# Offshore Renewable Energy

Testimony of Willett Kempton
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Before the

## Senate Committee on Commerce, Science and Transportation
## Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard

My name is Willett Kempton. I am Associate Professor at the University of Delaware College of Earth, Ocean and Environment, and Director of the University's Center for Carbon-free Power Integration. I serve as Chair of the R&D Subcommittee of the Offshore Wind Working Group of the American Wind Energy Association. At the University, I direct research on carbon-free energy by about 25 researchers. I have published extensively on energy and the environment.

Today I speak on the basis of my expertise; I am not representing the position of any organizations with which I am affiliated.

### Comparing Ocean Energy Resources

I start by estimating the size of several ocean energy resources. This is important both to know how much economic activity each could stimulate, and to see which of them could make significant impact on other national goals such as energy independence, reduction $CO_2$ emissions, and reduced external payments.

Unfortunately, careful resource assessments have not been done. In Table 1, I review existing estimates that are imprecise but allow an initial comparison for discussion. The ocean renewables estimates draw on a recent NREL/DOE report (Musial 2008, table 3, in turn based on EPRI and earlier studies). I have added US electricity consumption (top line) and OCS oil (bottom line) for comparison, and I convert TWh/yr to $GW_a$.

A GW is 1,000,000,000 watts, the size of one of the largest nuclear or coal plants, and $GW_a$ ("a" for "average") is a fluctuating amount with an average at one GW. For scale, one watt runs an iPod. One to two thousand watts runs an average house. A little over one $GW_a$ runs Delaware. 419 $GW_a$ runs the United States. By the estimate below, the US offshore wind resource is 450 $GW_a$. I make a more detailed regional estimate below.

Table 1. Sizes of ocean energy sources.

| Energy Source | TWh/yr | $GW_a$ |
|---|---|---|
| *US Electricity Use*[1] | *3,670* | *419* |
| Deep Water >30-m Offshore Wind | 3270 | 373 |
| Shallow Offshore Wind | 678 | 77 |
| Wave Energy | 252 | 29 |
| Tidal Current | 17 | 2 |
| Ocean Current (Florida) | 50 | 6 |
| In-stream River Current | 110 | 13 |
| Thermal gradient (OTEC) | Very large | |
| Offshore oil (64 BBO)[2] | 1627 | 185 |

The above table illustrates that offshore wind is the United States' largest ocean energy resource, even in comparison to offshore oil resources. Even based on the assumption in Table 1 that we drill very fast and pump oil out at a rate that would exhaust the supplies in 20 years, offshore oil is only ½ the size of the offshore wind resource.[3] Of course, when we are done pumping, the oil is gone along with the associated jobs.

## Offshore Wind Commercial Availability

Fortunately, offshore wind is not only the largest ocean energy resource, but also the most commercially ready. Like the wind industry on land, it can be roughly divided into four industries: manufacturing, developing sites, installation, and operating. Over the past four years, a handful of US developers have emerged, that is, firms that now have expertise in designing, siting, permitting, raising capital, closing the power contract, and preparing to build offshore wind facilities. And our marine construction firms could, with minimal re-tooling (including purpose-built vessels), build offshore wind farms. Our country lacks offshore wind manufacturing, but Denmark has been developing it for the past 15 years, and has had wind turbines operating at sea since 1990. So the industries and equipment are available to construct commercial-scale offshore wind facilities today. To add offshore wind manufacturing will take some policy effort, described subsequently.

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[1] US EIA, Table 5.1. "Retail Sales of Electricity to Ultimate Customers" Electric Power Monthly with data for February 2009, Report Released: May 15, 2009. This figure is 2007 retail sales.

[2] Mean Undiscovered Economically Recoverable Resources of the OCS, at $110/BBL, from Table 2, OCS Report MMS 2009-015. If natural gas is included, the resource would approximately double. To compare with electricity, oil energy is equivalenced to its energy content (1 BBL = 1,695 TWh), then to electric power at 30% conversion, and assuming a 20 year burn. If gasoline versus electric automobiles are compared, the conversion multiplier for oil should be 20% rather than 30%.

[3] If we assume instead that it takes 40 years to pump out all the offshore oil, the flow of oil would be roughly ¼ the energy of the offshore wind resource.

In short, the US has offshore wind companies covering developers and operators, but currently not manufacturers. In 2009, for the first time we are beginning to see RFPs for offshore wind R&D. If we want manufacturers, we need an active and expanding set of developments, and DOE support for R&D in this area must continue and expand.

Because offshore wind technology was developed in Denmark, it is best suited for offshore areas like Denmark – relatively shallow, and lacking both hurricanes and sheets of ice. This means the Northeast, parts of the west coast under 30 m depth, and some areas of the Great Lakes (Lake Erie). As R&D and private investment advance, the areas appropriate will expand as well.

Table 2. Wind technology goals to expand offshore wind's geographical application.

| Technology goal | Current state/need | Added application regions |
|---|---|---|
| Current technology | In serial production | Northeast plus shallow areas of West Coast and Great Lakes |
| Withstand floating ice impact on tower | A few examples in Europe | Great lakes |
| Withstand Category 5 hurricanes | Requires re-engineering of blades, turbine and controls | Gulf; South of North Carolina |
| Deeper platforms | Prototype in North Sea; US developer has licensed | Expand turbine count in all areas above, especially West Coast |
| Floating platform | Many designs; Statoil floats 2.3 MW prototype this weekend | More for West Coast; expand reach further out OCS elsewhere |
| Overall optimizations | Ongoing | Reduce price and increase reliability in all regions |

That is, with some continued development, offshore wind can be a very large power resource for all coastal areas of the United States, including the Great Lakes.

## Environmental impacts

Offshore wind will have both positive and negative environmental impacts. The negative environmental impacts of offshore wind can be projected based on a long-term study of a Danish offshore wind farm (DONG Energy 200x), along with the now-completed Environmental Impact Statement for the Cape Wind proposal.

The primary projected impacts are related to wildlife and aesthetics. To summarize, most birds that encounter offshore wind farms simply fly around. A few birds are displaced or killed. Off Denmark, Nysted was built in a duck flyway (Common Eiders). Despite that poor siting, estimated mortality was only 1.2

birds/year/tower. Since bats rarely fly over the ocean, significant bat effects are unlikely. Some people find the visual intrusion on the ocean negative; in Cape Cod our surveys show 43% opposed, whereas in Delaware, we found only 4% opposed (Firestone, Kempton & Krueger 2008). Noise during construction could plausibly have an impact on marine mammals; knowing this, European offshore wind construction companies have developed methods for attenuating noise of construction. The towers offer new habitat for smaller organisms, in turn making them attractive to sports fishermen. No other significant impacts have been found in the cited studies. We should continue to study effects, but from thorough studies to date, the only notable negative environmental impact seems to be modest avian mortality.

With offshore wind power, like other renewable energy, impact analysis is misleading without quantifying the positive impacts. For construction of a 600 MW offshore wind farm off Delaware, consisting of 200 turbines, each 3 MW, we did a cursory impact analysis based on literature rather than direct measurement. We used the health impact of Delaware's current power production that would be displaced, along with a report on fish kills from current Delaware power plant cooling water[4]. Offshore wind reduces air pollution and fish kills because the wind power production leads other power plants to throttle back and reduce output, and thus reduce pollution and water intake. We found that this one offshore wind farm would have the following yearly impacts:

Negative impacts (projected)

Up to 240 birds killed (240 is worst case--if mistakenly built in flyway)
View shed impact

Positive impacts (projected)

10-12 human deaths/year prevented
203 emergency room visits (due to respiratory distress) prevented
5,156 asthma attacks prevented
... total human health benefit $53 million/year
683,000 fish fry and yearlings saved from death in power plant cooling water
17% reduction in power plant $CO_2$ emissions statewide

The above figures are based on literature and approximation rather than measurement after the fact or detailed modeling. However, it appears that the net environmental effect is positive rather than negative, by a substantial margin, even without considering $CO_2$ reduction benefits.

[4] The study found that one large Delaware coal plant killed the equivalent of 800,000 year-old winter flounder during one year studied, more than 518,000 year-old Atlantic croaker and nearly 2.7 million bay anchovy (Montgomery 2008). If we here estmate byc considering the 17% reduction in power brought by the offshore wind facility as a rough approximateion of fish and fry saved, that would be a reduction in fish kills of 683,000 per year.

If CO2 reduction is considered an environmental benefit, as I emphatically believe it is, my assessment of the importance of offshore wind is this: Offshore wind is today the only large scale power source that coastal states have at hand, that can significantly slow CO2 emissions at moderate cost. Due to the versatility of electricity, wind power is capable of displacing fossil electric generation, fuel for building heat, and fuel for cars. Because of both the potential for CO2 reductions, and the economic benefit, I recommend some improvements to the permitting process in sections below.

## State and Federal Permitting process; How to identify optimal sites

Our research group has observed the process of picking sites and negotiating with state governments and publics in Massachusetts, Rhode Island, New York, New Jersey, and Delaware. There are two aspects, power planning and site selection.

Regarding power planning, unlike offshore oil and gas, the process we have seen for offshore wind has been that a US state initiates a process soliciting electric power. After the state government has established a need for power, and possibly negotiated an agreement to buy power via a power purchase agreement, the offshore wind developer begins the process to permit with Federal MMS. Cape Wind has been the sole exception, with the developer initiating the process, and the Federal permitting initiated prior to any power agreement with the state.

The process is quite different from offshore oil, which in Federal waters has been permitted by the Federal MMS with little state participation. The difference is due to the transportability of the energy sources—oil can be shipped worldwide for little incremental cost, whereas electricity must be transmitted by high voltage cables, which to date have taken a short path from the offshore wind development to shore. For similar reasons, oil is traded on global markets, while electricity (including that from ocean renewables) is sold on state or regional markets.

A processes that we see working well for identifying sites is:

1. The state requests bids, for power or specifically for offshore wind, along with criteria for picking the winning bidder.
2. Developers seek information about existing ocean uses, in order to avoid conflict areas–this is in their interest, to avoid places where coastal managers, residents, fishermen, etc may oppose their proposed development.
3. Developers study locations, including wind speeds, ocean and subfloor conditions, and considering current technology, value of power, their tolerance for delay due to controversy, etc., then propose two or more site options.
4. State environmental and power planning officials recommend for or against sites and power contract characteristics proposed by developer.
5. If any sites are acceptable to the state, developer proceeds to permitting, including environmental review by MMS, and contract for use of ocean space.

6. Upon successfully completion of all permits and reviews, and financing, project is built.

There is one problem in this process, created by the law that authorized MMS to carry out these leases. The developer has already gone through a bidding process and has been awarded a contract or permit to sell power to one or more electric entities ashore. One important criterion in their section would presumably be that the price of power was competitive. But since MMS requires competitive bids for ocean space, the space that the developer has already bid on in the state power process, now must be bid again with MMS, possibly against speculators who have no ability to even sell the power they would generate. In the announcement of rule, MMS tried to address this problem by saying that prior state competition would be considered in the competition for ocean space. However, it would be appropriate to examine whether it is appropriate to change the law, given that electricity is not oil, and that rules for competition are already well established in state and regional electric markets, and subsequent competition for offshore space may lead to speculation and gaming.

Regarding choice of location, I feel that the optimum process is close to the numbered sequence above—that the state sets parameters, the private developer studies many sites then proposes a site, and the state selects. The developer must go through environmental review including any conflicting use and consistency with the state's coastal zone management plan. I do not include advanced spatial planning in this list, because I believe that no-one today can plan what will be the best location for a variety of technologies several years in the future. Also, I do not believe that spatial planning by state or Federal officials will be as thorough as that by a developer with investment at risk, followed by established EIS or EA processes.

The agreement last week (June 4, 2009) among the Governors of New York, New Jersey, Delaware, Maryland, and Virginia, was that spatial analysis might proceed, but it should not cause any slowdown in project proposal and development. I believe this is the correct approach.

## Economic potential

Here I summarize our more detailed resource estimate for the Northeast, then show how that translates into economic opportunity. In 2008 we estimated the total offshore wind resource adjacent to the Mid-Atlantic coastal states from North Carolina through Massachusetts (Kempton et al, 2008; attached). This was an arbitrary area manageable for a low-cost study, but one more detailed than anyone had previously done. We used 20 years of wind speed data from NOAA buoys, bathymetric data and sampled data on ocean uses such as shipping lanes or bird flyways that would exclude wind turbines. We assume only machines and towers that were either available or prototyped at the time of the study. And, we compared the offshore wind resource against energy demand of those Mid-Atlantic coastal states, electricity as well as gasoline for cars and heating fuels.

Table 3. Mid-Atlantic offshore wind resource compared with energy demand (from Kempton et al 2008).

| Source/demand | GWa |
|---|---|
| Offshore wind | 330 |
| Electric load | 73 |
| Cars | 29 |
| Heating | 83 |
| Total demand | 185 |

In other words, for the Mid-Atlantic, with a large shallow continental shelf, but with very high levels of population and energy use, our more careful resource assessment shows that the practical offshore wind resource is enough to power all electricity, all gasoline for automobiles, and all fuel oil, natural gas, and other building heating fuels. (My use of average GW is a simplification, as I do not address the match of fluctuating wind power and fluctuating load, which have to be matched.)

To estimate the economic impact, assume we plan to build enough offshore wind to power electricity and cars but not heat, 108 $GW_a$. To produce 108 $GW_a$, assuming a 40% capacity factor, would require 54,000 wind turbines each rated at 5 MW. Current wind turbine factories running five days and three shifts can produce 350 turbines per year. If we wanted to build 54,000 turbines within 15 years, we would require 10 factories. In addition we would need about 10 factories for blades and 10 for towers. This would be like 10 large automobile manufacturing factories, each employing perhaps 500 people, with approximately a 4x multiplier for indirect jobs among suppliers, a total of 20,000 jobs. This is one of several reasons that coastal states officials have preferred offshore wind to distant onshore wind (Bowles 2009; Svenvold 2008).

I do not give these estimates in order to say that we should produce exactly this much offshore wind, or at this pace, but to show that the resource is very large, yet it could all be developed with a manageable industrial complex in the region. We can build a great deal, and even substitute electricity for end uses that not depend on liquid fuels, and not exhaust the resource. If the entire 185 $GW_a$ were developed, the Mid-Atlantic would reduce its $CO_2$ emissions by 68%. And such large reductions in CO2 would have global significance in reducing the impact of ocean acidification and climate change on the oceans.

## Industry needs for development

Below are recommendations that would follow from my experience and from the above.

1. Longer-term extension of the PTC, possibly limited to ocean renewables. An offshore wind project could take 5 or 6 years to complete, much longer than a land-based project. Investment in manufacturing for offshore class turbines, towers and blades would require at least 6-7 years of sales to return investment in plant. The current 3-year PTC extensions insure that

manufacturing stays in Europe. Congress should pass a 10-year PTC. This could limited, if necessary specific to offshore renewable energy.
2. Facilitate development of manufacturing of offshore-wind manufacturing in the US.
3. As noted above, R&D is needed to develop offshore wind turbines that work in more US regions, to improve on current designs, to extend the coastal areas for which we have turbines, to understand the resource, and for policy and public opinion studies. The attached R&D Subcommittee document suggests specific needs and rationale. In addition to the attached wind R&D document, the US should invest in long-term research on other ocean energy technologies in Table 1.
4. In particular, we should develop expertise in assessing the offshore wind resource by several independent parties, not only MMS or DOE but also by state governments and/or universities working with state government power planners. My group has produced guidance for others who want to get up to speed and analyze their state offshore wind resource (Dhanju et al 2008). Small grants for partnerships between states and universities would seed this activity and provide local expertise on this resource assessment.
5. With many permit applications already headed to MMS, the agency already needs more people. Need to fund MMS to allow it to hire individuals to oversee the NEPA and licensing process.

## Supplemental material (attached)

1. Kempton, W., C. L. Archer, A. Dhanju, R. W. Garvine, and M. Z. Jacobson , 2007 "Large CO2 reductions via offshore wind power matched to inherent storage in energy end-uses", *Geophys. Res. Lett.*, 34, L02817, doi:10.1029/2006GL028016.

2. Research and Development Needs for Offshore Wind, R&D Subcommittee, Offshore Wind Working Group, American Wind Energy Association. April 2009

## References

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Amardeep Dhanju, Phillip Whitaker, Willett Kempton (2008), Assessing offshore wind resources: An accessible methodology. *Renewable Energy* 33(1): 55- 64. doi:10.1016/j.renene.2007.03.006

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Montgomery, Jeff , 2008, "Indian River center of fish debate: Power plant's cooling system said to destroy millions of fish each year." *The News Journal* , January 3, 2008

Musial, Walt , 2008, Status of Wave and Tidal Power Technologies for the United States. *Technical Report* NREL/TP-500-43240, August 2008

Report to the Secretary, U.S. Department of the Interior, 2009, Survey of Available Data on OCS Resources and Identification of Data Gaps. OCS Report MMS 2009-015

Mark Svenvold "Wind Power Politics" *New York Times Magazine*.

For further information on offshore wind, including our articles cited above, see www.ocean.udel.edu/windpower, and www.carbonfree.udel.edu