VALUING PUBLIC PREFERENCES FOR OFFSHORE WIND POWER: A CHOICE EXPERIMENT APPROACH

by

Andrew D. Krueger

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Marine Studies.

Fall 2007

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ACKNOWLEDGMENTS

First and foremost, I would like to thank Dr. Jeremy Firestone for his dedicated service as my advisor during my graduate studies at the University of Delaware. His constant support and thoughtful insight has been invaluable, and I owe many thanks to him for encouraging me and inspiring me to conduct high quality dissertation research.

I also would like to thank Dr. Willett Kempton and Dr. George Parsons for the wonderful experiences I have shared during my time in the marine policy program. I have learned a great deal about survey research from Dr. Kempton's vast experience and knowledge, and my dissertation benefited immensely from Dr. Parsons' extraordinary knowledge of econometric choice modeling. I also thank Dr. Rodney Cluck for taking time out of his busy schedule with Minerals Management Service to serve on my committee, and I thank you for your perspective on offshore renewable energy regulation. As committee members, your insights and your advice was more helpful and appreciated than you know.

I would like to thank my family (Mom, Dad, Kelly, Kristen, Amy, Carol, and Cindy) who have supported me throughout the years. My parents have always instilled in me a desire to achieve this degree, and I thank them for their unending support and the high expectations that they have placed upon me. Finally, I want to thank the many friends that I have shared so many good times with over the years. Without all the laughs, school would just be a job.

I dedicate this dissertation to Mom, Dad, and Kelly.

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ABSTRACT

This dissertation research uses a stated preference mail survey to collect data on public preferences for offshore wind development in Delaware. The survey was sent to 2000 randomly selected residents in September, 2006. Response rate was 52 percent.

The primary goal of this research is to shed light on how Delawareans feel about offshore wind development, and more specifically, to value public preferences for different wind development scenarios. This research is the first to use discrete choice mixed logit techniques to examine public preferences for offshore wind power in the United States. Choice experiments are used to predict whether, and if so, how, offshore wind development should proceed in Delaware. Respondents were asked to choose among different offshore wind power scenarios which can differ in five basic characteristics: the location of the wind farm; its distance from shore; the amount of rent/royalty payments made to Delaware; to where those payments would be funneled (e.g. Green Energy Fund, Beach Nourishment Fund, or General Fund); and the amount of a fee, if any, that would be added to consumers' monthly electricity bill for three years.

The data collected in this dissertation research shows overwhelming support for offshore wind power among Delaware residents. Of the approximately 2695 total recorded choice occasions in the dataset, a combined 93 percent chose offshore wind power while 7 percent chose coal or natural gas. While 95 percent of the respondents chose wind power when offered at no cost, more than 91 percent still chose wind power even when told they would have to pay a monthly fee for three years. This suggests that factors other than initial cost may be more important in people's preferences for offshore wind power, such as cleaner air and increased price stability in the long-term.

Results indicate there will be significant social benefits associated with moving wind turbines offshore to reduce visual impacts. Statewide, Delaware residents are willing to pay a

grand total of $132, $181, $219, $247, $268 and $296 million dollars to move turbines out from a baseline of 0.9 miles to 3.6, 6, 9, 12, 15, and 20 miles, respectively. Moreover, simulation results indicate a willingness to pay of between $45 and $50/month/household for three years for wind power projects located off the Delaware coast. When aggregated over the total number of households in the State, Delaware residents as a whole show a total willingness to pay of between $500 million and $555 million for wind power projects to be located in Delaware Bay, off of Rehoboth Beach, or off of Fenwick Island, versus expansion of coal or natural gas power.

CHAPTER 1

INTRODUCTION

1.1 Goals and Policy Significance

The primary goal of this dissertation research is to shed light on how coastal residents feel about offshore wind development, and more specifically, to value public preferences for different wind development scenarios. This research is the first to use stated preference methods to examine public preference for offshore wind power development in the United States. Choice experiments are used to predict whether, and if so, how, offshore wind development should proceed in Delaware. Such analysis is timely as State and Federal agencies are currently making decisions about offshore wind power in several states in this region, including Delaware, where policymakers are deciding whether a new natural gas power plant, coal gasification power plant, or offshore wind power facility will be built to supply Delaware's future electricity needs. Public opinion is one of several factors considered in these important decisions.

1.2 A Climate Change Perspective—Wind as One Part of the Solution

There is no doubt that, throughout time, human activity has negatively impacted Earth's ecosystems. Increasing greenhouse gas (GHG) emissions from anthropogenic sources (most notably electricity production, transportation, and land-use) also have begun to impact the world's oceans and climate.[1] Fossil-fueled electricity generation is known to cause air pollution, carbon dioxide emissions, land disturbance, fisheries impacts, acid deposition, and human health impacts, among others. Sea level rise, ocean acidification, and threats to marine species have

[1] For a good discussion on the causes and consequences of climate change, see the Royal Society's "Climate Change" web site at http://www.royalsoc.ac.uk/landing.asp?id=1278; accessed 3/15/2007.

emerged as potentially devastating direct consequences of increased CO_2 emissions, and humanity must address these concerns if we are to change the course of our oceans' future.

Although some would argue that the scientific community lacks sufficient evidence to draw a definitive causal link between human activity and climate change, it has become quite clear that the majority of reputable scientists worldwide believe that existing evidence and years of ongoing research shows that human activity has increased atmospheric CO_2 and other greenhouse gases, and this in turn has directly caused—and will continue to cause—warming over the coming decades, if not centuries. As the Stern (2006) report notes, "the scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response."

Recently the Intergovernmental Panel on Climate Change (IPCC)[2] released its summary findings[3] for policymakers for its "Climate Change 2007" report, due out in November 2007. The full report will be the IPCC's fourth assessment on climate change. In its summary findings for policymakers, the IPCC discusses trends in GHG emissions, warming trends, climate events, and presents model findings for future global temperature trends. A few key points from the summary findings are:

- The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years. The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use.
- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.
- Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.
- Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century.

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[2] See the IPCC web site at http://www.ipcc.ch/; accessed 3/15/2007.

[3] Summary findings available at http://www.ipcc.ch/SPM2feb07.pdf; accessed 3/15/2007.

With increased confidence in the causal link between anthropogenic GHG emissions and climate change, policymakers should take the opportunity to enact appropriate policies that will help address the pressing issue of climate change and its global consequences. Simmonds and Isaac (2007) note that, while the scientific evidence is clear that climate change is in part anthropogenically forced, "what is less clear is to what extent climate change is being factored into plans for nature conservation, and this is particularly lacking in the context of the marine environment" (p24). This is an important point, considering projected increased CO_2 emissions will only serve to magnify the effects and consequences of predicted sea level rise (IPCC, 2007), destruction of the ocean's coral reefs and shellfish via ocean acidification (The Royal Society, 2005), and various disturbances to marine mammals, including reduced population sizes, changes in predator-prey relationships, distribution shifts, and impact on breeding success (see Simmonds and Isaac, 2007). Indeed, the recently proposed rule to list the polar bear under the Endangered Species Act by the U.S. Fish and Wildlife Service—an action necessitated by the effects of climate change and sea ice change on the distribution and abundance of polar bears and their principal prey—serves as a stark reminder of just how far human impacts can reach (See WWF, 2002; USFWS, 2007).

From an environmental policy perspective, wind offers a way to provide us more energy with minimal environmental impact. Kempton et al. (2007) found that the Middle-Atlantic Bight wind resource, from Massachusetts to North Carolina, can produce 330 GW average electrical power, and by matching this power to different end uses, the MAB wind power would reduce by 68% the region's CO_2 emissions, and reduce by 57% its greenhouse gas forcing. Recognizing that the yet undeveloped global offshore wind energy resource is large enough to supply a significant fraction of the world's energy needs, perhaps the use of offshore wind power is one part of the solution to decreasing global GHG emissions. Indeed, many European countries have embraced offshore wind development, and although the U.S. has been slower in its adoption of offshore wind, land-based wind power capacity is increasing at an astounding rate, and various offshore proposals are under consideration in multiple coastal states. The offshore sector of the wind industry certainly has massive potential for growth in the U.S.—

provided that wind developers are successful in overcoming the various obstacles they face, such as public opposition, political and regulatory obstacles, and lack of financial incentives.

1.3 Potential for Wind Power in Delaware

Wind power is both technically feasible and commercially available. Currently in the U.S. land-based wind power capacity stands at over 11,600 megawatts (MW), well enough to power over 2.9 million average American homes; this, however, represents less than 1% of the nation's electricity requirements.[4] Although there are no offshore projects operating in the U.S., the recognition that coastal waters offer a strong wind resource has sparked an interest among a number of states that need to increase their electricity supply to meet future demands while at the same time meeting renewable energy portfolio standards.[5]

Recently researchers at the University of Delaware have examined Delaware's offshore wind resource potential. Results indicate Delaware has a significant offshore wind resource, with more than enough to provide all of Delaware's electricity needs. Dhanju et al. (2007) provide the first in-depth look at offshore wind energy potential in Delaware Bay and off the Delaware Atlantic coast. After mapping the total available area, delimiting bathymetric areas based on current wind turbine tower technology, and excluding competing uses of the ocean zone, they report a wind energy resource of 7,412 MW (in average production), more than five times the amount needed to meet the State's 1,300 MW average use. Table 1.1 presents the findings, taking into account exclusion zones and capacity factors.

For Delaware, and the U.S. as a whole, offshore wind power is currently the only cost-competitive, renewable, non-CO_2 producing energy source large enough to become a significant fraction of the electric supply. Although offshore wind could provide a number of short term and long term benefits (including alleviated congestion of electric transmission,

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[4] See http://www.awea.org for the most recent statistics on installed wind power capacity.

[5] Renewable portfolio standards are laws that states pass requiring a utility to generate a certain percent of electricity using renewable energy sources by a given date. The Pew Center on Global Climate Change keeps an inventory of states that have passed renewable portfolio standards at: http://www.pewclimate.org/what_s_being_done/in_the_states/rps.cfm.

reduced criteria pollutants from electric generation, direct employment, and reduction in CO_2 and other greenhouse gases), a number of

Table 1.1 Delaware offshore wind resource to 50 m depth

Location	Area (km^2)	Max Turbines	Installed Capacity	Capacity Factor	Average Power Production
Delaware Bay	504	933	3,359	.36	1,209
Atlantic Ocean	2,386	4,418	15,905	.39	6,203
Total	2,890	5,351	19,264		7,412

Source: Dhanju et al. (2007, p25)

obstacles, as noted above, could prevent the development of wind power in Delaware. The prospects for offshore wind power in Delaware, however, have recently become clearer. In response to a 2006 Delaware State law (House Bill No. 6),[6] which resulted in Delmarva Power & Light's[7] RFP for a new power plant in Delaware, Bluewater Wind, LLC[8] has proposed to build a 600 MW facility off of Delaware's Atlantic Coastline. At the completion of a competitive biding process ending in May 2007, Delaware's Public Service Commission, and three other State agencies, granted Bluewater Wind the right to negotiate a long-term power purchasing agreement with Delmarva Power & Light. Once these power purchasing negotiations are complete, the State agencies will make a final decision on whether or not to approve the proposed offshore wind power project off the Delaware Atlantic coast.

[6] See State of Delaware House Bill No. 6 at: http://www.legis.state.de.us/LIS/lis143.nsf/vwLegislation/HB+6/$file/legis.html?open; accessed July 29, 2007.

[7] Delmarva Power & Light: http://www.delmarva.com/home/

[8] Bluewater Wind: http://www.bluewaterwind.com/index.htm

1.4 Research Design

This dissertation research uses a stated preference mail survey to collect data on public preferences on offshore wind development in Delaware. The survey was sent to 2000 randomly selected residents in September, 2006. Each survey packet included (1) a cover letter addressed to the selected respondent describing the survey and why their participation was important, (2) the survey, (3) a map and photo simulation prop, and (4) a stamped return envelope with the College's address. A random stratified sample was drawn from three strata, named "Bay," "Ocean" and "Inland." Bay includes 400 selected respondents living along Delaware Bay in Kent and Sussex Counties; Ocean includes 400 selected respondents living along the Delaware Atlantic coastline in Sussex County; Inland includes 1,200 selected respondents throughout the whole of Delaware, excluding any individuals living within the selected Bay and Ocean strata.

The survey itself has four general sections. The first section asks respondents about their attitudes and opinions concerning wind power and the possibility of having offshore wind power in Delaware. The second section contains the choice experiment questions in which respondents are asked to choose among different offshore wind power scenarios which can differ in five basic characteristics: the location of the wind farm; its distance from shore; the amount of rent/royalty payments made to Delaware; to where those payments would be funneled (e.g. Green Energy Fund, Beach Nourishment Fund, or General Fund); and the amount of a fee, if any, that would be added to consumers' monthly electricity bill for three years. The third section gathers data on respondents' beach-going habits in Delaware, and how those beach-going habits might change with the presence of a visible wind farm off the coast. The final section of the survey collects demographic data for statistical analysis of the survey responses.

In the choice experiment section of the survey each respondent faced three hypothetical referendum questions (questions 17, 18, and 19). In each question respondents voted on one of two different wind development scenarios; respondents also could "opt out" by voting for a status quo option of expanding natural gas or coal power rather than wind power

development. Modeling the choice data from these three questions is the focus of this dissertation.

1.5 Description of Chapters

Chapter Two opens with a general discussion on current energy production statistics in the United States and in Delaware. A brief history of wind power is then presented, followed by a global snapshot of wind power capacities, both onshore and offshore. The chapter closes with an overview of the current regulatory regime for wind in the U.S.

Chapter Three discusses the wind power "debate," including a review of two recent public opinion surveys conducted in Cape Cod and New Jersey regarding offshore wind, and a comparison of impacts among different sources of energy production.

Chapter Four provides an overview of stated preference (SP) methodology, choice experiments (CE), and recent SP studies related to wind power. The purpose of this chapter is to give the reader sufficient background to understand why SP methodology is appropriate for this dissertation research.

Chapter Five describes the survey development and pilot testing, survey administration and sampling, the experimental design of the choice experiments, and the choice experiment mixed logit random utility model.

Chapter Six presents selected survey descriptive data results, including information on survey response rate and respondent demographic data.

Chapter Seven presents the choice experiment modeling results, simulation results, and welfare estimation results.

Chapter Eight discusses the policy implications of the dissertation research results and offers final thoughts and conclusions.

CHAPTER 2

ENERGY PRODUCTION, WIND POWER AND REGULATION

2.1 Introduction

Chapter Two opens with a general discussion on current energy production statistics in the United States and in Delaware. A brief history of wind power is then presented, followed by a global snapshot of wind power capacities, both onshore and offshore. The chapter closes with an overview of the current regulatory regime for wind in the U.S.

2.2 Electricity Production in the U.S.

The U.S. energy production picture has not changed much over the past fifty years; while energy demands have steadily increased, fossil fuels have consistently remained the dominant form of energy production, followed by nuclear and renewable energy sources. Although natural gas and crude oil were the primary sources of energy between 1960 and 1980, coal has remained the largest primary source of energy generation for the past 26 years. Figure 2.1 shows energy production by major source from 1949-2005.

The Energy Information Administration[9] reported 69.165 quadrillion Btu's of energy produced from all sources in 2005.[10] Total fossil fuel production equaled 54.971 quadrillion Btu's, nuclear accounted for 8.133 quadrillion Btu's, and renewable sources combined for a total of 6.061 quadrillion Btu's. Coal was the largest primary source of energy production and solar was the smallest source. Table 2.1 lists energy sources and associated production in 2005.

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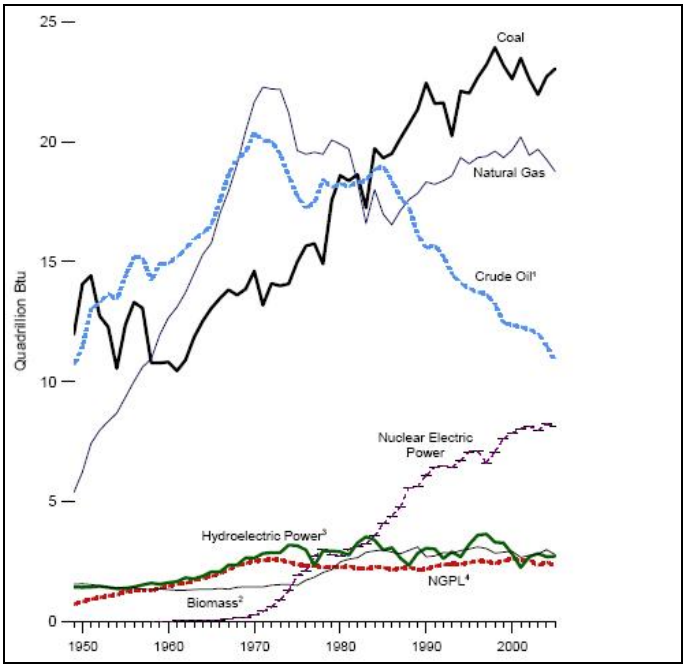
[9] The Energy Information Administration (EIA) is a statistical agency within the U.S. Department of Energy that compiles official energy statistics. See http://www.eia.doe.gov for more information.

[10] See http://www.eia.doe.gov/emeu/aer/txt/ptb0102.html; accessed November 1, 2006.



Source: http://www.eia.doe.gov/emeu/aer/pdf.gif

Figure 2.1 Energy production by major source, 1949-2005

2.3 Energy Production in Delaware

As of 2004, Delaware's net summer generation capacity equaled 3,428 megawatts (MW). Delaware ranked 43rd in the nation in electricity retail sales in 2004, producing 11.76 million MWh of electricity.[11] Dividing this number by 8760 hours (the number of hours in one year), Delaware's average power consumption is 1342 MW. The top five distributors of electricity in Delaware are Delmarva Power and Light Company

[11] See http://www.eia.doe.gov/cneaf/electricity/st_profiles/delaware.html; accessed November 1, 2006.

Table 2.1 Total U.S. energy production by source in 2005 (Quadrillion Btu)

Category	Energy Source	Quadrillion Btu[a]	Percent Total
Fossil Fuels	Coal	23.046	33.32
	Natural Gas	18.761	27.13
	Oil	10.840	15.67
	NGPL	2.323	3.36
	Total fossil fuels	54.971	79.48
Nuclear	Nuclear	8.133	11.76
Renewable Energy	Hydro-electric	2.715	3.93
	Biomass	2.781	4.02
	Geothermal	0.352	0.51
	Solar	0.064	0.09
	Wind	0.149	0.22
	Total renewables	6.061	20.52
	Grand Total	69.164	100

Adapted from: http://www.eia.doe.gov/emeu/aer/txt/ptb0102.html
[a] 1 btu = 0.000293 kWh

(8 million MWh), Delaware Electric Coop Inc (1 million MWh), City of Dover (0.74 million MWh), City of Newark (0.39 million MWh), and Select Energy (0.32 million MWh).[12] Similar to the U.S. energy picture (see Table 2.1), coal and natural gas are the two largest fuels for electric generation in Delaware. In 2004, coal accounted for 60.5% of Delaware's electric production, natural gas accounted for 21.8%, and petroleum accounted for 13.9% of Delaware's electric production.[13]

Table 2.2 shows Delaware's electric power generation by primary source in 2004. Renewable energy is so small that it rounds to zero in the table. In July 2005, the Delaware State legislature passed the Renewable Energy Portfolio Standards Act, which established renewable energy phase-in obligations for all electricity suppliers, beginning in 2007.[14] By 2019, retail electricity suppliers and municipal electric companies must produce at least 10% of their

[12] See http://www.eia.doe.gov/cneaf/electricity/st_profiles/sep2004.pdf; accessed November 1, 2006.

[13] See http://www.eia.doe.gov/cneaf/electricity/st_profiles/sep2004.pdf; accessed March 11, 2007.

[14] See http://www.state.de.us/delpsc/electric/delrps.shtml; accessed November 6, 2006.

electricity to meet the renewable portfolio standard requirements. In 2007, this level was updated to 20%. The Act also establishes incremental penalties to be paid by suppliers on a per MWh basis for those who do not meet the annual obligations. In addition to newly adopted RPS requirements, Delaware recently became a participating member of the Regional Greenhouse Gas Initiative (REGGI), a cooperative effort by nine Northeast and Mid-Atlantic states to design a regional cap-and-trade program aimed at reducing CO_2 emissions from power plants.[15]

Table 2.2 Delaware electric power energy generation by primary source, 2004 (megawatthours)

Source	2004	Percent Share in 2004
Coal	4,750,119	60.5
Petroleum	1,091,341	13.9
Natural Gas	1,714,762	21.8
Other Gas	299,329	3.8
Other Renewable	0	0

Source: http://www.eia.doe.gov/cneaf/electricity/st_profiles/sep2004.pdf

2.4 Wind Power: A Brief History

The concept of harnessing the power of wind is at least 1100 years old. The first windmills on record were built by the Persians in approximately 900 AD, and by the Middle Ages using wind energy was common across Europe (Manwell et al., 2006). The typical European windmill consisted of four blades built on wooden posts which could be turned to face the wind, and these structures were used for a variety of mechanical tasks, including pumping water, grinding grain, powering tools, and sawing wood (ibid). Wind continued to be a major energy source throughout Europe up until the Industrial Revolution, when coal's advantages of transportability and load matching diminished wind energy's importance (ibid).

The idea of using wind energy to produce electricity began in the late 19th Century. Charles H. Brush was one of the earliest wind power pioneers, building the first turbine for

[15] See http://www.rggi.org/index.htm; accessed June 26, 2007.

electrical generation in Cleveland, Ohio in 1888 (DWIA, 2006). The Brush turbine was larger than any other turbine constructed in that period, with a diameter of 17 meters and 144 cedar blades (ibid). Although the Brush turbine operated for some twenty years, its design never resulted in any trends, and it was the Dane Poul la Cour who later determined that faster rotating turbines with fewer blades were more efficient at producing electrical power (ibid). Throughout the remainder of the 20th Century, a number of wind manufacturers continued to improve on the early designs, leading to modern turbines with larger capacity, more efficient designs and more advanced features. McGowan and Connors (2000, p191) note, "[t]he beginning of the 21st century sees the wind power industry moving ahead, with manufacturers of wind turbines producing more mature and robust technologies."

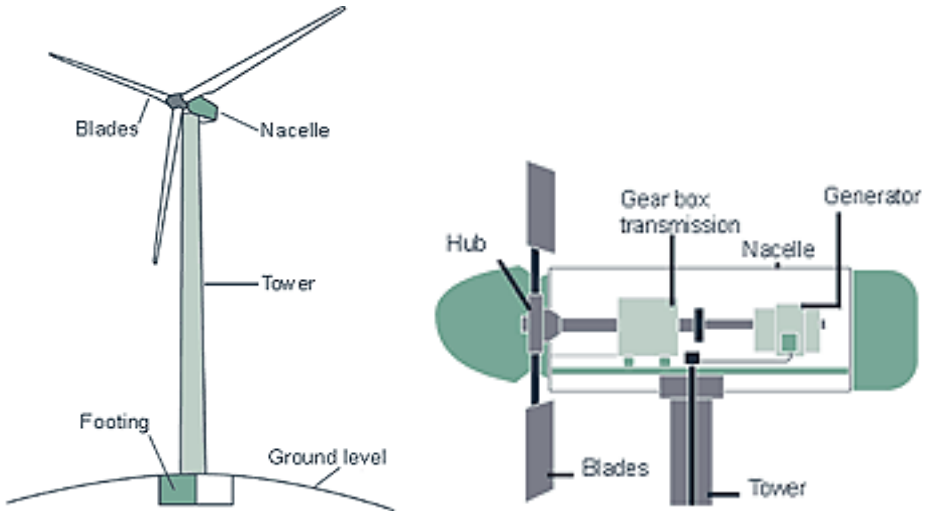
2.5 Wind Power Today

Although the basic concept of capturing energy from the wind has remained unchanged, modern wind turbines are far more advanced than the early designs. Automated controls, advanced blade designs and gear systems, and composite materials have increased the cost efficiency and reliability of wind power. The typical wind turbine consists of a rotor (the hub and blades of the turbine), a drive train (the rotating parts of the turbine, including the drive shaft and gearbox), a generator, a nacelle and yaw system (allows for the protection, mounting, and proper alignment of the drive train system), a tower and foundation, and various controls (Manwell et al., 2006). Figure 2.2 shows a typical wind turbine tower, blade, and nacelle assembly.

Wind turbines come in a variety of sizes and generation capacities. Today's turbines generally possess a generating capacity of 500 kW to 3 MW. The main U.S. manufacturer, General Electric, is currently designing a 5 MW unit to be used exclusively offshore. Repower Systems,[16] a German-based company, already has a 5-MW offshore unit operating, and is preparing to install six new 5-MW turbines for the German "Borkum West" wind farm by 2008.

[16] See http://www.repower.de/index.php?id=347&L=1

For a more detailed discussion of the technical aspects of wind turbine technology and design, refer to Manwell et al. (2006) and McGowan and Connors (2000).

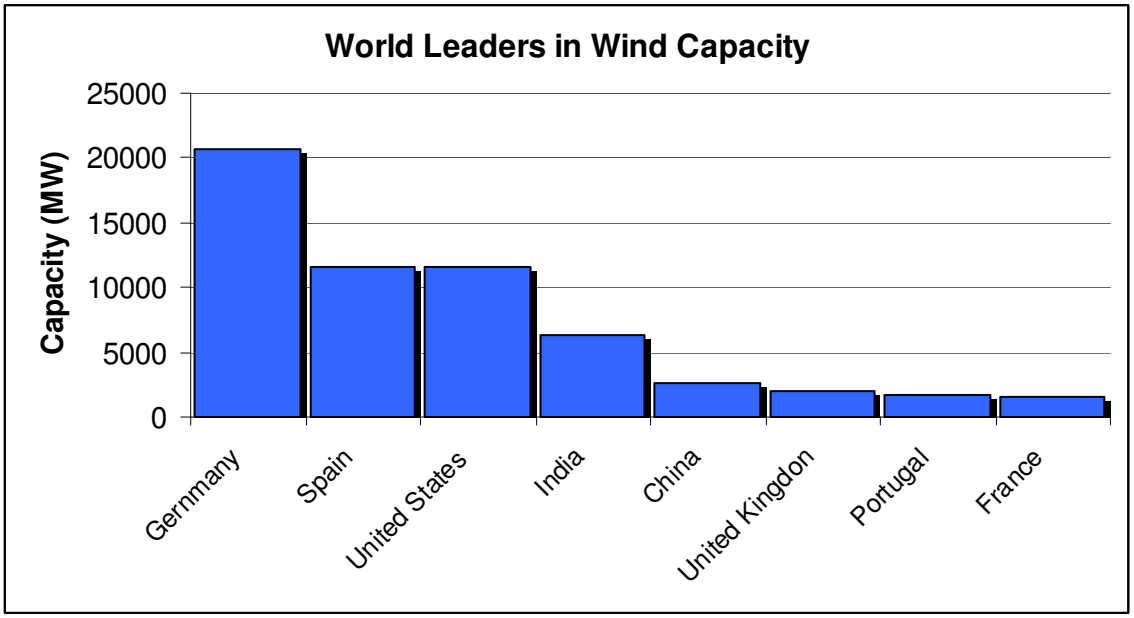


Source: http://www.deus.nsw.gov.au/energy/Renewable%20Energy/Wind.asp#P10_962

Figure 2.2 Typical wind turbine tower, blade, and nacelle assembly

2.5.1 Total Capacity

Wind power capacity has been increasing steadily over the past few decades, both globally and within the U.S. By the end of 2006, over 85,000 turbines were operating in 50 countries, putting global capacity at more than 59 GW (GWEC, 2007). Figure 2.3 lists global leaders in total wind power capacity as of 2006. Germany led all nations with wind power capacity at 20,622 MW, while the U.S. was third, just behind Spain, with 11,603 MW installed capacity. It is worth noting that although Denmark falls behind Germany, Spain, and the United States in total wind power capacity, approximately 20% of all Denmark's power consumption is supplied from wind power, and by 2008 this is projected to reach 25% (DWIA, 2006).

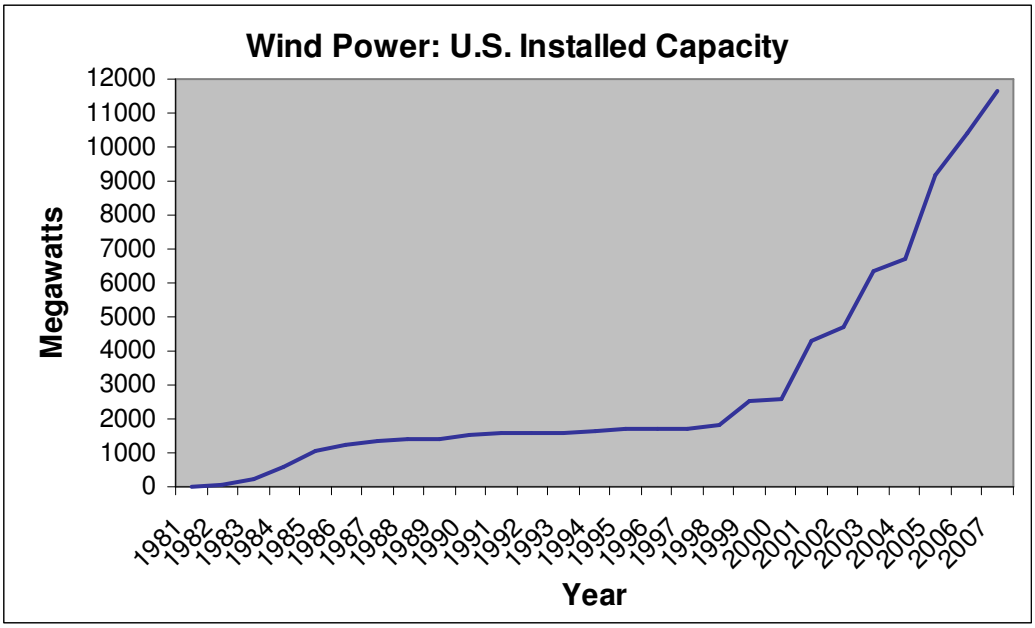


Source: http://www.gwec.net/fileadmin/documents/Publications/gwec-2006_final_01.pdf

Figure 2.3 World Leaders in Wind Energy Capacity, 2006

As of December 31, 2006, forty US states were operating wind energy projects for a total capacity of 11,603 MW,[17] although as previously mentioned, this represents less than 1% of the total energy production from all sources. AWEA reports another 5,000 MW in US capacity will be added over the next five years. Figure 2.4 maps the total US installed capacity between 1981 and 2007.

[17] AWEA maintains a state-by-state listing of all current wind energy projects and capacities at http://www.awea.org/projects/index.html



Adapted from: http://www.awea.org/faq/instcap.html

Figure 2.4 Total US installed wind power capacity, 1981-2005

According to the U.S. Department of Energy, wind facilities produced over 14 billion kilowatt-hours of electricity in 2004, up from only 5 billion kilowatt-hours in 2000. The over 11,600 MW installed wind power capacity today supplies enough electricity for some 2.5 million average American households (AWEA, 2006). For a comparison with other renewable energy sources, Table 2.3 presents total installed renewable energy production capacity for years 2000-2004.

Table 2.3 U.S. electric net summer capacity (megawatts)

Source	2000	2001	2002	2003	2004	% Total in 2004
Biomass	10,016	9,709	9,689	9,674	9,709	10.01
Geothermal	2,793	2,216	2,252	2,133	2,133	2.20
Hydro-electric	79,359	79,484	79,354	78,694	78,703	81.18
Solar	386	392	397	397	397	0.41
Wind	2,377	3,864	4,417	5,995	6,010	6.20
Total renewable	94,931	95,664	96,109	96,893	96,952	100
Total nonrenewable	716,788	752,590	809,193	851,553	870,943	
Grand total	811,719	848,254	905,301	948,446	967,895	

Source: http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table12.html

2.5.2 Offshore Wind Power Capacity

The first offshore wind turbine—a 220 kW unit—was installed in 1991 off the coast of Sweden (Junginger et al., 2004). To date offshore wind energy accounts for a very small fraction of the total installed wind capacity. Currently twenty six projects in eight different countries are producing 3.29 billion kWh of electricity, with a total installed capacity of 918 MW.[18] Denmark currently operates the world's two largest offshore wind farms, Horns Rev[19] (80 turbines with 160 MW total capacity) and Nysted[20] (72 turbines with 165 MW total capacity).

2.5.3 Offshore Wind Projects in the U.S.

While Europe has been steadily increasing its offshore capacity, the United States has yet to develop any offshore wind facilities. Currently, however, there are offshore wind projects in the proposal and/or permitting stage. The Cape Wind project and the Long Island Offshore Wind Park (LIOWP) are the first two U.S. projects to file complete permit applications.

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[18] For a complete up-to-date listing of all operating and planned offshore wind projects see http://home.wxs.nl/~windsh/offshore.html

[19] See http://www.hornsrev.dk/Engelsk/default_ie.htm for more information.

[20] See http://uk.nystedhavmoellepark.dk/frames.asp for more information.

The Texas Land Office is the first state agency to enter into lease agreements with private developers for offshore wind farms, and Delaware recently completed a competitive bidding process for new power generation from coal, natural gas, or offshore wind, with the Bluewater Wind bid being selected as the lead bidder to enter into power purchasing agreements with Delmarva Power & Light.

The Cape Wind Project,[21] proposed by the private developer Energy Management Inc., is currently undergoing the Environmental Impact Statement (EIS) review process required under the federal National Environmental Policy Act of 1969, as well as other various permitting requirements required by Massachusetts State law. The project will place 130 - 3.6 MW turbines that stand 440 feet high in Horseshoe Shoal in Nantucket Sound, approximately 4.7 miles from the closest shoreline on Cape Cod. The project's maximum rated capacity is 468 MW, and with an average anticipated production 170 MW, or almost 75% of the 230 MW average electricity demand of Cape Cod and the Islands, or 10% of the demand of the entire state of Massachusetts. The first draft EIS was issued by the then lead agency U.S. Army Corps of Engineers (USACE) in November 2004. A second draft EIS is to be issued by Minerals Management Service (MMS) this summer, with a final EIS due out in fall 2008.

Another wind farm project has been proposed off New York's Atlantic coast. Unlike the Cape Wind project, this project was proposed by a state power authority. The Long Island Power Authority (LIPA), Long Island's primary electric supplier, has contracted with Florida Power & Light Energy (FPL is the largest wind energy developer in the U.S.) to develop, build and operate the Long Island Offshore Wind Park.[22] Consisting of forty 3.6 MW turbines and a rated capacity of 140 MW, the project stands to be one of New York's largest renewable energy projects. Turbines will be sited 3.6 to 5.5 miles offshore. NEPA compliance is currently underway for this project, and should be completed in 2007.

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[21] See http://www.capewind.org for more information about the project.

[22] See http://www.lipower.org/cei/offshore.html for more information about the LIPA offshore wind project.

The Texas General Land Office, which is responsible for leasing out the State's land and mineral resources, recently approved lease agreement for two offshore wind farms. In October 2005, Texas became the first state to enter a lease agreement with a private developer for testing and construction of an offshore wind facility.[23] The 2005 agreement leases some 11,355 acres of Gulf of Mexico seabed to Galveston Offshore Wind, LLC, for a planned 150 MW wind farm off of Galveston Island.

After a dramatic price increase shocked many Delaware Delmarva Power & Light electric consumers in 2006, the Delaware legislature passed House Bill No. Six,[24] requiring Delmarva Power[25] to seek bids for new power sources. In response to Delmarva's RFP for a new power plant in Delaware, Bluewater Wind LLC proposed to build a 600 MW facility off of Delaware's Atlantic Coastline.[26] In May, 2007, upon completion of a competitive bidding process, Bluewater Wind was awarded the right to enter into negotiations with Delmarva Power. It is worth noting that this is the first time offshore wind power has competed on equal terms with coal and natural gas in a competitive bidding process for new power generation.

2.6 Regulatory Overview of Land-based Wind Power in the U.S.

The regulatory process for land-based wind power in the U.S. is straightforward, although it does involve a host of different players, including land owners, private developers, utilities, state and local governments, and the federal government, among others. The typical wind developer is required to obtain permits from multiple government agencies at the local, state or federal level, and the number of agencies involved and the level of jurisdiction will

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[23] See press release at http://www.glo.state.tx.us/news/archive/2005/jpgs/Offshore-FINAL-PR-10-24-05.pdf ; accessed November 1, 2006.

[24]See State of Delaware House Bill No. 6 at: http://www.legis.state.de.us/LIS/lis143.nsf/vwLegislation/HB+6/$file/legis.html?open; accessed July 29, 2007.

[25]Delmarva Power & Light: http://www.delmarva.com/home/

[26] Bluewater Wind: http://www.bluewaterwind.com/index.htm

depend of a number of pre-existing factors, such as ownership of the land, ownership and size of the project, and the existing laws and regulations (Firestone et al., 2004; NWCC, 2002).

Local level regulations are usually in the form of zoning ordinances and building permit codes. At the state level, the environmental or natural resource agency typically takes the lead in coordinating a project review, with input from local jurisdictions, utility commissions, the state's energy office and state historic preservation offices (ibid). The federal government also can be involved in the review and leasing process, notably when such projects are placed on Federal lands. For example, the U.S. Department of Interior (DOI), Bureau of Land Management (BLM), currently leases approximately 50,000 acres of federal lands under twenty-two right-of-way grants for wind energy production in California and Wyoming, with over 500 MW of installed wind power capacity (BLM, 2005a). An additional nine right-of-way authorizations have been granted for wind energy testing and monitoring sites in Idaho, Nevada, Oregon and Washington, and sixty new applications have been recently filed in California, Wyoming, Nevada, Idaho, Arizona, Utah and New Mexico (ibid). Also, power marketing agencies that operate under the U.S. Department of Energy are involved in either wind power development or the purchasing of electricity from wind power projects (Firestone et al., 2004). For example, the Bonneville Power Administration, which supplies most of the energy to the Pacific Northwest, incorporates electricity from five different wind power projects into its grid for marketing and distribution (ibid).[27]

In 2005 the DOI issued its Record of Decision (ROD) to implement a comprehensive Wind Energy Development Program and amend fifty-two BLM land use plans (BLM, 2005b). The program and proposed amendments were evaluated through the preparation of the Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western United States, a process initiated to address the impacts of future wind developments on public lands (BLM, 2005a). All wind energy projects on federal

[27] See Bonneville Power Administration, Wind Projects, at http://www.bpa.gov/power/pgc/wind/wind.shtml; accessed 12/14/2006.

lands must be applied for under Title V of the Federal Land Policy and Management Act of 1976, as well as Title 43, Part 2800 of the Code of Federal Regulations. Under the BLM program, wind developers apply for energy right-of-way grants for three different types of energy projects: a site-specific wind energy site testing and monitoring right-of-way grant for individual meteorological towers and instrumentation facilities with a term that is limited to three years; a wind energy site testing and monitoring right-of-way grant for a larger site testing and monitoring project area, with a term of three years that may be renewed; and a long-term commercial wind energy development right-of-way grant with a term that is not limited by the regulations, but usually in the range of 30 to 35 years (BLM, 2006c). The program also stipulates financial bond requirements and annual rental fees to be paid by the developer based on the total number of instrumentation facilities or towers installed, total number of wind turbines installed, total generation capacity, and acreage, depending on the type of grant applied for (ibid). More detail can be found in BLM's Instruction Memorandum[28] for providing guidance for implementation of DOI's ROD.

2.7 Regulatory Overview of Offshore Wind Power in the U.S.

Agencies like DOI's Bureau of Land Management and Minerals Management Service (MMS) have long had the responsibility to manage energy and minerals resources on public lands, both onshore and offshore, respectively. Today's jurisdiction for federal waters was established by the U.S Submerged Lands Act of 1953 (SLA). The SLA effectively modified a seminal decision by the Supreme Court in *United States v California*, which had confirmed the federal government's ownership of the submerged lands and associated natural resources in oceanic waters. The SLA, however, gave states exclusive rights to these resources and ownership of submerged lands out to three nautical miles.[29] The Outer Continental Shelf Lands Act (OCSLA) also was passed, authorizing the Secretary of the Interior to lease OCS lands beyond

[28] See http://www.blm.gov/nhp/efoia/wo/fy06/im2006-216.htm; accessed November 6, 2006.

[29] See 43 U.S.C. §§1301-1315

three nautical miles for mineral development.[30] In 1982 Congress passed the Federal Oil and Gas Royalty Management Act, and the Secretary designated a new agency—Minerals Management Service—responsible for overseeing the leasing of federal lands for minerals rights and royalty production.

Although MMS has managed oil, gas, and other mineral activities on offshore Federal lands since its creation in 1982, there has been a glaring lack of any framework for regulating new uses of the ocean in Federal waters, including offshore wind energy and aquaculture, among others (Firestone et al., 2004). The lack of a clear offshore policy regarding new uses of the coastal zone has caused concern—and sometimes confusion—in the ocean policy sector. Firestone et al. (2004, p74) note, "without a policy framework in place, new uses—even ones that in the abstract hold as much popular appeal as offshore wind power production—will lack full legitimacy and face difficulty negotiating a variety of environmental, social, and political obstacles that are likely to affect both their public perception and economic viability." The U.S. Commission on Ocean Policy also has recognized that, as a result of the lack of a comprehensive offshore framework, "the nation runs the risk of unresolved conflicts, unnecessary delays, and uncertain procedures" (U.S. Commission on Ocean Policy, 2004, p 320). In addition, Firestone at al., 2004 (p 82) point out the "hodgepodge of legislation and jurisdiction" can cause competition among federal agencies such as USACE, MMS, NOAA, and EPA when coordination is needed to address concerns from new offshore uses.

Until recently, the U.S. Army Corps of Engineers was tasked with overseeing the permitting process for offshore wind development, based on its authority under Section 10 of the Rivers and Harbors Act of 1899 to protect the navigability of U.S. waterways. In amending Section 8 of the OCSLA, the Energy Policy Act of 2005[31] has recently given some clarity on the issue of regulatory jurisdiction of new uses of the coastal zone. Section 388 of the Act authorizes DOI to grant leases, easements, or rights-of-way on the U.S. Outer Continental Shelf for the

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[30] See 43 U.S.C. §§1301 *et seq.*

[31] See 42 U.S.C. §15801 et seq.

development of renewable energy and for alternate uses of existing structures.[32] This section also authorizes the Secretary to establish royalty payments for energy projects on the OCS. DOI has delegated its authority to MMS to serve as the lead agency in Federal offshore renewable energy projects. In the near term, this means MMS will assumes oversight of existing renewable energy projects, most notably the Cape Wind and LIOWP offshore wind projects.[33] In the long term, however, MMS must develop a comprehensive program to manage and integrate new and existing uses of offshore resources.

MMS is currently preparing a programmatic EIS for its Alternative Energy-Related Use program, to ensure NEPA consistency. The Draft EIS, issued in March, 2007, focuses on the potential environmental effects of MMS implementing its Alternative Energy-Related Use Program and associated rulemaking.[34] Under this program, MMS will have jurisdiction over alternative-energy related projects on OCS lands such as wind power, wave energy, ocean current technology, and projects that make alternative use of existing natural gas and oil platforms.[35] The Final EIS is due out in August of 2007.

It is interesting to note that FERC (Federal Energy Regulatory Commission) also may have a jurisdictional role in the permitting and licensing process of alternative offshore energy projects. For example, in *AquaEnergy Group Ltd v. FERC* (still pending), FERC has asserted jurisdiction over an offshore underwater hydroelectric project off of Washington State. The Makah Bay Project, proposed by AquaEnergy, would place a string of underwater buoys in the waters of the Olympic Coast National Marine Sanctuary for the purpose of electricity

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[32] This authorization does not extend to any area located within the external boundaries of the National Park System, the National Wildlife Refuge System, the National Marine Sanctuary System, or any National Monument.

[33]See http://www.mms.gov/ooc/PDFs/AlternateEnergy-relatedUsesontheOCS.pdf; accessed 6/26/2007.

[34] Available at http://ocsenergy.anl.gov/documents/dpeis/index.cfm; accessed 6/26/2007.

[35] See http://ocsenergy.anl.gov/index.cfm; accessed 12/14/2005.

generation.[36] AquaEnergy asserts that the project is exempt from regulation under Part 1 of the Federal Power Act, while FERC maintains the project is subject to regulation and its licensing authority.[37]

The permitting of any offshore facility is a complicated matter which involves coordination among many federal and state agencies. Permitting new uses of the ocean zone can be even more difficult, as Firestone et al. (2004, p72) note, "any attempt to develop the promise of these new uses requires the government to spin together a hodgepodge of laws that were enacted prior to the development of these technologies and…without the benefit of having them in mind." The following list contains a number of potentially applicable federal laws and regulations during the permitting process of an offshore wind facility (from Firestone et al. 2004; Jarvis 2005):

- Endangered Species Act
- Marine Mammal Protection Act
- Migratory Bird Treaty Act
- National Historic Preservation Act
- Coastal Zone Management Act
- Clean Water Act
- Marine Protection, Research and Sanctuaries Act
- Federal Aviation Act
- Magnuson-Stevens Fishery Conservation and Management Act
- National Environmental Policy Act

With such an extensive list of laws, regulations, and the multiple federal, state, and sometimes local agencies involved in the permitting process of offshore facilities, it is no surprise that the U.S. Commission on Ocean Policy recommends a streamlined process for

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[36] AquaEnergy has been acquired by Finavera Renewables Limited. See http://finavera.com/wave/makah_bay for project details; Accessed 1/31/07.

[37] See *AquaEnergy Group, Ltd. v. FERC, No. 03-1109 (D.C. Cir., filed Apr. 24, 2003).*

licensing, leasing, and permitting of renewable energy facilities sited in U.S. waters. In it's final report, the Commission states:

> What is urgently needed is…a comprehensive offshore management regime…that considers all offshore uses within a larger planning context. A coherent and predictable federal management process for offshore renewable resources that weights the benefits to the nation's energy future against the potential adverse effects on other ocean users, marine life, and the ocean's natural processes, should be fully integrated into the broader management regime (U.S. Commission on Ocean Policy, 2004, p368).

CHAPTER 3

THE OFFSHORE WINDPOWER "DEBATE": PUBLIC OPINION AND ENVIRONMENTAL IMPACTS

3.1 Introduction

Chapter Three discusses the wind power "debate," including a review of two recent public opinion surveys conducted in Cape Cod and New Jersey regarding offshore wind, and a comparison of impacts among different sources of energy production.

3.2 Offshore Wind Power: Public Opinion

Public opposition has already derailed land-based wind projects throughout the world (Righter 2002, p.37), and although most U.S. wind projects (whether land or sea based) would not require citizen approval per se, public opinion can enter the policy process and influence public policy as well as political leaders and their decisions. Researchers have found that a disparity often exists among the public between support for renewable energy in general and support for specific projects (Ek 2005; Wolsink, 2005). Ek (2005), for example, conducted a postal survey of 1,000 Swedish residents, noting,

> "[t]he experience in Sweden and in many other European countries is that the public opinion in general expresses a positive attitude toward wind power. However, in spite of this expressed general acceptance, specific wind power projects often face resistance from the local population" (p1678).

Wolsink (2005) contends that although there seems to be moderate to strong support for the implementation of renewable energy across Europe, public attitudes toward wind power in general are fundamentally different from attitudes towards specific *wind farms*, and "[t]his gap causes misunderstandings about the nature of public support for renewables," resulting in poor communication between developers, planners, and the public.

3.2.1 Explaining Support for and Opposition to Offshore Wind Power

The numerous studies on attitudes, beliefs, and opinions on wind power—some mentioned above—offers a chance to highlight some of the generalizations and recurring principles in the literature that attempt to explain public support and opposition. These will be revisited in Chapter 8 in order to relate the findings of this dissertation research back to the wind power public attitudes literature.

NIMBY: One classical hypothesis for opposition of local projects is NIMBY ("not in my backyard"), which has been defined as "an attitude ascribed to persons who object to the siting of something they regard as detrimental or hazardous in their own neighborhood, while by implication raising no such objections to similar developments elsewhere" (Simpson & Weiner, 2003, quoted in Kempton et al., 2005, p. 124). Devine-Wright (2005) concludes that "the NIMBY concept that has been most frequently used to describe negative perceptions of wind farms has failed to receive empirical support" in the literature, and advocates moving toward a more integrated framework for understanding public perceptions of wind energy. Kempton et al. (2005) argue that the use of the NIMBY label does not explain the public opposition they reported during a qualitative analysis of support and opposition to wind power in Cape Cod, nor does it adequately explain opposition to wind power seen in Wolsink (2000) or Ek (2005). Moreover, Kempton et al. recommend moving away from the use of the NIMBY label, since it merely serves to obscure the true reasons for opposition.

Ocean as a special place: An interesting finding in the Kempton et al. (2005) study was that people opposed offshore wind power because it intruded on the ocean as a "special place" where human structures and development do not belong. Moreover, there seems to be a sense of uniqueness and special value of Nantucket Sound among many of the Cape Cod residents (ibid).

Importance of landscape: Somewhat related to this feeling of uniqueness and special value is the importance of landscape and place attachment (see: Short, 2002; Hoppe-Klipper & Steinhauser, 2002; Schwahn, 2002; Pasqualetti, 2002). Some of these researchers have focused on the cultural importance of landscape protection and aesthetics, and how changes in the local

landscape affect public opinion. Schwahn (2002) notes that although there is often general support for wind power, local projects may cause residents to feel "expelled from their homeland", described as a "public sense of angst brought about by the rapid changes in the landscape that wind power can bring" (ibid; Kempton et al., 2005). Short (2002) notes that developers in the wind industry often fail to "grasp the important links among landscape, memory and beauty in achieving a better quality of life" (Short, 2002, quoted in Kempton et al., 2005, p. 132). A similar analysis by Pasqualetti (2002) offers insights into public opposition to wind power development in the San Gorgonio Pass, California. Although that particular area was suitable for wind power and somewhat unsuitable for other types of development, there existed considerable local opposition toward wind power development. Pasqualetti attributes much of this opposition to what he calls "landscape permanence"—the notion that wind turbines will convert the desert area into "an industrial landscape," thereby violating residents' expectations that the desert landscape will remain forever unchanged (ibid; Kempton et al., 2005). Kempton et al. (2005) argue the same feelings can be present among coastal residents for the preservation of the seascape, and that on a deeper level, "there appears to be something special about the ocean, a feeling which for many people underpins their opposition to the [Cape Wind] project" (p. 132).

Acceptance through time: Other explanations for public acceptance of wind power from the literature are that (1) acceptance follows a "U" shape through time, and (2) that negative perceptions for projects decrease over time due to increased public experience. Various longitudinal studies in different countries, conducted prior to development and some years afterward, have shown that negative perceptions of the local wind farm declined over time, or that residents become more supportive following construction (see Devine-Wright, 2005; Gipe, 1995; Wolsink, 1989; Krohn & Damborg, 1999; Walker, 1995). For example, Wolskin (1989) concluded that approval of wind farms improves post-construction, and Gipe (1995) reported initially high levels of public support for a Dutch wind farm, followed by a decrease in support during the planning and construction phases of the project, with recovery to almost initial levels of support once the project was built and operational (Devine-Wright, 2004; Gipe, 1995 cited by Krohn & Damborg, 1999). This would indicate that support or opposition for any specific project

is dynamic and should be reported over different phases of the planning, construction, and operation periods.

Devine-Wright (2005) notes that Gipe's generalization of the "U" shaped pattern of acceptance is not always supported, as can be seen in Bishop and Proctor's (1994) longitudinal study of public perceptions of three Welsh wind farms. Furthermore, Devine-Wright argues that although Gipe (1995) and Wolsink (1989) conclude that in general wind farms become more acceptable to the public with increased exposure over time, the variability in perceptual change seen across study sites speaks to a lack of empirical evidence for such an assumption to be held. Moreover, Walker (1995) argues that it is difficult to generalize "what people think" about wind turbines since many of the studies have been limited in extent and relate to different scales of development in different parts of the world. Also, the multitude of studies has adopted different quantitative methodologies at varying levels of sophistication, and the timing of research has varied across different countries (ibid).

Financial incentives: Financial incentives and benefits are a part of many factors influencing public acceptance of wind farms, such as ownership of the wind turbines, ownership of public and private lands where a wind farm will be located, and stakeholder participation in the planning and development process (Jobert et al., 2007). Case studies in Germany and France have shown that financial incentives, such as ownership of turbines or the collection of rents/royalties from turbines located on public and private property, are important factors in the acceptance of local wind power projects (ibid). Moreover, Van der Loo (2001) identified the PIMBY (Please In My Backyard) syndrome—opposite of NIMBY—which occurs when individuals want wind turbines to be placed on their property in order to act as a source of income.

Table 3.1 lists some of the more recent studies examining public attitudes and opinions toward wind power and offshore wind power. Subsequent discussion covers three public opinion surveys regarding offshore wind power in Cape Cod, Massachusetts, New Jersey, and North Carolina. Additional insights into support and opposition for offshore wind power will be drawn from these three studies.

Table 3.1 Recent studies examining public opinion regarding offshore wind power development

Author(s)	Year published	Title	Method	Journal Citation/ Organization
Grady and Cousino	2004	Public attitudes toward wind energy in coastal North Carolina: a systematic survey	404 completed telephone interviews of North Carolina residents	North Carolina Energy Policy Council
Kempton, Firestone, Lilley, Rouleau, Whitaker	2005	The offshore wind power debate: views from Cape Cod	24 semi-structured interviews of Cape Cod residents	Coastal Management Journal
Ladenburg, Dubgaard, Martinsen, Tranberg	2005	Economic valuation of the visual externalities of off-shore wind farms	694 completed mail surveys of Danish residents	Food and Resource Economic Institute
Mills and Rosen (of Lieberman Research Group)	2006	New Jersey shore opinions about offshore wind turbines	4,026 personal interviews of New Jersey residents and visitors	New Jersey Commerce, Economic Growth & Tourism Commission
Firestone and Kempton	2007	Public opinion about large offshore wind power: underlying factors	504 completed mail surveys of Cape Cod and the Islands residents	Energy Policy

3.2.2 Public Opinion: Lessons from Cape Cod

A May 2006 statewide Massachusetts poll conducted by The State House New Poll found that nearly 70.8% of residents supported while 17.2% opposed the placement of offshore wind turbines in Nantucket Sound (Chervinsky, 2006). These statewide numbers are quite different from the local picture seen around Cape Cod and the Islands. Firestone and Kempton (2007) recently conducted a public opinion survey of Cape Cod, Massachusetts residents to study the support and opposition for the nation's first proposed offshore wind farm.

The Cape Wind project "has generated a vigorous local opposition movement" focused primarily around a local environmental organization called the Alliance to Protect Nantucket Sound, "an organization specifically created to oppose the [Cape Wind] development" (ibid, p2). The organization is well-funded and politically well-connected, using television and radio spots as well as newspaper editorials to address the public (ibid). Although there has been ample public discussion and debate on the Cape Wind project, Firestone and Kempton (2007) note that the project will be permitted and authorized on the basis of applicable state and federal laws and regulations, and not based on an approval vote from local citizens. Nevertheless, policy makers should understand how the public views wind power in order to take into account the public's concerns when making decisions in the public interest and drafting appropriate policies and regulations.

Firestone and Kempton (2007) analyzed data from approximately 500 surveys returned from a random sample of residents of Cape Cod and the Islands. The survey identified support and opposition for the Cape Wind project, beliefs about the project, factors that might increase or decrease support, and support for alternative projects (ibid). Results indicated the majority (55.5%) of Cape Cod respondents opposed or were leaning toward opposing the project, while 43.8% supported or were leaning toward supporting the project, with 0.7% unsure. Also, the "overwhelming majority" of the population expected negative impacts from the project, while a much smaller percentage expected positive impacts. Supporters were found to be younger and better educated, while opponents were more likely to earn over $200,000 a year and more likely to see the project from their daily routine. Firestone and Kempton (2007) note that many players within the wind industry characterize opposition to the Cape Wind project as being primarily a visual-aesthetic concern. However, a detailed review of two-dozen in-depth interviews conducted with both proponents and opponents suggests that a broader set of reasons are just as important (or more so) than the visual impact, including: the ocean existing as a special place, where human structures do not belong; the project causing local impact, yet locals feeling they have minimal control over what occurs; the question of why the turbines need to be

placed out on the ocean rather than on land; and the positive effects of wind power in pollution prevention and U.S. energy security (Kempton et al., 2005).

Two key findings of the Firestone and Kempton (2007) survey should be considered when studying public opinion for offshore wind in other areas. First, the survey data shows that "many of the beliefs upon which opinion are based appear to be inconsistent with prior scientific studies and/or with the DEIS for [the Cape Wind] project" (Firestone and Kempton, 2007, p13), suggesting the need for better public education outreach regarding potential environmental impacts, particularly on marine life and avian impacts. Second, the survey reveals a net 36% increase in support for the Cape Wind project (19% of which had earlier indicated they were opposed) if the project were the "first of many" new offshore wind projects along the East Coast. This finding suggests that proponents of offshore wind power could increase support for future projects by conveying a more articulated "larger vision—that offshore wind is abundant in many areas of the world, including this region, and that large scale development is a plausible outcome of individual successful projects" (ibid, p13).

3.2.3 Public Opinion: Lessons from New Jersey

With the recently released May 2006 findings of the State of New Jersey's Blue Ribbon Panel[38] on the Development of Wind Turbine Facilities in Coastal Waters, New Jersey is officially considering the use of offshore wind turbines to generate clean and renewable electricity. Given the importance of tourism to the New Jersey shore, the New Jersey Commerce, Economic Growth & Tourism Commission and Brushfire, Inc recently commissioned a consulting firm to conduct a public opinion study about offshore wind power in New Jersey to assess possible impacts to its tourism sector and to gauge residents' support for a wind project.

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[38] The NJ Blue Ribbon Panel was created by then-acting Governor Codey to study the economic and environmental costs and benefits of developing wind power off of the NJ coast. A 15 month moratorium also was established by the Governor at the time. See http://www.state.nj.us/dep/newsrel/2006/06_0033.htm and http://www.njwindpanel.org/ for press release and final report.

The Lieberman Research Group[39] conducted 4,026 personal interviews[40] in Monmouth, Ocean, Atlantic, and Cape May Counties between July and August 2006 (Mills and Rosen, 2006). Respondents were read a description and shown pictures representing the hypothetical wind project at one of four offshore distances (3 miles, 6 miles, 12 miles, or 20 miles) and asked a series of questions (ibid). Data show that overall, 47% of respondents are in favor of the project, 21% are opposed, and 32% are indifferent. Also, 72% of respondents identified as visitors to the New Jersey shore indicated they would not change their future vacation plans if wind turbines were located offshore. As the project is moved further offshore, favorability of the project increases [as found in the Firestone and Kempton (2007) Cape Wind study]. For example, at 3 miles distance, 38% of respondents favor the project; this increases to 57% if the project were moved to 20 miles offshore.

The fact that distance from shore plays a major role in support for offshore wind projects could indicate that many of the respondents are concerned with the visual impact on the ocean view. These results contrast somewhat with a Scottish telephone survey of public attitudes towards wind, where researchers found that people living closest to the wind farms tended to be most positive about them and most supportive of their expansion. Braunholtz (2003) found that those who most frequently saw the wind farms on their day-to-day routine were most favorable toward them. As discussed earlier, perhaps this acceptance and favorability is acquired by the local population after a wind project is built.

In the New Jersey study, of the 66% of respondents who mentioned a disadvantage with the project, 32% identified an impact on aesthetics (more than any other category), while 13% mentioned environmental issues and 11% mentioned perceived costs. In comparison, Firestone and Kempton (2007) also identified believed negative and positive impacts of the Cape

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[39] See http://www.liebermanresearch.com/home.html

[40] 1,987 were New Jersey residents; 2,039 were visitors. Personal communication between Dr. Jeremy Firestone, University of Delaware, and Karen Wolf, N.J. Dept of Commerce, revealed the sampling strategy used by the Lieberman Research Group was opportunistic; hence, it is difficult to generalize results and findings of this study to the general population.

Wind project in Massachusetts, with 72% of respondents expecting a negative impact on aesthetics of the ocean view (again, more than any other issue identified). Firestone and Kempton take the issue a step further by asking respondents to rank which issues were most important in deciding whether respondents supported or opposed the project. In an open-ended response, respondents ranked marine life and environmental impacts higher than aesthetic concerns, and fishing impacts and boating safety were almost identical to aesthetic concerns, though aesthetic concerns were significantly more important to opponents than to supporters.[41]

3.2.4 Public Opinion: Lessons from North Carolina

A 2003 telephone survey conducted for the North Carolina Energy Policy Council examined public attitudes toward wind energy in coastal North Carolina (Grady and Cousino, 2004). A total of 404 interviews were completed out of 3,716 residential telephone numbers over an eight-week period.[42] Researchers found that 68.6% and 63.6% of respondents said that wind turbines should not be prohibited from being placed in the ocean or in sounds, respectively, while 13.9% said turbines should be prohibited from the ocean and 16.6% said they should be prohibited from sounds. Interestingly, 66.6% of respondents agreed that wind turbines should not be prohibited out on the water *even if visible* from their home, while 20% said they should be prohibited. When the researchers controlled for the respondents' experience with seeing a modern turbine in operation they found that 74.1% of those who had seen a turbine in operation would approve of turbines if they were visible from home, while 63.8% of those who had not ever seen a turbine also would approve.

Respondents also were asked to identify problems with placing wind turbines either on the mainland, out on the ocean, or in sounds. About 20% of respondents identified

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[41] Opponents ranked marine life/environmental impacts (65%), aesthetics (51%), fishing impacts/boating safety (50%), and electricity rates (20%) as the top three factors most affecting their decision to support or oppose the project. Supporters ranked these factors at 48%, 14%, 15%, and 47% respectively. See Firestone and Kempton (2007, p6) for the full list of rankings.

[42] A response rate of 10.8% is low and somewhat of a concern when generalizing results to the general public.

problems with placing turbines in sounds, 17.6% in the ocean and 15% for the mainland. For offshore development, respondents were much more concerned with environmental/wildlife impacts and safety impacts than aesthetics (22%, 14%, and 6% respectively). Aesthetics dominated identified concerns for placing turbines on the mainland. In the sound, respondents were more concerned with environmental/wildlife impacts than aesthetics (31% versus 19%). This study indicates that, at least among the sample population, the majority of North Carolina residents support the placement of wind turbines in the state's coastal waters, even if visible from respondents' homes.

3.3 Comparative Environmental Impacts

Wind energy development has both positive and negative environmental impacts (Manwell et al., 2006; Jarvis, 2005; USACE, 2004). Wind energy is generally recognized as a clean source of renewable energy and "environmentally friendly," especially when addressing such concerns as global warming and climate change from anthropogenic greenhouse gas emissions. As wind energy has increased both in Europe and the U.S., the focus on environmental impacts from wind farms has increased, and a number of potential wind energy projects have been delayed or denied permits because of strong environmental opposition based on potential negative impacts (Manwell et al., 2006). In general, such impacts could include avian and wildlife impacts, noise impacts, electromagnetic interference, land-use considerations, and visual concerns, among others. In the marine environment, environmental concerns may be focused more toward blade and turbine collisions with migratory shorebirds, impacts on fishing, boating, and navigation safety, underwater noise effects on marine mammals, habitat alteration and mortality of benthic organisms during pile construction and decommissioning phases, and visual impact on ocean aesthetics.

3.3.1 Cape Wind and Brayton Point

Although wind energy projects are not without some adverse environmental impacts, such impacts and other associated negative externalities should not be considered in isolation, but rather relative to impacts of other sources of energy production (Jarvis, 2005; Firestone et al.,

2007; USACE, 2004; BLM, 2005b; European Commission, 2003). Jarvis (2005) in particular notes that this type of comparison has been absent from the wind power debate:

> Many people indicate concern for impacts to fish and wildlife species as a reason for not supporting the Cape Wind site, yet they do not appear to consider how nearby power stations like Brayton Point and Canal Electric impact fish and wildlife species (Jarvis, 2005, p98).

The Jarvis thesis is the first to take an in-depth look at the DIES' suggested impacts of the Cape Wind project and to scale[43] and compare these impacts with the primary fossil-fuel burning power plant in the region, Brayton Point. Direct impacts of the Brayton Point power plant include the millions of fish larvae and fish eggs destroyed each day; indirect effects such as oil spills, heavy metal contamination, and acid rain, among others, occur from normal the operation of a power plant (including fuel extraction processes, transportation, and combustion) (ibid). One telling example of Jarvis' comparative analysis reveals a much larger land-use footprint for the Brayton Point power plant. When comparing the land requirements for the Cape Wind site to the coal burning portions of Brayton Point, the total disturbed area per gigawatt would be 27 acres to 19,305 acres, respectively.[44]

After scaling and comparing the various noted impacts, Jarvis (2005) concludes:

> From a strictly quantitative perspective, Brayton Point station has a larger impact on fish and wildlife species than Cape Wind, if one considers the hundreds of birds killed by oil spills, the thousands of acres of land disturbed, and the billions of fish, fish larvae, and fish eggs killed via impingement, entrainment, and/or thermal discharge (Jarvis 2005, p91)

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[43] To account for differences in power output, Jarvis (2005) scaled by calculating actual power output in MW, converting to GW, and dividing this number into 1.0 GW, to provide a scaling factor on a per gigawatt basis.

[44] The land area required for coal extraction, processing, and transportation (rather than the land required for the power plant itself) is the driving factor behind the large land use requirements for Brayton Point. On the other hand, the area between wind turbines is assumed to be a productive and multiple-use area, and thus not calculated as part of the total disturbed area of the wind farm. See Jarvis (2005, p85-88).

3.3.2 Emissions

One of wind energy's primary advantages is the lack of emissions during electricity production. Carbon dioxide, sulfur dioxide, and nitrogen oxides are of particular concern in stemming atmospheric pollution and GHG emissions from power generation. The Energy Information Administration (EIA),[45] responsible for keeping official energy statistics from the U.S. government, estimates that in 2005, fossil fuel burning power plants produced a combined total 2.5 million thousand metric tons of CO_2, 10,340 thousand metric tons of SO_2 and 3,961 thousand metric tons of NO_2 air emissions.[46] Trends for each are shown in Figure 3.1.

Interestingly, the Cape Wind Draft EIS, issued by U.S. Army Corps of Engineers, itemizes the tons of criteria pollutants that would be emitted on a yearly basis from a comparable natural gas power plant: NOx (101); C (75.5); VOCs (24.7); PM (164); SO_2 (31.5); and NH_3 (37.1) (See USACE, 2004). Levy and Spengler (2002) estimates that the two power plants currently serving Cape Cod result in 79 premature deaths each year due to particulate matter alone. Kempton et al. (2005) note that if the Cape Wind project were to displace an equivalent amount of power produced from these two power plants, approximately 11 fewer premature deaths would occur each year—an important point they consider missing from the wind power "debate."

While SO_2 and NO_2 emissions from fossil fuel power plants have actually decreased over the past decade (in a large part due to EPA regulations addressing acid rain), CO_2 emissions continue to rise. AWEA notes:

> A single 750-kilowatt wind turbine, operated for one year at a site with Class 4 wind speeds (winds averaging 12.5-13.4 mph at 10 meters height), can be expected to displace a total of 2,697,175 pounds of CO_2, 14,172 pounds of SO_2, and 8,688 pounds of nitrogen oxides, based on the U.S. average utility generation fuel mix.[47]

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[45] See http://www.eia.doe.gov/

[46] Source: http://www.eia.doe.gov/cneaf/electricity/epa/epat5p1.html; accessed 2/5/2007.

[47] See http:// www.awea.org/pubs/factsheets/EmissionKB.PDF; accessed 3/11/2007.

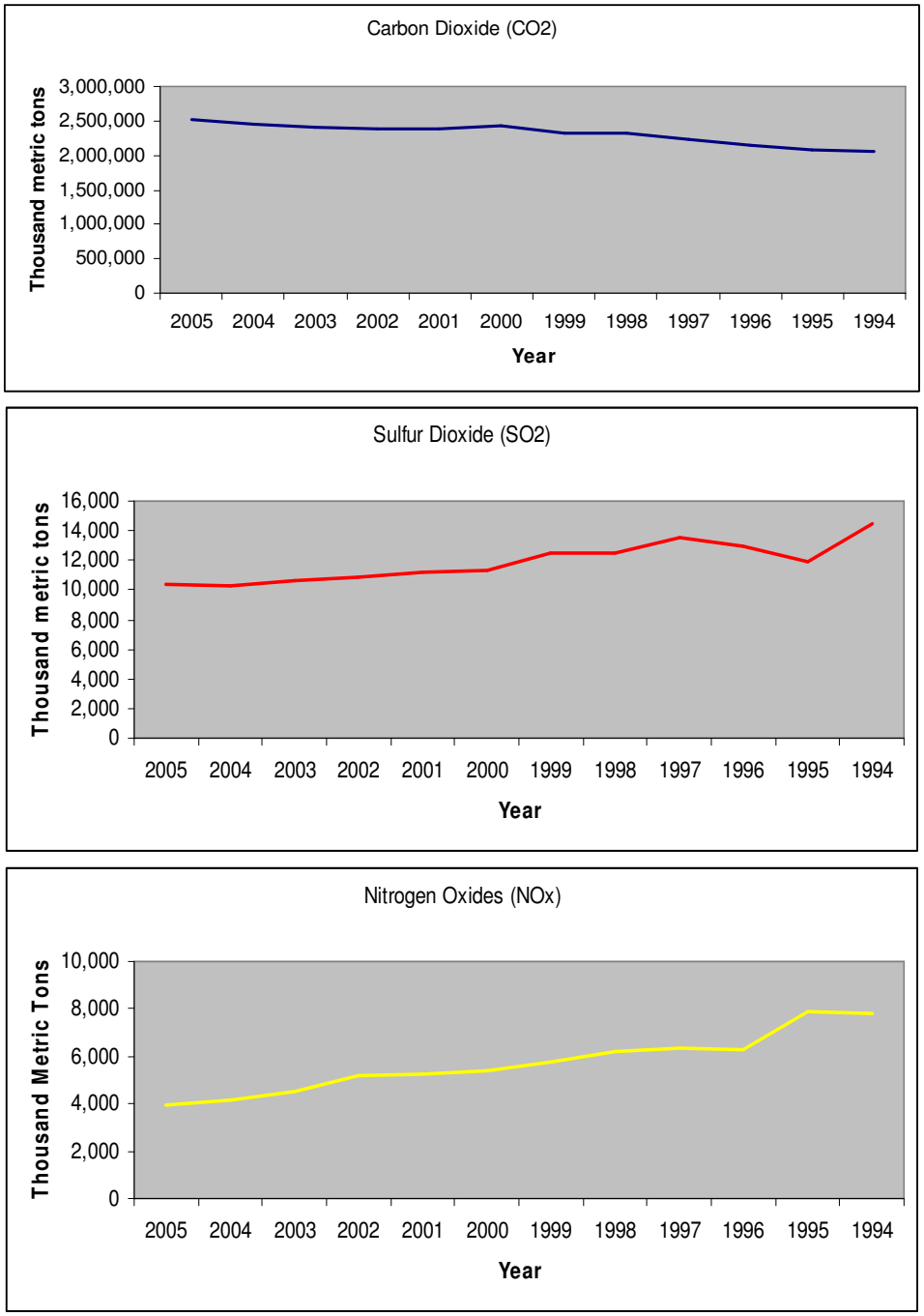

Figure 3.1 CO_2, SO_2, and NO_2 emissions from 1994 to 2005, thousand metric tons

It is important to note that, "while wind turbines produce no GHG emissions during normal operation, current reliance on fossil fuels for manufacturing and transportation result in emissions from turbine construction, installation, and maintenance" (Denholm, 2005, p1908). Even so, when including these associated criteria pollutants and GHG emissions, it becomes

obvious that emissions from wind power are much less than the emissions from a fossil fuel fired power plant (Jarvis, 2005). Table 3.2 compares the life cycle emissions of wind power plants to those of coal power plants.

Table 3.2 Life cycle emissions of wind compared to coal power plants, including manufacturing, operations, and fuel

Emissions	Wind Power[a]	Coal Power
SO_2	<0.02 g/kWh	2-10 g/kWh
NO_x	<0.01 g/kWh	2-4 g/kWh
CO_2	5-25 g CO_2eq/kWh[b]	900-1100 g CO_2eq/kWh

Source: Denholm et al., 2005; Jarvis 2005
[a] Assumptions: no compressed air energy storage, 25-50 percent capacity factor
[b] CO_2eq = CO_2 mass equivalent

3.3.3 Water Use

In 1995, U.S. fossil-fueled power stations required 135 billion gallons of water per day (Bgal/d), nuclear plants used 55 Bgal/d, and geothermal used 2 Bgal/d (Serchuk, 2000). Energy-related activities also use water; mining, for example, uses 3,770 Bgal/day (ibid). Table 3.3 compares consumption of water among conventional power plants. In comparison, wind uses 1/600 as much water per unit of electricity produced as nuclear, 1/500 as much as coal, and approximately 1/250 as much as natural gas.[48]

[48] Wind requires small amounts of water to clean the wind turbine rotor blades in areas where rainfall does not adequately clean the blades of dust and insect buildup.

Table 3.3 Water consumption among conventional power plants,[a] wind,[b] and solar power[c]

Power Source	Gallons/kWh
Nuclear	0.62
Coal	0.49
Oil	0.43
Combines cycle gas	0.25
Solar	0.30
Wind	0.001

[a] According to the California Energy Commission, cited in Gipe (1995)
[b] AWEA estimate
[c] Meridian Corp. (1989)

3.3.4 Bird Mortality

Bird mortality associated with wind turbines has been studied since the early 1980s, with initial concern stemming from serious ongoing avian mortality events at the first large-scale wind developments in California (Erickson et al., 2005). Many of these early studies focused on Altamont Pass, where some 5,400 turbines produce 548 MW (ibid). A 2005 report by the Government Accountability Office (GAO) reviewed wind power and wildlife impacts. In reviewing studies and talking to experts in the field, the report notes that impacts of wind power facilities on birds and other wildlife vary by species and by region. Some studies have estimated as many as 1,000 raptors (birds of prey, like hawks and golden eagles) have been killed each year by the wind turbines in Altamont Pass; however, these high mortality estimates are an anomaly when compared to the generally low number of reported bird death estimates from wind turbines in other parts of the country. Experts theorize that the sheer number of turbines in the Altamont Pass area, combined with their older design and poor siting location, have contributed to the abnormally high number of bird kills (ibid). Bat mortality also is a concern as another recent study, conducted in Appalachia, showed that thousands of bats were killed by a single wind power facility over a one-year period (ibid).

Bird mortality associated with offshore wind turbines has recently been a topic of increased importance as offshore wind capacity continues to grow in Europe and as proposals are being reviewed and permitted in the U.S. Jarvis (2005) estimates that 285 birds will be killed per

year from the Cape Wind project (2.19 bird collisions per year per turbine; alternatively, 2400 birds per year per gigawatt), and notes:

> While this number may seem insignificant compared to the millions of birds estimated to be killed each year as a result of collisions with cars, buildings, communication towers, windows, etc., bird kills resulting from the construction and operation of a new facility are still an adverse environmental impact that must be considered as an environmental cost of the project (Jarvis 2005, p88).

Desholm and Kahlert (2005) are the first to investigate whether certain avian species can detect and avoid a large offshore wind farm. They used radar to track the spatial migration patter of ducks and geese at the Nysted offshore wind farm in Denmark, both pre- and post-construction. Results suggest a strong avoidance response by water birds, suggesting avian impacts from offshore wind farms may not be as great as once thought. The diurnal percentage of flocks entering the wind farm area decreased by a factor of 4.5 from pre- to post-construction (from 40.4% to 8.9%). Moreover, "only 0.9% of the night migrants and 0.6% of the day migrants flew close enough to the turbines to be at risk of colliding with the turbines" (p296). These results highlight the importance including avoidance behavior when modeling estimates of wind farm-related avian mortality.

Although wind turbines do in fact kill birds, it is important to put this contribution in context with overall sources of bird mortality. Erickson et al. (2005) estimate between 500 million to over 1 billion birds are killed annually in the U.S. due to anthropogenic sources.[49] Collisions with buildings, power lines, and predation by cats are the top three mortality sources. Wind turbines account for less than 0.01% of the annual mortality. Table 3.4 presents annual predicted avian mortality.

[49] These sources do not include hunting takes, which would significantly increase bird mortality estimates.

Table 3.4 Predicted annual avian mortality

Mortality source	Annual Mortality Estimate	Percent Total
Buildings	550 million	58.2
Power lines	130 million	13.7
Cats	100 million	10.6
Automobiles	80 million	8.5
Pesticides	67 million	7.1
Communication towers	4.5 million	0.5
Wind turbines	28.5 thousand	<0.01
Airplanes	25 thousand	<0.01
Other sources (oil spills, oil seeps, fishing by-catch, etc.)	Not calculated	Not calculated

Source: Erickson et al. (2005, p1039)

3.4 Offshore Wind Farms and the Environment: Insight from Denmark

The Danish Energy Authority and other partners have recently published results from a multi-year study on the environmental effects from offshore wind farms (entitled: "Danish Offshore Wind: Key Environmental Issues"). During years 1999-2006, a comprehensive environmental monitoring program evaluated environmental aspects of the Nysted and Horns Rev wind farms in Denmark (the world's two largest operating offshore wind farms). The findings from this study are important since this is the most comprehensive study of the effects of offshore wind farms on the marine environment to date. According to the executive summary of the report, "[T]he Danish experience from the past 15 years shows that offshore wind farms, if placed right, can be engineered and operated without significant damage to the marine environment and vulnerable species" (ibid, p 8).

Environmental monitoring began before construction and erection of the wind turbines, and continued during and after construction. The monitoring program focused on both ecological and social effects—the effects on infauna, epifauna and vegetation, fish, marine mammals, birds, as well as people's attitudes and preferences. Research methods included underwater and seabed surveys, collection of species, photo and video sampling, acoustic, satellite and infrared monitoring, as well as video and visual observations. Summarized findings are presented in Table 3.5. In short:

[t]he comprehensive environmental monitoring programs of Horns Rev Offshore Wind Farm and Nysted Offshore Wind Farm confirm that, under the right conditions, even big wind farms pose low risks to birds, mammals and fish, even though there will be changes in the living conditions of some species…(ibid, p 8).

Table 3.5 Summary findings from the Danish environmental monitoring program of the Horns Rev and Nysted offshore wind farms, Denmark

	Horns Rev	Nysted
Fauna and vegetation	The turbine foundations and scour protections are changing the benthic communities from soft to hard bottom with increased abundance of species and biomass	Monocultures of common mussels have developed at the turbine structures, due to low salinity and lack of predators
Fish	• Introduction of new artificial reef habitats with positive effects on fish communities • No linkage between the strength of the electromagnetic field and the migration of selected fish species	
Marine mammals	Seals were only affected by pile driving operations. No change in behavior seals could be linked during construction or operation of the wind farms	
	Harbor porpoise population decreased slightly during construction, but increased again during operation	Harbor porpoise population decreased significantly during construction and only slight recovery was observed after 2 years of operation
Birds	• Birds generally show avoidance response. Some species are displaced from former foraging areas • The collision risk with turbines is low • Effects on overall bird populations are negligible	
Attitudes	• More than 80% of respondents from the local areas were “positive” or “very positive” towards the wind farms • The prevailing perception is that the impact on birds and marine life is neutral • Almost two-thirds of the respondents stated that they found the wind farm effect on the landscape either “neutral” or “positive” • More than 40% stated that they preferred future wind farms to be moved out of sight	

CHAPTER 4

BACKGROUND ON STATED PREFERENCE METHODS AND CHOICE MODELING

4.1 Purpose

Chapter Four provides an overview of stated preference (SP) methodology, choice experiments (CE), and recent application to wind power. The purpose of this section is to give the reader sufficient background to understand why SP methodology is appropriate for this particular research and how SP surveys are developed and conducted.

4.2 Background on Stated Preference Methods

This dissertation uses a mail survey to describe hypothetical, constructed market scenarios to analyze people's preferences and willingness to pay for offshore wind power along Delaware's coast. Although the wind development scenarios are hypothetical, respondents are asked to vote for certain options as if they were real. Asking respondents to state what actions they would take in a given scenario is termed "stated preference" (SP) methodology, whereas observing *actual* behavior is termed "revealed preference" (RP) methodology (Mitchell and Carson, 1989).

There are a variety of SP approaches for asking valuation questions. Contingent valuation (CV), conjoint analysis, and choice modeling are a few of the major SP methodologies. These techniques use a variety of approaches, "from the straightforward request for maximum willingness to pay of open-ended contingent valuation, to indirect methods using choice, ranking, or ratings" (Brown, 2003, p102). SP methods have been used by economists for decades where actual observable market data and behavioral data are limited (Holmes and Adamowicz, 2003). SP methods "involve finding an individual's willingness to pay (WTP) for a good by posing a set of questions regarding preferences directly to the individual" (Kolstad, 2000, p 356). In summary, these techniques are used to construct hypothetical market scenarios and then ask

respondents to indicate their preferences for goods or services as if they were facing real choice situations.

Davis (1963) was the first to use SP methods by studying the value of the Maine backwoods to recreators in the early 1960s. Although stated preference methods were not widely applied to environmental valuation until the 1970s, since that time there have been thousands of CV studies for environmental and nonmarket goods, though most of these have remained unpublished (Kolstad, 2000).

Despite their focus on hypothetical situations, many researchers have shown that SP techniques can accurately measure WTP and generate sound welfare estimates. All survey-based welfare measures face validity issues, and because SP methods rely on questions about hypothetical situations, these methods are subjected to careful scrutiny by researchers (Brown, 2003). Moreover, since SP methods can lead to situations in which the respondent's personal constraints (like income, for example) are not considered as constraints at the time of choice, it is the task of the researcher to make the hypothetical scenarios as realistic as possible (Hensher et al., 2005). Although SP data are rich in preference and tradeoff information, the validity of the welfare measures is affected by the degree of "contextual realism" established in the survey (Louviere, Hensher et al., 2000). Also, many economists have been weary of SP methods because they distrust people's willingness or ability to answer questions truthfully and carefully (Brown, 2003). Scrutiny on these points, however, should not be misconstrued as an indication that SP methods are less valid than RP methods (Brown, 2003; Manski, 2000). In fact, well designed surveys can avoid many of the potential problems economists have cited with SP methods, and surveys are often the most effective way to understand people's preferences (ibid). Some of the differences between RP and SP data are shown below (taken from Louviere, Hensher et al., 2000, p24):

RP data typically:

- Depict the world as it is now (current market equilibrium)
- Possess inherent relationships between attributes (technological constraints are fixed)
- Only have existing alternatives as observables
- Embody market and personal constraints on the decision maker
- Have high reliability and face validity
- Yield one observation per respondent at each observation point

SP data typically:

- Describe hypothetical or virtual decision contexts (flexibility)
- Control relationships between attributes, which permits mapping of utility functions with technologies different from existing ones
- Can include existing and/or proposed and/or generic (i.e., unbranded or unlabelled) choice alternatives
- Cannot easily represent changes in market and personal constrains effectively
- Are reliable when respondents understand, are committed to and can respond to tasks
- Usually yield multiple observations per respondent at each observation point.

4.3 Choice Modeling

Choice modeling (CM) techniques include choice experiments, contingent ranking, contingent rating, and paired comparisons. Table 4.1 presents the four major choice modeling approaches and the associated tasks that respondents are expected to perform. CM techniques, particularly choice experiments, are based on two fundamental building blocks: (1) Lancaster's characteristics theory of value and (2) random utility theory (Bergmann et al., 2006). Lancaster's consumer theory (see Lancaster, 1966) states that the utility an individual derives from a good comes from the characteristics of that good, not from the consumption of the good itself. Thus, the value of the good is represented by the sum of the value of the good's characteristics (ibid). Random utility theory recognizes that there is both an observable and unobservable component to the utility that individuals derive from the consumption of goods. While the former is "observed" through survey response data, researchers must make assumptions about the distribution of the unobserved components of utility in modeling the probability function to predict which alternatives are most preferred over the sample population (Hensher et al., 2005).

Table 4.1 Four main choice modeling approaches

Approach	Respondent Task
Choice experiments	Choose between (usually) two alternatives versus the status quo
Contingent ranking	Rank a series of alternatives
Contingent rating	Score alternative scenarios on a scale of 1-10
Paired comparisons	Score pairs of scenarios on similar scale

From: Bateman et al., 2002, p250

Individuals have preferences for different goods (and the characteristics of these goods), and these preferences matter in the everyday decisions that people make. It is an individual's *preferences* for specific alternatives in any choice decision that best determine what alternative is chosen (Hensher et al., 2005). In addition, there are a number of *constraints* (personal income, for example) that often deny the individual decisonmaker the most preferred alternative in any choice decision (ibid). In general, it is assumed that individuals follow "utility maximizing behavior," meaning they choose alternatives or make decisions that will yield the *highest level of satisfaction*, given certain constraints (ibid).

Because a good can be described in terms of its attribute levels, changing those levels will essentially result in a different good being produced (Bateman et al., 2002). Choice modeling focuses on the value of such changes in the attributes, and CM is especially useful in a policy context by identifying the following (see Bateman et al., 2002, p249-250):

1. Which attributes are significant determinants of the values people place on non-market goods.
2. The implied ranking of these attributes
3. The value of changing more than one of the attributes at once
4. The total economic value of a resource or good

4.3.1 Common Design Stages in Choice Modeling

Bateman et al. (2002) list five general design stages for choice modeling, presented below in Table 4.2.

Table 4.2 Design stages for choice modeling

Stage	Description
Selection of attributes	The good being evaluated in the choice scenario must be described by a number of characteristics, or "attributes."
Assignment of levels	Each attribute must be assigned a range of levels. Levels should be realistic and relate to respondents' preferences.
Experimental design	Statistical design theory is used to generate a number of alternatives to be presented to respondents.
Construction of choice sets	Alternatives are paired to create choice sets.
Measuring preferences	A method is chosen to collect the appropriate data, and the survey is conducted.

Adapted from: Bateman et al., 2002, p259

Stage 1 is the selection of the relevant attributes of the good to be valued. Attributes are typically chosen through literature reviews, focus groups, direct questioning, or from the nature of the problem itself. A monetary cost—or "payment vehicle"—is included as one of the attributes to allow for the estimation of willingness to pay (WTP). Stage 2 is the assignment of attribute levels. Levels should be realistic and should span the range over which respondents are expected to have preferences for the good being valued. Stage 3 is the experimental design, where statistical design theory is used to combine the levels of the attributes into a number of alternatives or profiles. Stage 4 is the construction of the choice sets, where the various profiles created during the experimental design are grouped into choice sets to be presented to the respondents. Stage 5 involves the administration of the survey and hence the measuring of preferences.

4.3.2 Choice Experiments

Choice experiments present a hypothetical scenario in which respondents choose the most preferred option among two or more alternative options. Usually each respondent is asked a series of three to five questions, depending on the complexity of the design and the overall length of the survey. Typically, the levels of the attributes are varied across alternatives and across

choice sets to allow respondents to face a wide variety of choice scenarios. A baseline alternative corresponding to the status quo is generally included in each choice set to ensure welfare-consistent estimates (Bateman et al., 2002). The status quo option, called an "opt-out" option, helps generate welfare-consistent estimates by mimicking actual market situations whereby individuals are able to choose neither of the two alternatives offered (Holmes and Adamowicz, 2003). Choice experiments produce welfare-consistent estimates for four reasons (Bateman et al., 2002, p251):

1. They force respondents to trade off changes in attribute levels against the cost of making these changes
2. Respondents can opt for the status quo (no increase in the good or service being provided at no extra cost to them)
3. The econometric techniques are used in a way which are parallel to the theory of rational, probabilistic choice
4. Estimates of compensating and equivalent surplus can be derived

There are a number of advantages and disadvantages one must consider when choosing to use choice experiments over other SP methods. One major advantage is that choice experiments provide a natural way to value changes in a good or policy since they examine more than two alternatives at one time (Bateman et al., 2002). Although this is possible to do in a CV study as well, it is much more difficult and very costly, since one would have to design different valuation scenarios for each level of each attribute (ibid). Also, choice experiments do a better job than CV at measuring the marginal value of changes in the characteristics of the good being provided, which may be particularly useful from a policy and management perspective (ibid). Another advantage is that the experimental design of CE can reduce the multi-collinearity that may exist between attributes, thereby reducing problems in the modeling process (Bateman et al., 2002; Holmes and Adamowicz, 2003). Also, because of the nature of the hypothetical scenarios, CE can value changes in the levels of attributes or goods that do not currently exist, but that may be of interest for some future policy (ibid). CE also may avoid some of the response difficulties

in CV, and thus reduce yea-saying. As Bateman et al. (2002, p273) state, "in CE, respondents are faced with a very simple problem: do I prefer Option A, Option B, or neither?"

A number of disadvantages are also recognized. Although CE does derive welfare estimates, these estimates are sensitive to study design. In other words, the selection of attributes, attribute levels, and format of the survey itself can all impact the values of the welfare estimates. Also, because of the nature of the design, attributes that are important in a respondent's decision process yet unknown to the researcher may be excluded. Choice and ranking complexity also can be a problem for respondents, especially if the scenarios contain multiple attributes with multiple levels.

4.4 Recent Stated Preference Studies on Wind Power and Green Energy

The most recent SP studies regarding wind power and green energy are listed in Table 4.3.

Table 4.3 Recent SP studies conducted on wind power and renewable energy

Author(s)	Year published	Title	Method	Journal/Citation
Alvarez-Farizo and Hanley	2002	Using conjoint analysis to quantify public preferences over the environmental impacts of wind farms. An example from Spain	488 personal interview conducted; contingent ranking and choice experiments	Energy Policy
Ek	2002	Valuing the environmental impacts of wind power: a choice experiment approach	219 completed mail surveys; choice experiments	Lulea University of Technology thesis
Bergmann, Hanley, Wright	2006	Valuing the attributes of renewable energy investments	219 completed mail surveys; choice experiments	Energy Policy
Ladenburg and Dubgaard	2007	Willingness to pay for reduced visual disamenities from offshore wind farms in Denmark	375 completed mail surveys; choice experiments	Energy Policy

Alvarez-Farizo and Hanley (2002) compared two methods (contingent rating and choice experiments) to quantify public preferences over the environmental impacts of wind farm development in Spain. The primary environmental impacts considered in this study were the protection of cliffs, the protection of habitat and flora, and the protection of the landscape. Both methods indicated that impacts on flora and fauna are valued more highly than impacts on landscape or on cliff-sites. Also, methodologically, choice experiments gave higher estimates of willingness to pay to prevent environmental damages than contingent rating.[50] Both CE and CR results indicated that significant social costs in the form of environmental impacts can result from wind farm developments. For example, CE results indicate a willingness to pay for the

[50] The authors suggest the choice experiments showed higher WTP estimates because respondents paid more attention to the price attribute during the contingent rating exercise.

protection of habitat & flora, the landscape, and cliffs of $50, $49 and $29 dollars/household/year, respectively.

Bergmann et al. (2006) used choice experiments to value different external costs and benefits of renewable energy investments, particularly visual impacts, wildlife impacts, air pollution, employment, and the price of electricity. Given these five attributes and their seventeen associated levels, twenty choice sets were created and blocked into sets of four (so each respondent was presented with four choice tasks). A total of 547 surveys were mailed to the general public of registered voters in Scotland; 219 were returned for a response rate of 43%. Results show that reducing air pollution, improving wildlife, and reducing landscape impacts were highly valued by the respondents. For example, households were willing to pay $28.50 to have renewable energy projects that had no increase in air pollution, compared to a program which resulted in a slight increase in air pollution. Bergmann et al. (2006) also conducted a welfare analysis for alternative energy investment plans for wind power. When compared to the base scenario of fossil fuel power expansion, the construction of a large offshore wind farm was most valued (welfare gain of $13.20/househould/year), while the construction of a large on-shore wind farm is least valued, requiring that each household be compensated $38.80 per year.

Ek (2002) sent out a postal survey to Swedish residents and found that the majority of respondents were positive towards wind power, that wind was considered an environmentally benign electricity source, and that the aesthetic impact was viewed as a negative effect among most residents (See also Ek, 2005). Choice experiment results indicated that location of the wind turbines was important in respondents' decisions, and that respondents preferred offshore capacity (wtp of $39/househould/year) over turbines being located onshore (wtp of $16/household/year) or in mountainous areas (wtp $0/household/year) (ibid).

Ladenburg and Dubgaard (2007) calculated willingness to pay for reducing the visual disamenities associated with offshore wind farms using choice experiments in a mail survey of Denmark residents. The choice experiments posed different numbers of wind farms (either 5,7, or14 throughout Denmark) of varying sizes (49, 100, or144 turbines) at different distances from shore (8, 12, 18, or 50 km), with an annual per household cost attribute of 0, 12.5,

23, 40, 80, or 175 Euros. Using a fixed effect logit model, results indicate that residents are willing to pay $44, $126, and $143/household/year for having the wind farms located at 12, 18, and 50 km from the coast, as opposed to 8km, respectively. Respondents who can see an offshore wind farm from their residence were willing to pay much higher amounts—as much as $627/household/year—to move wind farms further offshore, indicating considerable social benefits for reducing the visual disamenities of future offshore wind turbines.

CHAPTER 5

METHODOLOGY

5.1 Purpose

Chapter Five describes the survey development, pilot testing, survey administration, sampling, the experimental design of the choice experiments, and the CE econometric model.

5.2 Semi-structured Interviews and Initial Survey Development

Beginning in February 2006 the University of Delaware wind research group commenced weekly scheduled team meetings for this project. The primary focus of these early meetings was (1) to develop an appropriate semi-structured interview protocol and (2) to plan mail survey development.

An initial interview protocol was developed from the experience gained in a series of semi-structured interviews in Cape Cod, Massachusetts in 2003 (see Kempton et al., 2005) as well as a series of unstructured interviews in New Jersey during 2005. The semi-structured interview process was the first critical phase of the research, allowing us to better understand the public's opinions on energy issues, their thoughts about wind power development, and to gauge the public's general understanding about wind power and associated issues in Delaware. Once an appropriate interview protocol was developed, twelve in-depth, semi-structured interviews were conducted with various members of the public between March and May 2006. All interviews were conducted, taped, and transcribed by several team members. As the lead person on survey development, I analyzed the interview transcripts in order to (1) find common themes and areas of agreement and disagreement among interviewees and (2) to allow for a better understanding of people's opinions regarding offshore wind power.

Survey development began in May 2006. In order to compare results with the previous Firestone and Kempton (2007) Cape Cod wind survey, specific questions from that

survey instrument were incorporated. Additional new questions were developed during a review of pertinent literature, from input during weekly wind team meeting discussions, and based on prevalent themes and ideas uncovered from the Delaware semi-structured interview process.

5.3 Pilot Testing

After numerous draft iterations, a pilot survey was developed and tested at the Department of Motor Vehicles (DMV) office in Wilmington, Delaware on June 29 through June 30, 2006.The pilot test was used to refine question wording and survey formatting, to ensure that respondents understood what was being asked of them, to test the layout and usefulness of a map and photo prop, to test for general understanding of the questions, to gather information on whether respondents perceived the survey instrument to be biased, and to see if the survey was of an appropriate length. In particular, the pilot test was critical to ensure that the choice experiment (CE) wind scenario was understandable and realistic; that the attributes chosen (and the range of their corresponding levels) were appropriate to the questions being asked and thus meaningful to respondents' choices; the respondents could understand and properly complete the choice experiment questions; and the questions were producing usable data. To this end, extensive time and effort was spent developing, reviewing, and testing the CE section.

We chose to pilot the survey at the DMV because it provides a large, random cross section of citizens. A face-to-face pre-test rather than a mail pre-test was also deemed to be advantageous because it allowed us to ask follow-up questions to gauge clarification, understanding, survey bias, and appropriate survey length. A table was set up outside the DMV entrance and all individuals coming in and out were asked to fill out a survey and offer comments and suggestions.[51] Persons waiting in the emissions inspection line also were asked to fill out a survey during their wait. A total of 82 completed pre-test surveys were collected.

[51] We were not particularly concerned about having a strict and formal random sampling strategy for this stage of the research.

5.4 Finalizing the Survey

Appropriate revisions were made after pretesting and a final survey was produced. The survey went through nineteen different versions in total between May and September 2006.

The survey has four general sections. The first section asks respondents about their attitudes and opinions concerning wind power and the possibility of having offshore wind power in Delaware. The second section contains the CE questions in which respondents are asked to choose among different offshore wind power scenarios which can differ in five basic characteristics: the location of the wind farm; its distance from shore; the amount of rent/royalty payments made to Delaware; to where those payments would be funneled (e.g. Green Energy Fund, Beach Nourishment Fund, or General Fund); and the amount of a fee, if any, that would be added to consumers' monthly electricity bill for three years. The third section gathers data on respondents' beach-going habits in Delaware, and how those beach-going habits might change with the presence of a visible wind farm off the coast. The final section of the survey collects demographic data for statistical analysis of the survey responses.

5.5 Administration of the Survey

The survey was administered to 2000 randomly selected members of the Delaware population. Names and addresses were supplied by Survey Sampling International.[52] Protocol for survey construction, testing, and administration followed Dillman's Tailored Design Method (Dillman, 2000) as closely as possible, given certain time and budget constraints.

Between September 9 and September 20, 2006, survey packets were sent out to all respondents. Each packet included (1) a cover letter addressed to the selected respondent describing the survey and why their participation was important, (2) the survey, (3) a map and photo simulation prop, and (4) a stamped return envelope with the College's address. Also, each survey included a tracking number identifying the version of the survey (see Section 5.7) and the recipient. Three weeks later reminder postcards were sent out to thank all respondents for their participation and to remind those respondents who had not yet completed their survey to

[52] See http://www.surveysampling.com

promptly do so. To help increase response rate even further, an additional 1,250 survey packets were sent out between October 28 and October 30, 2006 to those individuals who had not yet returned their original completed surveys. These packets contained a modified cover letter reaffirming the importance of the study, reminded respondents of their confidentiality, and asked respondents to take a few minutes to complete and mail back the survey. As packets were returned data were coded and entered into a Microsoft Access database.

The cover letters, survey, post card reminder, and map and photo props can be found in Appendix 1 and 2. The survey packets were mailed out in a 9" by 12" manila envelope with white shipping labels and depicting the University of Delaware College of Marine and Earth Studies logo. Respondents returned their completed surveys in a stamped 6" by 9" manila envelope.

5.6 Sampling

Delaware has three counties: New Castle County is the most northern and urban; Kent County is in the middle of the State, and includes the capitol; Sussex County is the most southern and rural of the counties. All of Delaware's Atlantic coastline (approximately 24 miles) is located within Sussex County. Also, all three counties contain some Delaware Bay Coastline.

Most of Delaware's population (520,000 or 63%) lives in New Castle County, over ninety miles from Delaware's Atlantic Coastline. About 139,000 people live in Kent County and about 172,000 people live in Sussex County. In order to ensure the sample contained an adequate number of responses from residents living near the coastline (where visual impacts from offshore wind projects would be most prevalent), specific coastal areas of Kent and Sussex Counties were over-sampled using year 2000 census tract and block data. A random stratified sample of 2000 residents was drawn from three strata, named "Bay," "Ocean" and "Inland." Bay includes selected respondents living along Delaware Bay in Kent and Sussex Counties; Ocean includes selected respondents living along the Delaware Atlantic coastline in Sussex County; Inland includes selected respondents throughout the whole of Delaware, excluding any individuals living within the aforementioned Bay and Ocean strata. Table 5.1 lists the strata, the

sample size (n) and associated census tracts and blocks, as well as the major towns and beaches that are located within those census areas.

Table 5.1 Sampling strata, strata size, census tracts, and associated towns

Strata	Sample Size (n)	Census Tracts/Blocks	Major Towns and Beaches
Bay	400	501.03 509 (1) (2)	Slaughter Beach; Fowlers Beach; Prime Hook Beach; Broadkill Beach
Ocean	400	511 512	Rehoboth Beach; Dewey Beach; Bethany Beach; South Bethany; Fenwick
Inland	1200		All of Delaware, excluding the above.

5.7 Experimental design of choice experiments

Choice experiments were used in this research because they provide certain advantages over other SP methods: they provide a natural and simple way for respondents to choose between different choice scenarios; they give the researcher greater flexibility and control in experimental design of hypothetical scenarios; marginal WTP measures can be generated from modeling results; and they allow the researcher to identify preferences and derive welfare estimates for changes in policies or goods that do not currently exist, but may exist in the future.

5.7.1 CE question format, preamble, and attributes

In the choice experiment section of the survey each respondent faced three hypothetical referendum questions (questions 17, 18, and 19). In each question respondents voted on one of two different wind development scenarios; respondents also could "opt out" by voting for a *status quo* option of expanding natural gas or coal power rather than offshore wind power development. A short introductory preamble entitled "Offshore Wind Power in Delaware"

was presented just prior to the CE questions. The text of this preamble is presented in Figure 5.1. Preamble statements used in stated preference questions must be clear, realistic, and meaningful to respondents, and balanced to ensure that responses are legitimate and that the questions are taken seriously. Considerable effort was spent testing and reviewing the CE preamble, particularly to ensure that respondents would understand the wind power development scenario, that respondents would consider the scenario unbiased, and that they would not reject the payment vehicle (the "renewable energy fee"). Attributes also must be meaningful to the scenario under evaluation; in order to yield valid welfare estimates, attributes must be realistic, unambiguous, and important to respondents in making their decision choices. Attributes for this study were chosen based on a review of current policy, pertinent literature and from insight gained during semi-structured interviews. Selected attributes and their corresponding levels are presented in Table 5.2. Figure 5.2 presents a sample choice experiment question.

"Offshore Wind Power in Delaware"

Assume Delaware needs to increase its energy supply by 20% and that you have the opportunity to vote on energy development options. One way to meet the energy demand would be to place a 500 turbine wind farm offshore. Another option would be to continue Delaware's current energy policy and obtain additional energy from a new plant that burns coal or natural gas.

Because wind energy uses no fuel, your electric bill would not increase over time due to higher fuel cost; however, like other sources of electricity, it could increase for other reasons. To offset the initial costs of providing wind energy to Delaware residents, assume that there would be a **"Renewable Energy Fee"** added **each month** to your electric bill, for the first **three years** only.

We are now going to ask you three questions where you get to vote on wind power development. For each question, assume the option that receives the most votes will be carried out.

Continue on and vote→→→

Figure 5.1 Preamble to questions 17, 18, and 19

Table 5.2 Attributes and their corresponding levels for the choice experiment questions

Attribute	Levels
Location of wind farm	Delaware Bay; North Ocean (Rehoboth Beach); South Ocean (Fenwick Island)
Distance from shore (miles)	0.9; 3.6; 6; 9; too far out to see
Royalty fund	Beach nourishment fund; Delaware green energy fund; Delaware general fund
Renewable payment	$1 million; $2 million; $8 million
Renewable energy fee	$0; $1; $5; $10; $20; $30

Typically, two of the most controversial aspects of any offshore wind proposal are the location of the site and its distance from shore. In Delaware, there are three logical areas where an offshore wind farm might be built: in Delaware Bay, off of the northern Atlantic coast of Delaware (Rehoboth Beach), or off the southern Atlantic coast of Delaware (Fenwick Island). A map was provided in each survey packet to help respondents visualize these general areas. Also, a range of realistic distances from shore was presented based on existing proposals to site offshore wind farms off other parts of the US Atlantic coast. A page with photo simulations[53] also was provided to help respondents visualize changes that would occur to the seascape if wind turbines were to be placed at different distances from shore. Royalty funds were selected based on Delaware's existing Green Energy Fund and the State General Fund; we created a hypothetical Beach Nourishment Fund to test whether individuals living near the coastline would be more willing to accept a visual disamenity from a wind project if a nearby beach would benefit in turn. The range of royalty payments to be made to the State ($1 million, $2 million, and $8 million annually) was based on low and high estimates of other wind project royalty payments. The justification for including royalty payments as an attribute is augmented by the Energy Policy Act of 2005, which established the Department of Interior's authority to establish royalty payments for ocean energy related leases on the Outer Continental Shelf. Additional discussion and arguments for developing an appropriate royalty scheme for new uses of the ocean zone can be found in Firestone, et al., 2005.

[53] Selected photo simulations were taken from the Cape Wind DEIS prepared by USACE and simulations of the proposed LIPA project. Our budget did not allow us to produce visual simulations from Delaware beaches.

18) Now for which option would you vote?
Refer to the Delaware map insert for the "wind farm location." Refer to the ocean photo insert for simulated views of the wind farm at different distances.

	Option A	Option B	Option C
Wind farm location	Ocean (South)	Ocean (North)	No Wind power Expansion of coal or natural gas power
Distance from shore	0.9 miles	6 miles	
Annual rent/royalty	$1 million to Beach Nourishment Fund	$8 million to Beach Nourishment Fund	
Renewable energy fee on your monthly electricity bill for 3 years	$1	$20	

I would vote for…

□ Option A
□ Option B
□ Option C

Figure 5.2 Sample choice experiment question

5.7.2 Designing choice profiles for questions 17, 18 and 19

Five attributes and twenty attribute levels result in a total of 810 different treatment combinations. It would be too difficult a task for respondents to evaluate and choose between all of the resulting choice combinations. In order to make the survey a reasonable length and to reduce respondent fatigue, a simple orthogonal main effects only design was used to generate

fifty total *treatment combinations*.[54] Following a method discussed in Hensher et al. (2005), the treatment combinations were then randomly paired back upon themselves to create fifty *choice combinations*.[55] The fifty choice combinations were then blocked, creating twenty five versions of question 18 and 19.

Question 17 was designed to focus specifically on the tradeoff between distance and willingness to pay. While the distance attribute and the fee attribute varied in a given choice set, the other attribute levels were randomized and then held constant. These choice combinations were designed in a way to ensure that each choice scenario presents two different distances from shore, with the further distance always costing more. See Table 5.3 to see the designed profiles for question 17.

5.8 The Choice Experiment Econometric Model

5.8.1 Background: Discrete Choice Random Utility Maximization Model

Choice modeling techniques, particularly choice experiments, are based on two fundamental building blocks: (1) Lancaster's characteristics theory of value and (2) random utility theory (see Chapter 4 for discussion).

Results from the choice experiments are modeled within a random utility maximization (RUM) framework. McFadden (1974) originally formulated RUM theory, which has been widely used in econometrics and environmental valuation studies. RUM theory "provides a logical way to link observed choices to actions, and develop statistical choice models that explain the observed choices" (Louviere, 1994, p226). RUM theory is based on the notion that given a set of alternatives, an individual will choose the alternative which provides the

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[54] In this experiment, a single "treatment combination" is essentially a single wind development scenario with its own unique attribute levels (location of wind farm, distance from shore, royalty fund, royalty payment, and renewable energy fee). In other words, each treatment combination corresponds to a single option that respondents may choose in the choice problem—"Option A" or "Option B".

[55] A choice combination results from the random pairing of two treatment combinations. Hence, respondents have a choice between "Option A" and "Option B".

greatest level of utility. In other words, it is assumed that individuals are rational and follow "utility maximizing

Table 5.3 Twenty five choice combinations used in question 17

Survey Version	"Option A"		"Option B"		Royalty	Fund
	Distance	Fee	Distance	Fee		
1	0.9 miles	$0	TF	$5	Green	$2 M
2	0.9 miles	$1	9 miles	$10	Beach	$8 M
3	0.9 miles	$5	6 miles	$20	Green	$8 M
4	0.9 miles	$10	3.6 miles	$30	Beach	$2 M
5	0.9 miles	$20	TF	$30	General	$1 M
6	3.6 miles	$0	6 miles	$10	Green	$1 M
7	3.6 miles	$1	9 miles	$20	Beach	$1 M
8	3.6 miles	$5	TF	$10	General	$8 M
9	3.6 miles	$10	6 miles	$20	General	$2 M
10	3.6 miles	$20	9 miles	$30	Green	$2 M
11	6 miles	$0	9 miles	$1	Beach	$8 M
12	6 miles	$1	TF	$30	Green	$1 M
13	6 miles	$5	9 miles	$30	Green	$8 M
14	6 miles	$10	TF	$30	Beach	$1 M
15	6 miles	$20	9 miles	$30	Beach	$2 M
16	9 miles	$0	TF	$20	General	$1 M
17	9 miles	$1	TF	$5	General	$2 M
18	9 miles	$5	TF	$20	General	$8 M
19	9 miles	$10	TF	$20	Beach	$2 M
20	9 miles	$20	TF	$30	Beach	$8 M
21	0.9 miles	$5	3.6 miles	$10	Green	$8 M
22	3.6 miles	$10	6 miles	$30	Beach	$1 M
23	6 miles	$5	9 miles	$20	Green	$1 M
24	0.9 miles	$10	TF	$20	General	$2 M
25	3.6 miles	$1	9 miles	$10	Green	$2 M

Note: TF = too far out to see

behavior," choosing alternatives or making decisions that yield the *highest level of satisfaction*, given certain constraints (e.g., personal income) (Hensher et al., 2005). RUM theory recognizes there is both an observable ("representative") and unobservable ("stochastic") component to the utility that individuals derive from the consumption of goods. While the researcher can observe an individual's choice decision outcome, certain aspects of the decision process cannot be

observed, forcing researchers to make assumptions about the distribution of the stochastic components of utility during the modeling process.

Assume an individual n faces a decision among a known set of alternatives, J, where i represents a specific alternative under consideration from the full set of alternatives J. The utility of the nth individual for alternative i can be specified as:

$$U_{ni} = \beta' x_{ni}, y_{ni} + \varepsilon_{ni} \qquad 5.1$$

where x_{ni} and y_{ni} are vectors of the observed variables relating to the chosen alternative and to the individual, respectively, β is a vector of the variables' parameters, and ε_{ni} is a random error component accounting for those preferences which are known to the individual, yet unknown to the researcher. For the nth individual, equation 5.1 can be further decomposed into the following:

$$U_{ni} = \beta_{0in} + \beta_{1in} f(\chi_{1in}) + \beta_{2in} f(\chi_{2in}) + \beta_{3in} f(\chi_{3in}) + ...\beta_{kin} f(\chi_{kin}) \qquad 5.2$$

where β_{0in} represents an alternative-specific constant not associated with any observed attribute,[56] and β_{1in} through β_{kin} represents the parameters associated with each attribute X for alternative i, which may enter the utility expression in different functional forms denoted by f.

Faced with a set of J alternatives, an individual will chose the alternative i which yields the greatest level of utility. The researcher, however, can explain an individual's choice only up to a *probability* of alternative i being chosen (Hensher et al., 2005). Thus, equation 5.3 states the probability of choosing alternative i is equal to the probability that the utility of alternative i is greater than (or equal to) the utility associated with alternative j after evaluating each and every alterative.

$$\text{Prob}_i = \text{Prob}[(\beta' x_{ni} + \varepsilon_{ni}) \geq (\beta' x_{nj} + \varepsilon_{nj}) \; \forall \; j \in j = 1,...i,....J; i \neq j]. \qquad 5.3$$

Recognizing that equation 5.3 contains information not directly measurable by the researcher (i.e., ε_{ni}), it is useful to rearrange it into equation 5.4:

$$\text{Prob}_i = \text{Prob}[(\varepsilon_{nj} - \varepsilon_{ni}) \leq (\beta' x_{ni} - \beta' x_{nj}) \; \forall \; j \in j = 1,...i,...J; i \neq j]. \qquad 5.4$$

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[56] An alternative-specific constant can be considered a "shifter," representing on average the roll of the unobserved sources of utility.

This simple probabilistic relationship is the basis for estimating a maximum likelihood function for observing the pattern of choices actually made by the individuals within the data set (Thur, 2003). The likelihood function is determined by the assumed distribution of the error term ε_{ni} (ibid). The EV1 IID distribution (extreme value type 1, independent and identically distributed) is the most popular error term distribution in discrete choice analysis (Hensher et al., 2005). By imposing this distribution, choice probability can be explained using the standard multinomial logit model—the "workhorse" of discrete choice analysis (ibid). In this form, the probability of an individual choosing alternative *i* out of set *J* is:

$$\text{Prob}_i = \frac{\exp \beta' x_{ni}}{\sum_{j=1}^{J} \exp \beta' x_{nJ}}; \;\; j = 1,...i,...J; i \neq j. \qquad 5.5$$

5.8.2 Background: Mixed Logit Specification

Although the multinomial logit has been the backbone for discrete choice modeling for years, the mixed logit model offers the latest advancement in specification. When compared with the standard multinomial logit, mixed logit (also called "random parameter") techniques have the advantage of offering more flexibility and the ability to relax certain assumptions—mainly the independence of irrelevant alternatives (IIA) property. IIA is a restrictive assumption stating that the ratio of the choice probabilities between any two alternatives is independent of the presence or absence of any other alternative in a choice set. This implies that the probability of choosing one alternative over another remains constant and is unaffected by the presence of the other alternatives available within the choice set; however, it becomes difficult, and in many cases unrealistic, to satisfy such an assumption when multiple alternatives are introduced or removed from a choice set. Also, as in the multinomial logit specification, the error term ε_{ni} in the mixed logit is independent and identically distributed (IID) extreme value type 1 across individuals, alternatives, and choice situations (Hensher et al, 2005). This distribution is restrictive in that it does not allow for the error components of different alternatives to be correlated (ibid). To account for this restriction, new stochastic terms must be introduced to allow for hederoskedasity and correlation across alternatives (ibid).

The mixed logit utility function can be expressed as:

$$U_{ni} = \beta' x_{ni} + \mu' x_{ni} + \varepsilon_{ni} \qquad 5.6$$

where β is a vector of the parameters for the x_{ni} variables and μ_{nj} is a vector for the new random terms. The unconditional choice probability is the expected value of the mixed logit probability integrated over all possible values of β, weighted by the density of $f(\beta)$ (Train, 1999). Thus, the unconditional probability that individual n will choose alternative i out of set J can be expressed as:

$$P_{ni} = \int \left(\frac{e^{\beta' x_{ni}}}{\sum_{j=1}^{J} e^{\beta' x_{nJ}}}\right) f(\beta) d(\beta); \;\; j = 1,...i,...J; i \neq j. \qquad 5.7$$

One of the key characteristics of the mixed logit specification is that β is assumed to vary across individuals (whereas in the multinomial logit specification these parameters are fixed). Parameters associated with an attribute of an alternative are treated as "random" instead of "fixed" by specifying both a mean and a standard deviation for each element of β. Additionally, the random parameters can take on different distributional forms such as normal, lognormal, uniform, or triangular (Hensher et al., 2005). The standard deviation of the random parameters accommodates the presence of unobserved preference heterogeneity in the sampled population—perhaps the most advantageous trait of the mixed logit model (ibid). A large random parameter standard deviation signals greater dispersion around the mean, implying larger taste variation for that parameter among the sampled population. A smaller random parameter standard deviation indicates a tighter dispersion around the mean. In conclusion, the mixed logit model offers more flexibility and accuracy by (see Hensher et al., 2005; Train, 2002):

1. alleviating violation of the IIA property
2. allowing for random taste variation across the sample population
3. allowing for correlation in the unobserved error terms
4. allowing unrestricted substitution patterns

This increased flexibility offers the ability to estimate more complex RUM models which in turn may more accurately portray the sample population's decision-making process (Thur, 2003).

5.8.3 The Choice Experiment RUM Model

Initial model specifications were investigated using standard multinomial logit techniques, as described in Hensher et al., 2005. It is standard practice to begin model specification on the multinomial logit before using more complex models like the mixed logit. Thus, final predictors included in the mixed logit models presented below were selected based in part on their performance in the standard logit trials; results from the standard logit trials are not presented in this dissertation.

Recall that 2000 Delaware residents were randomly chosen to participate in the survey, and that the sample was stratified to include 1200 residents living inland, 400 residents living along the Delaware Bay, and 400 residents living along Delaware's Atlantic coastline. Logically it made sense to specify a model and to estimate it over each of the three sample strata—and thus to test for differences in preferences across the three different sampled groups.

5.8.4 The Model

The discrete choice model can be expressed as:

$$U_{wind\,\mathrm{i}} = \underline{\beta'}\,\underline{x_{wi}} + \underline{\alpha'}\,\underline{y_w} + \varepsilon_w \quad (i = 1,2) \qquad 5.8a$$

$$U_{sq} = \varepsilon_{sq} \qquad 5.8b$$

where U_{wind} represents the utility of choosing one of the two "wind" options (i=1,2), and U_{sq} represents the utility of choosing the "status quo" option of coal or natural gas for increased energy production. x_{w1} is a vector of attributes describing the given wind power options, and varies across the choice scenarios; y_{w} is a vector of characteristics describing the respondent, and remains constant for each individual over the given choice scenarios. ε_w and ε_{sq} represent the error terms of the given wind and status quo options, respectively. See Table 5.4 for variable definitions.

When estimating the bay and ocean models, the *bchhouse* variable was excluded, as we were only interested in those residents from the inland stratum that had a beach house as a second home. The *Delmarva* variable also was excluded from the ocean model, since the overwhelming majority of ocean residents have Delmarva Power as their power provider.

5.9 Hypotheses

Hypothesis testing was not the primary focus of the modeling process for this dissertation; however, in the beginning stages of this research, there were a number of hypotheses and ideas that in general we wanted to confirm, refute, or shed some light on. These questions helped guide the survey design in general, and in particular, the choice experiment module design. The hypotheses we considered regarding the public's opinion and preferences for offshore wind power development are:

1. **Residents will be willing to pay a premium on their utility bill for offshore wind power versus expansion of coal or natural gas power.**

BASIS: (1) Delaware citizens have pollution and air quality concerns over the existing Indian River coal power plant; (2) A recent rate hike for Delmarva customers has citizens concerned about the price stability of electricity over the long term.

2. **Delaware residents will show a location preference for where offshore wind turbines should be located. Residents will prefer turbines to be placed off the Atlantic coastline rather than in Delaware Bay.**

BASIS: (1) Residents may have a greater place attachment to bays than to the open ocean; (2) There is great concern over wildlife (Firestone and Kempton, 2007), and this concern may be even greater in bays and estuaries than for the open ocean; (3) Delaware Bay is one of most important international flyways for migratory birds, and has the world's largest gathering of horseshoe crabs during the mating season.

3. **Delaware residents will prefer wind turbines to be located further offshore.**

BASIS: Wind turbines seem to be a disamenity, and people are willing to pay a premium to have turbines located further offshore (Ladenberg and Dubgaard, 2007).

4. **Delaware residents will prefer higher royalty fees over lower fees for offshore wind power.**

BASIS: Financial incentives increase support for local wind power projects (Jobert et al., 2007), and royalties can serve as compensation and incentives for placing wind turbines on public lands (ibid),

5. **Residents living along the ocean or bay will be more likely to support offshore wind power if royalty monies are deposited into a beach nourishment fund.**

BASIS: A beach nourishment fund would provide a financial incentive (Jobert et al., 2007) for those who are concerned about possible tourism impacts, and nourishment project money would serve as compensation for any visual impact felt by coastal communities.

Table 5.4 Model variable definitions

VARIABLE	DEFINITION OF VARIABLE
Bay	Wind farm placed in Delaware Bay
Rehoboth	Wind farm placed off of Rehoboth Beach
Fenwick	Wind farm placed off of Fenwick Island
Ln(distance)	Natural log of the wind farm distance (in miles) from shore
Green Fund	Green Energy Fund for wind option
Beach Fund	Beach Nourishment Fund for wind option
General Fund[1]	Delaware General Fund for wind option
Roy1[2]	Royalty payment of $1 million/year to Delaware
Roy2	Royalty payment of $2 million/year to Delaware
Roy8	Royalty payment of $8 million/year to Delaware
Fee	Amount of renewable energy fee for the wind options
Income[3]	Personal income of the respondent
High school or less[4]	Respondent has no college education
Some college	Respondent has limited college education
4-year degree	Respondent has an associate's or bachelor's degree
Post-grad	Respondent has a graduate or professional degree
Age[5]	Age of the respondent in years[5]
Male	Dummy variable indicating gender, "1" male and "0" female
Retired	Respondent is retired
Delmarva[6]	Respondent receives electricity from Delmarva Power
See ocean[7]	Respondent can see the ocean from primary or secondary residence
See*distance	Interaction term between seeocean and ln(distance) variables
Distfbch[8]	Distance (in miles) from respondent's primary or secondary residence to nearest beach
Beach days	Number of days respondent has spent at the beach in the past 12 months
Seen turbine	Respondent has seen a wind turbine in operation
Beach house	Respondent owns a beach house as a primary or secondary residence in Delaware
Bay	Wind farm placed in Delaware Bay

[1,2,3]*General fund*, *roy1* and *high school or less* were excluded from the model and serve as comparison categories.
[4]*Income* was collected categorically, based on total household income before taxes, and converted into a continuous variable for modeling purposes. Missing values were assigned median household income based on zip code data from year 2000 census information.
[5]Missing age values were assigned median value of 58 from the sample population.
[6]Missing values were assigned the median value, *Delmarva,* since the majority of the State is supplied by Delmarva Power
[7]Missing values were assigned median response "0"
[8]Missing values were assigned median values of: 30 miles for inland stratum, 2.5 miles for bay stratum, and 0.5 miles for ocean stratum.

CHAPTER 6

DESCRIPTIVE DATA

6.1 Purpose

Chapter Six summarizes responses of Delaware residents who completed the mail survey and presents results of selected survey questions.[57] The choice experiment question data is analyzed in Chapter 7.

6.2 Survey Response Rate, Over-sampling, and Weighting

Surveys were mailed to 2000 randomly selected Delaware residents. A total of 949 returned surveys were used in the analysis. After accounting for bad addresses and for deceased and otherwise incapacitated respondents, the response rate is 52%.[58] Table 6.1 presents the sample size and response rate by stratum.

The Ocean and Bay regions were over-sampled to ensure an adequate number of representative responses from these areas. As a result, when examining Delaware opinion statewide, each response was weighted by the inverse of the probability that it was included. The sample also was weighted due to response biases. Survey respondents were more likely to be male, older, and wealthier than the population being studied (those members of the Delaware population who are over 19 years of age). These biases are not uncommon in survey research (Firestone and Kempton, 2007). After adjusting the weights, statewide sample demographics mirror population demographics.

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[57] A large portion of the analysis and text of this chapter is taken from Firestone, Kempton, Krueger, 2007.

[58] Additional surveys have since been returned completed, but not used in analysis because they were returned after the cut-off date of December 31, 2006. This date was selected because a bid for an offshore wind power project in Delaware was publicly announced.

Table 6.1 Sampling size by area

Area (Stratum)	Sample Size (n)	Completed Surveys Analyzed	Census Tracts/Blocks	Description	Average Distance to Beach (miles)
Bay	400	203	501.03 509 (1) (2)	Slaughter Beach; Fowlers Beach; Prime Hook Beach; Broadkill Beach	4
Ocean	400	182	511 512	Rehoboth Beach; Dewey Beach; Bethany Beach; South Bethany; Fenwick	0.6
Inland	1200	564	All remaining census tracts and blocks in Delaware	All of Delaware, excluding the above.	35
Post-Stratification of Inland					
Second Home	1200	111	Varies	Own Second Home	2.5
No Coastal Home		453	Varies	Inland	39.8

Over-sampling does not need to be accounted for when looking at individual areas; however, corrections for demographics biases are still needed. The inland sample was weighted so that it would match the age, sex, and income demographics of the State, as the inland area includes 89 percent of Delaware households, and thus likely follows statewide demographics closely. The ocean and bay samples were individually weighted to match statewide gender demographics only, mainly because these areas represent such a small percentage of the Delaware population and because age and income demographics of these areas may be significantly different than the state as a whole. All results presented are weighted, unless otherwise noted. Table 6.2 presents a characterization of the surveyed sample by stratum.

Table 6.2 Characterization of surveyed population: median values

	Overall	Inland	Bay	Ocean
Age	58	57	61	61
Education	Bachelor's degree	Associate's Degree	Associate's degree	Bachelor's degree
Distance from nearest beach	6 miles	35 miles	2.5 miles	0.5 miles
Household income	$50,000-$75,000	$50,000-$75,000	$50,000-$75,000	$100,000-$150,000

6.3 General Attitudes Regarding Wind Turbines

As seen in Table 6.3, 54.2% of the respondents have seen a wind turbine in operation. Modeling results, presented in Chapter 7, indicate that in general, this is a significant factor in gaining positive utility from wind power for the ocean and bay area respondents. Partial correlation results show that respondents who are *male*, who have a higher *income* and higher *education* are more likely to have seen a wind turbine (see Table 6.4). Also, correlation results indicate that those whom have seen a wind turbine in operation tend to be less likely to support a Delaware *Cape Wind*-type project; however, in a regression logit model on support for the Delaware Cape Wind project, discussed later, seeing a turbine does not have any effect (positive or negative) on support for the project, meaning seeing a turbine could instead be a proxy for being a male or having a higher income or education.

Table 6.3 Responses to survey question #1: Have you ever seen a wind turbine in operation?

Response	Percent Total
Yes	54.2
No	45.8

Number of observations= 943

Table 6.4 Partial correlation results for the "seen turbine" variable

Variable	Correlation	p-value
Male	0.22*	0.00
Age	0.42	0.23
Education	0.06◊	0.07
Income	0.13*	0.00
Employment	0.03	0.45
Cape Wind Project	-0.12*	0.00

Number of observations= 814
*Significant at the α=0.01 level of confidence
◊ Significant at the α=0.001 level of confidence

Table 6.5 and Figure 6.1 present data on how respondents think wind turbines affect the appearance of the landscape. Results indicate the majority of respondents believe the effect to be neutral (57.9%), with a higher percentage believing the effect to be positive (27.9%) than negative (14.2%).

Table 6.5 Responses to survey question #3: In your opinion, what effect do land-bases wind turbines have on the appearance of the landscape?

Response	Percent of Total
Very positive	6.3
Positive	21.6
Neutral	57.9
Negative	12.8
Very negative	1.4

Number of observations= 936

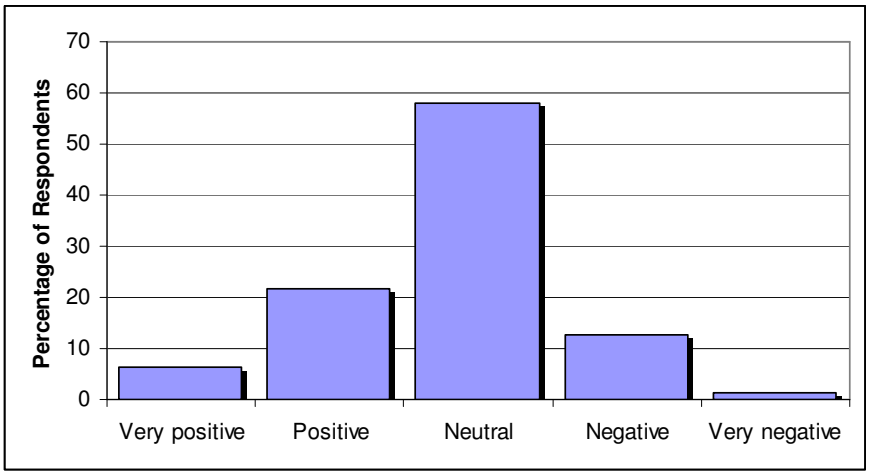

Figure 6.1 Responses to survey question #3: In your opinion, what effect do land-bases wind turbines have on the appearance of the landscape?

Table 6.6 and Figure 6.2 present data on how respondents think wind turbines affect the environment. Results indicate that an overwhelming majority (77%) believes the effect to be positive; a smaller percentage believes the effect to be neutral (21.7%), and a minimal percentage believes the effect to be negative (1.3%).

Table 6.6 Responses to survey question #4: In your opinion, what effect do wind turbines have on the environment?

Response	Percent Total
Very positive	41.4
Positive	35.6
Neutral	21.7
Negative	1.0
Very negative	0.3

Number of observations= 925

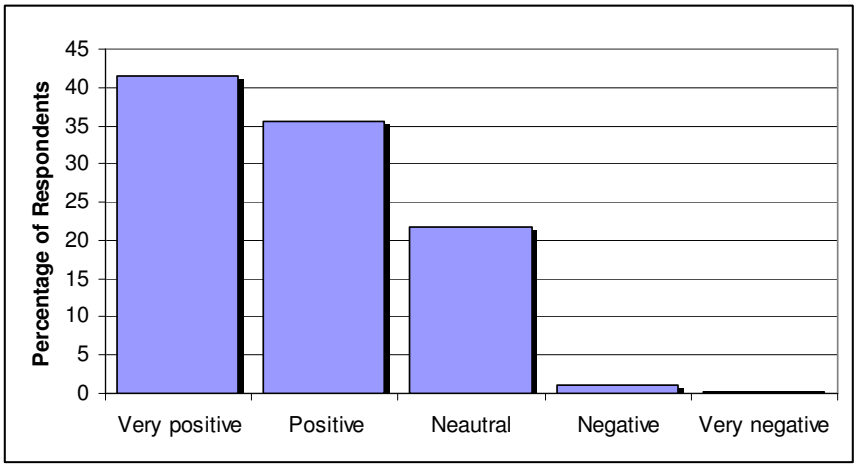

Figure 6.2 Responses to survey question #4: In your opinion, what effect do wind turbines have on the environment?

6.4 Placement of Wind Turbine in the Ocean or Bay

As seen in Table 6.7, there is strong support for offshore wind power among Delaware residents. More than 90% want the state to either encourage and promote or allow in appropriate circumstances offshore wind power development in the ocean while less than one percent desire wind turbines be prohibited in all instances in the ocean. Very strong support for a state policy advocating wind turbines in the ocean is found among ocean area residents as well, although opposition increases to 6.4%. There is also strong support for offshore wind development in Delaware Bay, although the support is somewhat less than in the ocean. When asked their preference between placing turbines either in the ocean or the Bay, the majority of inland Delawareans expressed no preference, although 31.5% prefer the ocean to only 16.3% preferring the Bay (See Table 6.8 and Figure 6.3).

Table 6.7 Placement of Wind Turbine in the Ocean or Bay

Turbine Placement	Out on the Ocean		In Delaware Bay	
Sample Area	**Statewide (%)**	**Ocean (%)**	**Statewide (%)**	**Bay (%)**
Policy				
Encouraged and Promoted	55.3	49.1	47.3	40.4
Allowed in Appropriate Circumstances	36.7	33.3	39.1	38.4
Tolerated	3.1	6.6	5.3	1.7
Prohibited in all instances	0.7	6.4	2.7	11.4
Not Sure	4.2	4.6	5.2	8.0

Table 6.8 Responses to survey question #7: If Delaware decided to develop wind power for electricity generation, where would you prefer the wind turbines be located?

	Overall	Inland	Bay	Ocean
In the ocean	39.5%	31.5%	40.4%	37.6%
In Delaware Bay	15.6%	16.4%	10.8%	22.0%
No preference	44.9%	52.1%	48.8%	40.4%

Number of observations= 925

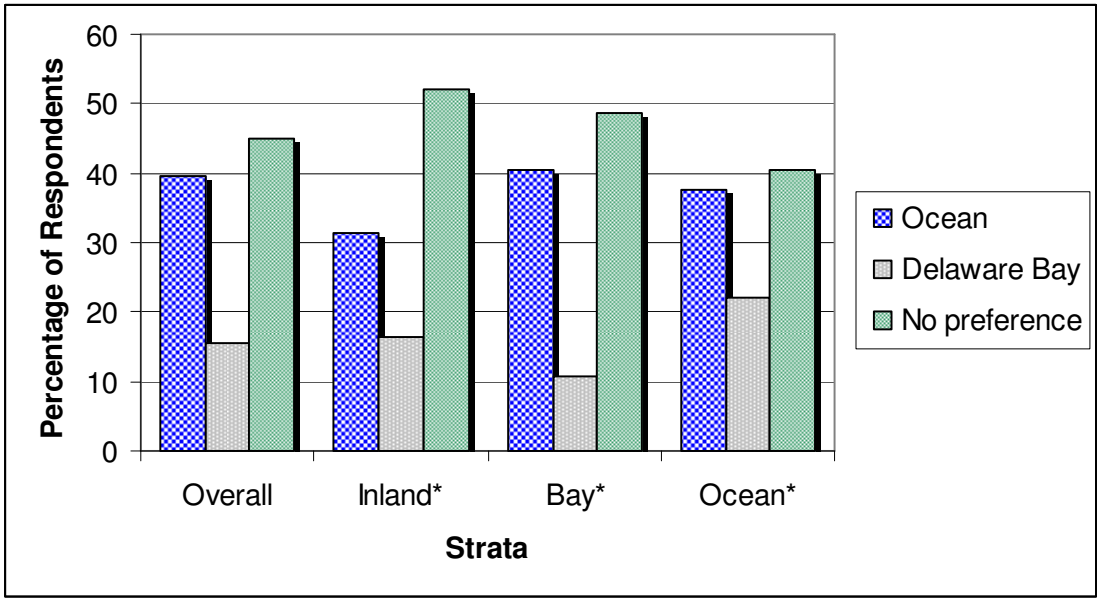

Figure 6.3 Responses to survey question #7: If Delaware decided to develop wind power for electricity generation, where would you prefer the wind turbines be located?

6.5 A Delaware "Cape Wind" Offshore Project

Residents also were given a description of the proposed Cape Wind project off of Cape Cod, Massachusetts, and asked whether they would support or oppose the same project if it were instead moved off of the Delaware coast. Specifically, the question said:

> A private developer has proposed to place 130 wind turbines that stand 423 feet high out on the ocean off of Cape Cod, Massachusetts for electricity generation. The project would be approximately 6 miles from the nearest coastal town. *For questions 9-13, suppose this project were instead developed off the Delaware coast.*

The results, provided in Table 6.9 and Figure 6.4, indicate that an offshore wind farm is likely to garner significant support throughout the state. Statewide, support registers 18.5 times as much as opposition, and even in the ocean area (where respondents live on average approximately 0.6 miles from the coast), support outnumbers opposition 3.33 to 1. And of those individuals who live in the inland portion of the state, "Second Home" beach house owners are as supportive as those individuals who do not own a beach house (labeled "No Coastal Home" in Table 6.9). The high support for a Cape Wind-type project in Delaware contrasts sharply with results from the

Kempton and Firestone (2007) survey. In that study, 55.5% of respondents opposed while 43.8% supported the project, with 0.7% unsure. The divergence in results is interesting and perhaps suggests that support for and opposition to a project may be highly place-specific, or that in general the public is more supportive toward offshore wind power today than it was two years ago.

Table 6.9 Support for a 130 turbine wind farm 6 miles off the Delaware coast

	Areas/Populations of Delaware				
	Statewide (%)	**Ocean (%)**	**Bay (%)**	**Second-home (%)**	**No Coastal Home (%)**
Support	77.8	65.0	73.5	79.0	77.9
Oppose	4.2	19.5	9.0	3.5	4.0
Unsure	18.0	15.5	17.5	17.5	18.1

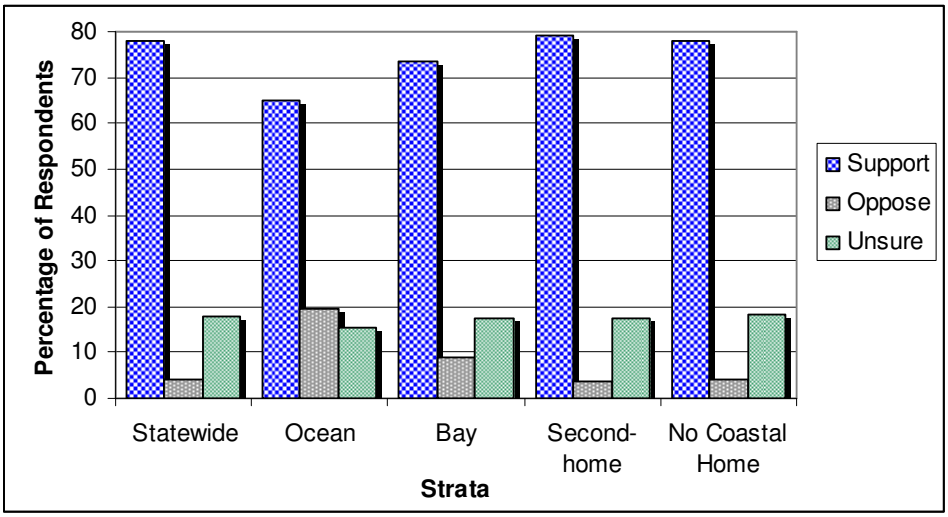

Figure 6.4 Support for a 130 turbine wind farm 6 miles off the Delaware coast

A simple logit model was run to look more closely at factors that might explain support or opposition to this project among ocean area respondents. Results from Table 6.10 show that all variables in the model, except age, are insignificant. The positive coefficient on age

indicates that those who are older are more likely to support the project. Furthermore, the odds ratio for the age variable in Table 6.10 indicates that the odds of support for the project increases by 5.8% as a person ages one year. When examined over a 30 year period, the odds of someone who is 65 old that will support the project compared to someone who is 35 years old increases by 82.4%.[59] These findings are essentially opposite of those by Firestone and Kempton (2007), where support for the Cape Wind project among Cape Cod and the Islands residents decreased with increasing age, at a rate of 3% for each year aged. In summary, while support for a Cape Wind-type in project in Delaware is high (among inland, ocean, and bay respondents alike), those ocean area respondents whom are older are more likely to support than those who are younger.

Table 6.10 Logistic regression of factors influencing support for a Cape Wind-type project in Delaware, ocean area residents only

Variable	Coefficient	Odds ratio	Standard error	p-value
Age	0.057*	1.058	0.025	0.025
Male	-0.414	0.661	0.554	0.447
Income	-0.043	0.957	0.109	0.692
Education	-0.069	0.932	0.229	0.761
Seen turbine	0.595	1.81	0.568	0.295
See ocean	-0.06	0.95	0.549	0.993
Distance from beach	1.08	2.94	0.737	0.143
Constant	-1.87	NA	2.61	0.475

Number of observations: 130
*Significant at the α=0.05 level of confidence
Log pseudo likelihood = -56.073882; Wald chi^2 = 13.98; Prob > chi2 = 0.0516;
Pseudo R^2 = 0.1132

Respondents also were presented with a list of possible impacts of this wind farm and for each, asked if they thought this project would have positive impacts (improve), negative impacts or no impact at all. Table 6.11 presents the results, divided by supporters and opponents from the ocean stratum only, since this sub-sample had the most divergence of opinion, and thus an analysis of that opponent group is potentially more policy relevant. A large majority of the

[59] The odds are calculated as follows: $e^{-0.058x30}$=0.1755. 0.1755 – 1= 0.824. See Firestone and Kempton, 2007; Long, 1997.

ocean area *opponents* perceive negative impacts to aesthetics (100%), tourism (85%), property values (85%), navigation (76%), bird life (68%), recreational boating and fishing (61%), and the local fishing industry (58%). A much smaller percentage believes there will be an improvement in electricity rates (26%), job creation (11%) and marine life (11%). Somewhat puzzling, more opponents see the wind farm as having negative impacts on air quality and climate change than positive impacts. A smaller, but still large majority of ocean area *supporters* believe the wind power project would have positive effects on electricity rates (78%), air quality (68%), and job creation (57%) and climate change (39% positive, 0% negative), but negative impacts on aesthetics (41% negative to 3% positive).

Table 6.11 Believed negative and positive impacts of the Delaware Cape Wind project for the Ocean Area by support and opposition

	Opponents			**Supporters**		
Item	Improve	No Impact/ Not Sure	Negative	Improve	No Impact/ Not Sure	Negative
Local Fishing Industry	2%	39%	58%	19%	76%	5%
Tourism	0%	15%	85%	5%	88%	8%
Job Creation	11%	81%	8%	57%	42%	2%
Air Quality	2%	92%	6%	68%	32%	0%
Electricity Rates	26%	66%	8%	76%	23%	1%
Aesthetics of view	0%	0%	100%	3%	56%	41%
Property Values	0%	15%	85%	9%	81%	10%
Marine Life	11%	44%	45%	20%	76%	4%
Bird Life	6%	26%	68%	6%	79%	15%
Recreational Boating/fishing	0%	39%	61%	8%	77%	14%
Reduce Climate Change	2%	87%	8%	39%	61%	0%
Navigation Safety	0%	24%	76%	6%	72%	22%

Respondents also were asked to write-in the three most important issues in deciding whether they would support or oppose the project. This was an open-ended question. Table 6.12 presents the statewide results by supporters only (given the very small percentage of opponents

~4%, this data is not presented here), and the results for the Ocean area by both supporters and opponents.

Table 6.12 Factors reported to most affect decision to support or oppose Delaware Cape Wind Project, (open-ended, ordered by overall statewide rank of Top)

	Statewide	Ocean Area	
	Supporters Top (%)	Supporters' Top (%)	Opponents' Top (%)
Issue			
Electricity Rates	29	18	6
Air Quality	18	19	0
Marine Life/Environmental Impacts	14	6	23
Jobs/Economic Concerns	7	6	0
Recreational Boating and Fishing/Boat Safety	6	6	3
Alternative/Renewable Energy	4	8	0
Foreign Oil Dependence	4	8	0
Aesthetics	3	15	53
Global Warming/Climate Stability	2	4	0
Fishing Impacts	2	1	0
Distance From Shore	1	<1	0
Tourism	1	1	6
Property Values	1	1	6
Private Use of Public Lands	<1	0	0
Other	8	5	4
Total*	100	98	101

*May not total 100% because of rounding

Delawareans' strong support for offshore wind power appears to be based primarily on concerns over electricity rates and air quality. This is true statewide and in the ocean area. Ocean area opponents are primarily driven toward opposition based on aesthetic grounds and concerns over marine life impacts. Interestingly, aesthetics ranks a strong third for Ocean area supporters, however to the extent they find offshore wind turbines to have a negative impact on aesthetics (41% negative; only 3% positive, Table 6.11), they remain supporters of offshore wind power for other reasons; presumably they believe that offshore wind power's potential positive

impacts on electricity rates, climate change and air quality outweigh its anticipated negative impact on aesthetics.

To examine the aesthetic concerns more closely, partial correlations were run for those ocean area respondents who listed the aesthetic impact as their primary reason or one of their top three reasons for opposing a Delaware Cape Wind-type project. Table 6.13 shows that those respondents who are of a *younger age* and whom have a *higher income* are more likely to hold aesthetic objections to this project. Interestingly, though, those ocean area residents who can *see the ocean* from their residence seem to be less likely to hold aesthetic objections. This finding is somewhat counterintuitive, and implies that those living close enough to the coast to see the ocean should not necessarily be stereotyped as automatically objecting to offshore wind farms solely because of aesthetic concerns. In fact, for those individuals who can see the ocean from their residence, other factors, such as environmental impacts or impacts to wildlife or marine life, may be more important than aesthetic concerns.

Table 6.13 Partial correlation results for listing aesthetic impacts as a primary reason of concern

Variable	Correlation	p-value
Seen a turbine	0.01	0.94
Male	-0.08	0.35
Age	-0.18*	0.03
Education	-0.07	0.43
Income	0.21*	0.01
Employment	0.13	0.11
See ocean	-0.15◊	0.07
Distance from beach	-0.11	0.19

Number of observations= 155
*Significant at the α=0.01 level of confidence
◊ Significant at the α=0.001 level of confidence

Table 6.14 Partial correlation results for listing aesthetic impacts as one of the top three reasons of concern

Variable	Correlation	p-value
Seen a turbine	-0.14	0.09
Male	-0.08	0.34
Age	-0.21*	0.01
Education	-0.00	0.99
Income	0.13	0.10
Employment	0.26*	0.00
See ocean	-0.09	0.25
Distance from beach	-0.03	0.68

Number of observations= 155
*Significant at the α=0.01 level of confidence.

For the ocean area residents whom listed aesthetic impacts as one of their top three concerns, the fact that "see ocean" is not significant implies that those respondents who can see the ocean from their residence are just as likely to have aesthetics as a top three concern as anyone else (see Table 6.14). Also, those respondents who are *younger* and *employed* are more likely to hold aesthetic objections.

6.6 Royalty Payments

The Energy Policy Act of 2005 directs the U.S. Minerals Management Service (MMS) to promulgate regulations setting forth rents and royalties to be paid by developers of

alternative energy on the U.S. continental shelf. It also provides for cost sharing with states for any wind farm project in which at least one turbine is within six miles from its ocean coast. Thus, there is the potential for coastal states to earn revenues from offshore wind power development in federal offshore waters. Moreover, it is possible that Delaware may adopt a rent and royalty scheme for any wind power development that occurs in Delaware State waters. We asked individuals to identify their preference among three funds into which any windpower-related royalty revenue would be deposited: (1) the Delaware General Fund; (2) the existing Green Energy Fund; and (3) a Beach Nourishment Fund that would be created and that would dedicate its funds toward the addition of sand to any eroded Delaware beach from which the wind farm would be visible.

Table 6.15 presents the results. Overall, the Green Energy Fund garners the most support and is supported by a substantial percentage in the three areas of the State that we studied; however, in the ocean area, the Beach Nourishment Fund has even more support (45% to 35%). If we examine separately only those individuals in the ocean area who were opposed to a 130 turbine wind farm six miles from the coast ("Cape Wind in Delaware"), 68.8% prefer the Beach Nourishment Fund. Although the General Fund receives the same amount of support as the Beach Nourishment Fund in the state overall, it receives substantially less support (less than ten percent) in the bay and ocean areas. These findings suggest that the State of Delaware might facilitate support for wind farm development by dedicating any revenues collected to either the Green Energy Fund, or if beach residents are of particular concern or it is considered important to "compensate" coastal communities for any potential negative effects of offshore wind farm development, a combination of the Green Energy Fund and a new Beach Nourishment Fund.

Table 6.15 Royalty fund preference

	Area/Population of Delaware				
	Statewide (%)	**Inland (%)**	**Bay (%)**	**Ocean (%)**	**Ocean if Opposed Cape Wind (%)**
Green Energy Fund	46.0	46.1	48.5	35.0	17.7
Beach Nourishment	19.0	18.6	26.3	45.0	68.8
General Fund	18.8	19.2	9.5	9.4	4.1
No preference	16.1	16.1	15.6	10.6	9.4

6.7 Additional Demographic Data

As can be seen in Table 6.16, a majority of the survey respondents, 68.7%, were male. As noted earlier, these response biases are not uncommon in survey research. After adjusting the weights, statewide sample demographics mirrored population demographics.

Table 6.16 Are you male of female?

	Overall Frequency	Percent Total
Male	637	68.7%
Female	290	31.3%

As seen in Table 6.17, 16.4% of respondents indicated they could see the ocean or bay from their home or beach house, meaning almost a fifth of the sampled population has the potential to see a wind farm if developed off the Delaware coast. In contrast, Firestone and Kempton (2007) had only 18 respondents (less than 0.04%) indicate they would be able to see the Cape Wind project from their home.

Table 6.17 Can you see the ocean or bay from your house or beach house?

Response	Percent Total
Yes	16.4
No	83.6

Number of observations= 882

Table 6.18 shows that the majority of respondents obtain their electricity from Delmarva Power (this is true statewide). Because of a Delmarva recent rate increase and associated price shock for Delaware customers (60% rate increase), a dummy variable was included in the inland model to predict whether or not Delmarva customers were more supportive of wind power over non-Delmarva customers, given wind's potential to lead to long term price stability over coal or natural gas (see Chapter 7 for results).

Table 6.18 Who supplies your electricity?

Response	Percent Total
Delmarva	64.3
Delaware Electric Cooperative	19.5
City/Town	15.3
Unsure	0.9

Number of observations =931

Table 6.19 and Figure 6.5 show that the majority of respondents are well educated. Approximately 59% have earned a college degree, while an additional 20.5% have some college experience. Less than 3% have less than a high school diploma.

Table 6.19 What is the highest degree or level of school that you have completed?

Response	Percent Total
Grade school	0.3
Some high school	2.5
High school graduate	17.6
Some college credit	20.5
Associate degree	8.1
Bachelor's degree	25.7
Graduate/ professional degree	25.3

Number of observations= 926

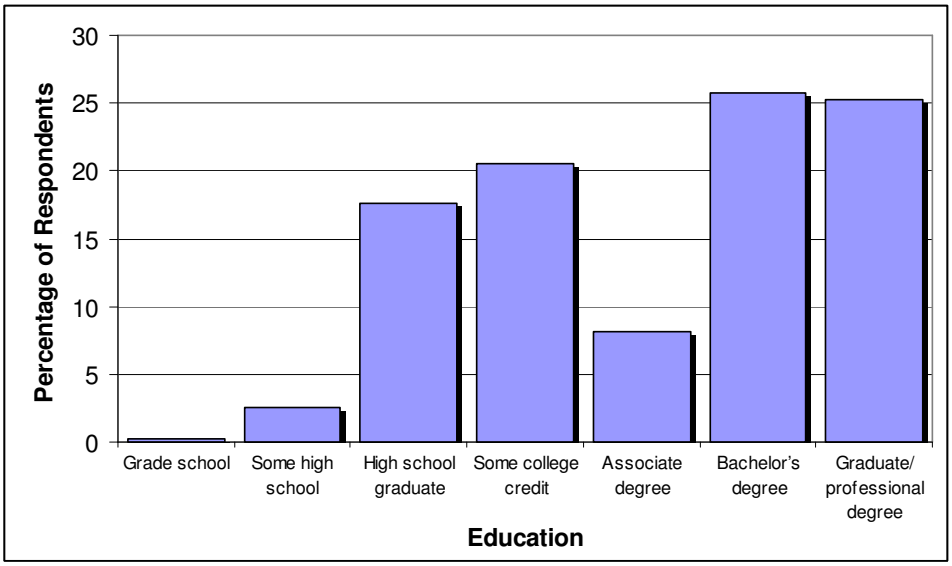

Figure 6.5 What is the highest degree or level of school that you have completed?

Table 6.20 and Figure 6.6 show that respondents were most likely to have an annual household income of $50,000-75,000 (21.2%), $75,000-$100,000 (17%) or $100,000-$150,000 (16.6%). Close to 8% had an income over $250,000. Survey respondents were wealthier than the general population under study, and this was compensated for during data analysis and modeling.

Table 6.20 Which category best describes your household income (before taxes) in 2005?

Category	Percent Total
< $10,000	1.5
$10,000-$15,000	2.7
$15,000-$25,000	5.3
$25,000-$35,000	8.0
$35,000-$50,000	11.8
$50,000-$75,000	21.2
$75,000-$100,000	17.0
$100,000-$150,000	16.6
$150,000-$200,000	5.7
$200,000-$250,000	2.1
$250,000 and above	7.9

Number of observations= 853

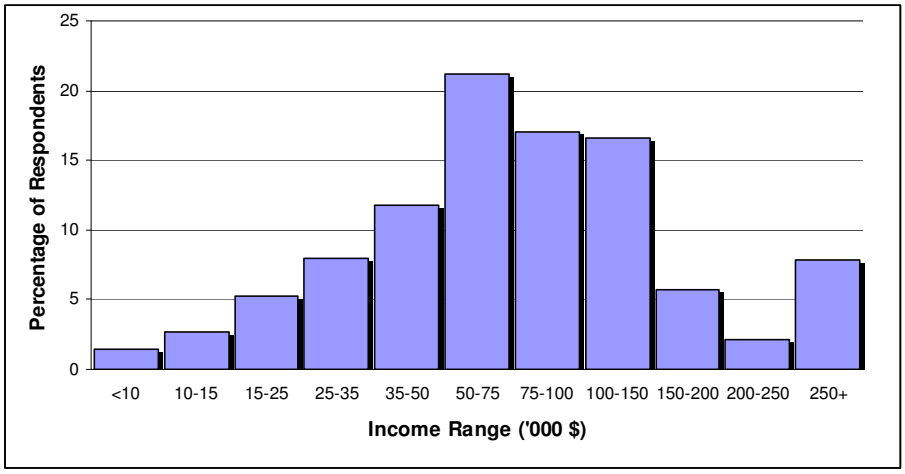

Figure 6.6 Which category best describes your household income (before taxes) in 2005?

Table 6.21 What is your current employment status?

Response	Percent Total
Employed for wages	43.5
Self-employed	13.7
Out of work	1.2
A homemaker	2.1
Student	0.4
Retired	39.1

Number of observations= 932

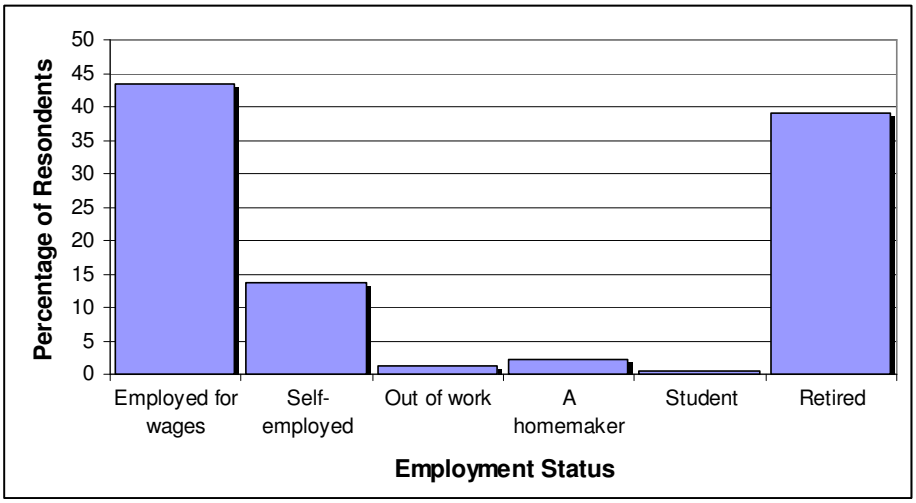

Figure 6.7 What is your current employment status?

Table 6.21 and Figure 6.7 shows the majority of respondents are employed (57.2%); a larger percentage, however, is retired (39.1%). A dummy variable was included in the inland, ocean and bay models to test whether retirees were different than non-retirees in their support for offshore wind power development in Delaware (see Chapter Seven for results). The large number of retirees is consistent with the large number of older respondents who completed the survey.

Table 6.22 and Figure 6.8 shows the majority of respondents are between the ages of 50-61. As noted earlier, respondents were more likely to be older, and this was corrected for during data analysis.

Table 6.22 What is your age?

Category	Frequency	Percent Total
< 31	32	3.49
31-40	92	10.03
41-50	172	18.76
51-60	235	25.63
61-70	196	21.37
71-80	142	15.49
81-90	44	4.80
>90	4	0.44

Number of observations= 917

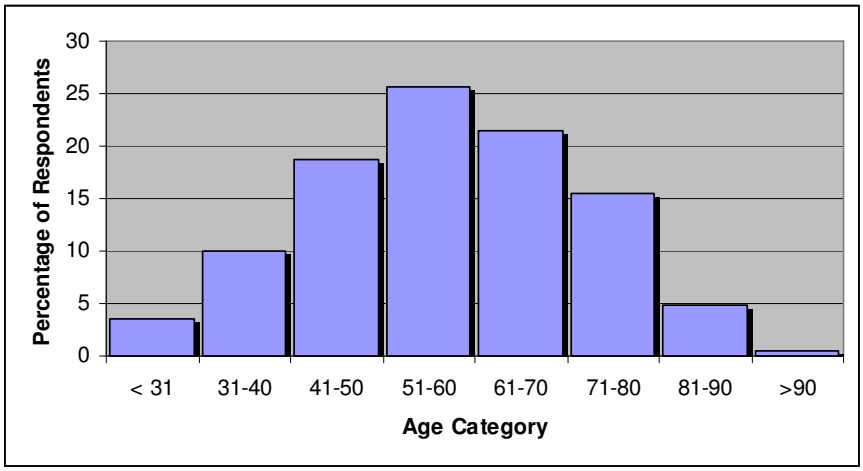

Figure 6.8 What is your age?

CHAPTER 7

MODEL RESULTS, WILLINGNESS TO PAY, AND SIMULATIONS

7.1 Purpose

Chapter Seven presents (1) the CE question response data, (2) the model results (3) welfare estimates and (4) simulation results. Policy implications and conclusions are discussed in Chapter Eight.

7.2 CE Question Descriptive Statistics

Table 7.1 shows the response rate data for the three CE questions. A total of 83 respondents (8.7%) did not answer one of the three choice questions; 17 individuals (1.8%) did not answer all three choice questions.

Table 7.1 Response rate for questions 17-19

Question	Wind Option A	Wind Option B	Coal/Nat Gas Option C	Total Responses	Response Rate
17	394	402	96	892	93.7 %
18	617	294	86	897	94.2 %
19	526	280	100	906	95.2 %

Of the approximately 2695 total recorded choice occasions in the dataset, a combined 92.9% chose offshore wind power while 7.1% chose coal or natural gas (see Table 7.2). Of those responses voting for wind power, 64.2% voted for the least-cost option (including cases where the fee for wind was $0) while 35.8% voted for the more costly wind power option. This suggests that for some individuals, initial price is less important than other factors, such as location, distance, amount of royalty payment and where royalty payments will be applied.

Table 7.3 compares only those answers where both the wind power options were said to cost more initially than the coal/natural gas option—that is, choice responses are tabulated only for those questions in which the three year renewable energy fee for both Option

A and Option B was between $1 and $30 per month. Of these 1521 recorded choice occasions, a combined 91.1% voted to expand electricity with offshore wind power while 8.9% voted for coal or natural gas (see Table 7.4). Of those responses voting for wind power among non-zero fees, 65.9% voted for the least-cost option while 34.1% voted for the more costly wind power option. Again, this suggests that for some individuals, initial price is less important than other factors.

Table 7.2 Percentage choosing Option A, B and C in questions 17-19

	Wind Option A	Wind Option B	Coal/Nat Gas Option C
Number of total responses	1437	976	282
Percent who chose each option*	59.6	33.3	7.1
Percent choosing a specific wind option*	64.2	35.8	NA

*Weighted

Table 7.3 Percentage choosing Option A, B and C in questions 17-19 with non-zero fees

	Wind Option A	Wind Option B	Coal/Nat Gas Option C
Number of total responses	774	576	171
Percent who chose each option*	60.1	31.0	8.9
Percent choosing a wind option*	65.9	34.1	NA

*Weighted

It is clear that the majority of respondents would vote to expand electricity with offshore wind power rather than coal or natural gas, even when told they would pay more for the wind power. Moreover, when one of the two wind options has a $0 fee (and hence no "premium" for wind power), offshore wind power is preferred by 95% of the respondents.

Table 7.4 Wind Power versus Coal or Natural Gas*

	$1-30 Monthly Wind Power Premium	No Premium
Wind (%)	91.1	95.0
Coal or Gas (%)	8.9	5.0

*Weighted

7.3 CE Model Results

The mixed logit models were estimated using NLOGIT 3.0/LIMPDEP 8.0 software. Parameter estimates for the inland, bay and ocean models can be found in Table 7.5. Full statistical results of each model (standard errors, t-ratios and p-values) are reported in Appendix 3.

7.3.1 Random Parameters

Bay, *Rehoboth Beach*, *Fenwick Island*, *ln(distance)*, *green fund*, *beach fund*, *roy2*, and *roy8* were estimated as random parameters with normal distributions.

In the inland and bay models, parameter estimates for *Bay*, *Rehoboth Beach* and *Fenwick Island* are all positive and statistically significant. There is no significant difference between *Bay*, *Rehoboth Beach*, and *Fenwick Island*—an indication that there is no single-held preference for one location over another—but the positive coefficients on these parameters, as well as their overall significance, indicate a higher derived utility from wind power than from coal or natural gas, all else being equal. In the ocean model, the *Rehoboth* (-3.67) and *Fenwick* (-3.45) parameters are negative and statistically significant; the *bay* (-2.81) parameter also is negative, but not statistically different from zero. In contrast to the inland and bay models, the negative values on all three location parameters in the ocean model suggests a general decrease in utility for offshore wind power versus coal or natural gas (though, as will be discussed later on in Figure 7.8, ocean area residents are willing to pay for wind over coal or natural gas, even when turbines are placed at just over a mile from shore).

As expected, the *ln(distance)* parameter is positive and statistically significant in all three models, indicating greater utility is derived as the wind turbines are placed further offshore.

The *ln(distance)* parameter coefficient is larger in the ocean model (1.12) than in the bay (0.87) and inland (0.51) models. This implies that ocean area residents would gain the most utility from wind turbines being placed further offshore, followed by bay area residents, all else being equal. Inland residents seem least concerned about turbines being located close to shore.

Both the *green fund* (0.50) and *beach fund* (0.62) parameters are positive and statistically significant for the inland model, indicating an increase in utility when royalty monies are deposited into these "specialty" funds rather than Delaware's General Fund. The *green fund* and *beach fund* parameter estimates are not significantly different from each other, however. Also, the *green fund* and *beach fund* parameters are not statistically significant for the bay and ocean models. Although these funds were preferred over the State general fund descriptively (see Table 6.15), model results indicate that when it comes down to choosing offshore wind power over coal or natural has, ocean and bay area residents show no preference for these specialty funds over the general fund, all else being equal.

The *roy2* and *roy8* parameters are not statistically significant for the ocean and bay models, indicating no preference for higher royalty monies to be paid to the State by wind farm developers. Although one would expect higher royalty monies to increase utility for wind power, this suggests that higher royalty monies are actually not an important factor to individuals when choosing between wind power or coal or natural gas. In the inland model, the *roy2* (-0.35) parameter is both negative and statistically significant. The *roy8* (-0.31) parameter also is negative; however, it is not statistically significant. The negative coefficient on the *roy* parameters is puzzling and counterintuitive, suggesting a decrease in utility when the State receives higher royalty payments from a wind farm developer. Perhaps respondents perceive that royalty payments to the State might increase the actual cost of delivered energy, or that such payments might hamper development of offshore wind power.

Table 7.5 Parameter estimates for the mixed logit inland, bay and ocean models

Variable	Inland	Bay	Ocean
Random parameters in utility functions			
Bay	4.88***	3.85*	-2.81
Rehoboth Beach	4.91***	4.12*	-3.67*
Fenwick Island	4.85***	4.45*	-3.45*
Ln(Distance)	0.51***	0.87***	1.12***
Green Energy Fund	0.50**	0.45	0.72
Beach Nourishment Fund	0.62***	-0.13	0.62
Royalty $2 million	-0.35*	-0.05	0.15
Royalty $8 million	-0.31◊	0.02	0.02
Nonrandom parameters in utility functions			
Fee	-0.07***	-0.07***	-0.04**
Income	-0.002	-0.01	0.002
Some college education	0.50	-0.94	0.78
4-year college degree	-0.43	-3.30**	-0.02
Post grad degree	-1.43***	-1.75	-0.31
Age	-0.05***	-0.02	0.01
Male	-0.07	0.27	-0.87◊
Retired	0.34	0.56	0.82
Delmarva	-0.34	2.98**	NA
See ocean	2.80**	0.09	0.19
See*Distance	0.02	0.50	0.35
Distance from beach	0.01*	-0.06◊	2.50**
Beach days	0.003	0.001	-0.004*
Seen a turbine	0.33	1.71*	1.41**
Beach house	-0.29	NA	NA
Derived standard deviations of parameter distributions			
Bay	1.31*	0.15	3.68
Rehoboth Beach	0.58	3.85**	3.59**
Fenwick Island	0.46	2.00◊	0.06
Ln (distance)	0.13	0.99*	0.55
Green Energy Fund	0.99*	1.44	2.57*
Beach Nourishment Fund	0.80	0.24	0.01
Royalty $2 million	0.001	0.06	0.09
Royalty $8 million	1.17***	0.02	0.06

◊Significant at the α=0.1 level of confidence.
*Significant at the α=0.05 level of confidence.
**Significant at the α=0.01 level of confidence.
***Significant at the α=0.001 level of confidence.
Log likelihood values: Inland (-1424.107), Bay (-461.7562), Ocean (-442.9057)
Number of observations: Inland (1692), Bay (609), Ocean (546)

7.3.2 Nonrandom Parameters

As expected from economic theory, the *fee* coefficient is negative and statistically significant for all three models, indicating that utility decreases as the price for wind power increases. The *fee* parameter coefficient is smaller in magnitude in the inland and bay models (-0.07) than in the ocean model (-0.04), indicating a lower marginal utility of income for ocean area residents. This *fee* parameter value, combined with the higher *ln(distance)* parameter value, implies that ocean residents would need a higher monetary inducement than inland or bay area residents to compensate for any increased visual disamenity resulting from closer turbines (in other words, ocean area residents would be willing to pay more to move turbines further offshore).

For the inland model, the *post grad* (-1.43) parameter is negative and statistically significant, indicating that those with a post-graduate or professional degree derive less utility from wind power compared to those with an education level of high school or less. Likewise, for the bay model, the *4-year college degree* (-3.3) parameter is negative and statistically significant. These results are somewhat surprising, given that Firestone and Kempton (2007) found supporters of the Cape Wind project to be better educated. Perhaps at Cape Cod, the more educated respondents had a better understanding of the benefits of wind power versus the continued use of fossil fuels.

For the inland model, the coefficient on *age* (-0.05) is negative and significant, indicating that as age increases, the utility an individual derives from a wind option decreases. Similar results were reported in Firestone and Kempton (2007), where older respondents were more likely to oppose the Cape Wind project. The *age* parameters for the ocean and bay model are not statistically significant.

The *Delmarva* (2.98) parameter for the bay model is positive and significant. Considering Delmarva customers recently faced a 59% increase on their utility bills, it is not surprising that a wind option would result in higher utility for Delmarva customers if these respondents reasoned that wind power might offer increased price stability in the long-term.

Inland model parameter estimates for *see ocean* (2.80) and *distfbch* (0.01) are both positive and statistically significant. Those inland respondents who can see the ocean are presumably second-home or coastal beach house owners. Partial correlations of inland beach house owners show that they are less likely to have seen a wind turbine and more likely to have a higher income than inland non-beach house owners (results not reported here). Also, the positive *distfbch* parameter indicates that as living distance from the coast increases, utility for wind power increases—perhaps because any perceived impacts from wind turbines are reduced as one moves further from the coast. Because both *see ocean* and *distfbch* are positive and significant, it also is possible that those with beach houses right along the coast—that is, close enough to see the ocean—are categorically different in that they seem to gain more utility from offshore wind than those who cannot see the ocean, all else being equal. Or, perhaps those who can see the ocean from their residence or beach house do not necessarily hold strong aesthetic objections.

For the ocean model, the *distfbch* (2.5) coefficient is positive and statistically different, indicating that residents living further away from the beach gain a higher utility from wind than those living closer to the beach, consistent with the inland model (though the ocean model parameter value is much larger in magnitude). Also, the *seeocean* (0.19) parameter is not statistically different from zero, implying that there is no difference between those ocean area respondents who live right on the beach versus those living further inland.

The *seenturbine* parameter for the ocean (1.41) and bay (1.71) models is positive and significant, indicating that individuals from these strata who have seen a wind turbine in operation have a higher utility from offshore wind power than those who have not. If those who had seen a wind turbine had actively sought it out, such individuals may be pre-disposed to support wind power. Also, for the ocean model, the *bchdays* (-0.004) parameter is negative and statistically significant, implying that those respondents spending a greater number of days at the beach for recreation gain less utility from offshore wind power, all else being equal.

The remaining nonrandom parameter estimates are not statistically different from zero.

7.3.3 Derived Standard Deviations of the Parameter Distributions

One of the appeals of the mixed logit model is its ability to detect taste variation that may exist among the sampled population for random parameters in the model. According to Train (2003, p153), "means and standard deviations of the normally distributed coefficients provide information on the share of the population that places a positive value on the site attribute and the share that places a negative value." Judging from the number of statistically insignificant derived standard deviations of the fixed parameter distributions, it seems that there is not a large amount of taste variation across the sample population. In other words, the population is quite homogenous. Some taste variation, however, does exist.

The derived standard deviations of the *bay* (1.31) parameter for the inland model and the *Rehoboth Beach* (3.85, 3.59) parameter for the bay and ocean models are statistically significant, indicating the existence of preference heterogeneity among the sample population for these location parameters. By graphing the cumulative probability of the *Rehoboth Beach* (3.85) random parameter in the bay model, for example, one can see that 13.14% of the distribution around the mean is below zero while 86.86% is above. This implies that a wind farm off of Rehoboth Beach is a positive inducement for almost 90% of the sampled bay population, and a negative factor for the rest (see Figure 7.1). For the ocean mode, the dispersion around the mean of this parameter indicates that for 83.15% of those sampled from the ocean strata, placing turbines off of Rehoboth Beach would be negative inducement, while for 16.85% it would be a positive factor in utility. Even so, this is qualified by the fact that simulations show quite high support for a Rehoboth Beach project among ocean area residents (see Table 7.10)and positive willingness to pay values, even when turbines are placed close to shore (see Figure 7.7).

For the bay model, the derived standard deviation of the *ln(distance)* random parameter is significant. Interestingly, 18.94% of the distribution around the mean is below zero while 81.06% is above the mean. This suggests that for most of the bay area residents, but not all, each increased unit of distance to locate turbines further offshore results in a positive inducement on utility.

The derived standard deviations of the *green fund* random parameters are significant for both the inland (0.99) and the ocean (2.57) models, though the *green fund* random parameter was not statistically significant in the overall ocean model. Thus, for the inland model, 28.77% of the distribution around the mean is below zero, while 71.33% is above, implying that royalty monies being deposited into the State's green energy fund is a positive factor for the majority of inland area residents.

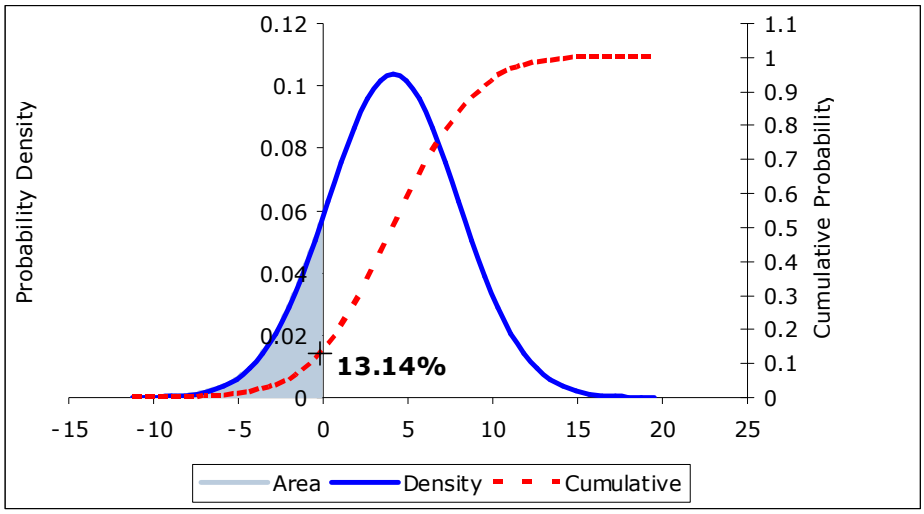

Figure 7.1 Cumulative probability of being above or below zero for the *Rehoboth Beach* parameter estimate

7.4 Willingness to Pay to Move Wind Turbines Further Offshore

One of the purposes of stated preference techniques like choice modeling is to estimate welfare losses and gains for decreases and increases in the quality of an environmental good. Indeed, a common objective in the use of discrete choice models is the derivation of willingness to pay—some monetary value that individuals are willing to forfeit to obtain some stated benefit, holding all else constant (Hensher et al., 2005). Because choice models are linear in nature, willingness to pay measures are calculated as the ratio of two parameter estimates, provided at least one attribute is measured in monetary units (ibid).

Willingness to pay (WTP) figures are presented to highlight Delawareans' preferences for moving wind farms further offshore. WTP was calculated for each model (inland, bay and ocean) for moving turbines from a baseline of 0.9 miles out to 3.6, 6, 9, 12, 15, and 20 miles. Results are presented in Table 7.6. For each model, estimates of WTP were calculated using Equation 7.5. Following conventional welfare economics, WTP is measured as compensation or equivalent variation (see Just, Hueth, and Schmitz, 2004). The compensating variation measure seeks the money equivalent that returns an individual to his or her baseline level of utility following some change. In this case, that change is moving the wind farm closer to shore. In a linear model the compensating and equivalent variation are the same and are found by choosing the value of WTP that solves:

$$\underline{\alpha}'\underline{x}_1 + \underline{\beta}\,\underline{x}_2 - \gamma fee = \underline{\alpha}'\underline{x}_1 + \underline{\beta}\,\underline{x}_2^* - \gamma(fee + wtp) \qquad 7.1$$

$$\underline{\beta}\,\underline{x}_2 - \gamma fee = \underline{\beta}\,\underline{x}_2^* - \gamma fee - \gamma wtp \qquad 7.2$$

$$\underline{\beta}\,\underline{x}_2 - \underline{\beta}\,\underline{x}_2^* = -\gamma wtp \qquad 7.3$$

$$wtp = \frac{\underline{\beta}\,(\underline{x}_2 - \underline{x}_2^*)}{-\gamma} \qquad 7.4$$

where X_1 is a vector of characteristics describing the respondent, X_2 is a vector of attributes describing a baseline wind farm at 0.9 miles from shore, and X_2^* is a vector of characteristics describing a wind farm at a distance further than 0.9 miles from shore. Thus, in Equation 7.5, X_i represents the specific distance i from shore under evaluation (3.6, 6, 9, 12, 15, or 20 miles), and $-\beta_{fee}$ represents the marginal utility of income.

$$WTP = \frac{\beta_{ln(distance)}\,(\ln X_i - \ln 0.9)}{-\beta_{fee}}; i = 3.6, 6, 9, 12, 15, 12. \qquad 7.5$$

Because models were estimated using a mixed logit specification, it was necessary to account for the possibility of preference heterogeneity for the *ln(distance)* parameter during WTP estimation.

To do this, 5000 draws (random and normally distributed) were created in Microsoft Excel for each model's $\beta_{ln(distance)}$ parameter by using the parameter's mean value and its estimated derived standard deviation value. These draws create a distribution of WTP figures, and the reported WTP estimates below represent the mean of the distributions.

Table 7.6 Willingness to pay ($/month for 3 years) to move wind turbines from a baseline of 0.9 miles to 3.6, 6, 9, 12, 15, or 20 miles offshore

Distance (miles)	Inland	Bay	Ocean
3.6	$9.38	$16.62	$40.83
6	$12.84	$22.74	$55.87
9	$15.58	$27.60	$67.81
12	$17.53	$31.05	$76.28
15	$19.04	$33.72	$82.85
20	$20.98	$37.17	$91.33

Results indicate that residents living along the Delaware coastline, particularly the Delaware Atlantic coast, have a higher willingness to pay to move turbines further offshore than those living inland. For example, inland residents would on average be willing to pay around $9 per month for three years to have wind turbines moved from 0.9 miles out to 3.6 miles, while bay and ocean area residents would pay almost $17 and $41 per month, respectively. The fact that those individuals living in coastal areas would be willing to pay more to move turbines further offshore is not surprising, and indicates that offshore wind turbines are more of a disamenity for those living along Delaware Bay and the Delaware Atlantic coastline than for those residents living inland. On average, inland, bay and ocean residents would be willing to pay $21, $37 and $91, respectively, *per month for 3 years*, in order to move wind turbines from a distance of 0.9 miles out to 20 miles—a distance where any turbines would not be visible even on the clearest of days.

The fact that respondents indicate a willingness to pay does not necessarily mean that moving turbines out to a distance where they are no longer visible is the best policy. In a policy context it is perhaps more useful to evaluate these willingness to pay figures on a marginal

scale. Marginal WTP trends are calculated by taking the difference of two calculated WTP measures and dividing that difference by the corresponding change in distance (see Ladenburg and Dubgaard, 2007). Table 7.7 and Figure 7.2 show marginal willingness to pay estimates.

Table 7.7 Marginal willingness to pay ($/month for 3 years) to move wind turbines further offshore

Distance (miles)	Inland	Bay	Ocean
0.9 to 3.6	$3.47	$6.15	$15.12
3.6 to 6	$1.44	$2.55	$6.27
6 to 9	$0.91	$1.62	$3.98
9 to 12	$0.65	$1.15	$2.82
12 to 15	$0.50	$0.89	$2.19
15 to 20	$0.39	$0.69	$1.69

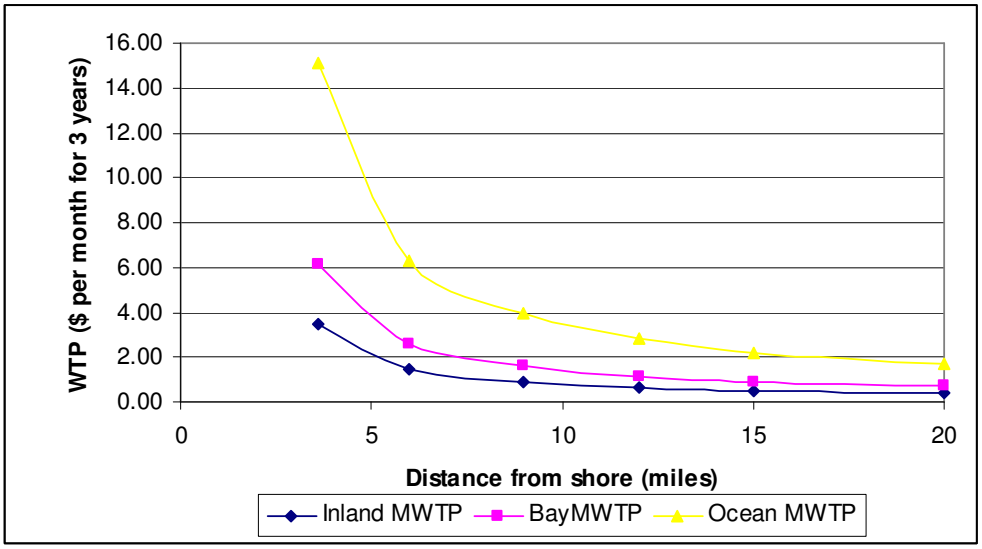

Figure 7.2 Marginal willingness to pay ($/month for 3 years) to move wind turbines further offshore

Figure 7.2 illustrates the diminishing return on moving wind turbines further and further offshore. Marginal WTPs are highest for distances closer to shore, meaning that the majority of social benefits are derived when initially moving wind turbines out further than 0.9

miles. The additional benefits received from moving turbines out decreases with increasing distance. Marginal willingness to pay values are highest for the ocean population, especially for distances closest to shore. As can be seen in Figure 7.2, however, all three marginal WTP curves substantially level off around a distance of 7-10 miles.

For the inland population, marginal WTP drops below a value of one near nine miles. This rate of change indicates that for the inland group, the benefits of placing wind turbines at a distance greater than about nine miles are minimal. Likewise, for the bay residents, the marginal WTP value falls to less than one around fourteen miles. Clearly, the ocean residents have the most benefit to gain from moving turbines out to twenty miles, or out of view, while the inland residents (the majority of the State's population) have the least to gain. Using fifteen miles from shore as a baseline, for example, inland, bay and ocean residents have a marginal WTP of $0.36, $0.69, and $1.69 per mile, respectively, to move the wind turbines out to 20 miles.

It also is useful to examine aggregate values of WTP. Recall the valuation scenario posed a possible increase on consumers' utility bill which would occur each month for 3 years only. Table 7.8 shows the total average WTP per household, discounted back three years at a rate of three percent. Results show that inland residents have lower WTP estimates than bay residents, who have lower WTP estimates than ocean residents. The total number of households along the ocean (22,579) and bay (12,369) areas makes aggregate WTP figures from these areas somewhat negligible when compared to the total number of households in the inland area (282,691).[60] Aggregate WTP values for each stratum are presented in Table 7.9 and Figure 7.3.

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[60] For the total number of households in Delaware, see U.S. Census Bureau, American Fact Finder, at: http://factfinder.census.gov/servlet/ADPTable?_bm=y&-context=adp&-qr_name=ACS_2005_EST_G00_DP1&-ds_name=ACS_2005_EST_G00_&-tree_id=305&-redoLog=true&-_caller=geoselect&-geo_id=04000US10&-format=&-_lang=en; accessed August 3, 2007. To determine the total number of households in the inland, bay, and ocean areas, the total number of households in Delaware (317,640) was multiplied by the proportion of households that occur in each stratum (inland 0.89; bay 0.07; ocean 0.04), as calculated using the sample strata weights.

Table7.8 Total average WTP per household to move wind turbines further offshore, by sample population, discounted

Distance (miles)	Inland	Bay	Ocean
3.6	$327.95	$580.98	$1,427.34
6	$448.79	$795.06	$1,953.29
9	$544.71	$964.98	$2,370.77
12	$612.77	$1,085.55	$2,666.97
15	$665.56	$1,179.06	$2,896.72
20	$733.61	$1,299.63	$3,192.92

Table7.9 Total statewide aggregate WTP (in $ millions) to move wind turbines further offshore, discounted

Distance (miles)	Inland	Bay	Ocean	State-wide total WTP
3.6	$93	$7	$32	$132
6	$127	$10	$44	$181
9	$154	$12	$54	$219
12	$173	$13	$60	$247
15	$188	$15	$65	$268
20	$207	$16	$72	$296

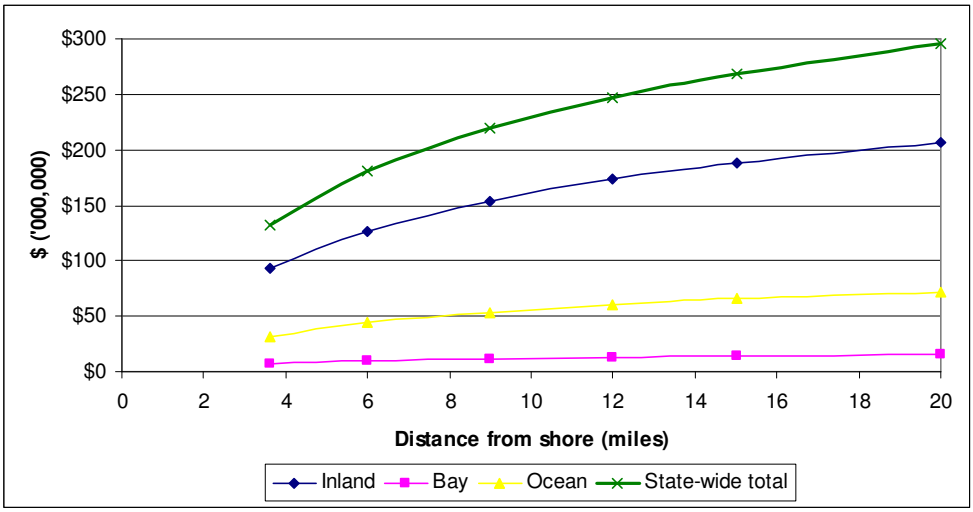


Figure 7.3 Total statewide aggregate WTP (in $ millions) to move wind turbines further offshore, discounted

Again, although ocean and bay residents are willing to pay more on a per household basis to move wind turbines further offshore, inland aggregate WTP measures are highest due to the sheer number of households in comparison to the number of households in the bay and ocean areas. Statewide totals show substantial social benefits—in the hundreds of millions of dollars—can be achieved by moving wind turbines further offshore. Statewide, residents would be willing to pay a total of approximately $132 million to move turbines from 0.9 miles out to 3.6 miles, or a total of $296 million to move wind turbines out of view. It is important to remember, however, that these welfare gains should be compared to the actual costs of moving wind turbines further offshore.

It is prudent to note that in the choice experiment questions, the highest presented fee for wind power was $30 for a total of 3 years (or, a grand total of $1,080). For this reason, there is a higher confidence in the WTP measures that fall near or below that total value, although it is conceivable that some respondents, particularly those living in the coastal areas, would pay much more to move turbines further offshore. It is accepted that pre-testing only in the Wilmington DMV is a potential shortcoming of this survey research, and that, indeed, pre-testing in a bay and ocean-area DMV might have shed light on bay and ocean area residents' willingness to pay higher fees to move turbines further offshore. Also, the high proportion of respondents who voted for wind power, even when told they would have to pay for it, highlights another potential shortcoming of the survey design—that the maximum monthly utility fee in the choice experimental design should have been greater than $30, or perhaps extended over a greater number of years. Finally, the fact that ocean area respondents had such high WTP estimates, coupled with the high proportion of residents who voted for wind power even when told they would have to pay for it, suggests that a budget reminder statement would have been particularly useful in ensuring that respondents were stating their true intentions and ability to pay for wind power over coal or natural gas.

7.5 Model Simulations

7.5.1 Support for Three Potential Delaware Offshore Wind Power Projects

Simulations were run in NLOGIT to determine how changes in the price attribute impacted the choice probabilities for the wind and coal/natural gas alternatives. Table 7.10 presents simulation results for the three models (inland, bay and ocean) for three possible wind farm development scenarios off the Delaware Coastline. Simulations were run so that respondents had to choose between a wind power option or coal/natural gas.

Each model was simulated using the following constraints:

1. A wind farm would be built in Delaware Bay (6 miles offshore), or off Rehoboth Beach (12.5 miles offshore), or off Fenwick Island (7 miles offshore).
2. Delaware would receive approximately $1 million each year in royalty monies, to be funneled to the Green Energy Fund.
3. Monthly utility fees varied from $0 to $30.

These scenarios were set up to mimic reasonable scenarios for actual offshore wind development in Delaware. While monthly fees are hypothetical, the locations and distances from shore correspond to actual project proposals from Blue Water Wind, LLC. Delaware already has an existing Green Energy Fund to which royalty payments could conceivably be funneled, and the $1 million in royalty monies represents a reasonable and conservative value.

Simulation results indicate strong support for wind power among all three population samples and across all three location scenarios; in general, ocean residents show the least amount of support for offshore wind when compared to ocean and bay residents, except for the high price scenarios of the Fenwick Island project. Also, as expected, support among all three groups is highest when wind power is free, and support declines as the monthly utility fee for wind power increases.

Table 7.10 Model simulations of Delaware resident percent support for three proposed wind farm projects, evaluated at different monthly utility fees for 3 years

Population	Inland Residents	Bay Residents	Ocean Residents
Fee ($)	Delaware Bay Project		
0	93.9	93.7	75.3
1	93.6	93.4	75.1
5	92.0	92.3	74.2
10	89.8	90.7	73.1
20	83.8	86.8	70.7
30	75.9	82.0	68.2
Fee ($)	Rehoboth Beach Project		
0	96.9	87.5	76.2
1	96.7	87.2	76.0
5	95.7	86.1	75.0
10	94.2	84.6	73.8
20	89.8	81.4	71.3
30	83.1	77.7	68.8
Fee ($)	Fenwick Island Project		
0	96.0	98.3	93.2
1	95.8	98.1	92.9
5	94.6	97.0	91.9
10	92.7	95.0	90.5
20	87.3	87.6	87.3
30	79.5	73.9	83.3

Examining the simulated percentages[61] in Table 7.10, Inland residents appear to prefer the Rehoboth Bay project over the other two proposed projects (however, inland residents show overwhelming support for all three projects). Bay residents prefer the Fenwick Island project at lower costs, followed by the Bay project. The Rehoboth Beach project is the least preferred for bay residents. Ocean residents clearly prefer the Fenwick Island project over the other two proposed projects. Figures 7.4, 7.5 and 7.6 graph resident support for the Delaware Bay project, Rehoboth Beach project, and Fenwick Island project, respectively.

[61] Because of the way simulation results are reported in NLOGIT, there is no way to determine if the differences in support are statistically significant.

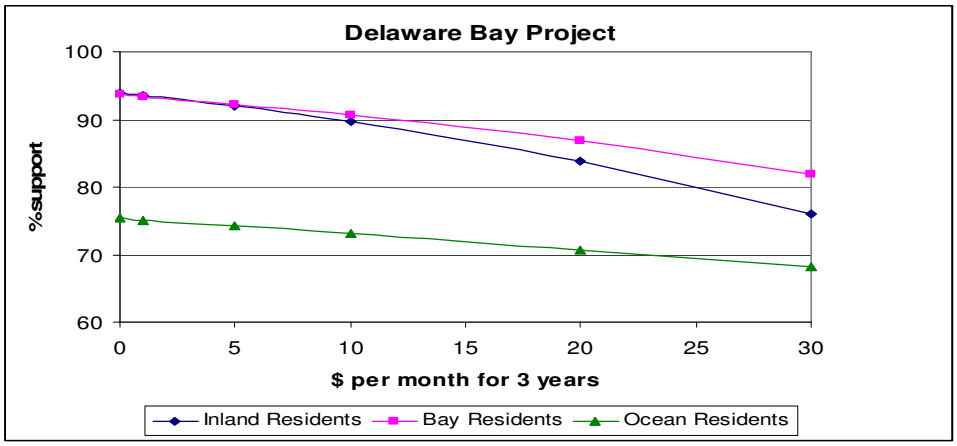


Figure 7.4 Simulated Delaware resident support for a wind project located 6 miles offshore in the Delaware Bay

Figure 7.4 indicates that bay and inland residents are the most supportive of a wind project being placed in Delaware Bay, with bay residents being most supportive at higher costs. Ocean residents are least supportive of this project. This is an interesting finding, as one might hypothesize that in general ocean residents would be more supportive of a Delaware Bay project since the turbines would not be placed or be visible directly off the Atlantic coastline. Table 6.7 helps lend support to these findings, reporting that of those ocean residents who hold a preference, the majority would prefer wind turbines being placed out on the ocean rather than in Delaware Bay. One also might assume bay residents would be least supportive of the Bay project since they would be directly impacted by the visual presence of the turbines. Although bay residents do show the highest amount of support for the Bay project (when compared to ocean and inland residents), they show higher support for a project located off of Delaware's southern coast (see Table 7.10), where any assumed impact on Delaware Bay would be minimal, a finding that also is consistent with Table 6.7.

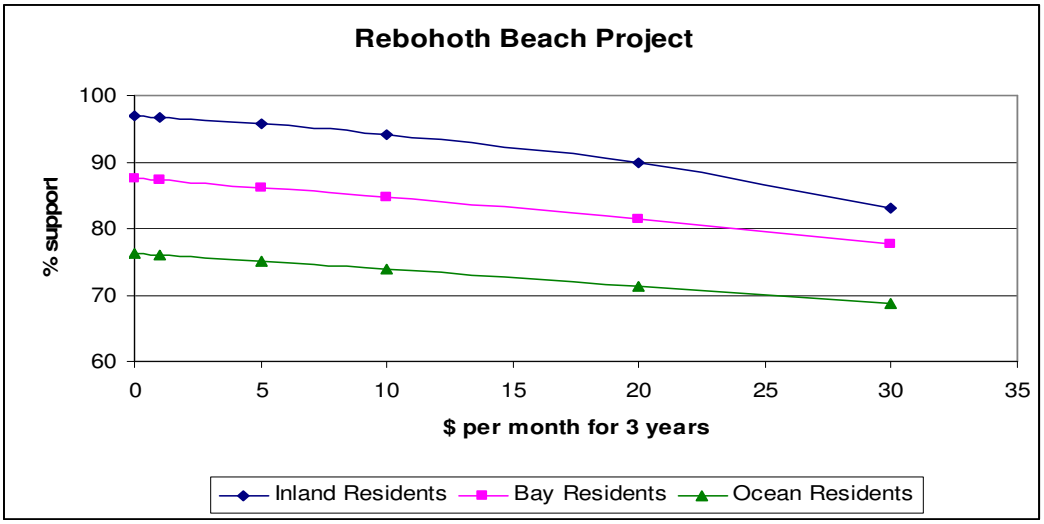


Figure 7.5 Simulated Delaware resident support for a wind project located 12.5 miles offshore of Rehoboth Beach, Delaware

Figure 7.5 indicates inland residents are most supportive of a wind project being located off Rehoboth Beach and ocean residents are least supportive. Perhaps ocean area residents believe that the presence of turbines off of Rehoboth Beach might negatively impact Delaware's most significant beach tourist area. Support decreases similarly for all three populations as monthly utility fees are increased.

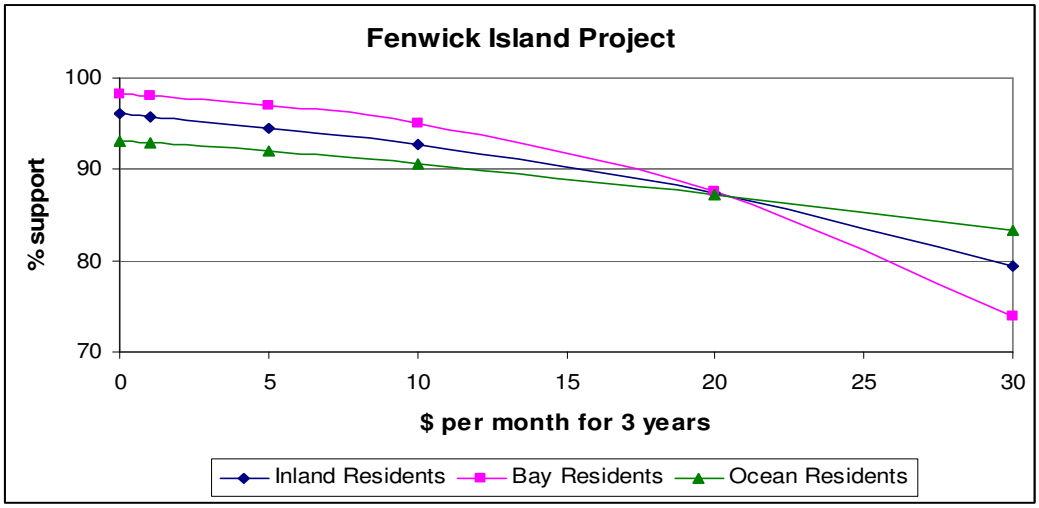


Figure 7.6 Simulated Delaware resident support for a wind project located 7 miles offshore of Fenwick Island, Delaware

Figure 7.6 indicates strong support among all sample populations for a wind project located off of Fenwick Island. Initially, support is highest among bay residents, though this changes at higher costs. Interestingly, percent support for the inland, bay and ocean areas converge around a monthly utility fee of about $20. Here, all three population groups exhibit an 87% level of support.

7.5.2 Willingness to Pay for Three Potential Delaware Offshore Wind Projects

Utilities for each respondent in the database were calculated for simulated wind developments in Delaware Bay, off of Rehoboth Beach and Fenwick Island. The median "wind" utilities for each project were then divided by the estimated *fee* parameter coefficient to yield a willingness to pay for that specific wind project.

Simulations were run for the three potential wind power development scenarios described in Section 7.5.1; in these simulations, however, fee was fixed at $0 in order to permit a direct comparison to the status quo of coal or natural gas. Table 7.11 presents the three project WTP simulation results for the inland model only. As seen in the table, inland respondents are willing to pay about $45/month for 3 years for a project located in Delaware Bay or off of Rehoboth Beach, or about $50/month for 3 years for a project located off of Fenwick Island. As a conservative estimate, multiplying the total WTP values for the inland stratum by the total number of households in Delaware (317,640 households) yields aggregate WTP figures for the whole of Delaware. Table 7.11 shows that Delaware residents as a whole would be willing to pay between $499 million to $555 million for a wind project in Delaware over coal or natural gas power, depending on its location. Presumably, the higher WTP figures for the Rehoboth project are due to its greater distance from shore (12.5 miles offshore, whereas the Bay and Fenwick projects are 6 and 7 miles offshore, respectively).

Table 7.11 WTP for three simulated Delaware offshore wind projects

Project Location	WTP ($/month/household for 3 years)	3-Year Total WTP, discounted ($/household)	Aggregate WTP
Delaware Bay	$45	$1,573	$499,734,637
Rehoboth Beach	$50	$1,748	$555,260,708
Fenwick Island	$45	$1,573	$499,734,637

Finally, it is worth presenting WTP estimates for the simulated Rehoboth project for the ocean stratum. Figure 7.7 indicates that ocean area residents are willing to pay more for the project as its distance from shore increases. Interestingly, the curve in Figure 7.7 intersects the x-axis ($0 WTP) at a distance of 1.03 miles, implying that at this distance, ocean area residents are indifferent to wind power over the expansion of coal or natural gas. Also, unlike the inland and bay strata (results not presented here), the ocean stratum has negative WTP values when wind turbines are placed closer than 1.03 miles from shore.

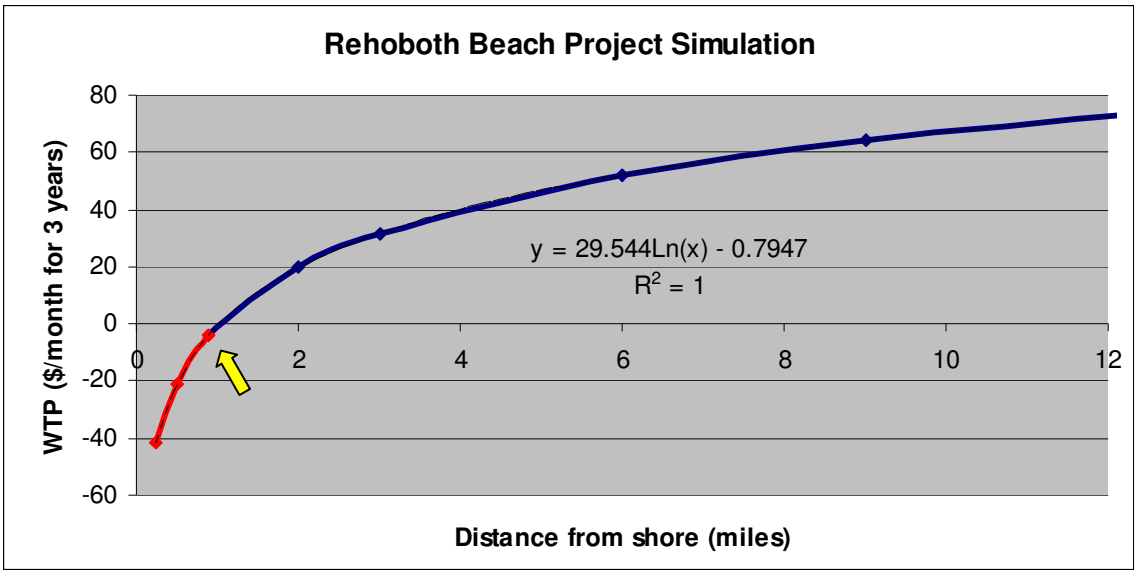


Figure 7.7 WTP function for simulated Rehoboth wind farm project, ocean stratum

CHAPTER 8

POLICY IMPLICATIONS AND CONCLUSIONS

8.1 High Support for Wind Power in Delaware

The data collected in this dissertation research shows overwhelming support for offshore wind power among Delaware residents. More than 90 percent of survey respondents want the state to either encourage and promote or allow in appropriate circumstances offshore wind development in the ocean while less than one percent desire wind turbines to be prohibited in all instances in the ocean. Among ocean area residents, whom show the most opposition, only 6.4 percent desire wind turbines to be prohibited in all instances (Table 6.7).

When asked about their support for a Cape Wind-type project off the Delaware coast, only 4 percent of respondents indicated they would oppose a 130 turbine wind farm six miles offshore, although about 20 percent of ocean area respondents indicated they would oppose such a project (Table 6.9). These numbers contrast sharply to results found in Firestone and Kempton (2007), where the majority of Cape Cod residents were opposed to the Cape Wind project. Thus, it seems unlikely that Delaware residents hold similar beliefs that the ocean is a "special place" where human development or structures—even wind turbines—do not belong, a feeling that Kempton et al. (2005) argues underpins Cape Cod and the Islands residents' opposition toward the Nantucket Sound project. Moreover, the high support for wind power in both the Delaware Bay and along the Delaware ocean coastline would suggest that Delaware residents are not particularly concerned with "landscape permanence," as described in Pasqualetti (2002).

Logistic regression results from ocean area respondents indicate that older respondents are more likely to support a Delaware Cape Wind project (Table 6.10). Support for this type of project in Delaware is centered on electricity rates (29%) and air quality (18%), whereas opposition among ocean area residents is centered on aesthetic concerns (53%) and impacts on the marine environment (23%) (Table 6.12). Partial correlation results indicate that

ocean respondents who are younger and who have a higher income are more likely to list aesthetic impacts as their primary reason of concern for such a project (Table 6.13).

The choice experiment question data also reinforces Delawareans' strong support for offshore wind power development. Of the approximately 2,695 total recorded choice occasions in the dataset, a combined 93 percent chose offshore wind power while 7 percent chose coal or natural gas. While 95 percent of the respondents chose wind power when offered at no cost, more than 91 percent still chose wind power even when told they would have to pay a monthly fee for three years. This suggests that factors other than initial cost may be more important in people's preferences for offshore wind power, such as cleaner air and increased price stability. Moreover, the positive and significant location parameters (*Bay*, *Rehoboth* and *Fenwick*) for the inland and bay models suggest that the majority of Delaware's residents gain higher utility from offshore wind power than from coal or natural gas, all else being equal.

Model simulations show that a high percentage of Delaware residents would support proposed wind projects in Delaware Bay, off of Rehoboth Beach, or off of Fenwick Island, though this support varies across inland, bay, and ocean area residents, and generally decreases when monthly utility fees increase. The most striking result from these simulations is that Delaware residents—even those living along the ocean and bay coastline—are highly supportive of three potential Delaware projects that are *visible from shore* (see figures 7.4, 7.5, 7.6). Thus, although modeling results indicate that respondents prefer turbines be moved further offshore, respondents do not seem to oppose projects in Delaware Bay (6 miles from shore), Rehoboth Beach (12.5 miles from shore), or Fenwick Island (7 miles from shore) based on aesthetic concerns.

Due to the vocal and highly publicized opposition to the Cape Wind project in Nantucket Sound off of Cape Cod, Massachusetts, it has been assumed by many that U.S. coastal residents generally are opposed to offshore wind. To some extent this may be true—ocean coastal residents seem to have a higher degree of opposition for wind power in Delaware than do inland residents. Moreover, various polls have shown that support for the Cape Wind project is higher among state-wide Massachusetts residents than for residents of Cape Cod and the Islands.

But the minimal opposition seen in this study, even among ocean residents, suggests that opposition may be place-specific and/or that attitudes regarding offshore wind are changing. Indeed, it would be interesting to analyze support and opposition for offshore wind power in other coastal states that are considering such development.

The strong public support seen in this survey suggests that Delaware State policymakers should be open-minded to future offshore wind power development. Indeed, survey results indicate a strong preference for wind development over additional coal or natural gas in order to meet future energy needs. These results are consistent with public comments from recent public hearings concerning the building of a new power plant in Delaware. Preliminary analysis of public comments—taken from multiple public hearings over an eight month period—indicate overwhelming opposition to new coal or natural gas power (Piero et al., 2007). These public comments, coupled with the survey results, are a clear indicator that Delaware residents strongly support offshore wind power over coal or natural gas, and state policymakers should take into account the public's opinion when deciding how Delaware will meet its future energy needs.

Survey results also suggest that the public is likely to support any proposed project from Bluewater Wind, LLC once it executes a power purchasing agreement with Delmarva Power & Light and presents a specific development proposal along the Delaware coast. Public support seems to be dynamic, however, and opinions do change over time. Some of the literature on public opinion and acceptance of wind power projects suggests that public acceptance follows a "U" pattern, with initially high levels of public support (perhaps as seen in the results of this survey), followed by a decrease in acceptance during planning and construction phases, with a recovery to almost initial levels of support once built and operational (see Devine-Wright, 2005; Gipe, 1995; Wolsink, 1989; Krohn & Damborg, 1999; Walker, 1995). Other studies have found increased support once wind projects have been built and are operational, and that public support increases over time (Walker, 1995; Krohn & Damborg, 1999; Bishop & Proctor, 1994). If these findings are applicable to the Delaware public, support for offshore wind power in Delaware may decrease during the planning and construction phases of an offshore wind power project, but

then would recover to the high level of support seen in this survey. Of course, it also is possible that for some reason support may decline over time. Devine-Wright (2005) points out that in two of the three sites studied by Bishop and Proctor (1994), the proportion of respondents with negative perceptions of wind power development actually increased over time. With so many varied studies showing sometimes conflicting results and different degrees (and directions) of change in public support over time, the best way to gauge change in the Delaware public is to conduct a longitudinal study or to do multiple follow-up surveys over time. Since this survey serves as a baseline for the public's support of offshore wind power development in Delaware, additional survey data during the construction of a project, some time after construction is completed, and several years after sustained operation have commenced would provide valuable insight.

8.2 Preferences for Offshore Wind Development: Delaware and Beyond

One of the primary goals of this research was to identify and quantify Delawareans' preferences for offshore wind development to determine whether, and if so, how, offshore development should proceed in Delaware. The choice experiment section of the survey tested preferences for offshore wind development by posing different development locations, distances from shore, royalty payments to be made to the State, and to where those payments would be funneled. Respondents also faced different costs for each hypothetical development scenario, allowing a monetary calculation of willingness to pay.

8.2.1 Location

Descriptively, Table 6.8 shows that a large percentage of respondents do not hold a preference between placing turbines out on the ocean or in the bay; of those that do have a preference, the ocean is largely preferred to the bay. Even so, this preference ultimately may not be a top consideration in support or opposition to offshore wind power in Delaware. For the inland and bay discrete choice models, the location parameter values (*Bay*, *Rehoboth*, and *Fenwick*) are all statistically significant; however, these parameters are not statistically different from each other, indicating that while the majority of residents would prefer offshore wind

power over coal or natural gas, all else being equal, there is not necessarily a strong preference for where turbines should be located. Also, the fact that inland, bay, and ocean residents do not seem to prefer one project site over another, coupled with the fact that there is such overwhelming support for offshore wind power development among all residents, suggests that NIMBYism is not influencing the Delaware public to oppose such development off the Delaware coastline (although when asked in a separate question whether they preferred the ocean or the bay, a statistically significant number preferred the ocean).

Before making assumptions on which locations may be most or least desirable from a public opinion standpoint, and in order to help guide appropriate decision making and minimize possible contention, coastal states and wind developers that are considering offshore wind development should conduct similar research to determine if location-specific preferences for projects exist in their state. This also can shed light on how specific environmental concerns and competing uses in a state's coastal zone can impact the public's preferences for offshore wind development.

8.2.2 Royalties

During the experimental design of the CE questions, it was hypothesized that residents would show preferences for higher amounts of royalty monies to be collected by the State in the event of a wind farm being built, and a preference for where those royalties would be funneled. It was hypothesized that ocean and bay residents would prefer the beach nourishment fund as a compensatory measure for any visual impacts from nearby offshore turbines. Indeed, other studies have shown that financial incentives, such as ownership of turbines or the collection of rents/royalties from turbines located on public and private property, are important factors in the acceptance of local wind power projects (see Jobert, 2007). Moreover, Van der Loo (2001) identified the PIMBY (Please In My Backyard) syndrome—opposite of NIMBY—which occurs when individuals want wind turbines to be placed on their property in order to act as a source of income.

While descriptive statistics in Table 6.15 show that ocean area respondents prefer a beach nourishment fund, model results show no preference for royalty amounts or funds in the ocean or bay models (these parameter estimates are not statistically significant).The green energy fund and the beach nourishment fund are statistically significant in the inland model, however, suggesting that residents prefer royalty monies from wind projects be deposited into specialty funds rather than the State's general fund. There is no statistical difference between the green energy fund and the beach nourishment fund, however. Given the overwhelming high support for offshore wind power and the seemingly insignificant importance of the amount of royalty monies, state and federal lawmakers should consider lower royalty rates for offshore wind, at least initially, to help private developers meet the financial obligations of developing such projects, and to help attract the wind industry to the offshore energy sector.

8.2.3 Distance from Shore

Model results clearly indicate that, when choosing between different offshore wind power projects, two of the most important attributes are the distance from shore and the price consumers would face. The *ln(distance)* and *fee* parameters are statistically significant across all three models. Also, the *ln(distance)* parameter estimates are higher for ocean and bay respondents, and highest for ocean area respondents, indicating wind turbines are more of a visual disamenity for these populations than for inland Delaware respondents as a whole. This finding is not surprising, as presumably coastal residents would be more affected by any change in the day-to-day view of the ocean or bay seascape. The strong *distfbch* parameter in the ocean model also supports this idea. These results contrast somewhat with a Scottish telephone survey of public attitudes towards wind, where researchers found that people living closest to the wind farms tended to be most positive about them and most supportive of their expansion. Indeed, Braunholtz (2003) found that those who most frequently saw the wind farms on their day-to-day routine were most favorable toward them. Perhaps this acceptance and favorability is acquired by the local population after a wind project is built. If so, ocean and bay area residents may become

the strongest proponents of offshore wind power in Delaware, even if visible from shore, once they are built and operational.

In short, preferences for offshore wind development in Delaware are most centered on a project's distance from shore, presumably because of ocean aesthetics, and the further offshore turbines are located, the higher the utility gained. This distance effect seems to be strongest for ocean area residents, and less of a factor for inland area residents. To the extent that these preferences hold for residents in other coastal states as well, developers should look to site projects at a distance that minimizes visual impacts, maximizes social benefits, and minimizes development costs. Looking back at Figure 7.7, it is important to note that, for Delaware, the marginal social welfare gains of moving turbines further than 9-10 miles offshore are minimal.

8.2.4 Willingness to Pay

WTP can be estimated by taking the ratio of two model parameters, provided at least one of the parameters is measured in monetary units. Equation 7.5 generates WTP values for moving wind turbines further offshore. Results show that Delaware residents are willing to pay in order to move turbines further offshore, thereby reducing visual impacts. Inland residents—whom, because of their sheer numbers, can be thought of as a proxy for the state as a whole—would be willing to pay a three-year total of $328, $449, $545, $613, $666 and $734 to move wind turbines from a baseline of 0.9 miles out to 3.6, 6, 9, 12, 15, and 20 miles, respectively (Table 7.8). When adding ocean and bay values, total willingness to pay is $2336, $3197, $3880, $4365, $4741 and $5226 to have wind turbines moved from a baseline of 0.9 miles, respectively. Clearly, those residents living along Delaware's Atlantic coastline have the highest WTP, while residents living inland have the lowest WTP. If these figures are aggregated over the total number of households in Delaware, results indicate there will be significant social benefits associated with moving wind turbines offshore to reduce visual impacts. Statewide, residents are willing to pay a total of $132, $181, $219, $247, $268 and $296 million dollars to move turbines out from a baseline of 0.9 miles to 3.6, 6, 9, 12, 15, and 20 miles, respectively.

Given that ocean aesthetics consistently rank as an important factor in people's support and opposition for offshore wind power, it is not surprising that (1) people are willing to pay to move turbines offshore, and (2) that those living closer to shore display the highest willingness to pay. Results from this research support findings of a recent mail survey of Danish residents. Ladenburg and Dubgaard (2007) found that residents were willing to pay 33, 94, and 107 Euros/household/year to move future turbines out from a baseline of 8 km to 12, 18, and 50 km, respectively. Additionally, respondents who could see already existing turbines were willing to pay much more—280, 422 and 468 Euros/household/year, respectively. Again, these results show that "there will be considerable social benefits associated with diminishing the visual disamenities from future offshore wind farms" (ibid, p12). Although there is a clear preference and WTP to move wind turbines further offshore, project costs also must be considered in order to make the most appropriate siting decisions. Marginal WTP estimates are a useful tool to gauge the marginal benefits from moving turbines out further and further. These estimates show that the return on social benefits decreases as turbines are moved further offshore. Thus, when considering both benefits and costs, it may not always be optimal to move turbines out as far as possible, or necessarily even out of sight.

Model simulation results presented in Table 7.10 indicate a high level of support among survey respondents for three proposed Delaware offshore wind scenarios. In general, support for these projects decreases as the monthly utility fee increases, and there is less support among ocean area respondents. As can be seen in Table 7.11, inland residents would be willing to pay a 3-year grand total of $1573, $1748, and $1573 for offshore wind projects located in Delaware Bay, off of Rehoboth Beach, and off of Fenwick Island, respectively, over coal or natural gas power. In the aggregate, Delaware residents as a whole are willing to pay between $500 million and $555 million for these projects over coal or natural gas power.

These WTP findings have important policy implications for the State of Delaware. Currently Bluewater Wind, LLC and Delmarva Power & Light are negotiating a power purchasing agreement for a potential 600 megawatt offshore wind farm in Delaware. The results of this purchase agreement are subject to approval by select Delaware State agencies, with one

consideration being if, and if so, the extent to which the price of offshore wind power is projected to exceed the expected, albeit highly uncertain price for electricity from 2013 to 2038. As part of the Delmarva RFP process for new power, the State Agencies contracted with an independent consultant (IC, 2007) to analyze the risks and benefits of directing Delmarva Power & Light to enter into long-term power purchasing agreements with Bluewater Wind and other bidders. According to the independent consultant, the Bluewater Wind bid is $493 million net present value (in 2005 dollars) over expected market price for a 25 year contract period. However, aggregate WTP results (those presented in Table 7.11), when adjusted to reflect the 81% of Delaware residents who are Delmarva customers, indicate that Delaware Delmarva customers would be willing to cover most of this cost within three years (between $391,230,000 and $434,970,000) to have stable electric prices and cleaner air in the long run.

As a result of deregulation, Delmarva residential electric rates were held constant for a number of years. During that time period, energy prices for coal, oil and natural gas increased substantially. As a result, when rates were unfrozen, the cost of supply had almost doubled, leading to a 59% 2006 rate increase, or on average, an additional $54 to consumers' utility bills (as reported on the Delmarva Power & Light webpage). In the aggregate, this amounts to an additional $512 million over a three year period, or $19 million more than the Bluewater bid for a 25 year period (Firestone, 2007). If this rate increase is extrapolated over a full 25 year period, Delaware Delmarva residential customers would pay an additional $4.3 billion in utility bills, versus just $493 million for offshore wind power as estimated by the IC (ibid). That the three-year aggregated rate increase to Delmarva customers is of the same magnitude as the three-year aggregated WTP estimates for offshore wind power indicates that those estimates are realistic.

8.3 Final Thoughts and Future Work

This research contributes to the stated preference green energy literature by extending the more complicated discrete choice mixed logit modeling techniques to the offshore wind power arena. Results from the mail survey also contribute more broadly to the public opinion literature on wind power, and offer new insights into an area where offshore wind power

was far from the public radar, in contrast to Cape Cod, where public opinion research was conducted during the fury of public debate and discourse over the proposed Cape Wind project. In addition, the stratified sampling strategy used in this research allows for a geographic comparison of preferences for offshore wind power development among inland, bay area, and ocean area residents. The public opinion results from this research should not be generalized to other specific populations without study; however, there are a number of important broader points to be considered.

First, the placement of wind turbines off the coast seems to be a visual disamenity for individuals. This finding has been confirmed by another choice experiment study as well (see Ladenburg and Dubgaard, 2007). In our research, wind turbines were more of an aesthetic concern for ocean and bay area residents than for inland residents.

Second, there appears to be significant social welfare benefits to be gained from moving turbines further offshore, though marginal benefits certainly decrease as the distance from shore increases. While other factors like location and royalties may not be as important as hypothesized, there is no doubt that respondents prefer turbines to be located further offshore, and this, to a point, can increase social benefits. Wind developers should take this into consideration when choosing offshore wind farm development sites, not only because of the potential to increase social benefits, but also as a mechanism to reduce visual impacts and thus minimize one of the more contentious issues with offshore development.

Third, although there is no doubt that respondents' utility for wind power increases as turbines are located further offshore, simulation results show high support for three proposed wind farms that are *visible from shore* (between 6-12 miles). Moreover, even among ocean area residents who live on average just over half a mile from the beach, there is a preference for offshore wind power over coal or natural gas at distances just over one mile from shore. These finding suggest that wind developers and policymakers may be placing too much emphasis on locating wind farms far from the coast, if not completely out of sight, in an effort to appease the public's aesthetic objections.

Another important point is that public opinion is dynamic and fluctuates over time. The literature suggests that the high support for offshore wind power in this study is somewhat temporal. Because this survey was conducted prior to the Bluewater Wind bid announcement, it serves as a baseline indication of the public's opinion on wind power development. Indeed, a longitudinal study or follow-up surveys would offer valuable insights into how public preferences and opinions for wind power development can change through time.

In the present survey, I employed a range of monthly household utility fees for wind power up to $30 a month and for a three-year period over which these fees would be paid. From the modeling analysis it is apparent that many residents, particularly those in the ocean area, would be willing to pay more than $30 a month. Thus, future choice experiment surveys of Delaware residents should include a higher range of fees for wind power. In addition, a three-year fee period limits the time over which a higher fee would be paid. This limitation may not be realistic and, in this research, likely limited the aggregate willingness to pay of Delaware residents over the 20-25 year life of an offshore wind project. Thus, future surveys also should vary the length of the fee (perhaps implemented as a one-time fee, a yearly fee over the life of the project, or a declining fee over the life of the project) to see how these changes affect support and willingness to pay for offshore wind power development.

As a final thought, I offer that policymakers considering wind power should not be overly concerned if it will cost more than traditional fossil fuel sources, like coal or natural gas, for consumers in the short-term. States along the east coast of the U.S. have an opportunity to take advantage of strong Atlantic winds to supply major metropolitan areas with a steady source of clean renewable energy. Not only is wind power a clean source of renewable energy with minimal environmental impacts, it offers the advantage of price stability for consumers over time, which fossil fuel energy sources lack. Clearly, the respondents in this study are highly supportive of wind power, even when told they would have to pay more to acquire it.

APPENDIX 1

DELAWARE MAIL SURVEY, COVER LETTERS, AND POSTCARD REMINDER

A1.1 The Delaware Mail Survey

The survey instrument appears on the flowing pages in its original format.

What will the future hold?

You are one of 2,000 Delaware residents randomly chosen to participate in this survey.

Your thoughts and opinions are important!

Your help is voluntary, and your answers are completely confidential.

If you have any concerns about this study, you can call Professor Jeremy Firestone at (302) 831-0228 or email at jf@udel.edu

University of Delaware
College of Marine and Earth Studies
Robinson Hall
Newark, Delaware 19716

Instructions:
In addition to the survey booklet, you have been provided with an insert of ocean photos and a map of Delaware. Please refer to them when directed to do so. When you are finished, please return the completed survey in the envelope provided. You need not return the map and photo insert.

Introduction:
A "wind farm" is a group of wind turbines that capture energy from the wind and generate electricity. There are no large-scale wind farms in Delaware; however, currently in the United States land-based wind farms are producing enough energy to power one million average American homes. Delaware has no wind resource on land, but there is a strong wind resource out on the ocean and in Delaware Bay.

1) Have you ever seen a wind turbine in operation?
- □ Yes
- □ No

2) What is your general attitude toward wind power?
- □ Very positive
- □ Positive
- □ Neutral
- □ Negative
- □ Very negative

3) In your opinion, what effect do land-based wind turbines have on the appearance of the landscape?
- □ Very positive
- □ Positive
- □ Neutral
- □ Negative
- □ Very negative

4) In your opinion, what effect do wind turbines have on the environment?

- □ Very positive
- □ Positive
- □ Neutral
- □ Negative
- □ Very negative

5) In general, the placement of wind turbines in Delaware out on the ocean for electricity generation should be:

- □ Encouraged and promoted
- □ Allowed in appropriate circumstances
- □ Tolerated
- □ Prohibited in all instances
- □ Not sure

6) In general, the placement of wind turbines in Delaware Bay for electricity generation should be:

- □ Encouraged and promoted
- □ Allowed in appropriate circumstances
- □ Tolerated
- □ Prohibited in all instances
- □ Not sure

7) If Delaware decided to develop wind power for electricity generation, where would you prefer the wind turbines be located?

- □ In the ocean
- □ In Delaware Bay
- □ No preference

8) In general, would the presence of visible offshore wind turbines make you more or less likely to visit the beach?

- □ More likely
- □ Less likely
- □ No difference

A private developer has proposed to place 130 wind turbines that stand 423 feet high out on the ocean off of Cape Cod, Massachusetts for electricity generation. The project would be approximately 6 miles from the nearest coastal town. ***For questions 9-13, suppose this project were instead developed off the Delaware coast.***

Now take out the page of ocean photos to see what the project might look like from different distances from shore.

9) Would you support or oppose this project in Delaware?

- □ Support
- □ Oppose
- □ Not sure

10) Do you think that this project would have positive impacts (improve), negative impacts, or no impact at all on the following in Delaware:

Items	Improve	No impact	Negative impact	Not sure
Local fishing industry	☐	☐	☐	☐
Tourism & related business	☐	☐	☐	☐
Job creation	☐	☐	☐	☐
Air quality	☐	☐	☐	☐
Electricity rates	☐	☐	☐	☐
Aesthetics of ocean view	☐	☐	☐	☐
Property values	☐	☐	☐	☐
Marine life	☐	☐	☐	☐
Bird life	☐	☐	☐	☐
Recreational boating/fishing	☐	☐	☐	☐
Reducing climate change	☐	☐	☐	☐
Navigation safety	☐	☐	☐	☐

11) In deciding whether you would support or oppose the project, please write in three issues you consider to be the <u>most important</u>, regardless of whether mentioned above, ranked in order of importance #1, #2, and #3.

#1_____

#2_____

#3_____

12) Suppose the same wind project was proposed by a state or local government rather than a private developer. Would that make you more or less likely to support it?

□ More likely to support
□ Less likely to support
□ No effect on my decision

13) Suppose that instead of an offshore wind project, an underwater hydropower turbine project in Indian River Inlet was proposed to generate electricity. Would you be more or less likely to support this than the wind project?

□ More likely to support
□ Less likely to support
□ No effect on my decision

14) Finally, suppose the wind project described was among the first of many offshore wind projects in the U.S. Would that affect your support? For example, suppose that building 300 such projects off the Mid- and Northeast Atlantic coast would supply ½ of the Mid-Atlantic and Northeastern United States' electricity. Those projects together would have a much larger impact on the ocean than one project alone. However, together they could greatly reduce air pollution, foreign oil dependence and substances causing climate change and sea level rise. Assuming the above to be true, would you be more or less likely to support the project?

□ More likely to support
□ Less likely to support
□ No effect on my decision

15) There are laws governing profit from structures (like wind turbines or oil platforms) in the ocean. If there were a wind farm close enough to shore, Delaware could receive **annual rent and/or royalty payments** from the wind farm developer for allowing the turbines to be placed in coastal waters. If this were the case, where would you prefer these royalty payments go?

□ Delaware's existing Green Energy Fund to offset the costs people have to pay to buy renewable energy for their homes

□ A Beach Nourishment Fund created to add sand to any eroded Delaware beach from which the wind farm is visible

□ Delaware's General Fund, which is a pool of dollars that finances the majority of state services in Delaware

□ No preference

16) If Delaware were to erect two or three wind turbines as a "test facility" in coastal waters to test how offshore wind power would work in Delaware, would you support or oppose this test project?

□ Support
□ Oppose
□ Not sure

"Offshore Wind Power in Delaware"

Assume Delaware needs to increase its energy supply by 20% and that you have the opportunity to vote on energy development options. One way to meet the energy demand would be to place a 500 turbine wind farm offshore. Another option would be to continue Delaware's current energy policy and obtain additional energy from a new plant that burns coal or natural gas.

Because wind energy uses no fuel, your electric bill would not increase over time due to higher fuel cost; however, like other sources of electricity, it could increase for other reasons. To offset the initial costs of providing wind energy to Delaware residents, assume that there would be a **"Renewable Energy Fee"** added **each month** to your electric bill, for the first **three years** only.

We are now going to ask you three questions where you get to vote on wind power development. For each question, assume the option that receives the most votes will be carried out.

Continue on and vote→→→

17) If a vote were being held today, for which option would you vote?

Refer to the Delaware map insert for the "wind farm location."
Refer to the ocean photo insert for simulated views of the wind farm at different distances.

	Option A	**Option B**	**Option C**
Wind farm location	Ocean (South)	Ocean (South)	No Wind power
Distance from shore	0.9 miles	Too far out to see	Expansion of coal or natural gas power
Annual rent/royalty	$2 million to Green Energy Fund	$2 million to Green Energy Fund	
Renewable energy fee on your monthly electricity bill for 3 years	$0	$5	

I would vote for…

- □ Option A
- □ Option B
- □ Option C

18) Now for which option would you vote?

Refer to the Delaware map insert for the "wind farm location."
Refer to the ocean photo insert for simulated views of the wind farm at different distances.

	Option A	**Option B**	**Option C**
Wind farm location	Bay	Ocean (North)	No Wind power Expansion of coal or natural gas power
Distance from shore	0.9 miles	Too far out to see	
Annual rent/royalty	$1 million to Green Energy Fund	$2 million to Beach Nourishment Fund	
Renewable energy fee on your monthly electricity bill for 3 years	$0	$20	

I would vote for…

- □ Option A
- □ Option B
- □ Option C

19) Now for which option would you vote?

Refer to the Delaware map insert for the "wind farm location."
Refer to the ocean photo insert for simulated views of the wind farm at different distances.

	Option A	**Option B**	**Option C**
Wind farm location	Ocean (South)	Ocean (South)	No Wind power
Distance from shore	Too far out to see	6 miles	
Annual rent/royalty	$8 million to Beach Nourishment Fund	$1 million to Beach Nourishment Fund	Expansion of coal or natural gas power
Renewable energy fee on your monthly electricity bill for 3 years	$0	$30	

I would vote for…

- □ Option A
- □ Option B
- □ Option C

Now we are interested in how your beach-going habits might change if there was an offshore wind farm in Delaware.

20) How many days have you spent at Delaware beaches in the past **12 months**? _____ days

21) What activities do you usually engage in at the beach or ocean?

□ Surf fishing
□ Bird watching
□ Boating/Sailing/Ocean fishing
□ Sunbathing/Swimming
□ Surfing
□ Walking/Running
□ Other

22a) On your next trip to a Delaware beach, which beach are you most likely to visit? From North to South *(check one)*:

□ Bowers Beach
□ Big Stone Beach
□ Slaughter Beach
□ Fowler's Beach
□ Prime Hook Beach
□ Broadkill Beach
□ Lewes Beach
□ Cape Henlopen State Park
□ North Shores
□ Henlopen Acres
□ Rehoboth Beach
□ Dewey Beach
□ Indian Beach
□ Delaware Seashore St. Park
□ RRRs
□ North Bethany Beach
□ Bethany Beach
□ Sea Colony
□ Middlesex
□ South Bethany Beach
□ Fenwick Island State Park
□ Fenwick Island

□ I am unlikely to visit ANY Delaware beach

22b) Now imagine there is a 500 turbine wind farm 6 miles offshore from that beach you are most likely to visit on your next trip. Some people would continue going to the same beach regardless of where a wind farm was located, while others might decide to switch to a different beach. The next time you go to the beach would you still go to *this beach*, or a *different beach*, or *no beach* at all?

□ Same beach
□ Different beach in Delaware
□ Different beach not in Delaware
□ No beach at all

23) Imagine there is an offshore wind farm visible from a beach in Delaware that you do not usually visit or that you have never visited before. How likely are you to visit this beach, at least one time, to see the wind farm?

□ Very likely
□ Somewhat likely
□ Somewhat unlikely
□ Very unlikely

Finally, a few questions about yourself to help us interpret the results of the survey.

1. Are you male or female? □ Male □ Female

2. What is your age? _____

3. What is your zip code? _____

4. How long have you lived in your current zip code? _____yrs.

5. What is the highest degree or level of school that you have completed? (check one)

□ Grade school
□ Some high school
□ High school graduate
□ Some college credit
□ Associate degree
□ Bachelor's degree
□ Graduate degree/ Professional degree

6. Do you own a house in a beach community as a second home?
□ Yes □ No

7. Can you see the ocean or bay from your house or beach house?
□ Yes □ No

8. Closest distance from your house or beach house to the nearest ocean or bay beach:
_____miles

9. Are you a member of an environmental organization?
□ Yes □ No

10. Who supplies your electricity?
□ Delmarva
□ Delaware Electric Cooperative
□ City/Town
□ Unsure

11. Which category best describes your household income (before taxes) in 2005?
□ LESS THAN $10,000
□ $10,000-$14,999
□ $15,000-$24,999
□ $25,000-$34,999
□ $35,000-$49,999
□ $50,000-$74,999
□ $75,000-$99,999
□ $100,000-$149,999
□ $150,000-$199,999
□ $200,000-$249,999
□ $250,000 and above

12. What is your current employment status?

□ Employed for wages
□ Self-employed
□ Out of work
□ A homemaker
□ Student
□ Retired

Your contribution to this effort is greatly appreciated. Please return the survey in the enclosed envelope. If the envelope was misplaced, return it to the address on the inside front cover. Thank you!

A1.2 Cover Letter #1

September 8, 2006

Respondent Name
Address

Dear Respondent Name:

I am writing to ask your help in a study being conducted by the University of Delaware, with funding from the Delaware Energy Office. This study concerns the opinions of Delaware residents regarding energy issues and the possibility of developing wind energy for Delaware. You are one of a few individuals chosen to participate in the research, and your name has been selected at random. This survey is voluntary; however, you can help our state make better choices by taking a few minutes to share your opinions on the enclosed survey.

Our purpose in conducting this study is neither to advocate for nor oppose offshore wind power. Rather, the purpose is to clarify areas of agreement among Delaware residents and increase understanding of why people hold differing views. The results will help educate policy makers about the most contentious issues related to offshore wind development and improve communication between legislators, government agencies and the public.

Be assured your answers are completely confidential and will be released only in summaries in which no individual's answers can be identified. We use a tracking number on the survey so we only send reminders to those who have not returned the survey; even the tracking numbers will be discarded after the surveys are returned.

If you have any questions or comments about this study, I would be happy to talk to you. My office number is (302) 831-0228, or you can write to the address on the letterhead.

Thank you very much for helping with this important study.

Sincerely,

Jeremy Firestone
Assistant Professor
College of Marine and Earth Studies
University of Delaware

A1.3 Cover Letter #2

September 8, 2006

Respondent Name
Address

Dear Respondent Name:

A few weeks ago we mailed you a copy of a survey regarding offshore wind power being conducted by the University of Delaware, and we have not yet received your returned survey. We appreciate that your time is valuable, and it may be hard to find time for this. But your responses are important to understanding how Delaware residents feel about these important issues for our future.

Enclosed is a second copy of the survey and we hope that you will take this opportunity to fill it out and return it to us in the provided envelope. Again, you are assured of completely confidentiality. You can help our state make better choices by taking a few minutes to share your opinions on the enclosed survey.

If you have any questions, I would be happy to talk with you. My office number is (302) 831-0228, or you can write to the address on the letterhead.

Thank you for helping with this important study.

Sincerely,

Jeremy Firestone
Assistant Professor
College of Marine and Earth Studies
University of Delaware

A1.4 Postcard Reminder

UNIVERSITY OF DELAWARE **College of Marine and Earth Studies**

Good afternoon,

We sent a questionnaire to you a few days ago asking your opinions about wind power and energy issues in Delaware. If you have already mailed back the survey, please accept our thanks.

If you have not yet completed and returned the questionnaire, will you please take a few minutes to do so today? Your reply is important because it will help educate policy makers about important public issues and help us work together to solve environmental and other problems.

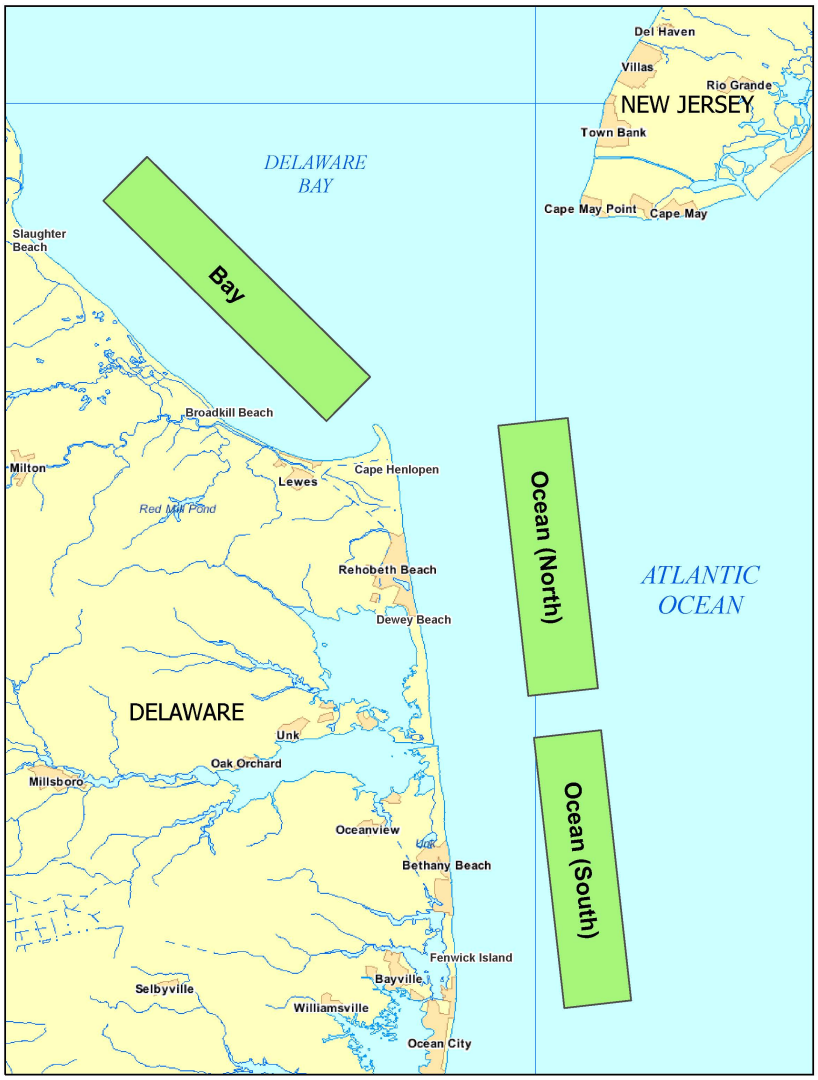
If you have any questions, please call Jeremy Firestone at (302) 831-0228

Thank you in advance for your help!

Appendix 2

SURVEY PROPS: DELAWARE MAP AND WIND PHOTO SIMULATIONS

A2.1 Delaware Map



A2.2 Photo Simulations

Simulation: 0.9 miles offshore

Simulation: 3.6 miles offshore

Simulation: 6 miles offshore

Simulation: 13.8 miles offshore

APPENDIX 3

DETAILED ECONOMETRIC MODEL RESULTS

Table A3.1 Inland Model Results

Variable	Coefficient	Std. Error	t-ratio	p-value
Random parameters in utility functions				
Bay	4.88***	0.69	7.03	0.0000
Rehoboth Beach	4.91***	0.69	7.09	0.0000
Fenwick Island	4.85***	0.69	6.99	0.0000
Ln(Distance)	0.51***	0.07	7.54	0.0000
Green Energy Fund	0.50**	0.16	3.07	0.0021
Beach Nourishment Fund	0.62***	0.15	3.99	0.0001
Royalty $2 million	-0.35*	0.14	-2.55	0.0108
Royalty $8 million	-0.31◊	0.17	-1.85	0.0637
Nonrandom parameters in utility functions				
Fee	-0.07***	0.01	-10.41	0.0000
Income	-0.002	0.003	-0.93	0.3516
Some college education	0.50	0.36	1.38	0.1688
4-year college degree	-0.43	0.31	-1.36	0.1753
Post grad degree	-1.43***	0.37	-3.81	0.0001
Age	-0.05***	0.01	-5.15	0.0000
Male	-0.07	0.23	-0.29	0.7756
Retired	0.34	0.35	0.98	0.3249
Delmarva	-0.34	0.26	-1.33	0.1842
See ocean	2.80**	1.04	2.70	0.0070
See*Distance	0.02	0.18	0.10	0.9234
Distance from beach	0.01*	0.005	2.18	0.0296
Beach days	0.003	0.01	0.56	0.5730
Seen a turbine	0.33	0.24	1.37	0.1706
Beach house	-0.29	0.47	-0.62	0.5367
Derived standard deviations of parameter distributions				
Bay	1.31*	0.55	2.37	0.0176
Rehoboth Beach	0.58	0.67	0.86	0.3920
Fenwick Island	0.46	0.70	0.66	0.5122
Distance	0.13	0.36	0.36	0.7186
Green Energy Fund	0.99*	0.46	2.17	0.0302
Beach Nourishment Fund	0.80	0.44	1.80	0.0717
Royalty $2 million	0.001	0.86	0.001	0.9994
Royalty $8 million	1.17***	0.35	3.34	0.0008

◊Significant at the α=0.1 level of confidence.
*Significant at the α=0.05 level of confidence.
**Significant at the α=0.01 level of confidence.
***Significant at the α=0.001 level of confidence
Log likelihood value: -1424.107; Number of observations: 1692

Table A3.2 Bay Model Results

Variable	Coefficient	Std. Error	t-ratio	p-value
Random parameters in utility functions				
Bay	3.85*	1.90	2.02	0.0433
Rehoboth Beach	4.12*	1.96	2.11	0.0351
Fenwick Island	4.45*	2.01	2.22	0.0267
Ln(Distance)	0.87***	0.26	3.34	0.0008
Green Energy Fund	0.45	0.42	1.07	0.2837
Beach Nourishment Fund	-0.13	0.33	-0.41	0.6851
Royalty $2 million	-0.05	0.35	-0.15	0.8784
Royalty $8 million	0.02	0.36	0.04	0.9658
Nonrandom parameters in utility functions				
Fee	-0.07***	0.02	-4.01	0.0001
Income	-0.01	0.01	-1.83	0.0678
Some college education	-0.94	1.14	-0.83	0.4065
4-year college degree	-3.30**	1.22	-2.71	0.0068
Post grad degree	-1.75	1.18	-1.48	0.1393
Age	-0.02	0.03	-0.61	0.5428
Male	0.27	0.61	0.45	0.6550
Retired	0.56	0.81	0.69	0.4905
Delmarva	2.98**	1.10	2.72	0.0066
See ocean	0.09	0.86	0.11	0.9138
See*Distance	0.50	0.30	1.70	0.0900
Distance from beach	-0.06◊	0.03	-1.89	0.0583
Beach days	0.001	0.003	0.20	0.8392
Seen a turbine	1.71*	0.70	2.46	0.0139
Derived standard deviations of parameter distributions				
Bay	0.15	1.34	0.11	0.9115
Rehoboth Beach	3.85**	1.44	2.67	0.0077
Fenwick Island	2.00◊	1.04	1.92	0.0552
Distance	0.99*	0.43	2.30	0.0213
Green Energy Fund	1.44	1.21	1.20	0.2315
Beach Nourishment Fund	0.24	1.07	0.23	0.8191
Royalty $2 million	0.06	0.87	0.07	0.9418
Royalty $8 million	0.02	0.99	0.02	0.9845

◊Significant at the α=0.1 level of confidence.
*Significant at the α=0.05 level of confidence.
**Significant at the α=0.01 level of confidence.
***Significant at the α=0.001 level of confidence
Log likelihood value: -461.7562; Number of observations: 609

Table A3.3 Ocean Model Results

Variable	Coefficient	Std. Error	t-ratio	p-value
Random parameters in utility functions				
Bay	-2.81	1.74	-1.61	0.1067
Rehoboth Beach	-3.67*	1.78	-2.06	0.0396
Fenwick Island	-3.45*	1.70	-2.03	0.0420
Ln(Distance)	1.12***	0.26	4.27	0.0000
Green Energy Fund	0.72	0.51	1.42	0.1562
Beach Nourishment Fund	0.62	0.38	1.62	0.1044
Royalty $2 million	0.15	0.35	0.41	0.6806
Royalty $8 million	0.02	0.37	0.04	0.9643
Nonrandom parameters in utility functions				
Fee	-0.04**	0.01	-3.10	0.0020
Income	0.002	0.00	0.65	0.5178
Some college education	0.78	1.14	0.69	0.4924
4-year college degree	-0.02	1.01	-0.02	0.9812
Post grad degree	-0.31	0.99	-0.32	0.7527
Age	0.01	0.02	0.57	0.5676
Male	-0.87[◊]	0.46	-1.90	0.0580
Retired	0.82	0.58	1.43	0.1539
See ocean	0.19	0.69	0.27	0.7839
See*Distance	0.35	0.29	1.22	0.2217
Distance from beach	2.50**	0.77	3.26	0.0011
Beach days	-0.004*	0.00	-1.96	0.0501
Seen a turbine	1.41**	0.51	2.77	0.0056
Derived standard deviations of parameter distributions				
Bay	3.68	2.05	1.79	0.0732
Rehoboth Beach	3.59**	1.36	2.64	0.0083
Fenwick Island	0.06	1.02	0.06	0.9547
Distance	0.55	0.33	1.66	0.0975
Green Energy Fund	2.57*	1.14	2.25	0.0247
Beach Nourishment Fund	0.01	0.67	0.02	0.9878
Royalty $2 million	0.09	1.10	0.08	0.9346
Royalty $8 million	0.06	1.15	0.05	0.9611

[◊]Significant at the α=0.1 level of confidence.
*Significant at the α=0.05 level of confidence.
**Significant at the α=0.01 level of confidence.
***Significant at the α=0.001 level of confidence
Log likelihood value: -442.9057; Number of observations: 546

LITERATURE CITED

Alvarez-Farizo, B. and N. Hanley. 2002. Using conjoint analysis to quantify public preferences over the environmental impacts of wind farms. An example from Spain. *Energy Policy,* 30: 107-116.

American Wind Energy Association (AWEA). 2006. See http://www.awea.org/; accessed November 6, 2006.

Bateman I.J., R.T. Carson, B. Day, M. Hanemann, N Hanley, T. Hett, M. J. Lee, G. Loomes, S. Mourato, E. Ozdemiroglu, D.W. Pearce, R Sugden, J. Swanson. 2002. Economic Valuation with Stated Preference Techniques: A Manual. *Ed.* I. J. Bateman. Edward Elgar Publishing.

Bergmann, A., N. Hanley, R. Wright. 2006. Valuing the attributes of renewable energy investments. *Energy Policy,* 34: 1004-1014.

Bishop, K. and A. Proctor. 1994. Love Them or Loath Them? Public Attitudes Towards Windfarms in Wales. Working Paper #8, Cardiff School of City and Regional Planning, Cardiff University, Wales, UK.

Braunholtz, Simon. 2003. Public Attitudes to Windfarms: A Survey of Local Residents in Scotland. Scottish Executive Social Research, 2003.

Brown, T. C. 2003. Introduction to Stated Preference Methods. A Primer on Nonmarket Valuation. P. A. Champ, A. C. Brown and K. J. Boyle. Boston, Kluwer Academic Publishers**:** 99-110.

Chervinsky, Gerry. 2006. The State House News Pole: Cape Wind. Available at http://www.statehousenews.com/public/poll/May06

Danish Wind Industry Association. (DWIA) 2006. See http://www.windpower.org/; accessed November 6, 2006.

Davis, R. 1963. The value of outdoor recreation: An economics study of the Maine woods. Boston, Harvard University. Ph.D Dissetation.

Denholm, Paul, G.L Kulcinski, T. Holloway. 2005. Emissions and Energy Efficiency Assessment of Baseload Wind Energy Systems. *Environmental Science and Technology*, 39: 1903-1911.

Desholm, M., and Kahlert, J. 2005. Avian Collision Risk at an Offshore Wind Farm. *Biology Letters,* (1) 3: 296-298.

Devine-Wright, P. 2005. Beyond NIMBYism: Towards an Integrated Framework for Understanding Public Perceptions of Wind Energy. *Wind Energy*, 7: 125-39.

Dhanju, A., P. Whitaker, W. Kempton. 2007. Assessing Offshore Wind Resources: An Accessible Methodology. *Renewable Energy*: In Press.

Dillman, D. 2000. Mail and Internet Surveys: The Tailored Design Method. 2nd Ed. Wiley: New York, NY.

Dong Energy, Vattenfall, Danish Energy Authority, Danish Forest and Nature Agency. Danish Offshore Wind: Key Environmental Issues. November 2006.

Ek, Kristina. 2005. Public and Private Attitudes Toward "Green" Electricity: The Case of Swedish Wind Power. *Energy Policy*, 33: 1677-1689.

Ek, Kristina. 2002. Valuing the Environmental Impacts of Wind Power: A Choice Experiment Approach. Licentiate Thesis, Lulea University of Technology, Lulea.

Erickson, W.P, G.D. Johnson, D.P. Young. 2005. A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191: 1029-1042.

European Commission. 2003. External Costs: Research Results on Socio-environmental Damages due to Electricity and Transport.

Firestone, Jeremy. 2007. Additional Point-Counterpoint on the Independent Consultant Evaluation. Before the Public Service Commission of the State of Delaware. PSC Docket No. 06-241; Review and Approval of the Request for Proposals for the Construction of New Generation Resources under 26 Del. C. § 1007(d). April 6, 2007.

Firestone, J. and W. Kempton. 2007. Public Opinion about Large Offshore Wind Power: Underlying Factors. *Energy Policy*, In Press.

Firestone, J., W. Kempton, and A. Krueger. "Delaware Opinion on Offshore Wind Power: Interim Report, 16 January 2007." Summarizes initial analysis of survey work undertaken in response to a Nov. 30, 2004 Green Energy Fund Request For Proposals issued by the Delaware Department of Natural Resources and Environmental Control, Delaware Energy Office. Available at: http://www.ocean.udel.edu/windpower/docs/DE-survey-InterimReport-16Jan2007.pdf

Firestone, J., W. Kempton, A. Krueger, C. Loper. 2004. Regulating Offshore Wind Power and Aquaculture: Messages from Land and Sea. *Cornell Journal of Law and Public Policy*, 14 (1): 71-111.

GAO. 2002. Wind Power: Impacts on Wildlife and Government Responsibilities for Regulating Development and Protecting Wildlife. Government Accountability Office. GAO-05-906. Available at: http://www.gao.gov/cgi-bin/getrpt?GAO-05-906

Gipe, Paul. 1995. Wind Power Comes of Age. John Wiley & Sons, Inc. U.S.A.

Grady, Dennis and K. Cousino. 2004. Public Attitudes Toward Wind Energy in Coastal North Carolina: A systematic Survey. Appalachian State University Energy Center. Available at http://www.energy.appstate.edu/docs/enc_pubsurvey.pdf

GWEC. 2007. Global Wind Energy Council. http://www.gwec.net

Hensher, D.A., J.M Rose, W. H. Greene. 2005. Applied Choice Analysis: A Primer. New York: Cambridge University Press.

Holmes, T. and W. Adamowicz .2000. Attribute Based Methods. A Primer on Nonmarket Valuation. P. A. Champ, A. C. Brown and K. J. Boyle. Boston, Kluwer Academic Publishers**:** 171-219.

Hoppe-Klipper, M. and U. Steinhauser. 2002. Wind Landscapes in the German Milieu. In: Pasqualetti, M., Gipe, P., Righter, R.W. (Eds.), Wind Power in View: Energy Landscapes in a Crowded World. Academic press, San Diego, pp. 83-99.

IC, 2007. Interim Report on Delmarva Power IRP in Relation to RFP. Before the Public Service Commission of the State of Delaware. Available at: http://depsc.delaware.gov/documents/Interim%20Report%20040407%20-%20Final.pdf

IPCC, 2007. Climate Change 2007: The Physical Science Basis. Summary for Policymakers. IPCC WGI Fourth Assessment Report. Available at http://www.ipcc.ch/SPM2feb07.pdf

Jarvis, C. 2005. Evaluation of the Wildlife Impacts of Offshore Wind Development Relative to Fossil Fuel Power Production. Master's Thesis, University of Delaware.

Jobert, A., P. Laborgne and S. Mimler. 2007. Local Acceptance of Wind Energy: Factors of Success Identified in French and German Case Studies. *Energy Policy*, 35: 2751-2760.

Junginger, M. A. Faaij, W,C, Turkenburg. 2004. Cost Reduction Prospects for Offshore Wind Farms. *Wind Engineering*, 28 (1): 1053-1073.

Just, RE, D.L. Hueth, and A. Schmitz. 2004. The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation. Northampton, MA: Edward Elgar.

Kempton, W., C.L. Archer, A. Dhanju, R.W. Garvine, and M.Z. Jacobson. 2007. Large CO_2 Reductions Via Offshore Wind Power Matched to Inherent Storage in Energy End-Uses. Geophysical Research Letters, 34, L02817, DOI: 10.1029/2006GL028016.

Kempton, W., J. Firestone, J. Lilley, T Rouleau, P Whitaker. 2005. The Offshore Wind Power Debate: View from Cape Cod. *Coastal Management*, 33: 121-151.

Kolstad, C. D. 2000. Environmental Economics. New York, Oxford University Press.

Krohn, S., and Damborg, S. 1999. On Public Attitudes Towards Wind Power. *Renewable Energy*, 16: 954-960.

Ladenburg, J., Dubgaard, A., Martinsen, L., and J. Tranberg. 2005. Economic Valuation of the Visual Externalities of Offshore Wind Farms. Report from the Food and Resource Economic Institute, The Royal Veterinary and Agricultural University, Copenhagen. Report No. 179.

Ladenburg, Jacob and Dubgaard, Alex. 2007. Willingness to Pay for Reduced Visual Disamenities from Offshore Wind Farms in Denmark. *Energy Policy*: In Press.

Lancaster, K. 1966. A new approach to consumer theory. *Journal of Political Economy,* 74: 132-157.

Levy, J. I., and Spengler, J.D. 2002. Modeling the Benefits of Power Plant Emission Controls in Massachusetts. *Journal of the Air & Waste Management Association*, 52: 5-18.

Lieberman Research Group. 2006. New Jersey Shore Opinions about Off-shore Wind Turbines. Available at http://www.state.nj.us/bpu/wwwroot/energy/windTurbines1.pdf; accessed November 6, 2006.

Long, J.S. 1997. Regression Models for Categorical and Limited Dependent Variables, Advanced Quantitative Techniques in the Social Sciences, Vol. 7. Sage Publications, Thousand Oaks, CA.

Louviere, J.J. 1994. ”Conjoint Analysis.” In R.P. Bagozzi, ed, Advanced Methods of Marketing Research. Blackwell Business.

Louviere, J. J., D. A. Hensher, et al. 2000. Stated Choice Methods: Analysis and Applications. New York, Cambridge University Press.

Manski, C.F. 2000. Economic Analysis of Social Interactions. *Journal of Economic Perspectives,* 14(3): 115-136.

Manwell, J.F., J.G. McGowan, A.L Rogers. 2002. Wind Energy Explained: Theory, Design and Application. John Wiley & Sons Ltd, England.

McFadden, D. 1974. ”Conditional Logit Analysis of Qualitative Choice Behavior.” In P. Zarembka, ed, Frontiers in Econometrics. Academic Press: New York, NY.

McGowan, J.G. and S. Connors. 2000. Wind Power: A Turn of the Century Review. Annu. Rev. *Energy Environ.*, 25: 147-197.

Mereidian Corporation. 1989. Energy System Emissions and Materials Requirements. U.S. Department of Energy, Washington, D.C.

Mitchell, R. C. and Richard T. Carson. 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method. Resource for the Future. Washington,

National Wind Coordinating Committee (NWCC) Siting Subcommittee, Permitting of Wind Energy Facilities: A Handbook (rev. Aug. 2002).

Pasqualetti, M. J. 2002. Living with Wind Power in a Hostile Landscape. In: Pasqualetti, M., Gipe, P., Righter, R.W. (Eds.), Wind Power in View: Energy Landscapes in a Crowded World. Academic press, San Diego, pp. 153-172.

Piero, J., Blaydes, M., Dhanju, A. 2007. “National Ramifications of Local Energy Decisions.” Poster presentation: American Wind Energy Association. Los Angeles, California, June 3-6.

Righter, R.J. 2002. Exoskeletal outer-space creations. In: Pasqualetti, M., Gipe, P., Righter, R.W. (Eds.), Wind Power in View: Energy Landscapes in a Crowded World. Academic press, San Diego, pp. 19-41.

Serchuk, Adam. 2000. The Environmental Imperative for Renewable Energy: An Update. Renewable Energy Policy Project (REPP).

Schwahn, C. 2002. Landscape Policy in the Northern Sea Marshes. In: Pasqualetti, M., Gipe, P., Righter, R.W. (Eds.), Wind Power in View: Energy Landscapes in a Crowded World. Academic press, San Diego, pp. 133-150.

Short, L. 2002. Wind Power and English Landscape Identity. . In: Pasqualetti, M., Gipe, P., Righter, R.W. (Eds.), Wind Power in View: Energy Landscapes in a Crowded World. Academic press, San Diego, pp. 43-58.

Simmonds, M. P. and Isaac, Stephen L. 2007. Review: The Impacts of Climate Change on Marine Mammals: Early Signs of Significant Problems. *Oryx*, 41 (1): 19-26.

Simpson, J.A. and E.S.C. Weiner. (Eds). 2003. *Oxford English Dictionary* (2nd ed.). 1989. Additions 1993-7 (eds. John Simpson and Edmund Weiner; Michael Proffitt), and 3rd ed. (in progress) Mar. 2000 (ed. John Simpson). OED Online. Oxford University Press.

Stern, N. 2006. The Economics of Climate Change—The Stern Review. Cambridge University Press, Cambridge, UK.

The Royal Society. 2005. Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide. The Royal Society, London, UK.

Train, Kenneth E. 2002. Discrete Choice Methods with Simulation. Cambridge, UK.

Train, Kenneth E. 1999. Mixed Logit Models for Recreational Demand. In Herriges and Kling, 1999.

U.S Army Corps of Engineers (USACE). 2004. Cape Wind DEIS.

U.S. Commission on Ocean Policy. 2004. An Ocean Blueprint for the 21st Century, Final Report of the U.S. Commission on Ocean Policy. Washington, D.C.

U.S Department of Interior, Bureau of Land Management (BLM).

--2005a. Energy Facts: Onshore Public Lands. Available at http://www.blm.gov/nhp/pubs/brochures/energy_brochure_2005.pdf; accessed November 6, 2006.

--2005b Final Programmatic EIS on Wind Energy Development.

--2006c. Instruction Memorandum No. 2006-216. Available at http://www.blm.gov/nhp/efoia/wo/fy06/im2006-216.htm; accessed November 6, 2006.

USFWS. 2007. Endangered and Threatened Wildlife and Plants; 12-Month Petition Finding and Proposed Rule To List the Polar Bear (*Ursus maritimus*). Available at: http://alaska.fws.gov/fisheries/mmm/polarbear/pdf/Polarbear_proposed_rule.pdf

Van der Loo, F.A. 2001. Mediating Windpower in the Netherlands: the Task Force Windpower Implementation. Novem, Utrecht.

Walker, G. 1995. Renewable Energy and the Public. *Land Use Policy*, 12 (1): 49-59.

Wolsink, Maarten. 1989. Attitudes and Expecancies about Wind Turbines and Wind Farms. *Wind Engineering*, 13(4): 196-206.

Wolsink, Maarten. 2000. Wind Power and the NIMBY-myth: Institutional Capacity and the Limited Significance of Public Support. *Renewable Energy*, 21: 49-64.

Wolsink, Maarten. 2005. Wind Power Implementation: The Nature of Public Attitudes: Equity and Fairness Instead of 'Backyard Motives.' *Renewable and Sustainable Energy Reviews*, 11: 1188-1207.

WWF. 2002. Polar Bears at Risk: A WWF Status Report, May 2002. World Wildlife Foundation, Washington, D.C.