Large-Scale Carbon-free Power for the East

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Testimony of
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Large-scale carbon-free power throughout the US

S. 1733 aims to create incentives that will lead to the development of new technologies for energy and power with less release of CO2 into the atmosphere. Existing central-station technologies such as nuclear and potentially coal with carbon capture could provide low-carbon power. Here I concentrate on new technologies that are carbon-free, that is, renewable power resources. I will show that carbon-free sources provide an important regional balance and that they offer substantial economic development and employment opportunities.

Many of the largest carbon-free power sources are regionally concentrated, as briefly reviewed in this paragraph. In the Great Plains, our country has tremendous wind resources, more than that region's energy needs. In the Southwest, strong direct sunlight enables concentrating solar, again with a resource greater than the local need, plus the possibility of inherent storage at relatively little incremental cost. Geothermal provides fairly constant power, now practical primarily in the far West. These three are all close to economically competitive so that several years of cost assistance like that in S. 1733 (section 202) are likely to bring them to market competitiveness. Solar photovoltaic, that is solar-electric cells, can be tapped most anywhere and their modularity makes them ideal for distributed building use, but they are further from competitive for wholesale power.

None of the foregoing large-scale, near-competitive sources are on the US East Coast, a region that represents roughly half of national electricity consumption. Representatives from this region have said that they do not want to continue to import most of their energy, even if it is clean electricity from the Great Plains (Bowles 2009). Also, we need new resources in all regions of the nation in order to preserve the geographic diversity that is critical to maintaining a robust, secure power grid.

Table 1 draws on a recent NREL/DOE report with approximate estimates for the entire US. [1] The estimate of the US offshore wind resource is 450 GW_a. (GW_a is the average power output of the resource over the course of a year; it allows easy comparison among capacity, variable resources like wind and solar and dispatchable sources like gasoline.) Since US national electric retail sales are 419 GW_a, there is enough offshore wind power to produce electricity for the entire country.

Table 1. US coastal energy sources (sources: DOE; EIA; MMS).

	TWh/yr	GW_a
US consumption		
Electricity retail sales[2]	3,670	419
Gasoline (delivered power)[3]	987	112
Offshore Renewable power		
Offshore Wind[4]	3,948	450
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 and gas, extracted over 20 years		
Offshore oil (64 BBO)[5]	1,627	186
Offshore gas (270 Tcf)[6]	1,620	185

Offshore wind is the United States' largest ocean energy resource, even in comparison to offshore oil and gas resources. Even based on an assumption in

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[1] From Musial 2008, table 3 (in turn based on EPRI and earlier studies). I have added US electricity and gasoline consumption (top lines) and OCS oil and gas (bottom lines) for comparison, and I convert TWh/yr to GWa.

[2] 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.

[3] US Energy Information Agency, Table "U.S. Product Supplied of Finished Motor Gasoline (Thousand Barrels)" 2008 year, Release Date: 6/29/2009 (on line as Petroleum Navigator, accessed Oct 2009). 3,290x10^6 BBL x 42 gal/BBL * 9.44 kWh/l = 4938 x 10^9 kWh * 20% efficient cars = 987 TWh/year delivered to wheels.

[4] The report split wind into 3270 TWh/yr deep water >30m, plus 678 TWh/yr shallow water.

[5] 64 BBO, from Mean Undiscovered Economically Recoverable Resources of the OCS, at $110/BBL, from Table 2, OCS Report MMS 2009-015. To compare with electricity in this table, 64 BBO 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%.

[6] 270 Tcf @ $11.79/Mcf (MMS 2009-15, Table II-3). Energy content 81x10112 kWh * 40% efficiency for gas to electricity / 20 years = 1620 TWh/year.

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 less than ½ the size of the offshore wind resource. Of course, when we are done pumping, the oil is gone along with the associated jobs.

The national analysis in Table 1 motivates a more careful regional examination of offshore wind. Could this be a large, carbon-free resource for the East Coast? And is it close enough to being economically competitive that incentives such as those in S. 1733, along with existing law, could stimulate larger deployment?

The US Atlantic Offshore Wind Resource

Next I examine more carefully the resource for offshore wind off the US Atlantic coast. This refines the total US national resource estimates in Table 1, and shows that this region does have potential a cost-competitive, near-term, large carbon-free resource. Furthermore, I will show that the regional RGGI carbon regime, a regional version of the bill under consideration by this committee, tipped the balance toward development of large-scale carbon free power, with concommitment economic development and employment benefits.

a. A refined regional estimate of power potential

The DOE figures for the entire US, in Table 1, are based on simplifications that yield quick but approximate figures. A team from the University of Delaware and Stanford University has carried out a more detailed study for the US Mid-Atlantic, from North Carolina through Massachusetts. This has been peer-reviewed and appeared in a major geophysical journal.[7]

We estimated the total offshore wind resource adjacent to the Mid-Atlantic coastal states from North Carolina through Massachusetts (Kempton et al, 2007; attached), as summarized in Table 2. We used 20 years of wind speed data from NOAA buoys, bathymetry (water depths), and sampled data on ocean uses such as shipping lanes or bird flyways that should exclude wind turbines. We assume only machines and towers that are either available or in preproduction prototypes. And, we compared the offshore wind resource against all energy demand of those Mid-Atlantic coastal states, existing electricity uses, plus assign in the assumption that cars would run on gasoline as would building heating; the latter assumptions also lower fuel costs, reduce oil dependence, and reduce carbon emissions.

[7] 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.

Table 2. Mid-Atlantic offshore wind resource compared with energy demand (from Kempton et al 2007).

	GW_a
Offshore wind resource	
Offshore wind	330
Electricity needs	
Electric use (existing)	73
Cars (new)	29
Heating (new)	83
Future electric need	185

We found that for the Mid-Atlantic, with a large shallow continental shelf, but with very high levels of population and energy use this detailed regional study showed 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.

I do not supply these estimates in order to say that we should produce this full amount of offshore wind, but to show that the resource is very large. We can build a great deal; we can provide all our electricity, and we can substitute electricity for end uses that now require liquid fuels, yet we would not exhaust the resource. If we developed sufficient wind resources to meet the regions demand for electricity, building heat and passenger automobiles, the Mid-Atlantic would reduce its CO_2 emissions by 68%.

I next review how a regional cap and trade regime helped lead to the first US power contract for offshore wind, then subsequently examine how this industry is scaling up in Europe and how it could do so in the US.

b. Impact of Cap and Trade (RGGI) on the Power Bid in Delaware

In assessing the impact of S 1773 on power and fuel decisions, we in Delaware have the advantage of a short history already with our Regional Greenhouse Gas Initiative, an existing regional cap and trade regime similar to the national proposal in S1773.

The impact of RGGI was felt even before trading began. A Delaware law, "HB 6", required competitive bidding for a new power plant, evaluated primarily on the basis of cost of power and price stability, with only minor consideration given to environmental benefits. Commercial bids were submitted for three power plants, one each using natural gas, offshore wind, and IGCC coal (this proposal was "clean coal" in reduced pollution, but without any carbon sequestration). Costs were compared over the lifetime of each generator. That is, the Commission used Energy Information Agency, RGGI and other sources to estimate the likely cost to

ratepayers, including fuel price increases and expected RGGI carbon costs. Cost analysis of the original proposals can be found in the Commission's reports.[8]

The offshore wind bid, by designing to large-scale power plant size, 450 – 600 MW, was able to achieve economies of scale and serial production. On the other hand, the coal plant, despite the advantage of cheap coal, was the most expensive, in part because it was assessed the likely cost of carbon dioxide emissions over its lifetime (several metrics were used, with levelized values ranging around $10/metric ton).[9] The natural gas bid was the least expensive per MWh, but was eliminated largely because it failed the price stability criterion. With the RGGI payments included, the price for IGCC coal was higher than the price for large-scale offshore wind. Nevertheless, the RGGI carbon price was not high enough to justify the coal proposal adding carbon sequestration. Rather, the coal bidder found it lower cost to emit all the CO2 and pay for the carbon allowances.

Ultimately, the offshore wind bid was selected by the Delaware PSC. The developer estimated that building it would create approximately 500 direct jobs during construction, and that operations and maintenance would create 70 direct jobs over the 25-year operation of the facility. If a series of subsequent offshore wind farms were contracted, then additional jobs would be created by local manufacturing of the turbines and blades themselves, now focused in Europe.

In sum, this Delaware state example of a public agency's careful analytic process under a carbon-trading regime offers several lessons for a national program like that in S. 1733:

1. Even modest fees as a result of carbon cap and trade can tip the balance in favor of cost-competitive new technologies (in this case, large-scale offshore wind).
2. Development in Europe has moved offshore wind technology along far enough that it can compete in high-cost electric markets, such as the US Northeast and Mid-Atlantic, with only modest policy incentives.
3. Although offshore wind is generally more expensive than onshore wind, there was insufficient nearby onshore wind to compete in this bulk power bid, and the combination of stronger winds offshore, economies of scale, and policy made offshore wind cost-competitive, even with fossil fuels.
4. The projected RGGI carbon fees were not sufficient to make carbon sequestration cost-effective for coal, but possible future escalation in carbon costs was sufficient to motivate the coal bidder to propose a plant to which sequestration could plausibly be added later as a retrofit.

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[8] Delaware Public Service Commission (prepared by New Energy Opportunities, Inc., et al), 2007, "Report On Evaluation of Bids Submitted In Response to Delmarva Power & Light Company's RFP" PSC Docket No. 06-241. Feb 21, 2007.

[9] The current (2009) RGGI price is $3.09 per ton of CO2; this is about $3.24 per MWh in a conventional coal power plant. (RGGI 2009). The plant lifetime projection was based on the minimum fees forward through the plant lifetime.

5. There are substantial employment benefits from building utility-scale carbon-free power generation.

Pace of Offshore Wind Development & Jobs

Denmark has been developing offshore wind for the past 20 years, and has had wind turbines operating at sea since 1990. Now, Danish, German and French manufacturers have large-scale offshore wind turbines, and large electric utilities are building large-scale offshore wind developments. Countries of the European Union, especially those bordering the Atlantic, the North Sea and the Baltic, are planning on offshore wind as the major technology to reduce carbon emissions from the power sector, and to stimulate economic growth. Table 3 shows facilities in operation, under construction, and planned to come on line in the next six years.

Table 3. Offshore wind operating, under construction, and planned in Europe, 2009 – 2015 (from Windpower Monthly 2009).

Country	Operating in 2009 (MW)	Operating and under construction (MW)	Total planned for 2015 (MW)
Ireland	25	25	1603
United Kingdom	598	2162	8756
Spain	10	10	1976
France	0	105	1070
Italy	0	0	827
Belgium	30	195	1446
Germany	12	769	10298
Poland	0	0	533
Netherlands	228	228	2834
Denmark	414	851	1276
Norway	0	0	1553
Sweden	134	164	3312
Finland	30	30	1330
Total	**1481**	**4,539**	**36,186**

The United States has more offshore wind resource as the countries above. Already, several states in the US areas with shallow waters and few hurricanes have committed to development using existing technology. The map in Figure 1 shows sites with substantial agreements already signed and/or advanced permitting accomplished, totaling about 1,200 MW, which could plausibly be completed by 2015. RPFs or preliminary negotiations are underway that could double this number in this same region, with additional preliminary discussions for the Great Lakes and the Texas Gulf coast.

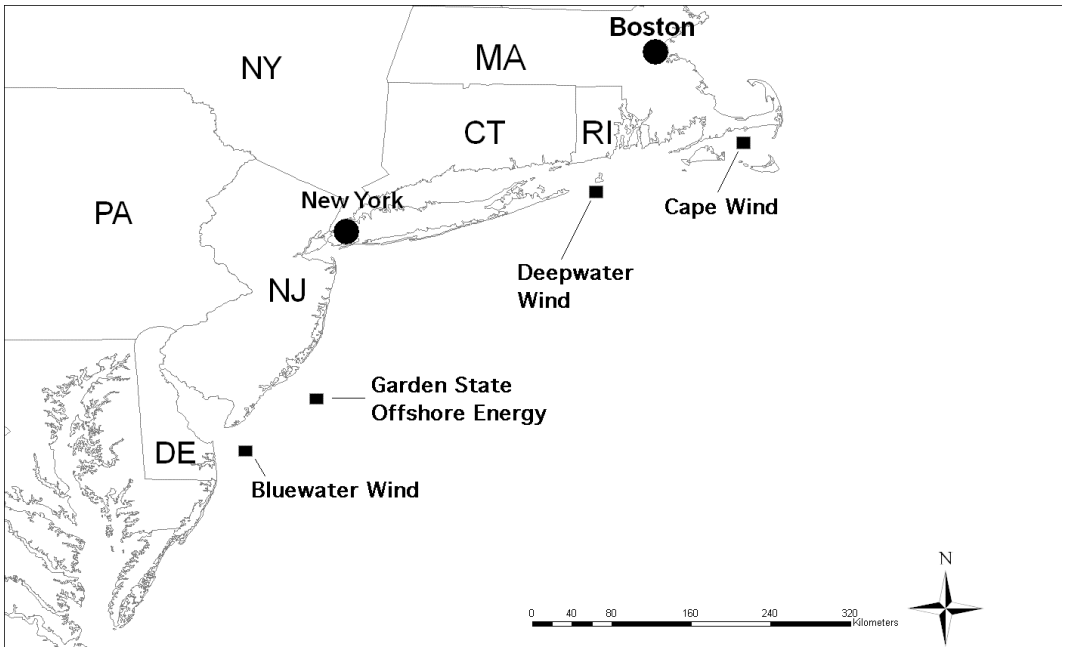

Figure 1. Current US offshore wind projects with permits and/or state agreements (map © 2008, U of Delaware)

Estimates were given above for the employment impact of a single offshore wind project. To estimate the economic impact of a substantial build in the North Atlantic, assume we plan to build enough offshore wind to power electricity and cars but not heat for the coastal states from NC through MA. Based on Table 2, that would be 108 GW_a. To produce 108 GW_a, assuming a 40% capacity factor, would require 54,000 wind turbines each rated at 5 MW, a total capacity of 270,000 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. These calculations are not meant to suggest that we must build to meet all our needs, nor that we much build this much to be useful. But as a rough calculation, it does show that employment benefits and very substantial reductions in CO_2 are possible in 15 years, from our existing local resources, just by redeploying some of our existing rusting industrial infrastructure.

It may seem that 54,000 is a large number of wind turbines to produce electricity for all these people. But the same states require 22,800,000 housing units to house them (Census 2009), and the adjacent grid operator, PJM, uses 56,300 miles of high voltage transmission lines, about three times that number of high voltage towers, and tens of millions of low-voltage poles, to move power in a similar but overlapping area (PJM 2009).

Federal Policy

Federal policy can help to advance US capability and installation of offshore wind, an example of many job creating new technologies that could be helped by S. 1733 and other Federal policies. Some specifics:

1. A recent Deutsche Bank analysis of investment in clean energy emphasized investors' need for consistency and certainty (Fulton 2009). In the context of. S 1733, if clean power facilities can sell credits, it will be important to have a floor price, so investors can predict a sure cash flow from sale of credits. An assured minimum cash flow is the basis for investments.
2. The same need for consistency and certainty can be applied to in tax policy. The PTC (now with an ITC option) has been extended 2 and 3 years at a time. However, for offshore wind, with a 6-year development period, a 3-year tax window is not helpful. Offshore wind needs a 10 year extension to PTC or ITC, as has been done for nuclear power. Investment in manufacturing for offshore class turbines, towers and blades would require at least 6-7 years of sales to return investment in plant. Thus, the current 3-year PTC extensions limit offshore development, and limit investment in manufacturing. A 10 year extension, possibly limited to ocean renewables, would solve this problem
3. 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. Section 202 of S. 1733 can be used for this purpose.
4. S. 1733 will be help develop new, job-creating and carbon-reducing technologies, by internalizing a modest cost for carbon emissions of competing technologies, by adding R&D funding to advance technology, and by directly incentivizing some clean energy projects.

This testimony is offered on the basis of my expertise; I am not representing the position of my employer nor any organizations with which I am affiliated.

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.

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For further information on offshore wind, see www.ocean.udel.edu/windpower, and www.carbonfree.udel.edu