foundations and support structures, reduced financing costs, increased project size, and improved component durability. For floating turbines, foundation and support structure design and manufacturing advancements, installation process efficiencies, increased project size, and innovative installation and transportation equipment are noted as particularly important.

These improvements to design and deployment affect the five key elements of LCOE: CapEx, OpEx, cost of financing, capacity factor, and project design life. As shown in Figure 2 for the 'median' and 'low cost' scenarios, survey respondents anticipate improvements in all five elements. For fixed-bottom offshore wind, lower CapEx and financing costs are the two largest drivers. For floating turbines, capacity factor improvements make a big difference, consistent with the belief that floating technology will tend to be deployed in windier sites as enabled by the ability to access deeper water locations.



Note: Floating offshore cost drivers are compared to the 2014 fixed-bottom baseline

Figure 2. Relative Impact on LCOE Reductions by 2030 under 'Median Cost' and 'Low Cost' Scenarios

These gains will only come from greater knowledge. Experts highlight the need for both 'learning by doing' (identifying ways to reduce costs as deployment occurs) and aggressive research and development programs. For a detailed assessment of the specific areas of possible technical advancement, see the recent study by BVG Associates.

Could these Cost Estimates Understate the Opportunities for Advancement?

A skeptic might question these survey results, pointing out that longer-term historical trends in offshore wind simply don't suggest the same opportunities for cost reduction. And some degree of skepticism is warranted, along with a recognition of the deep uncertainties associated with any cost forecast that stretches all the way to 2050.

Yet there are signs that the survey results may be, if anything, somewhat conservative, and that still-greater cost reductions might be underway and on the horizon.

1. *Leading offshore wind experts are more bullish about cost prospects:*
The survey investigated whether certain types of experts were more, or less, optimistic than others. The single most-significant difference came from the so-called 'leading experts': a hand-selected group of 22 individuals who are among the wind sector's most knowledgeable and senior leaders. Those experts were, on average, more optimistic about offshore wind energy cost reductions, as shown in Figure 3.

2. *Other cost forecasts suggest opportunities for greater near-term reductions:*
Cost forecasts can be derived from learning curves, engineering assessments, expert knowledge, or some combination of the three. Figure 3 also summarizes 43 different recent estimates of fixed-bottom offshore wind energy cost reductions that come from a diversity of government, academic, and industry sources. As shown, survey results tend to be somewhat more conservative than the broader literature, with a large number of other forecasts showing steeper near-term cost reductions than even the low-cost scenario expert survey results, especially when considering the full set of respondents.

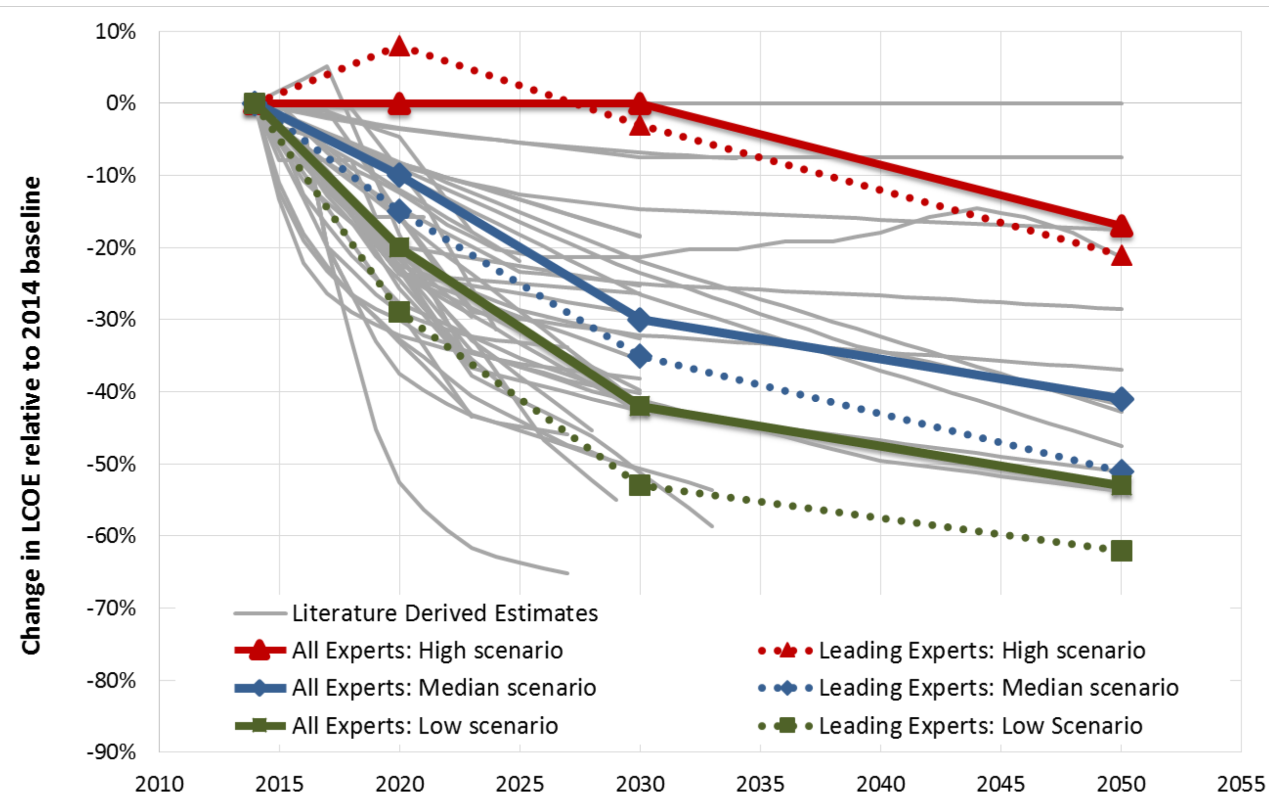
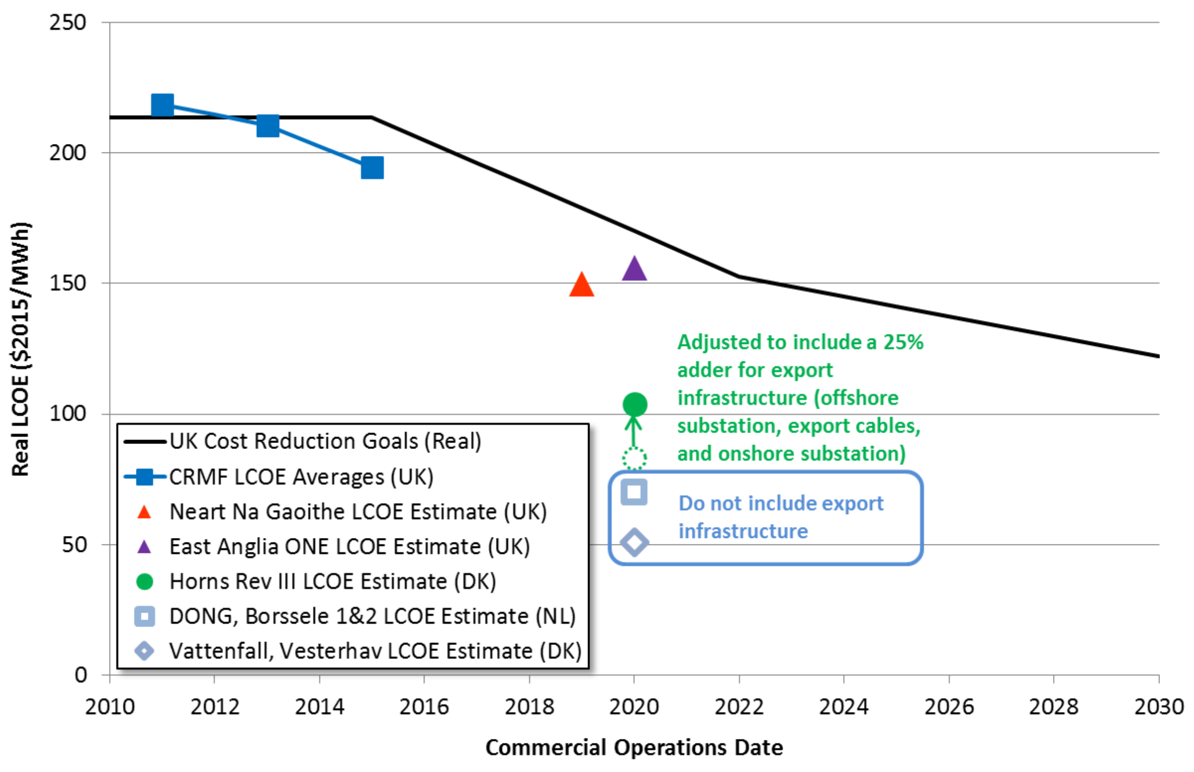


Figure 3. Estimated Change in LCOE for Fixed-Bottom Offshore Wind: Survey Results vs. Other Forecasts

3. *Recent project bids suggest aggressive competition within the offshore wind sector:*
A number of recent data points suggest that the cost of offshore wind is bending downwards, perhaps dramatically (Figure 4). In July 2016, DONG Energy clinched the 700 MW Borssele 1 & 2 projects in the Netherlands for a price of about $81 per MWh (lower on an LCOE basis, see Figure 4). In September, Vattenfall won a bid for a near-shore 350 MW project in Denmark at just $67 per MWh (again, lower on an

LCOE basis). There is a recognition that neither project is 'typical': they are in relatively shallow water and close to shore in comparison to many other projects, they come at a time of low interest rates and steel prices, and the prices quoted above exclude the cost of transmission to shore (transmission was also excluded from the expert survey, and often averages ~$20/MWh). Project costs in the UK within the last several years have also been falling, but those projects have nonetheless come in at higher prices; they are also, in general, in deeper water and farther from shore and have not faced the same competitive bidding pressures as the most recent price points. Regardless, the latest bids from Europe do suggest that costs are being pushed down faster than anticipated.



Sources: NREL, BNEF

Figure 4. European Offshore Wind LCOE Estimated from Empirical Surveys and Auction Results

Challenges Remain, but U.S. Offshore Wind Sector Beginning to Take Shape

Sizable challenges remain in establishing a vibrant, mature offshore wind industry that delivers net benefits to the energy system and to society at large. Here in the United States, the 30 MW Block Island project to be commissioned in 2016 is giving many people optimism as the first commercial offshore project to be built in the United States. But Block Island is a unique case, an island grid off the coast of Rhode Island run on diesel generators, with very high power prices.

Still, a number of other recent federal, state, and private actions have been taken that offer glimmers of hope to the offshore wind sector:

- Massachusetts adopted a new law calling for 1,600 MW of offshore wind, contracted through a staggered procurement schedule starting in 2017. Maryland, New Jersey, Maine, and Delaware also have offshore wind goals or incentives as part of their renewables portfolio standards.

- New York released an offshore wind blueprint, while LIPA previously announced tentative plans to purchase power from a proposed Deepwater Wind project off the Long Island coast.
- The Bureau of Ocean Energy Management (BOEM) and the U.S. Department of Energy (DOE) issued an offshore wind strategy in September 2016. BOEM has granted numerous leases for offshore wind project sites, with more planned, while the DOE continues to invest in R&D, including funding three advanced demonstration projects in Ohio, Maine, and New Jersey.

The offshore wind sector in the U.S. has experienced numerous setbacks, and faces stiff competition from a growing number of low-cost energy sources. As suggested by a recent NREL report, to grow and flourish, costs will need to substantially decrease and deployment may need to focus on areas of the country that can most-benefit from the value of offshore wind.

Though expert surveys are only one means of predicting the future, and uncertainties abound, trends seem to be moving in the right direction. The challenge will be for offshore wind to achieve cost reductions that are large enough to enable a thriving U.S. industry.

Additional Information

The survey was conducted under the auspices of the IEA Wind Technology Collaboration Programme. Berkeley Lab's contributions to this work were funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

The *Nature Energy* article can be found here.

A full report on the survey findings is available, as are presentation-style slide decks summarizing the results; a pdf version of this blog is also available. All of these files can be downloaded at on this page.

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