Free but Still Costly:
The Costs and Benefits of Offshore Wind Power in Massachusetts

Jonathan Haughton
with
Sarah Glassman
Michael Head

Beacon Hill Institute at Suffolk University
8 Ashburton Place, Boston, MA 02108
Web: www.beaconhill.org email: bhi@beaconhill.org
April 2008

Table of Contents

0. Executive Summary

Cape Wind Associates proposes to build the world's largest offshore wind farm, with 130 turbines on a 24 square mile area of Horseshoe Shoals in Nantucket Sound. The project is controversial. Cape Wind argues that the project will lower electricity costs to consumers, reduce emissions from power plants in the New England region, contribute to greater energy diversity and independence, and create more jobs on Cape Cod. Critics of the project are concerned about the high cost of wind-generated electricity, the environmental impacts, and public safety, as well as the economic and aesthetic effects of 130 wind turbines on the horizon, which may deter tourists and depress land values.

In our view the law requires the Minerals Management Service (MMS), the federal agency with authority to grant or deny Cape Wind a construction permit, to address in detail these factors, and the balance of costs and benefits among them. MMS must do this in an Environmental Impact Statement (EIS) subject to public notice and comment. MMS must also base its permitting decision on that analysis. To date, MMS has not prepared any EIS remotely fitting this description. This represents a significant failure in legal and responsible decision-making by the federal government that can only be corrected by the federal government itself undertaking the missing analysis and subjecting it to public notice and comment.

In an effort to promote public understanding of and debate on the issues involved, this report addresses the questions that MMS left unexplored. It quantifies the benefits that the project would bring - less fossil fuel burned, lower emissions, and greater energy independence. It then compares these benefits to the costs – of the project itself, of integration with the New England grid, and of the aesthetic effects, to the extent that aesthetic effects can be quantified.

By comparison with the resources that MMS could bring to the performance of a similar analysis, our budget has been small, and our access to facts has been limited. For that reason alone, this study is not a substitute for the work that MMS has not performed. Moreover, in the absence of more definitive information and analysis we have often used default assumptions favorable to Cape Wind when we believed a factual or analytic issue was in dispute. For that reason, our study may well give an unduly favorable picture of Cape Wind's costs and benefits.

In particular, we have not given any negative weight to aspects of the project that are in fact clearly negative and may be quite large, but are hard to quantify. These include the danger of oil spills, the damage to fish and fishing, and the impact of the turbines on birds and bats. Nor have we tried to assess the intangible value of impacts like damage to unique views or to endangered species. We believe any legally and socially adequate EIS would need to address these topics in more detail.

Despite these caveats, our results, set out in more detail in section 1, are clear: the cape Wind project would not be worth the resources it would cost. The economic costs of the project, which measure the resources used to build and operate the project, are expected to come to $2,216 million (in 2008 prices). This may be compared with the economic benefits, which are expected to amount to $1,184 million. These are the costs and benefits of the project to the public. Based on these numbers, it does not make sense to build the project; it would, in effect, waste $1,033 million in resources.

Yet Cape Wind continues to pursue the project. This may be optimistic: given the uncertainties related to this project, investors would insist on a high target rate of return, which would make the project financially unpromising – we estimate the net present value for investors would be -$5 million, and there would be a 48 percent probability that the return on equity would not meet the required rate.

The project may be close to being privately profitable but it is economically undesirable; the disconnect between these two conclusions is due to the very large subsidies that the project would receive.

In our view, by far the most important subsidy consists of the Renewable Portfolio Standard ("green") credits that result from recent changes to the law in Massachusetts: electricity consumers in the Commonwealth are required to buy a growing proportion of their electricity from renewable sources, and will in practice have to pay a premium for this power. We assume that there will be a continuing shortage of qualifying renewable power, that this will keep prices for that power near the maximum allowed by law, and that all of Cape Wind's power will qualify for the premium. This premium will raise the price received by Cape Wind by about 5.3 cents/kWh., and amounts to a subsidy (in present value terms) of $791 million from Massachusetts ratepayers.

Other analyses have suggested that the future shortage what we project may not materialize, in which case the Cape Wind project might actually displace more socially beneficial investments in renewable energy . Clearly, the whole RPS issue presents significant factual and analytic problems with a wide range of possible answers. It deserves more detailed analysis than we have been able to give it. A DEIS would be the logical place for that analysis. Such a DEIS should both address the questions we raise above in more detail, and explore issues that lay beyond our scope. It could, for example, explore the impact of the carbon caps now being adopted to control greenhouse gases on the likely future supply of RPS credits. The current DEIS, however, does not explore these issues at all.

A Federal Production Credit, which would be paid for the first ten years of this 20-year project, is likely to raise revenue by the equivalent of a further 0.9 cents/kWh on average over the life of the project, and represents a subsidy of $140 million. When all subsidies (net of taxes) are factored in, the project would benefit from a net subsidy of $1,062 million. This is far in excess of the optimal gross subsidy – the subsidy that is justified because the wind farm would produce cleaner electricity than the fossil fuel alternatives (or would reduce the expense of reducing emissions elsewhere in the system) – which we estimate to be at most $244 million (equivalent to 1.6 cents/kWh).

The most fundamental problem with the project is of course the very high cost of producing electricity at sea; we estimate that the levelized cost of producing electricity from the project itself, as measured at the weighted average cost of private capital, would be 18.8 cents/kWh (or more properly, between 13.3 and 24.8 cents with 90% probability). That is expensive when set against the average factory-gate price at which electricity was sold in Massachusetts, which was just under 7 cents/kWh in 2007.

1. Introduction

In March 2004, we released a report entitled *Free but Costly* in which we estimated the costs and benefits of building an offshore wind farm off the coast of Massachusetts. Since then, a number of factors have changed: the cost of energy has risen, the price of wind turbine generators (WTGs) has increased, and more is known about how to run a large wind farm. To take account of these and other changes, we have revised and updated our cost-benefit analysis. The methods we use, and the results we find, are set out in some detail in this report.

The Cape Wind Project

In November 2001, a private developer, Cape Wind Associates, filed an application with the U.S. Army Corps of Engineers for permission to construct the nation's first offshore wind farm in Nantucket Sound. The project would consist of 130 wind turbines, each approximately 426 feet tall, arrayed over a 24 square mile area of the Sound known as Horseshoe Shoals. The wind farm would be sited five miles off the coast, in federal Outer Continental Shelf (OCS) waters. From there, undersea cables would transmit power through state waters to an onshore distribution grid. The project, according to Cape Wind, would have an installed nameplate capacity of 468 megawatts (MW) of electricity.

The project is controversial. Cape Wind argues that the project will lower electricity costs to consumers, reduce emissions from power plants in the New England region, create more jobs on Cape Cod, and contribute to greater energy diversity and independence. Critics of the project are concerned about the high cost of wind-generated electricity, about environmental impacts, about the public safety impacts for sea and air travel, and about the aesthetic and economic effects of 130 wind turbines on the horizon, which may deter tourists and depress land values.

The project has been subject to an extensive regulatory review process, involving a number of federal, state and local regulatory authorities. Initially, the U.S. Army Corps of Engineers had permitting authority – given that the project is located in federal waters – and it published a Draft Environmental Impact Statement (DEIS) of the Cape Wind project in 2004. Subsequently, this authority was transferred to the Minerals Management Service of the U.S. Department of the Interior, which published another DEIS in January 2008 (MMS-DEIS).

Neither of the draft environmental impact statements includes a systematic attempt to weigh the social costs against the social benefits of the project. This lack is surprising, giving that Presidential Executive Order 12866 of September 30, 1993, which was expressly reaffirmed by President Bush, states that "each agency shall … propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs".[1]

In this report we present the results of a systematic cost-benefit analysis of the Cape Wind proposal. More specifically, we address three major questions:

1. What are the economic costs and benefits of the Cape Wind proposal?
2. What are the financial costs and benefits of the project, from the point of view of Cape Wind?
3. Is the level of subsidy to the project appropriate?

Our analysis is based on publicly-available data, and reports the range of plausible outcomes as well as our "best guess" point estimates.

2. Economic Costs and Benefits

Any project both uses and saves resources. These are the economic costs and benefits of the project. Sometimes these are reflected in market prices, but sometimes, as in the case of pollution and damage to natural resources, they are not. Where market prices do not reflect true economic values, estimated costs have to be used in the analysis. In the context of a wind power project, the economic benefits to the United States include the value of fuel saved, the reduction in spending on building generating capacity elsewhere, the health and other benefits of lower emissions (or the avoided expense of emissions reductions elsewhere, if emissions of the pollutant in question are subject to a binding overall limit or "cap"), and greater energy independence. Set against these are the costs, which include the initial expense of equipment and installation, plus operating and maintenance expenses, the costs imposed on the electricity grid of accommodating wind power, and possible environmental effects (e.g. on wildlife), as well as aesthetic and economic effects.

[1] Jonathan Haughton and David G. Tuerck. February 2008. *Comments on the MMS Draft Environmental Impact Statement for the Cape Wind Energy Project.* Beacon Hill Institute at Suffolk University.

These principles are quite straightforward and well established. Curiously, however, they continue to be misunderstood – or ignored – in the MMS-DEIS. For example, in Appendix F of the MMS-DEIS, the Minerals Management Service treats as "costs" some payments – royalties, and sales of green energy credits – that are not costs at all, but just transfers from one segment of society to another.

A breakdown of the economic benefits and costs of the project is shown in Table 1. Using a nominal discount rate of 9.2 percent, we estimate that the present value of the benefits from the project would be $1,184 million, equivalent to 7.9 cents/kWh; we are 90% confident that the benefits are somewhere between $996 million and $1,383 million.[2]

The economic cost of the project is expected to be $2,216 million; this represents the present value of all the resource costs related to the project, and includes both the initial capital cost of the wind turbines as well as subsequent operating and other expenses. There is considerable uncertainty about these costs, which average 14.8 cents/kWh: we are 90% confident that they fall within the range of $1,619 million to $2,865 million (i.e. between 10.8 and 19.2 cents/kWh).

We should note that the economic cost shown here differs from the cost as measured from the perspective of a private investor; for the latter, the cost of the project itself would come to 18.8 cents/kWh – or between 13.3 and 24.8 cents with 90% confidence. This number reflects the discounting of costs at the weighted average cost of private capital, which is relatively high due to the riskiness of the project. This private supply cost is the appropriate one to use when making comparisons with other estimates of the how much it would cost a developer to bring electricity to the market.

The net effect is that we expect the economic costs to exceed the economic benefits by $1,033 million; we are 90% confident that this net cost is between $400 million and $1,714 million. In other words, the proposed wind farm is expected to cost more to society than it would ever give back, and the difference is large. Based on economic criteria, this wind farm should not be built at this time.

---

[2] We discuss our choice of discount rate in more detail in section 4 below. The benefits are also larger if a higher value is put on reductions in CO_2 emissions; we also return to this point in section 4.

MMS may disagree. But the present DEIS provides no support for that disagreement. Accordingly, if MMS wants to base any permitting decision on that possible disagreement, it must first prepare a revised DEIS and make it available for public comment.

This conclusion is based on the following underlying data and assumptions, which serve as the basis of our analysis (and are summarized in Appendix Table 1).

Table 1. *Economic Costs and Benefits of the Nantucket Sound Wind Farm Project, 2008*

	Net Present Value (at 9.2% nominal)		Cents/kWh
	Mean	**90% confidence interval**	
	($ millions)		
Benefits	**1,184**	**996 – 1,383**	**7.9**
Of which:			
Fuel saved	938	761 – 1,130	6.3
Capital costs saved	145	118 – 172	1.0
Lower emissions or abatement costs	69	33 – 124	0.5
Greater energy independence	31	9 – 58	0.2
Costs	**2,216**	**1,619 – 2,865**	**14.8**
Of which:			
Project itself	2,100	1,503 – 2,748	14.0
Grid integration	32	21 – 43	0.2
Aesthetic effects (using royalty rates)	85	79 – 90	0.6
Benefits – Costs	**-1,033**	**-399 to -1,714**	**-6.9**
Benefits – costs using expected property value	**-2,438**	-1,804 to -3,120	
Benefits - costs using willingness to pay measure	**-953**	-318 to -1,634	
Benefits – costs with penalty on CO_2 emissions	**-838**	-178 to -1,535	
Memo: Levelized project costs at weighted average cost of capital (i.e. private supply cost)	**1,819**	1,312 – 2,367	18.8

Note: Totals may not add exactly, due to rounding errors. Confidence intervals are based on 10,000 drawings from underlying distributions of the variables determining costs and benefits.

Economic Benefits 1: Fuel Saved

The first benefit of the Cape Wind project is that it would reduce the need to generate electricity by other means. The main saving would be the ensuing reduction in fossil fuel use. We have analyzed this issue using default assumptions favourable to Cape Wind.

To measure the amount of fossil fuel saved one must begin by determining how much electricity the Cape Wind project would supply to the regional power grid. This depends on the rated capacity of the wind farm (468 MW) and the pattern of wind speed during the year. Readings from a 20-meter high test tower constructed by Cape Wind indicated an average wind speed of 7.64 m/s in 2004; adjusted for the height of the towers (78.5 meters), this gives an average wind speed of 9.29 m/s, or somewhat higher than Cape Wind's original estimate of 8.89 m/s. We use the average of 9.29 m/s. Wind speeds vary considerably during the year, and are four times more productive in December and January than in June and July. We use long-term data from Station 44018, which lies east of Nantucket, to measure the variation in wind speeds within the year; this is also the source of our assumption that monthly average wind speeds are normally distributed, with a standard deviation of 0.6 m/s.[3]

We then use information from the RETScreen International Wind Energy Project Model (Canada 2000) to convert the average wind data into capacity utilization rates.[4] We estimate that the actual output of the wind farm would be 40.9% of its rated capacity. In 2011, its first full year of operation, the wind farm is expected to deliver 1.53 million MWh of electricity to the grid – this factors in a transmission loss of 1.5% between the wind turbines and the on-shore substation – equivalent to 0.95% of the electricity produced in New England, declining gradually thereafter. Over time the equipment is expected to degrade slowly, but we adjust for this by allowing for the real cost off operating and maintenance expenditures to rise over time (see below for further details).

The next step is to determine how much fossil fuel would be saved. Electricity from the Nantucket wind farm would be fed into the New England power grid. Since it is non-dispatchable, the grid would first take electricity from wind farms before turning to generating facilities that are further up the "bid stack" (i.e. have offered to supply electricity at non-zero prices). In moving up the bid stack the ISO-New England operators, who run the regional grid, continue to add producers until demand is satisfied. The bid price of the last producer brought on line will then be the price paid to all producers by all purchasers. It follows that electricity from the wind farm will displace the "marginal" producers – in practice mainly those using natural gas, but also suppliers that use oil and coal.

[3] The source of the data for Station 44018 is http://www.ndbc.noaa.gov/station_history.php?station=44018 .
[4] Even if the wind speed averages 3 m/s, which would normally not suffice to turn the windmill, there will be periods when the wind is blowing strongly enough. The RETScreen model applies a Rayleigh distribution in order to estimate how much effective production one can obtain, given an average wind speed.

We have assumed that the wind-generated electricity will displace fossil fuel and other renewable energy (e.g. hydropower, biomass), but not nuclear energy, which provides base load generation. The EIA (2008) projects that by 2011, the non-nuclear sources of energy generation in New England will be as shown in Table 2, with a strong emphasis on natural gas (59% of the total) and coal (23%). At the margin, we believe that wind power will mainly displace natural gas, and so we allocate fuel savings as shown in the right hand column of Table 2.

Table 2. ***Fuel mix for non-nuclear energy generation, New England, 2011***

	Percentage of non-nuclear electricity generated	Marginal contribution to non-nuclear electricity generated (%)
Coal	23	12
Oil	11	5
Natural gas	59	79
Renewable energy	7	4

Source: EIA (2008); last column reflects our assumptions.

The projected real prices of these fuels – steam coal, residual fuel, natural gas, and biomass – are formed as an equal-probability distribution of (a) the real prices of these fuels in 2005-2007 (which are relatively high), and (b) the real prices as projected through 2027 by the U.S. Energy Information Agency (EIA 2008). Here, as elsewhere, we convert real values to nominal dollars, using an assumed future inflation rate of 3 percent.

The savings of fuel will occur over the 20-year life of the project. We compute the present value of the savings, as of 2008, by applying a (nominal) discount rate of 9.2 percent, which gives the total of $938 million in Table 1. By dividing this present value by the volume of electricity produced (discounted at an annual real interest rate of 6%) we obtain a measure of the "levelized cost" of fuel saved, which comes to 6.3 cents/kWh of electricity produced by the wind farm.

Economic Benefits 2: Less Capital Expenditure

Wind power is relatively unreliable, which is why it is sometimes assumed that dispatchable backup generating capacity, is still needed, in case there is a time when the wind does not blow. Simulation evidence from wind farms elsewhere in the United States suggests that electricity systems typically need to maintain additional reserve capacity (spinning and non-spinning) of at most 20% of the rated capacity of the wind turbines, and possibly less[5]. The system needs less

[5] M. R. Milligan. 2001. "A Chronological Reliability Model to Assess Operating Reserve Allocation to Wind Power Plants," National Renewable Energy Laboratory, Golden CO.

backup then the full capacity of the wind farm because there is typically enough variability in the entire system to take up some of the slack when the turbines are becalmed.

In the case of the Cape Wind project there is another consideration: peak electricity demand in the region is in the summer, yet this is the time when the wind blows least. The capacity utilization of the wind turbines is estimated at 15% in July and 24% in August, compared to an annual average rate of 39%. This limits the amount of capacity that could be removed from the system when wind comes on stream. We assume that when Cape Wind is operating, one could avoid building gas-powered plants to the extent of 19.5% of the Cape Wind rated capacity (this is the average capacity for July and August). The natural gas plants are assumed to cost $900/kW (in 2007 prices; see ISO-NE 2007), and have a 95% operating efficiency rate. Thus the wind farm would allow a saving of $145 million in capital costs elsewhere in the system, equivalent to 1.0 cents/kWh produced by the wind farm, as shown in Table 1.

Economic Benefits 3: Lower Emissions or Abatement Costs

Reduced emissions of conventional air pollutants, specifically sulfur oxides (SO_x), nitrogen oxides (NO_x) and particulates and of the greenhouse gas carbon dioxide (CO_2) are often claimed as benefits of constructing the Cape Wind project. This is just one possible outcome, but it is quite probable that the project will not reduce these emissions at all, and will be of limited benefit in controlling them, for the reasons set out below.

When wind power reduces fossil fuel use it also reduces emissions of combustion-related pollutants such as SO_x, NO_x, and CO_2.. The independent system operator of New England (ISO-NE) has undertaken a "marginal emissions analysis" that asks what the emissions effects would have been if it had bought an additional MWh of power at every point during a year. At each point in time, ISO-NE knows who the marginal power supplier would be, and how much pollution it would produce (ISO-NE 2006).[6] This information is available for 2004. We have spliced this information with projections from the EIA about trends in national emissions rates by fuel source between now and 2030,[7] and matched it with our assumptions about changes in fuel sources over time, to arrive at our projections for the emissions that would be averted by the Cape

---

[6] ISO New England Inc., *2004 New England Marginal Emission Rate Analysis*, May 2006.
[7] EIA. See file suptab_68(1).xls , which is largely based on the EIA's *Annual Energy Review 2005*.

Wind project. We estimate that in 2011, the first year in which the project would be operational throughout the year, it would reduce CO_2 emissions by over 716,000 tonnes, SO_x emissions by 1,110 tonnes, and NO_x emissions by 324 tonnes (Table 3).

The main benefit of lower emissions of SO_x, NO_x and particulates is a reduction in human mortality and morbidity. It is not easy to put a dollar value on these effects, and so estimates vary widely. We use the numbers reported by Levy et al. (1999); they are relatively recent, they accord well with more recent figures published by Levy et al. in the context of Massachusetts; and the assumption made by other studies that CO_2 emissions should be valued at the cost of planting enough trees to offset these emissions, is unrealistic. We estimate that the annual value of avoided emissions in 2011 would be $5.2 million.

The net result is that the present value of the reduction in emissions attributable to the Cape Wind project would be $69 million or about 0.5 cents/kWh. These numbers may seem modest, but they reflect the presumption that the wind power would mainly displace natural gas, which is a relatively clean fossil fuel.

Table 3. *Emissions avoided due to Cape Wind project*

	Emissions avoided in 2011, tonnes	Value of avoided emissions in 2011	
		$ per tonne	Total ($million)
SO_2	1,110	1,061	$1.178
NO_X	324	1,034	$0.355
CO_2	716,470	4.57	$3.274
Total			$4.807

Note: All figures are in 2008 dollars unless otherwise noted. A tonne is a metric ton.
Sources: Levy JI, Hammitt JK, Yanagisawa Y, Spengler JD. "Development of a New Damage Function Model for Power Plants: Methodology and Applications." *Environmental Science and Technology* 33: 4364-4372 (1999), for the valuation per tonne.

Cap and Trade. It may seem counterintuitive, but it is quite plausible that the Cape Wind project would not reduce air pollution at all. This is because emissions from power stations and other sources are increasingly subject to cap and trade programs. The federal Clean Air Act limits emissions of SO_2, while the EPA's Clean Air Interstate Rule puts seasonal or annual caps on emissions of NO_x in a number of states, including Massachusetts. In 2007, Massachusetts joined the Regional Greenhouse Gas Initiative, which has established a cap and trade system for emissions of CO_2 by power plants in the Northeast. It is also highly probable that a national cap on greenhouse gas emissions – mainly CO_2 – will be put in place during the life of the Cape Wind project.

Although the details vary, a typical cap and trade program sets a limit on the quantity of a pollutant that may be emitted. Anyone wanting to send pollution into the atmosphere must then buy or otherwise acquire an allowance – typically a market for such permits springs up; the only alternative is to incur the expense of reducing pollution, for instance by installing more scrubbers or low-NO_x burners or finding ways to sequestrate carbon. As long as the caps on emissions are binding, the introduction of a project such as that proposed by Cape Wind would not reduce overall emissions; by reducing the price of permits to pollute, it would make it profitable for other producers to emit more pollutants than they otherwise would have, because some of those producers would now purchase (cheaper) permits rather than install expensive pollution-controlling equipment or taking other pollution-abating measures.

In the context of a binding cap and trade program, the Cape Wind project would not reduce pollution, but it would generate benefits nonetheless. It would have the effect of allowing other producers to avoid the expense of emissions abatement; these avoided costs represent a real saving of resources, and so should be counted as benefits.

If a cap and trade program is designed in such a way that the price of permits to pollute reflects the marginal costs imposed by emissions – which would be the correct way to set up the program – then the dollar value of the emissions-related benefits of the Cape Wind project would still be valued as in Table 3. The difference is in the interpretation: without cap and trade, the benefits would be measured in terms of improved health; with cap and trade, the benefits would be measured in terms of avoided emissions abatement costs.

An alternative method of valuing allowances leads to slightly different values, although they would be of the same order of magnitude as those we have used. When EPA promulgated its Clean Air Interstate Rule, it designed it to impose marginal costs of about $700-1000 per ton of SO_{2c} removed, see 70 Fed. Reg. 25162, 25202 (May 12, 2005) and $1300-$1600 per ton of NO_x removed, see id. at 25209. These are slightly lower figures in the aggregate than the figures in the Levy study and would lead to slightly lower results.

Similarly, the RGGI program establishes a "safety valve" price for CO_2 allowances of $10 per ton that cannot be exceeded. See http://www.rggi.org/docs/mou_12_20_05.pdf This is approximately twice the figure used by Levy and would lead to correspondingly higher benefits.

Economic Benefits 4: Energy Independence

By using wind power, less oil would be used in the United States. Currently, 55% of the petroleum used in the country is imported, a figure that is expected to rise to almost 75% by 2025. This dependence on foreign oil has been blamed for some of the costs that the U.S. has incurred in the Middle East, particularly the Gulf War of 1991. Moore et al. (1997) put a price to this dependence that comes to about 9 cents per gallon (adjusted to 2004 prices). Ogden et al. (2004) argue that the costs are much higher, and are between $0.35 and $1.05 per gallon. We take a default position in the middle that is relatively favourable to Cape Wind. Specifically, we use a triangular distribution with a minimum price of $0.10, a maximum of $1.05, and a "most likely" value of $0.70 per gallon. On this basis, we find that the energy from the Cape Wind project may be associated with savings (in present value terms) of $31 million related to ensuring a reliable flow of oil to the country. This is equivalent to 0.2 cents/kWh. These benefits are small because relatively little oil is used to generate electricity; thus the Cape Wind project would lead to savings of an estimated 5.7 million gallons of distillate and residual fuel oil annually.

Adding together the benefits of fuel saved, avoided investment, emissions reduced, and greater energy independence, we calculate a total of 7.9 cents/kWh. The present value of this benefit is $1,184 million, which is our measure of the economic benefit of the output of the Cape Wind project.

The Economic Costs

By far the largest economic cost of the Cape Wind project is the main investment in building a power plant and the corresponding equipment. We do not have direct information on this, and so have pieced together estimates of the cost from a variety of sources, as set out in Table 4. We attach weights that reflect our judgment of the applicability of each estimate; and in our simulations, we assume that for each of these cases there is a 90% probability that the actual cost is at the level shown here, plus or minus 15%. We would expect that a legally adequate DEIS would rely more on specific facts and less on the default assumptions that we have used (in the absence of hard data).

Based on weighting the estimates in Table 4, we believe that the capital cost of the Cape Wind project will be about $3,890 per kW of installed capacity (in 2008 dollars). This gives an estimated total cost, for the turbines and towers, of $1.82 billion.

There are some other capital costs, of which the most important is the expense of decommissioning. We assume that the project will have a useful life of 20 years – in line with the standard assumptions about its duration – and that at the end of the project it will cost $550,000 (in 2008 prices) to dismantle each of the 130 towers, for a total of $71.5 million. This number is based on an estimate of the cost of decommissioning in the UK, which put the cost at £275,000 per wind turbine generator (ODA 2007).

Table 4. *Capital Costs for Offshore Wind*

Source/Case	$/kW	Weight	Notes and Sources
ODE Offshore Wind Farm Cost Model, UK	4,230	0.15	UK Department of Trade and Industry study, September 2006, p. 46. £2.963m/turbine (3.6MW), worth 36% of capital expenses, with allowance for cost reductions. Exchange rate: $2/£1.
North Hoyle	2,950	0.05	Installed at cost of £81m for 60MW; converted at $2/£1. Inflated to 2008 using 3% p.a.
US Dept. of Energy	3,890	0.25	Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends (2006). $1,100/kW for turbine plus 20% extra cost for offshore, and assumes this is 36% of initial capital cost. Inflate to 2008 prices at 3% p.a. from 2006.
Long Island Power Authority	4,901	0.15	Quoted by PACE (2007), of $5,200/kW for delivery in 2010.
Europe, current offshore	3,060	0.10	PACE Global Energy, August 2007.
Denmark: Horns Rev	2,829	0.05	€1,675, raised by 2% p.a. for euro inflation, and converted to dollars at $1.50/€.
Sweden	2,929	0.05	Buerskens and Noord. €1,700, raised by 2% p.a. for euro inflation, and converted to dollars at $1.50/€.
PACE evaluation	4,713	0.10	PACE Global Energy, "installed U.S. offshore wind farm costs can be expected to be approximately $5000/kW by 2010." Adjusted here back to prices of 2008.
International Energy Agency	2,865	0.10	€1,800/kW in Europe as of mid-2005. Converted at $1.5/€, and raised by 2% p.a. for euro inflation.
Weighted average	3,693		Note: Estimate based on simulation. The 90% confidence interval goes from $2,692 to $4,871/kW.

The operating and maintenance costs of wind plants are relatively low, when compared to plants that require fossil fuels, but they are by no means negligible. Our estimates are based on a weighted average of reported costs from six different studies, as set out in Table 5. The (weighted) mean cost is 2.71 cents/kWh initially (in 2008 prices); this price is expected to rise over time in real terms, because as the equipment of the wind farm ages, it is expected to require most-costly maintenance. Although the operating and maintenance costs are shown here in terms of cents per kWh, in practice a substantial proportion of the costs – perhaps as much as a third – are essentially fixed, and would include such costs as the expense of operating a lift boat.[8]

Table 5. *Operating and Maintenance Costs for Offshore Wind*

Source/Case	$/kW	Weight	Notes and Sources
Obdam et al.	0.045	0.10	Mention of 2-4 eurocents per kWh; converted at $1.50/€.
Musial et al.	0.0171	0.30	They assume costs of 1.5 cents/kWh in 2004 for shallow-water turbines.
Van Bussel and Schöntag	0.0267	0.15	They use 0.015 to 0.0154 ecu/kWh. Refers to about 2000. Inflated by 2% p.a. and then converted at $1.50/€.
Long Island Power Authority	0.0424	0.20	This is the number used by PACE, *LIPA Wind Final Report*.
North Hoyle, England	0.029	0.05	Based on report of actual operations in 2005; converted at $2/£1. Inflated to 2008 using 3% p.a.
Walford.	0.0176	0.20	Estimates costs at 0.005 – 0.006 cents/kWh for on-shore wind farms, rising to 0.02 cents/kWh by end of project. Applied rule of thumb that O&M for off-shore wind farms is three times as expensive.
Weighted average	0.0271		Note: Estimate based on simulation.

Note: Expressed as $/kW, even though some costs are related to capacity rather than output. Numbers on cost/kWh refer to 2008 dollars. The real price is expected to rise by 2% p.a. in every case except the last, where the annual price rise is expected to be 3.5%.

Our assumptions imply that operating and maintenance costs would be about $46.8 million in 2011, the first full year of project operation, and a time when the equipment would still be under warranty. In arriving at our results, we first randomly pick one of the six estimates, using the probabilities shown in Table 5, and then choose a value for the estimate that is chosen, and which is assumed to follow a Normal distribution with standard deviation equal to a tenth of the mean. This process is repeated many times to generate a distribution of outcomes for the analysis.

In addition to the cost of the project itself, there are costs related to the integration of wind power into the regional electricity grid. Since wind power is relatively unpredictable, other units must be available to provide power at very short notice ("regulation"), over a period of 10 minutes to several hours ("load following"), and over a period of several days ("load commitment"). This

[8] van Bussel, G.J.W and Schöntag, Chr. *Operation and Maintenance Aspects of Large Offshore Windfarms*. Internet, available at http://www.windenergy.citg.tudelft.nl/content/research/pdfs/ew97gvb.pdf

imposes fuel and operating costs on other operators, in effect to create reliability to accommodate wind power. Parsons et al. (2003) report integration costs of 0.18 cents/kWh; we apply a triangular distribution, with a peak of 0.18 cents/kWh (in 2003 prices) and a range of 0.09 to 0.27 cents/kWh. This is well below the figure of 0.74 cents/kWh that has been estimated as the grid integration cost in the UK that would result if a fifth of all electricity there were generated by wind power; however, the Cape Wind project would only provide about 1% of the region's electricity, which would make it much less costly to integrate.

Most controversial are the economic results of the decline in natural beauty that would result from siting the wind turbines in Nantucket Sound. In a companion study, the Beacon Hill Institute (2003) reported on the results of a survey of almost a thousand homeowners and tourists in the towns abutting Nantucket Sound in the summer of 2003. Among the key findings:

- Homeowners believed that the windmill project would reduce the value of property by $1.35 billion. If correct, this would be the appropriate figure to use for declines in property values, since in principle it capitalizes all the effects of the windmill project on those values. However, it also represents a hypothetical number.
- Tourists and homeowners alike said that they thought Cape Wind should pay royalties; the average amount suggested was 7.86% of sales. This might be interpreted as the price that tourists and homeowners believe Cape Wind should pay in order to compensate for the possibly negative effects (especially the interrupted ocean view) of the project.
- Respondents to the survey indicated a modest "willingness to pay" to ensure that the wind turbines would not be built.

The "royalties" measure implies costs of $85 million, equivalent to 0.6 cents/kWh. If these are included with other costs, the total economic cost of the project is expected to be $2,216 million, or 14.8 cents/kWh. There is considerable uncertainty about this figure; there is a 5% chance that it could be below 10.8 cents/kWh, and a 5% chance that it could be above 19.2 cents/kWh.

There are a number of other possible costs associated with the project. For instance, a study by the Massachusetts Fish Partnership finds a cost of $8-13 million over the life of the project. There are potential costs associated with an oil spill from the platform that will service the wind turbines; there may be risks to air traffic; and there are likely to be some effects on bird deaths. However, there is very great uncertainty about the magnitude of these costs, so we have not included them in our analysis. Even without these costs, our analysis shows that the project would not make economic sense; with the inclusion of such costs it would look even worse.

3. Financial Costs and Benefits

It might seem surprising that a project that is so economically unattractive is nonetheless able to attract the interest of a private investor. The explanation lies in the large size of the subsidies that the Cape Wind project would receive. In this section we set out the assumptions that underlie the financial analysis of the project, and follow that with a reconciliation of the financial and economic analyses.

The results of the financial analysis are shown in Table 6. Given the current structure of subsidies and other incentives, the present value of the return on equity (at the target rate of return) of would be -$5 million.

All of the subsidies are required for the firm to be financially viable. Without the Federal production tax credit, Cape Wind would achieve its target rate of return less than half of the time. And without the Massachusetts RPS ("green") credits, the project would be completely unviable. These results call for some further explanation.

Table 6. ***Financial Costs and Benefits of the Cape Wind project***

	Baseline	No green credits	No Fed'l PTC	No credits or PTC
NPV for firm at target rate, $ millions	**-5**	**-168**	**-73**	**-236**
Confidence interval for NPV, $ m	**-208 to 164**	**-379 to 8**	**-272 to 92**	**-448 to -63**
Probability that return on equity exceeds the required rate (%)	**52**		**29**	
Rate of return on equity (%)	**24.6**		**18.3**	
Levelized costs ($/kWh) at WACC	**18.8**	**18.8**	**18.8**	**18.8**
Of which:				
Operation and maintenance	2.8	2.8	2.8	2.8
Capital costs	16.1	16.1	16.1	16.1
Memo item:				
NPV for firm at 9.2%, $ millions	**273**	**-243**	**126**	**-385**
Confidence interval for NPV, $ m	–-113 to 628	-635 to 112	-240 to 457	-763 to -49

Notes: WACC is the Weighted Average Cost of Capital. The numbers in this table are based on 10,000 drawings from underlying distributions of the variables determining costs and benefits. The nominal return of 9.2% is equivalent to a 6% real return. Some of the totals may not add because of rounding.

The first source of revenue for the Cape Wind project would be from sales of electricity. We suppose that the project would be paid the "locational marginal price" that ISO-New England pays in south-eastern Massachusetts. Monthly information on this price is available through

February 2008, and we extrapolate the most recent numbers (which are at historically high levels) under two assumptions – each of which occurs with equal probability – which are that (a) the real price of electricity does not rise over time, and (b) the real price of electricity changes in line with the forecasts made by the U.S. Energy Information Administration. The real price forecast by the EIA would peak in 2009 and then fall slowly over time; between 2006 and 2030 the EIA expects the real price of electricity to fall by an average of 0.06 percent per year.

The second major source of revenue is the sale of "RPS credits". Under its Renewable Portfolio Standard (RPS) arrangement, Massachusetts requires that a growing proportion of electricity come from "new renewable sources" – the Cape Wind project would qualify – or else pay to the state a penalty, currently 5.858 cents/kWh, and indexed to inflation – on this electricity. The proportion of electricity in the Commonwealth that is supposed to come from new renewable sources was set at 1% of the total in 2003 and is set to rise by half a percentage point per year through 2009 (when it will amount to 4% of the total), and possibly rise by a percentage point per year thereafter. Utilities can satisfy the RPS requirement by buying "green credits" from a certified provider. Thus the question becomes one of what price Cape Wind can expect to receive by selling its green credits.

At least through early 2008, the production of electricity from new renewable sources has lagged behind the threshold, so that at least some utilities find they have to pay the penalty rate. It follows that the cost of green credits is essentially at the penalty rate. It is our assessment that over the life of the Cape Wind project, the production of energy from new renewable sources will consistently lag the mandated minimum; even if more than enough such energy is produced in a given year – a recent report by the Massachusetts Division of Energy Resources (2008) suggests that there may be enough energy from new renewable sources for the next couple of years – it can be "banked" in order to be offset against the threshold in future years, so it is only really necessary to assume that the minimum required level of production from new renewable sources will not be met *on average*. It follows that the price of green credits will generally be at or close to the penalty rate; we assume that it will be at 90% of the penalty rate, and that these values will be distributed normally with a standard deviation of 0.5 cents/kWh.

Our assessment differs from that of LaCapra (2003), which has projected the price of green credits through 2012 and estimated that they would be worth about 2.5 cents/kWh. Their result now appears to be based on an overly optimistic evaluation of the potential for relatively inexpensive new renewable sources of energy.

The Cape Wind project can also expect to benefit from a Federal Renewable Production Credit (RPC). This currently provides a tax credit of 2.0 cents/kWh produced by wind power over the first ten years of operation, and is indexed for inflation. This credit is not guaranteed, because it requires repeated authorization by the U.S. Congress. However, Congress has generally renewed this program in recent years, and is expected to do so for the foreseeable future. The RPC is a tax credit, and so is only useful for corporations that are profitable, but we assume that if Cape Wind were not making a profit, it would sell itself to a profitable entity that could make full use of the tax credit.

In calculating the private return on the Cape Wind project, we compute the cash flow to equity. This makes adjustments for accounts payable and receivable, as well as cash reserves. Given that this is a highly risky project for investors, it is likely that the debt/equity proportions will be close to 60%/40%; in our simulations we allow the equity share to be as low as 30% and as high as 50%.[9] If 60% of the project is financed by debt, the debt coverage ratio (i.e. cash inflow divided by debt service cost) would be a rather modest 1.1 in the early years of the project; this is at the lower end of what would be considered acceptable, and suggests that it would be difficult to obtain debt financing for a higher proportion of the costs. Given the high risks, we assume that equity investors would require a return of 25.2 percent (with 40% equity; we allow the target return to vary in inverse proportion to the equity share).

We assume that the project would need to borrow to (a) cover the appropriate proportion of construction costs (including interest during construction), (b) purchase a bond that would grow enough to cover decommissioning costs, and (c) provide for a debt service reserve equivalent to half a year's debt servicing costs.

As a renewable energy project, the wind farm would benefit from a 5-year Modified Accelerated Cost Recovery System (MACRS), rather than the standard 20-year schedule; this represents a substantial implicit subsidy. The project would not have to pay the Massachusetts corporation

[9] Specifically, we assume that there will be a 10% probability each of equity shares of 25% and 30%, and a 20% probability each of equity shares of 35%, 40%, 45% and 50%.

tax, since it is (largely) located in federal waters, but would pay Federal corporation income tax at the standard rate of 35%.

The results in Table 6 show that the expected return on equity would be 24.6%, which is lower than the mean target return of 25.2%.

Financial and Economic Returns Reconciled

A reconciliation of the financial and economic returns is presented in Table 7. The cash flow to equity would be -$5 million, but if this flow is discounted at the economic (rather than private) nominal rate of return of 9.2% then the total return would be $273 million. Beyond this, there are substantial "external" benefits to the rest of society, most notably the savings in capital expenditures for generating electricity from fossil fuels (mainly natural gas), the health benefits of lower emissions (or, alternatively, the saving in pollution control expenditures, as measured by the marginal allowance price, that results from adding a zero-emissions electricity generator to a cap and trade system), the security of greater energy independence, and tax revenue collected from the project. Note that we do not include, as a benefit, any measure of jobs attributable to the project; this is properly viewed as a cost of bringing the wind power on stream.

If the Cape Wind project goes ahead, it will also impose costs on the rest of society. These external costs include the expenses incurred by the electricity system in order to accommodate the variability of wind power, possible environmental and public safety costs, subsidies in the form of the federal production tax credit, the Massachusetts RPS ("green") credits, and accelerated depreciation.

Table 6 shows that there are two further technical adjustments; the difference between the value of electricity sales (which go to Cape Wind) and the value of fossil fuel saved shows up as an adjustment "for value of output;" and the fact that the cost of borrowing would be lower than the economic discount rate shows up in the adjustment "for loan effect."

Table 7. *Reconciling Private and Economic Returns for the Cape Wind project*		
	Cents/kWh	**PV ($m)**
Cash flow to equity at the target rate	-0.03	**-4.7**
Plus adjustment for the return differential (for risk)	1.85	**278**
Plus external benefits:		
+ Capital & operating expenditures saved	0.97	145
+ Emissions abated	0.46	69
+ Energy independence	0.21	31
+ Taxes paid	-0.88	-131
Less external costs:		
- Grid integration	0.21	32
- Environmental costs	0.56	85
- Federal production tax credit	0.94	140
- MA RPS ("green") credits	5.27	791
- Accelerated depreciation	0.86	130
Plus technical adjustments		
+ For value of output	-0.91	-136
- For loan effect	0.83	124
- Other technical adjustments	-0.12	18
= Economic Net Benefits	-6.85	**-1,028**
Memo: Actual subsidy (net of taxes)	7.07	1,061
Optimal subsidy: three measures		
1. Base case	-0.05	-7
2. Excluding aesthetic effects	1.62	244
3. Also including higher greenhouse gas benefit	5.45	817

The figures in Table 7 make it clear that by far the most important policy measure for the financial viability of the Cape Wind project is the Massachusetts RPC credit, which is expected to be worth a $791 million (in 2008 present value terms), or about $130 per resident of the state.

How Large Should the Subsidy Be?

Wind power is clean and it reduces the cost of energy dependence. However, that does not automatically mean that we should subsidize wind power production. The answer to that question depends in the first instance on whether we view the beneficial features of wind as public benefits to be rewarded, or whether we view the polluting and import-encouraging aspects of **other** energy sources as costs that society should require those sources to internalize. If we take the second view, and act to require such sources to internalize these social costs of their conduct, the fact that wind power will be free from these internalized costs should be encouragement enough. Giving wind a subsidy would amount in effect to double payment for the same benefit.

In fact, the trend of public policy over the past decades has been strongly in favor of this second approach, as market-based cap and trade systems have been adopted first for conventional pollutants and now for greenhouse gases. To the extent these programs take effect, they severely weaken the case for subsidies to projects like Cape Wind.

Nevertheless, in another default assumption favorable to Cape Wind, we will proceed to evaluate the optimum level of Cape Wind subsidy without taking account of this factor – in effect considering a wind subsidy as a "second best" policy that is only justified because the negative externalities caused by some other energy sources are not properly priced into fuel costs..

If the private operator could sell the electricity at a price that reflected its economic (rather than purely financial) benefits, and incurred costs that reflected its economic effects, then there would be no need to consider any subsidy. However, associated with the project are a number of spillover costs and benefits ("externalities") that need to be taken into account because they drive a wedge between the economic and private benefits and costs.

In principle, we have

Private cost of production

+ negative externalities due to production

- positive externalities du to production

= Economic cost of production,

which we may write as $PC + NE_P - PE_P = EC$. We also have

Private benefits (i.e. electricity sales)

+ positive externalities associated with consumption

- negative externalities associated with consumption

= Economic benefit of project,

which gives $PB + PE_C – NE_C = EB$.

The optimal subsidy is the level of subsidy that would align a private operator's incentives with the economic incentive, provided the project is worth doing. Thus we have

$$EB – EC = 0,$$

which is required for the project to be (just) worth doing. And so

$$0 = PB + PE_C – NE_C – (PC + NE_P - PE_P)$$

$$= PB – PC + [(PE_C + PE_P) – (NE_C + NE_P)],$$

where the term in square brackets equals the optimal subsidy. In the current study, most of the external effects are associated with the production of the electricity; there are positive benefits from cleaner air (or reduced abatement costs) and less reliance on foreign oil, but there are costs related to integrating wind power with the grid, in addition to aesthetic costs. The details are shown in Table 8.

In our base case, the subsidy would be -$7 million, which means that the optimal policy would be to tax the project! This is because the external benefits of the project are outweighed by the external costs that it imposes. However, if the aesthetic effects are excluded – the size of these effects is a matter of controversy – the optimal subsidy would rise to $77 million. And if reductions in CO_2 emissions are given an additional value of $25 per tonne (of CO_2) – which is the highest price mentioned in any control proposal being seriously discussed at present, – then the optimal subsidy would be $244 million, (in present value terms). This is the highest plausible level.

Table 8. ***Calculation of Optimal Subsidy***

	$ millions (in 2008 prices)	In cents/kWh
External benefits due to production (PE_P):		
Emissions effects	+69	0.46
Energy independence effect	+31	0.21
External costs due to production (PC_P):		
Grid integration costs	-32	-0.21
Environmental/aesthetic effects	-85	-0.56
Fuel and capital savings valued higher than electricity sales	+8	0.06
= Optimal subsidy (base case).	-7	-.05
Or: Optimal subsidy if aesthetic effects are excluded	77	0.52
Or: Optimal subsidy of CO_2 reductions are weighted more	**244**	**1.62**

Note: Totals may not add up exactly, due to rounding.

With an economically appropriate subsidy, the Cape Wind project would not be viable. This conclusion should not be surprising, because we have shown that the economic costs exceed the economic benefits; the most basic implication is that any subsidy regime that makes the project financially viable for a private firm must be excessive.

The gap between the actual subsidy that the Cape Wind project is expected to receive ($1,061 million) and even the largest plausible optimal gross subsidy ($244 million) is large by any standard.

As a matter of public policy, the subsidies to wind power, and particularly the Massachusetts RPC credits, are excessive in this case. **Put differently, as a society we could achieve cleaner air more cheaply in ways other than siting wind turbines in Nantucket sound.**

The underlying problem is that the production costs of offshore wind power are still very high. The problem is not the wind – averaging 9.3 meters per second, it is stronger than on land in West Texas (8 meters per second). The difficulty is with the very high costs of construction and of servicing complex equipment out at sea.

A good way to see this problem is to ask how much it would cost a private developer to bring electricity from the project to the market, given our assumptions about the cost of debt and equity as well as the price of turbines, towers, and the like. The costs would be discounted at the weighted average cost of capital, which is a weighted average of the cost of loan finance and the target return on equity. The answer is that it would cost 18.8 cents/kWh (or between 13.3 and 24.8 cents, with 90% probability). This is expensive, when set against the sales price of electricity, currently just under 7 cents/kWh.

In some parts of the country it appears to be privately profitable to generate wind with subsidy levels that are at or about the optimal level that we have calculated. Wiser and Langniss (2001) report that in Texas, which was a leader in developing a Renewable Portfolio Standard – it is very similar to the Massachusetts RPS – suppliers were delivering power to the grid for 3 cents/kWh; when the (then) 1.7 cents/kWh Federal production tax credit is factored in, it must have been possible to generate wind power in West Texas for about 4.7 cents/kWh. Certainly, on-shore wind power is expected to yield high private returns; in 2007, 5,244 MW of new wind-generating capacity was installed in the U.S., representing 30% of all new generating capacity installed and costing a total of $9 billion.

In short, on-land windpower may still be a preferable option to an off-shore wind farm. But there can be no presumption that the best place to site on-land wind turbines is in Massachusetts.

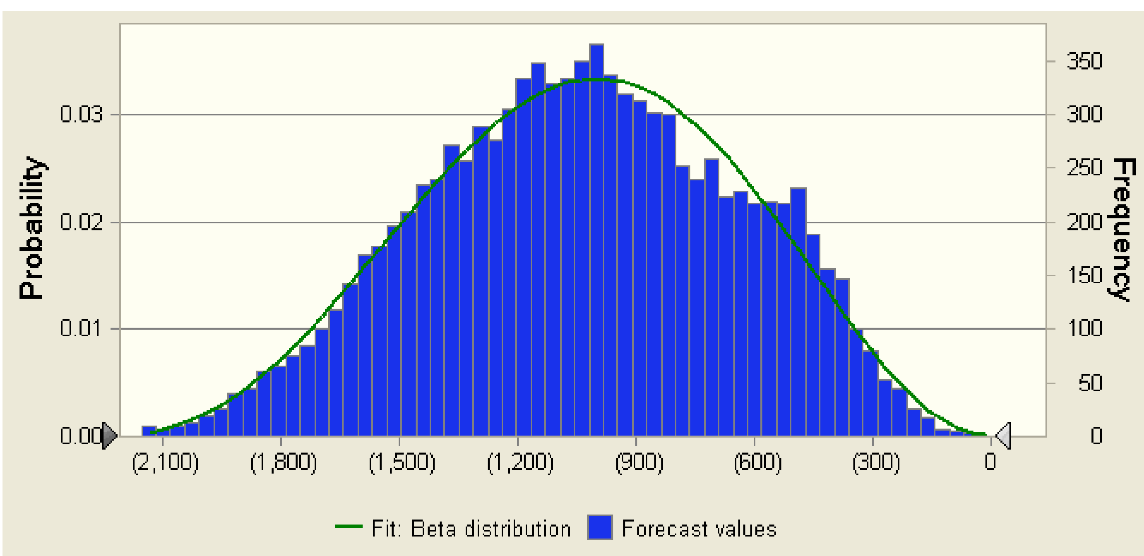
4. Robustness

It is reasonable to ask how robust these results are. Our approach has been to present not only our best estimates of the output variables of interest (e.g., NPV, costs, benefits), but also 90% confidence intervals that give a sense of the variability of those magnitudes.

To do this, we undertook a Monte Carlo analysis. For each of 79 key input variables, such as energy prices and construction costs, we specify a *distribution* of values rather than a single value. So, for instance, we assume that the price of Massachusetts RPS ("green") credits are valued at 90% of the maximum penalty price for new renewable energy, and that this value is distributed normally with a standard deviation of 0.5 cents/kWh.

We then take a random sampling of all the input values, and compute the output variables. This process is repeated 10,000 times, giving ten thousand results of the cost-benefit analysis. This generates a distribution for the results, such as that in Figure 1, which shows the net benefit from the project. Note that there is less than a 1% probability that the project might have a positive net benefit; this would occur in the unlikely event that the cost of building and operating the wind turbines would be at the low end of the distribution, and the cost of fossil fuels (i.e. the main benefits) would be at the high end of our distributions.

Figure 1. Distribution of Present Value of Net Economic Benefits of Cape Wind Project



The key point here is that our fundamental conclusion – that the economic costs of the project are expected to exceed the economic benefits – is fundamentally robust.

Throughout our analysis we have used a nominal discount rate of 9.2% (or 6.0% in real terms) to compute the net present value of the project. In our earlier study we used a 7% real discount rate, as recommended by the federal government.[10] There considerable debate about what rate is appropriate: in his report on climate change, Nicholas Stern used a rate of 1.4%. This has been criticized by William Nordhaus, who favors a rate of 5.5-6%.[11] The real return on US treasuries has fallen by about one percent since the early 1990s. It is these considerations that prompted us to use a real rate of 6% (Nordhaus 2007, p. 690) rather than 7% for version of our study. It is worth noting, however, that if we were to use the 7% real rate, the project would be economically even less attractive, essentially because the benefits, which accrue far into the future, now have to be more heavily discounted.

Opinions also vary widely about the appropriate way to value reductions in emissions of CO_2. In our basic analysis we have used the numbers suggested by Levy et al., which put a value of $3.90 (in 2003 prices) on each one-tonne reduction in carbon dioxide emissions. Some argue that this figure is far too low, and that a number in the range of $20-$40 would be more appropriate (see ISO New England 2007, p.29). So we have re-computed our analysis allowing for an additional premium on CO_2 reductions that averages $25/tonne – actually, equal-probability reductions of $10, $20, $30, or $40 – on top of the Levy number. This makes the Cape Wind project less unattractive, but the costs of the project still exceed the benefits by $838 million, as Table 1 shows. However, there appear to be many ways to reduce CO_2 emissions at a cost well below $25-30 per tonne (Creyts et al. 2007), so this should be viewed as a low-end estimate of the net costs of the Cape Wind project.

[10] Office of Management and Budget, Circular No. A-94, Revised October 29, 1992.
[11] See William Nordhaus, "A Review of the Stern Review on the Economics of Global Warming (May 2, 2007)", *Journal of Economic Literature*. And also William Nordhaus, "Critical Assumptions in the Stern Review on Climate Change," *Science*, 13 July 2007, 317(5835): 201-202.

5. Electricity Prices and the Consumer

In a report prepared for Cape Wind, LaCapra Associates (2002) argues that the wind farm would "lead to savings for the New England electricity market of approximately $25 million per year for the first five years of operation." An estimated $15 million of these savings would go to commercial electricity customers, $2.5 million to industrial users, and $7.5 million to residential consumers.

The argument is as follows. Currently, producers offer electricity to the regional grid at prices that they set, but which will certainly at least cover their marginal costs of production (i.e. the additional costs, such as fuel, that are incurred when they supply more electricity). The operators of ISO-NE stack the bids from lowest to highest price; if electricity demand rises, they will move up the bid stack, buying electricity at a higher price. All producers are paid the price that is determined by the supplier chosen at the margin.

Electricity from Cape Wind would have a negligible marginal cost, and so would be chosen first by ISO-NE operators. The effect would be to displace high-cost operators at the top of the bid stack, so that some of the time a lower-price plant would become the marginal supplier. This would result in a lower average price for electricity, creating savings that would be passed on to consumers. In some recent years during the summer, when demand for electricity is high, the slope of the bid stack can be very steep at the top.

LaCapra Associates used a utility dispatch simulation program (PROSYM) to quantify the effect of Cape Wind electricity on the price of electricity, using recent data from the NEPOOL bid stack and loads from 1999 as inputs. They used the model first to simulate the regional electricity market for 2005-2009 "reflecting recent long term planning assumptions", and then to simulate the effects when "the Cape Wind project is added to the New England supply." By comparing the two simulations, they estimated the cost savings at $25 million per year.

Two questions arise from this discussion: first, are the findings plausible? And second, does the $25 million represent an economic cost that our analysis needs to include?

The savings are plausible for one year only

A $25 million reduction in the cost of electricity to users is plausible for the first year in which Cape Wind operates. However, we do not believe that the project can take credit for suppressing the price of electricity for more than one year. There are two reasons for this. First, electricity demand in the region is rising by at least 1% per year, so that within a year demand will have expanded to fully absorb the expected production from the Cape Wind project. But any further increases in the price of electricity will elicit increased supply, because (and this is our second point), the supply of electricity is essentially completely elastic. With Cape Wind coming on line, other producers may delay a year, but once the market tightens again, they will prevent the price from rising any further, and it is they, rather than the Cape Wind project, that should get credit for preventing the price from rising.

The situation is summarized in Figure 2. Initially, the market is at point A. When the Cape Wind project comes on line, we move to B, and the price of electricity falls. But over the course of a year, demand rises to fully absorb Cape Wind production. Any further rise in demand would push up the price, and supply would expand along the horizontal long-run supply curve, from point C onwards.

In order to simulate this effect using PROSYM, it would have been necessary to change the "long term planning assumptions" in reaction to the arrival of power from the Cape Wind project. Otherwise one would have to apply the same logic to all electricity producers in the region – since all are somewhere in the bid stack – and argue that they all should be given credit for generating savings to consumers, for a total of about $2.5 billion annually.[12]

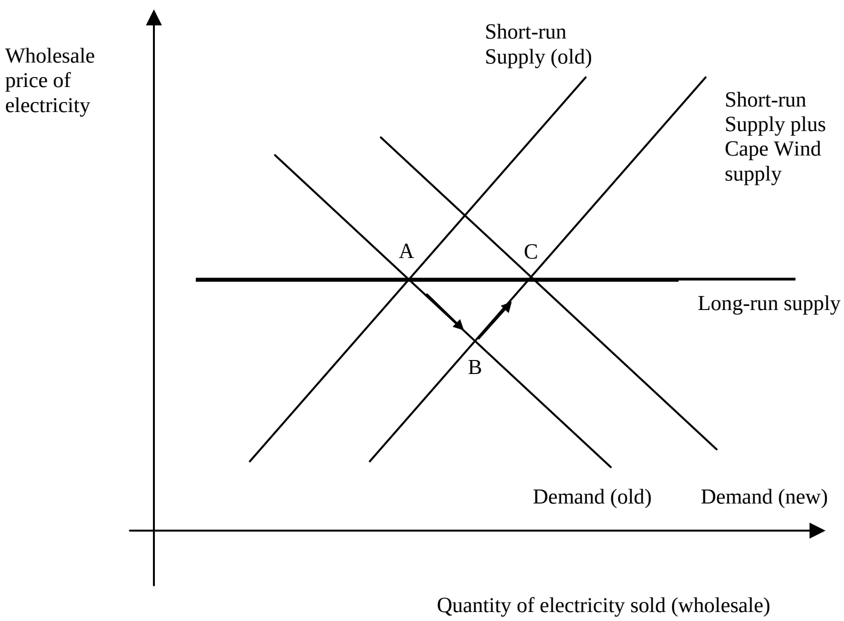
The savings to electricity users represent transfers, not economic benefits

To the extent that the Cape Wind project lowers the price of electricity, the main effects are to transfer revenue from other power generators (which now receive a lower price) to the public (which pays less). Certainly, those producers who now do not sell their electricity to the regional

[12] Cape Wind production will amount to about 1% of New England supply and, it is argued, would reduce electricity prices by $25 million annually; grossing this up by a factor of 100 gives $2.5 billion. GED, using somewhat different assumptions, estimated the reduction in electricity prices at $12 million (rather than $25 million) annually.

grid will incur lower costs (mainly of fuel and possibly of equipment), but these have already been taken into account in our economic cost-benefit analysis.

Figure 2. ***The Market for Electricity***



6. References

Bertel, E. and P. Fraser. 2002. "Energy policy and externalities," NEA updates, NEA News, 20(1): 14-17.

Cape Wind Associates. 2001. Application of Cape Wind Associates, LLC for US Army Corps Approval of The Cape Wind Project, Nantucket Sound and Yarmouth, Massachusetts, ESS Project No. E159-009.

Cape Wind Associates. February 2007. *Cape Wind Energy Project Final Environmental Impact Report.*

Cape Wind Associates. 2004. Draft Environmental Impact Statement [of the Cape Wind Energy Project; Reference file no: NAE-2004-338-1.]

Creyts, Jon, Anton Derkach, Scott Nyquist, Ken Ostrowski and Jack Stephenson. 2007. *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*, McKinsey & Company. Available at http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf

Earth Tech, Inc. 2003. *Cape Wind Emissions Displacement Evaluation*, Concord MA.

U.S. Government Printing Office. 2004. *Economic Report of the President 2004*. http://www.gpoaccess.gov/usbudget/fy05/pdf/2004_erp.pdf [Accessed March 20, 2008]

Energy Information Agency. 2004, January. *Annual Energy Outlook 2004 with Projections to 2025.* http://www.eia.doe.gov/oiaf/archive/aeo04/index.html Report #: DOE/EIA-0383(2004) [Accessed March 20, 2008]

Environmental Protection Agency, 1999. "The Benefits and Costs of the Clean Air Act 1990-2010", report to Congress, November 1999. EPA-410-R-99-001. http://www.epa.gov/air/sect812/index.html [Accessed March 20, 2008]

Environmental Protection Agency, 2003. "Benefits and Costs of the Clean Air Act 1990-2020: Revised Analytical Plan for EPA's Second Prospective Analysis" May 12. http://www.epa.gov/air/sect812/index.html [Accessed March 20, 2008]

Giuffre, Douglas. 2003. "Estimating Residential Demand for Electricity," Department of Economics, Suffolk University, Boston.

Global Insight. April 2, 2003. *Economic Impact Analysis of the Cape Wind Off-Shore Renewable Energy Project*, Lexington MA.

Grace, Robert and Karlynn Cory. December 16, 2002. "Massachusetts RPS: 2002 Cost Analysis Update – Sensitivity Analysis", Sustainable Energy Advantage and LaCapra Associates. [PowerPoint slides.]

Gul, Timur and Till Stenzel. June 2005. *Variability of Wind Power and Other Renewables, Management Options and Strategies.* International Energy Agency

Haughton, Jonathan, Douglas Giuffre, and John Barrett. October, 2003. *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Institute at Suffolk University, Boston MA.

Haughton, Jonathan, Douglas Giuffre, John Barrett, and David G. Tuerck. February, 2005. “Comments on the Draft Environmental Impact Statement for the Cape Wind Project,” Beacon Hill Institute at Suffolk University, Boston MA.

Haughton, Jonathan, Douglas Giuffre and David G. Tuerck. March 2004. *Free but Costly: An Economic Analysis of a Wind Farm in Nantucket Sound*, Beacon Hill Institute at Suffolk University, Boston MA..

Haughton, Jonathan and David G. Tuerck. May, 2006. *Subsidies to a Wind Farm in Nantucket Sound*. Beacon Hill Institute at Suffolk University

Haughton, Jonathan and David G. Tuerck. March, 2007. *Comments on "Cape Wind – Public Values and Perceptions" by Eric Steltzer*. Beacon Hill Institute at Suffolk University.

Haughton, Jonathan and David G. Tuerck. March, 2007. *Comments on the Final Environmental Impact Report for the Cape Wind Energy Project*, Beacon Hill Institute at Suffolk University.

Haughton, Jonathan and David G. Tuerck. February 2008. *Comments on the MMS Draft Environmental Impact Statement for the Cape Wind Energy Project*. Beacon Hill Institute at Suffolk University.

ISO New England. *Annual Energy Review 2002*. Accessed 2/24/04.

ISO New England Inc. May, 2006. *2004 New England Marginal Emission Rate Analysis*.

ISO New England Inc. June 11, 2007. *2006 Annual Markets Report.*

ISO New England Inc. Aug 2, 2007. New England Electricity Scenario Analysis.

LaCapra Associates and Sustainable Energy Advantage. 2000. *Massachusetts Renewable Portfolio Standard: Cost Analysis Report*, Boston.

LaCapra Associates. March 4, 2002. “Attachment APNS-N-15” entitled “Estimated Savings from the Cape Wind Project,” (from Karlynn Cory and Douglas Smith)/

Levy, J.I., J.K. Hammitt, Y. Yanagisawa, and J.D. Spengler. “Development of a New Damage Function Model for Power Plants: Methodology and Applications.” *Environmental Science and Technology* 33: 4364-4372 (1999).

Levy J.I. and J.D. Spengler. “Modeling the Benefits of Power Plant Emission Controls in Massachusetts.” *Journal of Air and Waster Management Association* 52: 5-18 (Jan 2002).

Massachusetts Division of Energy Resources. 2008. *Massachusetts Renewable Energy Portfolio Standard: Annual RPS Compliance Report for 2006*. Executive Office of Energy and Environmental Affairs, Boston MA.

Milligan, M.R. 2001. "A Chronological Reliability Model to Assess Operating Reserve Allocation to Wind Power Plants," National Renewable Energy Laboratory, Golden CO.

Moore, John, Carl Behrens and John Blodgett. 1997. Oil Imports: An Overview and Update of Economic and Security Effects, Environment and Natural Resources Policy Division. http://www.ncseonline.org/nle/crsreports/energy/eng-53.cfm?&CFID=12745071&CFTOKEN=232889 [Accessed March 20, 2008]

Musial et al. June 2004. *Future for Offshore Wind Energy in the United States.* National Renewable Energy Laboratory. Internet, available at http://www.nrel.gov/docs/fy04osti/36313.pdf .

npower Renewable Limited. 2006. *North Hoyle – 2nd DTI Operating Report.* http://www.berr.gov.uk/files/file41542.pdf [Accessed March 20, 2008]

Obdam, Tom, et al., 2007 *Estimating Costs of Operation & Maintenance for Offshore Wind Farms*. Presented at the European Offshore Wind Energy Conference, Berlin

Offshore Design Engineering (ODE) Limited. 2007. *Study of the Costs of Offshore Wind Generation*. URN #07/779

Ogden, Joan M., Robert H. Williams, and Eric D. Larson. 2004 Societal Lifecycle Costs of Cars with Alternative fuels/engines. *Energy Policy* 32 (2004) 7-27

Ottinger et al., Pace University Center for Environmental Legal Studies, *Environmental Costs of Electricity* (New York, NY: Oceana Publications, 1990).

PACE| Global Energy Services. 2007. Memorandum: U.S. *Offshore Wind Power Market Assessment and Project Cost Estimate.*

PACE| Global Energy Services. August 2007. *Assessment of Offshore Wind Power Resource*. Prepared for: Long Island Power Authority

Parsons, Brian et al. 2003. "Grid Impacts of Wind Power: A Summary of Recent Studies in the United States," presented at the European Wind Energy Conference, Madrid.

RETScreen International. 2000. *Wind Energy Project Model.* Natural Resources Canada. http://retscreen.gc.ca

Steltzer, Eric. December, 2006. *Cape Wind – Public Values and Perceptions: Application of Contingent Valuation Method*. Submitted in partial fulfilment of M.Sc. degree in Resource Administration Management, University of New Hampshire.

Sterzinger, G. et al. May, 2003. *The Effect of Wind Development on Local Property Values*. Renewable Energy Policy Project.

U.S. Army Corps of Engineers. 2004. *Draft Environmental Impact Statement* [of the Cape Wind Energy Project; Reference file no: NAE-2004-338-1.]

U.S. Congress, Office of Technology Assessment. September 1994. *Studies of the Environmental Costs of Electricity, OTA-ETI-134* (Washington, DC: U.S. Government Printing Office)..

U.S. Department of Energy, Energy Efficiency and Renewable Energy. May, 2007. *Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2006*.

U.S. Department of the Interior, Minerals Management Service. January, 2008. *Cape Wind Energy Project Draft Environmental Impact Statement.* .

U.S. Department of the Interior, Minerals Management Service. 2008. *Appendix F. Economic Model*. Cape Wind Energy Project Draft Environmental Impact Statement.

U.S. Energy Information Administration. *State Electricity Profiles 2006*. http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html [Accessed March 20, 2008]

U.S. Energy Information Administration. 2007. "Electricity Market Module," in *Assumptions to the Annual Energy Outlook 2007.*

U.S. Energy Information Administration. 2008. *Annual Energy Outlook 2008*.

Van Bussel, G.J.W. and Chr. Schöntag. Undated. *Operation and Maintenance Aspects of Large Offshore Windfarms.*

Walford, Christopher A. March, 2006. *Wind Turbine Reliability: Understanding and Minimizing Wind Turbine Operation and Maintenance Costs*, Sandia National Laboratories, Albuquerque, New Mexico

Wiser, Ryan and Ole Langniss. 2001. *The Renewables Portfolio Standard in Texas: An Early Assessment*, Lawrence Berkeley National Laboratory, Berkeley, CA.

About the Beacon Hill Institute

Founded in 1991, BHI is an independent, nonpartisan economic research organization, located within Suffolk University in Boston that applies a market-clearing approach to the analysis of tax, fiscal, environmental, and regulatory issues. In addition to analyzing tax policy, we study issues including education spending, charitable tax incentives, universal health care, tort reform and economic competitiveness. BHI develops innovative solutions and applies economic analysis to public-policy issues affecting the states and the nation.

About the Authors

Jonathan Haughton, CFA, PhD, is Senior Economist at the Beacon Hill Institute and Professor of Economics at Suffolk University. He holds a doctorate in economics from Harvard University and has published widely in refereed journals on economic development, energy, and taxation.

Sarah Glassman, MSEP. Ms. Glassman is Director of Operations at the Beacon Hill Institute. She holds a Master of Science in Economic Policy from Suffolk University.

Michael Head, MSEP. Mr. Head is a Research Economist at the Beacon Hill Institute for Public Policy Research at Suffolk University. He holds a Master of Science in Economic Policy from Suffolk University.