BROWN UNIVERSITY

Offshore Wind Development in Rhode Island

The Advisability of Long-term Contracting with the Proposed RIWINDS Offshore Wind Project

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This thesis is submitted for review by a Committee of Readers at Brown University in partial fulfillment of the requirements for the Honors Environmental Studies undergraduate degree.

TABLE OF CONTENTS

Table of Figures

Executive Summary

This thesis estimates the levelized cost and value of electricity from the proposed RIWINDS offshore wind project. This includes analyses of potential revenue streams and two positive externalities, which are global warming and health benefits. The options for long-term contracting with the project are discussed, and further study is recommended on the impacts of developing the offshore project, particularly on the externalities of wind energy such as its hedge value and economic development potential. The analysis presented in this thesis shows that the market value of the energy is forecasted to be lower than the levelized cost for the majority of the project lifetime.

The primary goal of this research is to shed light on the customer costs and benefits of a long-term contract between National Grid and the proposed RIWINDS project. The cost estimate for the project is informed by the Mineral Management Service's Cape Wind Final Environmental Impact Statement (2009). The levelized cost of energy is estimated to be $137 per MWh for an offshore wind project located near Block Island. This thesis uses various sources to forecast the electricity, capacity, carbon and Renewable Energy Credit (REC) markets, which cumulatively equal the estimated future market value of the RIWINDS energy. Assuming a project lifetime of twenty years from 2014 to 2033, the estimated market value of the energy is $95 per MWh at the beginning of operation and $147 per MWh at the end.

The positive health and global warming externalities of the project are quantified and compared to alternative scenarios. The health savings from the avoided emissions of the RIWINDS plant are $2.60 per MWh, primarily due to reduced sulfur emissions and the resulting decrease in premature mortality. The global warming impacts are determined in context of the Rhode Island Greenhouse Gas Action Plan (2002), which outlines carbon emission reduction strategies that would meet scientific goals. In this plan, renewable energy was expected to reduce carbon emissions by 140,000 metric tons per year by 2020. The RIWINDS project would reduce carbon emissions by an estimated 180,000 tons each year.

1 Introduction

1.1 Goal & Significance

The goal of this thesis is to assess the advisability of a long-term contract for electricity between the proposed offshore wind farm to be constructed by Deepwater Wind, and the primary Rhode Island electric distribution utility, National Grid. This research uses current information to update previous cost and revenue assumptions for the project, and incorporates a valuation of its emissions impacts. The relative costs, values, and risks of the project are discussed in context of the current political framework in Rhode Island that influences possible mandates and incentives for long-term utility contracts with renewables. This research is timely since several proposed offshore wind farms in the Northeast will require such long-term contracts, and a critical next step for the RIWINDS project is the successful negotiation of such a contract. The expected value of offshore wind is an important factor considered in this process.

1.2 Importance of Offshore Wind: Climate Change Perspective

Climate change is one of the most important challenges facing the world today. Its long and short-term implications will be both environmental and economic, and the goal of climate change mitigation is to minimize impacts on both fronts. To this end, offshore wind development will play an important role.

Climate change is already evident through changing weather patterns, increased storm intensity, desertification, melting glaciers, and consequent ecosystem, biosphere and socio-political impacts. The Intergovernmental Panel on Climate Change (IPCC)[1] stated in its most recent report that the existence of climate warming is now "unequivocal," as evidenced by global air and ocean temperature increases, sea level rise, and ice and snow melt. [2] Understanding the causes of climate change is key to determining which are anthropogenic and can be influenced and developing effective mitigation strategies. Global average temperatures have been closely correlated with the atmospheric concentration of carbon dioxide (CO_2) over the past 400,000 years, and studies show that this

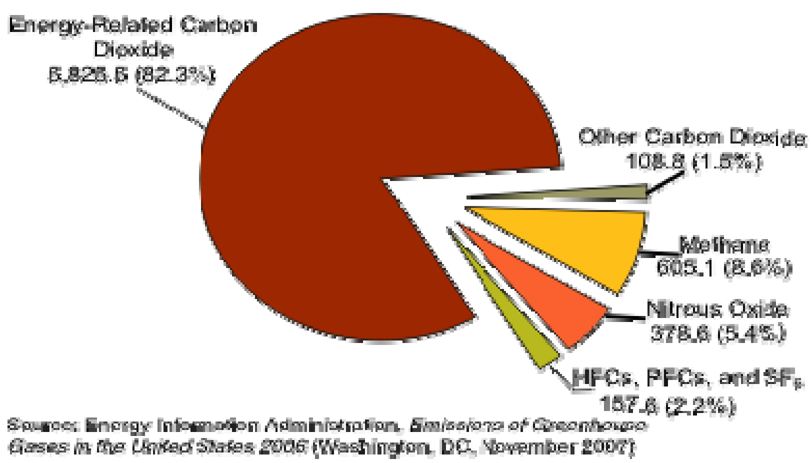
[1] A group of hundreds of scientists from around the world established by the UN to review all relevant scientific and socio-economic literature and to provide an objective analysis on the severity and causes of climate change.
[2] IPCC, "Climate Change 2007: Summary for Policy Makers." Intergovernmental Panel on Climate Change, Nov 2007. http://www.ipcc.ch/ipccreports/ar4-syr.htm, 2.

continues to be the case as temperatures have risen with rapidly increasing concentrations of CO_2 in the atmosphere since the 1960s.[3] IPCC scientists have concluded that:

> Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas [carbon dioxide, methane and nitrous oxide] concentrations.[4]

The IPCC modeling indicates that the worst aspects of climate change can be avoided if atmospheric CO_2 levels are stabilized at 550 parts per million, which requires the US to do its part by reducing its greenhouse gas emissions 80% by 2050. Over 80% of US greenhouse gas emissions are CO_2 and come from energy production, as shown in the figure below. Methane, nitrous oxide and other greenhouse gases make up 8.6%, 5.4% and 2.2% of US greenhouse gas emissions respectively.

Figure 1: U.S. Anthropogenic Greenhouse Gas Emissions by Gas, 2006

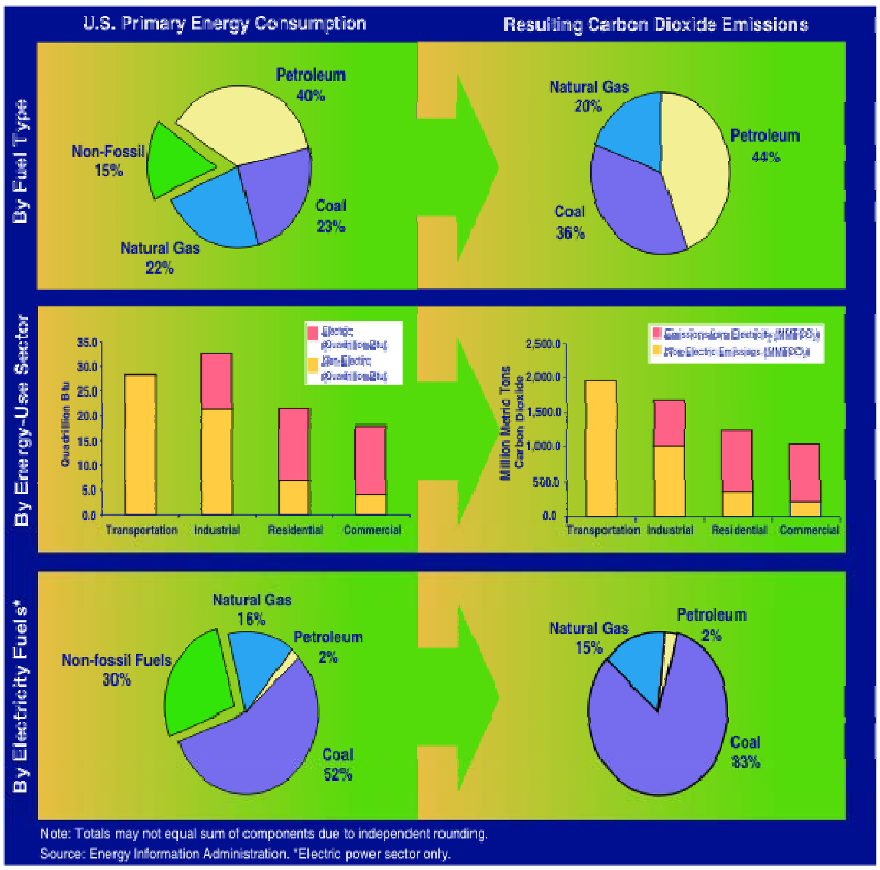


Fossil fuel combustion is the primary cause of increased CO_2 emissions,[5] and electricity generation accounts for 40% of CO_2 emissions in the US.[6] US electricity is generated by coal, natural gas, petroleum, and non-emitting fuels such as nuclear and renewables as shown in Figure 2, with each fuel having a different rate of CO_2 emissions. For the US to achieve the necessary greenhouse gas emission levels, our current electricity system will have to be significantly replaced with non-emitting generators. Efforts are already underway to spur clean energy development through renewable energy

[3] UNEP. "Vital Climate Graphics," http://www.grida.no/publications/vg/climate/ Accessed 10 March 2009.
[4] IPCC "Climate Change 2007: Summary for Policy Makers." 5.
[5] IPCC "Climate Change 2007: Summary for Policy Makers." 5.
[6] EIA, "Greenhouse Gases, Climate Change, and Energy." May 2008. http://www.eia.doe.gov/bookshelf/brochures/greenhouse/Chapter1.htm

portfolio standards (RPS) and emission cap and trade schemes in many states. Incremental changes are evident through the significant increase in renewable energy, and particularly onshore wind, in the US. However, if the necessary environmental goals are to be realized, a much greater fraction of renewable energy sources will need to be developed.

Figure 2: US Energy Consumption and Resulting CO_2 Emissions[7]



To this end, offshore wind is extremely important, particularly in coastal population centers in New England and the Mid Atlantic. New England has limited developable land-based renewable energy potential relative to many parts of the country, and relative to the electric load of the region. Siting onshore wind farms can be particularly difficult due to limited wind resources, compounded by viewshed issues. Offshore however, there is no lack of wind for electricity. The Middle-Atlantic Bight, the wind resource from Massachusetts to North Carolina, has the potential to produce an

[7] http://www.eia.doe.gov/bookshelf/brochures/greenhouse/Chapter1.htm

average of 330 GW per hour, enough to displace 68% of the region's electricity CO_2 emissions.[8] The RIWINDS project is one of several current proposals to exploit the Middle-Atlantic Bight.

1.3 Benefits of Offshore Wind

Offshore wind, similar to many other renewables, has additional benefits to being an effective climate change mitigation tool. The emission-free energy will displace some pollutants known to be detrimental to human health, including sulfates, nitrates, ozone, and in some cases mercury and particulate matter, as is discussed in Chapter 4. The health benefits of clean air range from longer lifespans to reduced asthma attacks and higher worker productivity. These benefits can be valued economically, and this important externality of offshore wind should be taken into account when valuing projects.

Similarly, offshore wind does not require cooling water, thereby avoiding an environmental impact associated with fossil fuel generation that has been particularly troubling in Rhode Island. Narragansett Bay in Rhode Island has already sustained significant damage to its marine life from billions of gallons of cooling water discharged from Brayton Point, an 1150 MW coal-fired power plant in Somerset Massachusetts.[9] Although quantifying the avoided environmental impact from the proposed offshore wind farm is beyond the scope of this thesis, this should be included in a comprehensive Environmental Impact Study for the project.

Offshore wind energy will also provide many benefits popular in current news, including energy independence and economic development. New England's electricity capacity is 38% natural gas and 25% oil fired, indicating a significant reliance on imported fuels that is unlikely to be relieved by new supply resources that are 87% natural gas fired.[10] Since the fuel for renewable energy is free (excluding biomass), renewable energy development represents independence from world markets for energy, one of the economy's most important commodities. This also would increase Rhode Island's GDP since the state would be purchasing less energy from out of state.

Renewable energy is also being lauded for its economic development potential, particularly at a time when America is losing many manufacturing jobs. Rhode Island, with the second highest

[8] Krueger, Andrew. "Valuing Public Preferences for Offshore Wind Power: A Choice Experiment Approach." Dissertation, University of Delaware, Marine Studies, Fall 2007, 3.
[9] Conservation Law Foundation. "Mount Hope Bay Brayton Point Power Plant: Thermal Water Pollution." Available: http://www.clf.org/programs/cases.asp?id=336. 2 May 2009.
[10] George, Anne. "ISO New England Renewable Initiatives." Northeast Energy & Commerce Association, Mar 5 2009. http://www.necanews.org/dev/documents/090305_george_anne_1.pdf 4, 6.

unemployment rate in the nation,[11] has specifically written into its energy legislation that renewable projects that sell electricity to Rhode Island utilities must provide direct economic benefits to the state. Offshore wind development would create local construction, assembly and maintenance jobs, however the bulk of employment in the wind industry comes from manufacturing the wind turbines, which is unlikely to create jobs in the state.

The project would also increase electricity price stability, which is inherently valuable to firms, and is even more valuable since fossil fuel prices are generally expected to rise in the coming decades. The cost of renewable energy is often described by its levelized cost of energy. Levelized cost of energy is a comparative metric that estimates the levelized-cost equivalent of the cash flows required to finance a project. This includes the costs of financing every aspect of a project, including construction, maintenance, permitting, interconnection, property tax and other costs.

Unlike most fossil fuel energy, this means the cost of the renewable electricity is known for the lifetime of the project and purchasing renewable energy acts as a hedge against volatile fossil fuel markets, which are influenced by a myriad of global factors, including violent outbreaks, natural disasters, and cartels. Also importantly, the global demand for fossil fuels is expected to outpace supply in the near future, meaning fossil fuel energy will generally become more expensive in the future. The hedge value of renewable energy and the increasing price of fossil fuels due to scarcity are evident in historic prices and futures of natural gas, as is further discussed in Chapter 3. Although scarcity and hedge values are not the focus of this thesis, they add significant value to wind energy and should be further quantified for the proposed RIWINDS project

Lastly, the RIWINDS project may decrease or delay the need for certain transmission upgrades in Rhode Island. Transmission lines have limited physical capacity to transmit power and near load centers they often reach capacity, making transmission congested and inefficient. The RIWINDS project would catalyze the construction of transmission lines from the project offshore to a new onshore substation that would presumably be linked to load in congested areas. In turn this would decrease congestion and delay the need for additional transmission upgrades.

[11] Goodnough, Abby; Zezima, Katie. “Smallest State Grapples With Oversize Problems.” New York Times, 28 Feb 2009. http://www.nytimes.com/2009/03/01/us/01rhode.html.

1.4 RIWINDS & Offshore Wind Development

Rhode Island has an abundant supply of offshore wind, and political decision makers are acting to catalyze its development. RIWINDS[*] is a program established in 2006 to promote the development of wind energy in the state. Its goal is to meet 15% of Rhode Island's electricity demand with wind energy. The state's average electricity demand is 1000MW, meaning 150MW of net capacity should be constructed to meet the goal, or specifically, enough wind development to produce 1,300,000 MWh per year.[12] The Rhode Island offshore wind program is unique in that its goal is determined by annual generation rather than constructed or net capacity.

The state commissioned the RIWINDS Phase I Siting Study, published April 2007, to analyze the location and energy potential of Rhode Island's wind resources. The main findings of the study were that Rhode Island has the wind resources to meet and exceed the RIWINDS goal—there is enough wind to generate 75% of the state's electricity, and that over 95% of that resource is offshore.[13] The study researched sites with adequate wind speeds to eliminate ones with obvious siting problems, and then conducted preliminary economic feasibility analyses on the remaining sites. The results showed that offshore wind projects of 200MW (constructed capacity) where the wind is strongest, above 9m/s, will be the most cost effective, with onshore developments of 10MW also very near the same cost effectiveness, however without enough capacity to meet the RIWINDS goal. Smaller onshore projects of 1.5MW and offshore projects closer to shore and therefore with lower wind speeds, 7.75m/s to 8.75m/s, were the least cost effective.[14]

In April 2008, Rhode Island put out a request for proposals (RFP) for an offshore wind farm that could generate at least 1,300,000 MWh/yr of electricity to meet the RIWINDS goal. To make the project more attractive to developers, the RFP outlined how the state would help expedite the permitting process for the wind farm.[15] Rhode Island is carrying out this commitment through its Special Areas Management Plan committee, which will establish a list of sites where many of the siting hurdles have already been overcome in August 2009.[16] The project could be located near Block

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[*] The RIWINDS program was subsequently renamed "Rhode Island Energy Independence 1."

[12] Applied Technology & Management, Loria Emerging Energy Consulting, Maguire Group, TRCCompanies, Birch Tree Capital. Final Report RIWINDS Phase 1: Wind Energy Siting Study, April 2007, 74.

[13] Final Report RIWINDS Phase 1, 4.

[14] Final Report RIWINDS Phase 1, 116.

[15] RFP # 7067847: Rhode Island Energy Independence I Project. 3 Apr 2008. Rhode Island Department of Administration. 5.

[16] Dzykewicz, Andrew: Commissioner RI Office of Energy Resources. "Offshore Wind Power in Rhode Island." Northeast Energy and Commerce Association Renewable Energy Conference, 5 Mar 2009, Doubletree Hotel Westborough MA, 9.

Island, in which case it would bring reasonably priced power to Block Island residents who currently pay some of the highest electricity prices in the continental US, up to four times as expensive as mainland energy.[17] Seven developers responded to the RFP, and Deepwater Wind was selected in the fall of 2008[18] based on cost estimates for construction and the selection team's confidence in their expertise.

The RFP also mentioned the state was developing a mechanism to execute long-term contracts with renewables.[19] The focus of this thesis is whether a long-term contract with the proposed RIWINDS project is likely to be a socio-economic gain for the state. It also recommends which of several long-term contracting mechanisms and details should be included. Since the developer has been selected, establishing the long-term contract is a critical next step for the project because a long-term contract could ensure adequate revenue for the project, thereby permitting Deepwater Wind to find willing investors. Without a long-term contract, the project is very likely too large and with unproven technology to obtain financing.

For this thesis, the proposed project is assumed to begin operation in 2014 with an expected commercial lifetime of 20 years.

1.5 Overview of Offshore Wind Development in the US

To date, no offshore wind has been constructed in the US, although proposals have been submitted for developments off the coast of eastern states, with other areas of interest being the Gulf of Mexico and Lake Michigan. In Europe, five countries have operating offshore wind farms: Denmark, Sweden, the UK, the Netherlands and Ireland. Germany has approved 22 proposals.[20] The table below summarizes proposals in the northeast US by location and developer.

[17] Venkataraman, Bina. "Block Island embracing offshore wind farm plan." The Boston Globe, 19 Oct 2008. http://www.boston.com/lifestyle/green/articles/2008/10/19/block_island_embracing_offshore_wind_farm_plan/.
[18] Dzykewicz 7.
[19] RFP 6.
[20] Jodziewicz, Laurie, "Offshore Wind Energy Fact Sheet." AWEA. 21 Aug 08.

Table 1: Offshore Wind Proposals in the Northeast[21]

State	Project/Developer Name	Size & Notes
Massachusetts	Cape Wind, Energy Management Inc.	454MW Final Environmental Impact Statement issued by Minerals Management Service
Massachusetts	Buzzard's Bay, Patriot Renewables	300MW
Massachusetts	Hull Municipal Project	15-20MW
Rhode Island	RIWINDS Deepwater Wind	371MW
New York	Long Island Power Authority	350MW, expansion potential to 700MW FPL was winning RFP bidder
New Jersey	Garden State Offshore Energy	350MW
Delaware	Bluewater Wind	450MW Long-term contract established with Delmarva Power

Of these proposals, two are leading the way in major respects. The Cape Wind project, likely the most famous, was proposed in 2001, and has recently completed the Environmental Impact Statement review process. As the first US project to undergo this process, it has 'paved the way' for this aspect of the regulatory process because it will be located in Federal waters, 4.7 miles offshore.[22] The project has met with significant public opposition from groups and individuals that did not want the development located in Nantucket sound. Cape Wind was proposed by a private developer, Energy Management Inc.

The Delaware Bluewater project is the first in the nation to successfully enter into a long-term energy purchasing agreement with a utility. In this case, legislative initiatives persistently pursued the negotiation of such a contract. The "Electric Utility Retail Customer Supply Act of 2006" enabled state agencies to force utilities into long-term contracts, which was ultimately carried out between the Delaware Public Utilities Commission and Delmarva Power[23] even though it was not the least cost

[21] Sheingold, Barry, New Energy Opportunities. "Recent Developments: Offshore Wind in the Northeast." Northeast Energy and Commerce Association: Renewable Energy and Distributed Generation Committee meeting. Framingham, MA. 28 Oct 2008.
[22] Krueger, Andrew 17.
[23] New Energy Opportunities, La Capra Associates, Merrimack Energy Group, McCauley Lyman. "Report on Final Power Purchase Agreement between Delmarva Power and Bluewater Wind Delaware LLC." 3 July 2008, 1.

option.[24] Currently, there are many instances where utilities are reluctant to enter into long-term contracts with renewables, which are necessary for renewable energy development although not for fossil fuel development as will be discussed further in Chapter 5. These contracts involve higher risk in the current electricity market than short term contracts, according to utilities, and the current credit crunch does not favor capital intensive projects.[25]

The Delmarva/Bluewater Wind long-term contract includes several characteristics that reduce risk for the utility and rate payers. First, the contract is not for the output of the entire project, 450MW of installed capacity, but for 200MW of installed capacity.[26] There is a Renewable Energy Credit (REC) multiplier associated with the RECs Delmarva purchases from the project of 350%, and the RECs will be sold at $15.32.[27] Another key aspect is that the power will be spread among the utilities distribution customers rather than is Standard Offer Service customers.[28] Delmarva, and Rhode Island's National Grid, have customers for whom they are responsible for procuring electricity supply, which it calls its Standard Offer Service (SOS). The SOS customers make up only a fraction of the customer base that the utility distributes energy to. In deregulated markets, utilities are not necessarily vertically integrated and can provide several levels of service, only distribution of electricity, electricity procurement and distribution, or only electricity procurement. Allowing Delmarva to spread the above-market costs of the Bluewater long-term contract among its distribution customers reduces the cost increase per customer, and importantly counters the potential incentive for SOS customers to switch electricity providers because costs had risen due to the contract.

Overall, a set of developers, state agencies, and Federal permitting agencies are working towards the first offshore wind developments in the US. Important precedents are being set with siting and long-term contracting, but many technical issues have not been addressed in detail the US since projects have not reached advanced stages of development yet. In the context of US proposals, the RIWINDS project may have expedited permitting due to state efforts and the Special Area Management Plan, and legislative and regulatory efforts are underway to require National Grid to negotiate a long-term contract.

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[24] Sheingold, Barry, New Energy Opportunities. "Offshore Wind in the Northeast: State Initiatives and Project Development." Northeast Energy and Commerce Association: Renewable Energy Conference, Westborough MA. 5 March 2009, 3.
[25] Ferenze, Gary, Conective Energy. "Offtake Deals, Equipment Procurement and Financing." Northeast Energy and Commerce Association: Renewable Energy Conference, Westborough MA. 5 March 2009, 4.
[26] New Energy Opportunities, 2.
[27] New Energy Opportunities 2, 3.
[28] New Energy Opportunities 3.

1.6 Description of Research

This thesis analyzes the costs and benefits of the RIWINDS project and discusses regulatory and political factors affecting long-term contracting. The qualitative understanding necessary for the analysis and discussion was developed through internship experiences in the renewable energy industry in New England and further informed by attending Rhode Island Public Utility Commission (PUC) meetings. The internship experiences were primarily working for Sustainable Energy Advantage, LLC, an industry consulting firm based in Framingham, MA, which is co-located with the New Energy Group , an industry consulting network of professionals functioning as an informal renewable energy industry incubator. New Energy Group firms regularly perform research and analysis on projected costs and revenues of renewable energy projects. Several of the professionals in this group worked closely with the RIWINDS project as well as other leading on- and off-shore wind proposals in the northeast. Over the course of writing this thesis, the Rhode Island PUC met several times to address National Grid's long-term contracting with renewables. Discussions at the meetings were informative and referenced key documents and studies incorporated in this research.

The quantitative analysis was informed by internship experience and course work with financial modeling and relevant markets. Data for these analyses was gathered from the most credible sources available, including the New England Independent System Operator (ISO), the US Energy Information Administration (EIA), and consultant reports. The methods for the analysis were guided by industry experts who were either involved with previous analysis of the RIWINDS proposal or had previously performed similar work. This thesis clearly notes when analysis methods were specifically informed by other studies; otherwise I have rationally adapted methods for this specific situation in consultation with professionals. In many cases the quantitative analysis is focused on predictions involving uncertain political and market outcomes. For these, multiple studies have been taken into account where possible, and in other cases the limits of the predictions are discussed.

1.6.1 Overview of Chapters

Chapter 2 determines cost projections for the RIWINDS project using two US offshore wind cost studies, and Chapter 3 analyzes the revenue streams for the project: electricity, RECs, carbon and capacity. Chapter 4 discusses the value of the avoided emissions impact with respect to global warming and health care costs. Chapter 5 details the history of renewable energy long-term contracting political efforts, and outlines the risks and benefits associated with probable paths in the future. Chapter 6 synthesizes cost, revenue and externality analysis in Chapter 2, 3 and 4 to provide an economic valuation of the project. Given this evidence of the benefits of the project for Rhode Island, a political path and long-term contract structure is recommended for National Grid and the RIWINDS project.

1.6.2 Definition of Several Key Terms

Capacity of Wind Projects

The nameplate capacity of project is the amount of energy it could potentially generate in one hour if it were operating under ideal conditions. For an offshore wind farm that has five 2MW turbines, the nameplate capacity would be 10MW.

However, wind projects usually generate less than their nameplate capacity sometimes do not generate at all depending on wind speeds. The project's capacity factor is a measure of how much energy is produced on average for an amount of installed capacity. For instance, if the 10MW wind farm described above has an estimated 30% capacity factor, an average of 3MW will be produced every hour, or 3MWhs. The precise definition of capacity factor is actual energy production divided by the potential energy production of a project (its nameplate capacity) in every hour.

Renewable Energy Credits (RECs)

A REC represents the environmental attributes of one MWh of renewable energy, most importantly that it was generated with emission-free fuel. It can be sold separately or bundled with the actual electricity. RECs were established as a mechanism to track compliance with state's Renewable Portfolio Standards (RPSs), including Rhode Island's Renewable Energy Standard (RES).

Offtake Agreement: Long-term Contracts & Power Purchase Agreements

An offtake agreement, also known as a Power Purchase Agreement, is a contract between a power generator and a power purchaser, such as a utility or a large electricity user such as a manufacturer. The parties agree on a price and amount of electricity and/or RECs that will be sold to the power purchaser, and the length of time of the contract. These offtake agreements are also known as long-term contracts if the term is appropriately long (5-20 years). Other important characteristics of offtake agreements are further discussed in the body of the thesis.

2 Cost Analysis

Of the many unknowns about the RIWINDS offshore wind farm, its economic feasibility is one of the most crucial. To date, there are no offshore wind farms in the US, and Deepwater Wind's jacket technology has yet to be tested commercially, leaving many unanswered questions about the project's cost of development. This chapter discusses the projected costs of RIWINDS project, drawing primarily on the RIWINDS Phase 1 study (2007), the Final Environmental Impact Statement for Cape Wind (2009) and the 2007 Annual Report on US Wind Power Installation, Cost and Performance (2008). The goals of this chapter are to describe and analyze offshore wind cost studies and determine the best-informed current cost prediction for the RIWINDS energy.

The true cost of construction and maintenance of offshore wind developments in the US has proved to be a significant obstacle in their development, along with other obstacles such as regulatory issues, turbine supply, and public opinion. However, with ten current offshore wind proposals in the US,[29] research has emerged on project costs, combining technology, market and development understanding with data from European projects. Cost estimates are now available for several offshore wind developments in the US, including for several sites offshore of Rhode Island.

2.1 RIWINDS Phase 1 Study

The purpose of the RIWINDS Phase 1 study was to evaluate the wind potential in Rhode Island and the feasibility of meeting the RIWINDS goal of having 15% of the state's electricity coming from wind. The study included wind potential and economic assessments of all possible wind generation locations in Rhode Island, and a main finding from the study was that 98% of Rhode Island's wind generation capacity lies offshore.[30] The study screened potential offshore wind sites for criteria such as a sufficient wind resource, commercial waterways and marine sanctuaries to determine the most feasible sites for offshore wind development.

Using the wind data and applying engineering knowledge of offshore wind development and its major cost components, the study estimated the costs of construction and maintenance for potential

[29] Musial, W.; Ram, B.. "Status of Offshore Wind Energy Projects, Policies and Programs in the United States." *2007 European Offshore Wind Conference*. Berlin, Germany, 4-6 Dec 2007. Published Jan 2008. 1.
[30] Applied Technology & Management, Loria Emerging Energy Consulting. Summary Report: RIWINDS Phase 1 Siting Study. September 2007, 2

offshore wind farms at ten locations in state and federal waters off of Rhode Island.[31] The study also examined the cost of financing and incorporated these into levelized cost estimates. Finally, it compared the levelized cost of energy estimates (including financing costs) of generation from an offshore wind farm to projected energy prices in Rhode Island.

The RIWINDS study assumed monopile technology would be used for the turbine foundations.[32] This was a reasonable assumption at the time the study was conducted since Deepwater Wind had not yet been awarded the project through Rhode Island's RFP process**.** Although the report deliberately states that it does not estimate costs with much precision due to the lack of experience with offshore wind projects in the US and the extremely early timing in the development process, the switch from monopile to jacket foundations may still impact the estimates. The industry standard to date has been to use monopiles driven into the ocean floor to support wind turbines, which is effective in water up to 70 feet deep[33]. On the other hand, Deepwater Wind touts jacket foundation technology that has been adapted from oil and gas offshore drilling rigs that they claim this can be used in water up to 150 feet deep.[34] This could be an important development in the offshore wind industry since wind speeds are higher further offshore, and therefore typically in deeper water. For other technology and construction assumptions, such as the use of GE 3.6 MW turbines, updated information may be available, but that is outside the scope of this thesis.

The cost estimates were considered high by the authors of the study at the time it was published because they assumed that the project would be responsible for all transmission construction and upgrades, rather than the interconnecting distribution utility taking some of the costs.[35] Additionally, the operation and maintenance costs were estimated conservatively due to a lack of public information.[36]

Cost estimates for each location were given in terms of the levelized cost of energy assuming a 20-year lifetime of the project.[37] As previously mentioned, the RIWINDS Summary Report listed the top ranked locations for development, and the predicted levelized costs of electricity are summarized

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[31] Applied Technology & Management, Loria Emerging Energy Consulting, Maguire Group, TRC Companies, Birch Tree Capital. Final Report RIWINDS Phase 1: Wind Energy Siting Study, April 2007, 74.
[32] Applied Technology, Final Report 76.
[33] Deepwater Wind. "The Technology." http://dwwind.com/technology.html. 3 Mar. 2009
[34] Deepwater Wind. "The Technology."
[35] Applied Technology, Final Report 81.
[36] Applied Technology, Final Report 82.
[37] Applied Technology, Final Report 115.

in the table below. The costs include the cost of financing using typical industry strategies.[*] Site ranking was based 70% on the cost of the energy produced from that site, 20% on whether or not the site was in state waters since this affects the ease of permitting, and 10% on visibility from shore.[38] Locations were ranked in pairs that had the capacity to fulfill the 15% RIWINDS goal, and the winning pair was Areas E & H, followed by J & K and H & K.[39]

Table 2: Projected Cost of Wind Energy for Highest Ranked Offshore Sites[40]

Location	Size	Projected Cost of Wind Energy
Area E	30 MW	$120.00
Area H	200 MW	$97.00
Area J	200 MW	$96.00
Area K	200 MW	$96.00

Figure 3: RIWINDS Map Showing Post Level 2 Screening Areas[41]

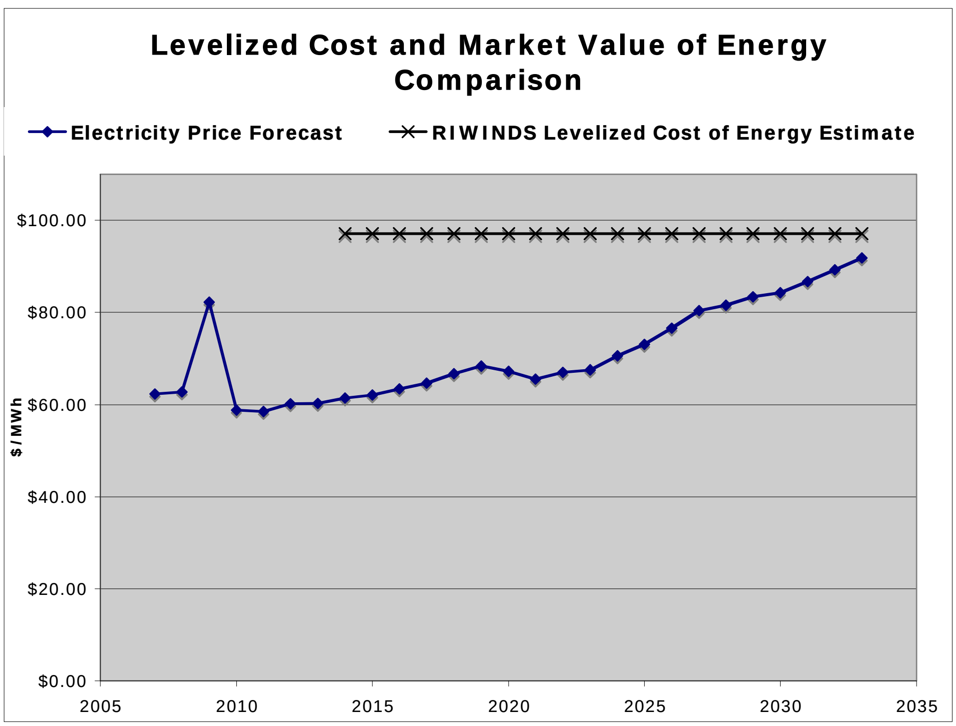
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

[*] See RIWINDS Phase I Report, pages 74-84 for further information. The basic assumption is that equity plus commercial debt financing would be used.
[38] Applied Technology, Summary 5.
[39] Applied Technology, Summary 6.
[40] Applied Technology, Final Report 116.
[41] Applied Technology, Final Report Figure 3.20.

2.1.1 Analysis

Because there was no further public information on the selected location of the project at the time of this research, a weighted average of the cost of wind energy is used based on each area's nameplate capacity and role in the ranking.* This method gave an average wind energy cost of $97.09 per MWh, or $0.097 per kWh. Figure 4 below shows the levelized cost compared to the forecasted price of electricity in New England*, assuming the project will begin operation in 2014 with a 20-year lifetime. The cost of energy is consistently above the projected energy market price, however as will be discussed in the following chapters, wind energy has other revenue streams and positive attributes that may nonetheless make this project a wise investment for Rhode Islanders.

Figure 4: RIWINDS Projected Levelized Cost vs RI Energy Price per MWh



* For each location (J, K, H, E), the nameplate capacity was multiplied by the levelized cost of energy, then this was multiplied by the number of times each area showed up in the ranking (H and K showed up twice→ multiplier = 2; J and E showed up once→ multiplier =1). Then, the total levelized cost of the nameplate capacity of each location in the ranking was divided by the total name place capacity of the ranking (200MW * 5 + 30MW=1030 MW) to get the average levelized cost of energy in the ranking, $97.09.

* The electricity forecast is an update performed specifically for this thesis, based on RIWINDS methods, and is further described in Chapter 3.

2.2 Cape Wind Study: Block Island Cost of Energy Estimate

In the Final Environmental Impact Statement (EIS) for Cape Wind published in January 2009 by the Department of the Interior's Minerals Management Service, ten alternative locations for the offshore wind farm were analyzed. One of these locations was off of Block Island, likely similar to locations J and K shown in Figure 3 above, although the map in the Cape Wind Final EIS is not specific enough to be certain. In addition, for the Block Island site, the EIS found an average water depth of 30 meters, warranting 'oil and gas platform technology' rather than monopile foundations.[42] The assumed foundation technology is likely very similar to that proposed by Deepwater Wind as jacket technology since theirs also draws principles from oil and gas offshore structures.

After adjustments due to peer review comments on the economic model used for the offshore wind cost estimates, the EIS estimate for the levelized cost of energy from the Block Island site was $137/MWh.[43]

2.2.1 Analysis

The Final EIS states that its cost estimates are for site comparison purposes, and therefore needed less accuracy than estimates for investment decisions. Despite the recognition of imprecision, the cost estimate of $137/MWh is more accurate than the RIWINDS average of $97.09/MWh due to several recent factors that can account for the 41% increase since the RIWINDS analysis in 2006 and 2007.

First, wind turbine costs have increased 85% since their lowest point in 2002, including a 15% increase between 2006 and 2007.[44] The Annual Report on US Wind Power found that this has had a direct impact wind project costs, and thereby wind energy costs in studied onshore cases. The authors of the report also expected project costs to continue to increase in the near future as the increased turbine cost continues to factor into project development. The most recent increase in turbine prices, between 2006 and 2007, was attributed to the relative weakening of the US dollar against the Euro,

[42] US Department of the Interior Minerals Management Service. "Cape Wind Energy Project Final EIS: Appendix F Economic Model." January 2009. http://www.mms.gov/offshore/AlternativeEnergy/PDFs/FEIS/Appendix%20F%20-%20Economic_Model.pdf. 15.
[43] US Department of the Interior 63.
[44] Wiser, Ryan; Bolinger, Mark. "Annual Report on US Wind Power Installation, Cost, and Performance Trends: 2007." May 2008. US Department of Energy: Energy Efficiency and Renewable Energy. http://eetd.lbl.gov/ea/ems/reports/lbnl-275e.pdf. 22.

increased energy and material inputs (oil and steel), and increased profit margins for turbine manufacturers.

The Final EIS takes the raise in turbine prices into account, as well as increasing copper prices, which will affect transmission construction costs.[45] In addition to these two cost increase factors, the Final EIS modeled the financial terms of the projects based on the updated condition of potential debt and equity markets for offshore wind projects.[46] The current recession and resulting tightening of financial markets also increased the levelized cost estimate of the energy.

Because the Cape Wind Final EIS levelized cost of energy reflects significant recent market changes that the RIWINDS estimate does not, it will be used in the rest of this analysis as the estimated cost of energy from the proposed offshore wind farm in Rhode Island. The assumed location off of Block Island is reasonable given the most likely location list from the RIWINDS summary included two sites off of Block Island and other factors.

Block Island frequently has very high electricity prices due to its reliance on diesel generators as mentioned in the introduction. Locating the wind farm near Block Island would make the construction of a transmission line from Block Island to the mainland economically feasible, meaning Block Islanders would have access to mainland electricity prices.[47] If the project is not located off of Block Island, this electric line is unlikely to be built, and residents risk facing exorbitant electricity bills in the future, such as the $700/month one resident paid in August 2008.[48]

Block Island sites also offer the benefit of higher wind speeds that are still within state waters. The wind speeds at the Block Island sites are the highest of those considered in the RIWINDS study, giving the potential for the most energy production, because they are furthest from the mainland. At the same time, the sites are less than three miles from the shore of state land, so the developers could bypass the presumably more complex Federal siting requirements.[49] Finally, some groups of residents, such as the Block Island Residents Association, which represents 550 households of year-round and seasonal dwellers, have come out in support for an offshore wind project near the Island.[50] This support would be significant since siting has historically been a controversial issue and major obstacle for US offshore wind development.

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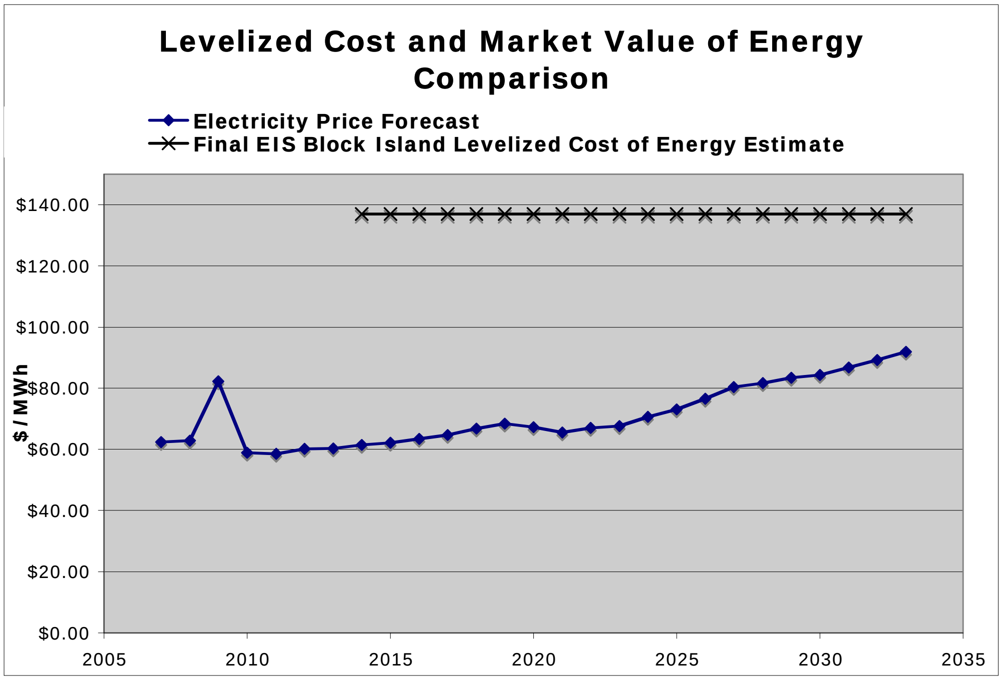
[45] US Department of the Interior 6.
[46] US Department of the Interior 5.
[47] Peregrine Energy Group. "Rhode Island Offshore Wind Stakeholders Final Report." Feb 2008. http://www.energy.ri.gov/documents/renewable/RI_Offshore_Wind_Stakeholders_Final_Report_February_2008.pdf 13.
[48] Venkataraman, Bina 1.
[49] Venkataraman, Bina 2.
[50] Venkataraman, Bina 2.

Figure 5: Final EIS Block Island Levelized Cost of Energy verses RI Electricity Price Forecast



2.3 Summary

This chapter summarizes the cost estimates relevant to the proposed offshore wind RIWINDS project. The two cost estimates based on the RIWINDS study and the Cape Wind Final EIS Block Island estimate depict the significant upwards shift in wind project cost estimates between 2006 and 2009, although little data exists to check the accuracy of the estimates. The Finale EIS levelized cost of energy, which is used for the remainder of this thesis, is consistently above the electricity price projections for Rhode Island, further described in section 3.1. However, electricity payments are not the only revenue the offshore wind project would receive, as is discussed in Chapter 3, and positive externalities of wind energy further add to the value of energy, as is discussed in Chapter 4.

3 Revenue Analysis

There are three major revenue streams for wind generators: electricity sales, REC sales, and capacity reimbursement. A traditional fossil fuel generator under development could predict its economic feasibility based on projected electricity prices, construction costs and fuel prices since the bulk of its costs are from the fuel needed to run the generator. Renewable generators are in a different situation since their fuel is free, but upfront construction costs are very high. This means they lack the flexibility of fossil fuel generators that can choose to burn expensive fuel only when its energy is being paid for. Capitol-intensive renewable generators generally cannot afford the risk of relying on market prices for their generation and environmental attributes (RECs), and they require long-term contracts to mitigate revenue risk sufficiently to get financing. Therefore, while market predictions are important for assessing feasibility and negotiating an offtake agreement for offshore wind developments, the price set in the contract determines the project's ability to get financed, not market prices.

Additionally, all of the potential revenue streams carry a significant degree of volatility and political uncertainty. Electricity price, the driver of the most important revenue stream, depends on notoriously volatile fossil fuel markets, as well as complex electricity future supply and demand scenarios. The second largest revenue stream for the RIWINDS project would likely be from Renewable Energy Credit (REC) sales, which depend on an intricate interplay of state regulations and possibly federal regulations. Thirdly, the revenue stream for the generator's capacity is complicated by wind's inherent intermittency, and lastly, a carbon market could have a positive impact on cash flows for the project, but to an unknown degree.

Finally, this analysis does not include any revenue from Federal Production Tax Credits. The lifetime of these credits has historically been in flux due to short-term legislation that is not always renewed. If it becomes clear after the writing of this thesis that Production Tax Credits will be available for the proposed offshore project, their impact should be added to the analysis.

3.1 Electricity

Electricity prices are determined by the structure of a region's electricity market, the balance of supply and demand, and the types of generators in the region. The electricity price would have a significant impact on the price negotiated in a long-term offtake contract for the wind energy.*

* Specifically, the prices electricity was procured for the Standard Offer Service in Rhode Island would be taken into account. Standard Offer Service is further discussed in Chapter 5.

Electricity market deregulation began in the US in the 1990's, clearing the way for the competitive wholesale market in New England that began in 1999.[51] In a competitive wholesale electricity market, suppliers bid a quantity and price of electricity they are able to deliver at a given time, and power purchasers bid a quantity and price of electricity that they are willing to buy. An independent system operator (ISO) is charged with matching the supply and demand bids to ensure that electricity generators are dispatched in a reliable and economically efficient way. Typically, ISOs use clearing price auctions, where the supplier's bids are stacked in order of cost until all of the demand is met. The bids of the last generator needed to meet the total demand sets the price that all generators are paid, called the clearing price.[52] In New England, natural gas generators typically set the clearing price because they have the highest variable cost of generators needed to meet normal regional demand. At peak demand periods, even more costly oil generators are sometimes dispatched and set the clearing price.

The clearing price auction above describes the process for setting the wholesale spot market prices. The price electricity customers ultimately pay, called the retail price, includes distribution, transmission, losses and other charges, but the wholesale price determines the revenue generators receive. Not all power is traded at spot market prices—short and medium length contracts are used to hedge risk in the market,[53] however, the contract prices are usually based on spot market projections. Because the clearing price in the New England spot market is set by natural gas generators, natural gas futures, such as those available on the New York Mercantile Exchange (NYMEX), are the basis of many electricity price projections.

Similarly, the long-term contract for the RIWINDS project would be informed by electricity spot market projections. If National Grid could enter into a long-term contract with the RIWINDS project for electricity at or below the projected spot-market prices, this would have a neutral or beneficial impact on customer's rates, and would likely be approved (specific long-term contracting issues which will be discussed later). Also, because the offshore wind contract would be over many years, there is a possibility of setting a contract price that is predicted to be more expensive for customers in the short term, but will save them money in the long term.

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[51] ISO New England. "Wholesale Electricity Markets." 4 Mar. 2009, http://www.iso-ne.com/nwsiss/grid_mkts/how_mkts_wrk/smd_overview/index-p2.html.
[52] Electric Power Supply Association, 'Electricity Primer,' 4 Mar 2009, http://www.epsa.org/industry/primer/?fa=prices.
[53] Electric Power Supply Association.

The final analysis in Chapter 6 assumes a contract price for electricity that is at or below the long-term average of projected electricity prices in Rhode Island. However, if development costs for the RIWINDS project are ultimately too high to be covered by an economical electricity contract, as is implied by the RIWINDS cost estimate and depicted in Figures 4 & 5 in Chapter 2, other revenues and values would need to be present to make the project economically feasible.

3.1.1 Electricity Price Analysis

Electricity prices can be forecasted using heat rates and fuel price projections: electricity price = (heat rate * fuel price).[54] The heat rate is a ratio of electricity produced per amount of fuel and depends are both the type of fuel and generator technology and efficiency. As discussed in Section 3.1, the electricity prices in New England are largely determined by marginal generators, which have evolved to be primarily natural gas combined cycle units as described in Section 4.1.

This analysis updates the electricity price forecast given in the RIWINDS study, conducted in 2006 and 2007. Since then, the heat rate and natural gas futures have changed, resulting in a new forecast that is significantly different. The heat rate assumed in the RIWINDS study was 8200 Btu/kWh,[55] where a Btu (British thermal unit) correlates to a volume of fuel, in this case mainly natural gas. The most recent marginal heat rate currently available is from the 2006 Marginal Emission Rate Analysis, and it shows a decline of 6.5% since the RIWINDS study to 7,667 Btu/kWh.[56]

The other main component of electricity price forecasts is the price projection for the marginal fuel, primarily natural gas in New England. A significant adjustment of natural gas futures in 2008 is responsible for the bulk of the shift in the electricity forecast. This was largely due to the global economic crisis that precipitated in 2008 and the preceding record-setting spike in fossil fuel prices. This spike can be seen in the updated EIA forecast in the figure below.

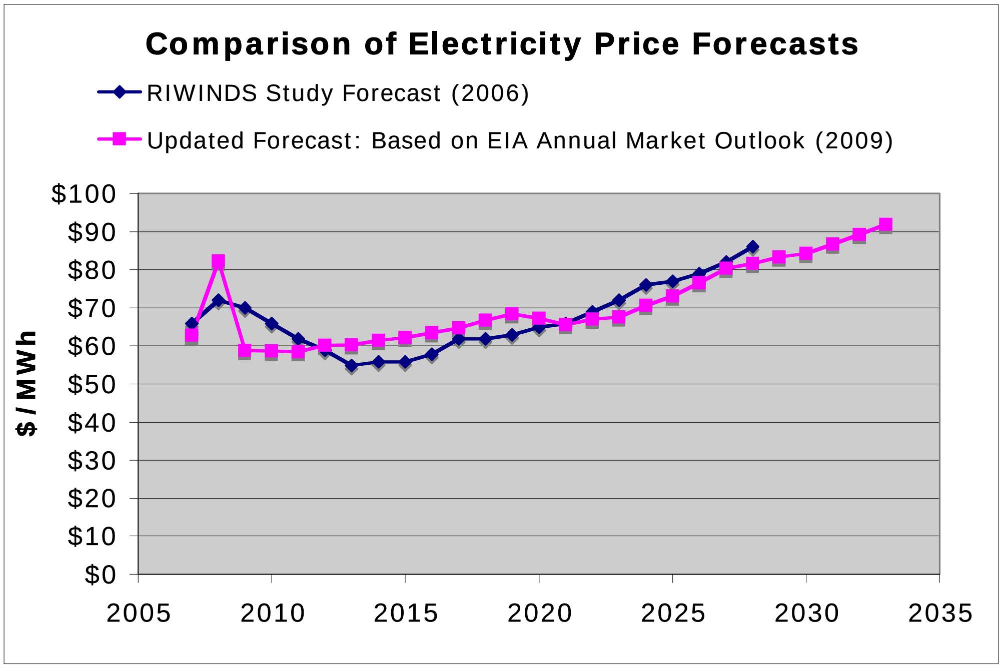
This thesis uses Henry Hub natural gas projections through 2030 from the EIA's 2009 Annual Energy Outlook to update the electricity forecast from the RIWINDS study. The Production profile adjustment factor of 1.006 and the derating factor of $2.50/MWh used in the RIWINDS analysis are retained because it is beyond the scope of this paper to update those. In addition, a basis adjustment

[54] Suez Energy Resources NA. "Understand Heat Rate Products." 2006.
[55] Applied Technology, Final Report 91.
[56] "2006 New England Marginal Emission Rate Analysis," 15.

factor of 1.216 has been added to account for the difference in price between Henry Hub and the New England natural gas delivery points.*

The equation for the updated electricity price is therefore: Electricity Price ($/MWh)=(Heat Rate * Natural Gas Price/Btu * 1.216 [basis]) * 1.006 – 2.50. The updated electricity prices based on the EIA natural gas projections and the 2006 heat rate are graphed below in comparison to the RIWINDS electricity price forecasts. For years beyond the EIA natural gas forecast (2030), I extrapolated the growth rate in electricity prices from the last five years of the forecast (2026-2030).

Figure 6: RIWINDS (2007) verses Updated (2009) Electricity Price Forecasts



This comparison shows that price projections have probably fallen and risen back to approximately the same level since the RIWINDS study was conducted. This is primarily due to the drop in natural gas futures, and is compounded by the decreased heat rate, which indicates higher generator efficiency. This is indicative of a larger trend, where fossil fuel prices reached an all-time high in 2008, making renewable energy seem more competitive with fossil fuel electricity. This is important to take into consideration as a 20-year renewable energy project is considered since it is likely fossil fuel prices will spike again during the offshore wind project's life time. Currently, when

* This thesis used historical natural gas price data from Algonquin Citygates to estimate the basis. Specifically, I took the average of Algonquin to Henry Hub prices from the 15th of each month from May 2008 to April 2009. For months where price data was unavailable for the 15th (weekends or holiday), I used data from the closest date to the 15th. All information was retrieved from: IntercontinentalExchange: Category: Indices; Market: ICE OTC; Report: North American Natural Gas. Available https://www.theice.com/marketdata/reportcenter/reports.htm?reportId=77. May 2009.

fossil fuel prices are lower, renewable energy's primary value may come from environmental attributes, particularly as dictated by legislative renewable energy incentives and carbon constraints.

3.2 Renewable Energy Credits (RECs)

RECs are a significant supplemental source of revenue for renewable energy generators, and their environmental and political objective is to cover the renewable energy 'premium', or additional expense of renewable energy compared to other forms of energy. The future of the REC market is currently the most difficult to predict of the renewable energy revenue streams.

RECs are used as a mechanism to track compliance with state's Renewable Portfolio Standards (RPSs). An RPS is a political mandate for electricity providers, utilities and other retail sellers of electricity, to include a certain percentage of renewable energy in the electricity they provide to customers. Each year, the quota of renewable energy needed increases, with the goal that renewable energy will ultimately provide a significant amount of the state's electricity. In Rhode Island, the equivalent legislation is the Renewable Energy Standard (RES), and it began with a quota of 3% renewables[*] in 2007 and increases to 16% by 2019.[57] To demonstrate compliance with the RES, National Grid must purchase RECs for the designated quota of electricity.

If a utility has not purchased enough RECs to meet its RPS/RES requirement, it must pay the alternative compliance payment, which is generally $50-$60 per MWh, and is set in state's RPS legislation and regulations. Historically, REC supply has not met demand, so the value of RECs was essentially the same as the alternative compliance payment. At $50-$60/MWh, this represents a very significant revenue stream when compared to the $137 price per MWh needed by the RIWINDS project.

Unfortunately, the REC market is volatile has shown a steep decline in the past few months as is described in the next section. Some renewable energy professionals perceive the market to be binary, and expect REC values could drop to near $0/MWh in the case of a surplus. However, with the introduction of banking into some state's RPS regimes, RECs will better maintain their value through market fluctuations. Regardless, the market is too unpredictable for developers and their financers to count on a certain value for this revenue stream unless it is included in a long-term contract. Long-

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[*] Of this 3%, 1% had to be from new resources and 2% could be from "existing" sources. The 2% stays the same over time, and the new requirement increases annually.

[57] Database of State Incentives for Renewables & Efficiency, 'Rhode Island State Incentives: Renewable Energy Standard,' 29 Jan 2009, Accessed 4 March 2009, http://dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=RI08R&state=RI&CurrentPageID=1&RE=1&EE=1.

term REC contracts to date have based the REC price on predicted averages for the life of the project. To maximize consumer benefit, a REC price should be included in the long-term contract for the RIWINDS project that is at or below the long-term average price of RECs.

3.2.1 REC Market Analysis

The REC market will determine the second highest revenue stream for the potential offshore wind project and is probably the most difficult market to predict. As mentioned in Chapter 2, the REC prices have historically stayed very close to the Alternative Compliance Payment. As recently as July 2008, the trading price for Rhode Island 'New' RECs was $48.00 per MWh.[58] However, as documented in the Massachusetts *Annual RPS Compliance Report for 2007*, there was a supply surplus for the first time in the history of New England RPS and RES programs for the 2007 compliance period.[59] This has caused regional REC prices to fall to $20 to $30 starting in the summer of 2008 REC trading periods. The dramatic increase in renewable energy project proposals in the New England, New York and PJM interconnection queues indicates that supply will continue to show strong growth. Demand is heavily tied to incremental percentage target annual increases in RPSs, and it is likely that the supply surplus will be sustained for the foreseeable future. Therefore, REC prices can be assumed to stay in the $20 to $30 range for the duration of the Rhode Island offshore wind project long-term contract, particularly due to the expected continued development of cheaper renewables, such as biomass.

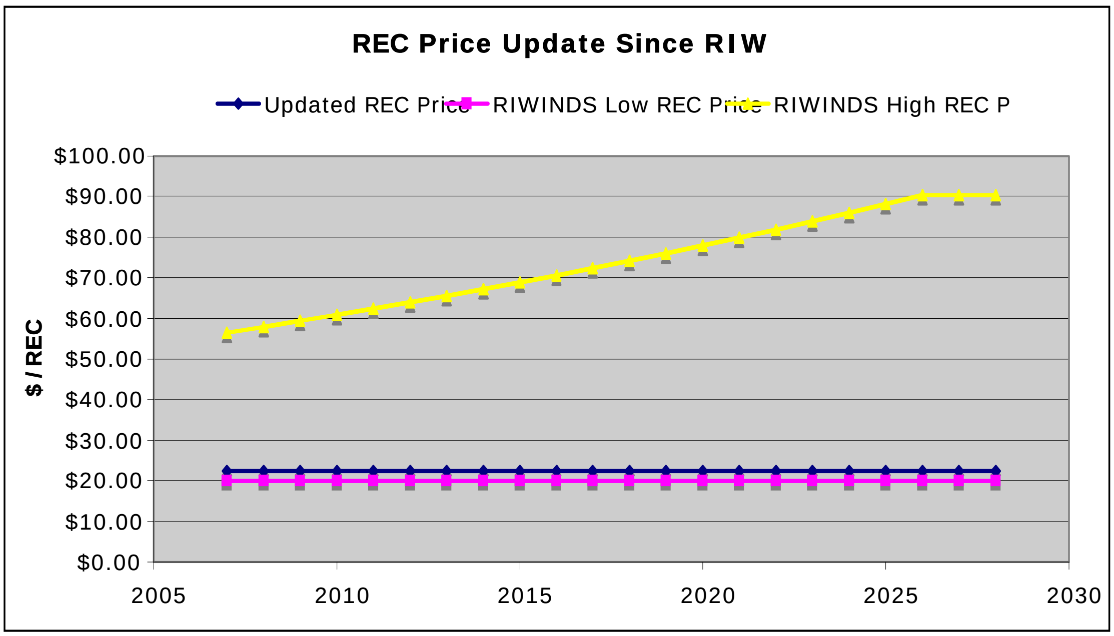
The only public information on long-term REC contracts in New England is from the Massachusetts Green Power Partnership, which extended long-term REC contracts to several renewable projects in 2003 and 2004. At the time, long-term REC forecasts showed the prices to be in the $20 to $25 range, so these were the prices established in the long-term contracts, although the partnership acknowledged significant volatility and uncertainty in the REC market.[60] Recently, a long-term contract for RECs was approved in Delaware with the proposed offshore wind project where a REC multiplier of 350% was used.[61] The price to consumers will be $15.32 per REC, [62] but due to the

[58] Evolution Markets. "REC Markets-July 2008." Evomarkets.com. http://new.evomarkets.com/scripts/getmmu.php?mmu_id=351.
[59] Department of Energy Resources, Massachusetts. "Annual RPS Compliance Report for 2007." 24 Nov 2008. http://www.mass.gov/Eoeea/docs/doer/rps/rps-2007annual-rpt.pdf. 3.
[60] Cory, Karlynn S., Bolgen, Nils, Sheingold, Barry. "Long-term Revenue Support to Help Developers Secure Project Financing." Global Windpower 2004 Conference and Exhibition, March 28-31, 2004. 9.
[61] New Energy Opportunities 2, 3.
[62] New Energy Opportunities 2, 3.

multiplier, the project owner will essentially receive $53.62 per REC for those bought by the utility in the agreement, and then can sell the remaining RECs on the market. A weaker REC market in the Mid-Atlantic could account for the low utility price per REC ($15.32) in the Delaware offshore wind project.

In this study, the long-term REC price is informed by New England data indicating prices in $20 to $30 dollar range with the only existing contracts in the $20 to $25 range. Therefore, the REC price projection for the Rhode Island offshore wind project is $22.50. This is very close to the low case REC price in the RIWINDS 2007 report of $20, and well below the high case scenario of staying at the Alternative Compliance Payment level.

Figure 7: REC Price Update Since RIWINDS



3.3 Influence of Carbon Markets

Carbon markets will influence the future price of electricity, and therefore the economical long-term contract price for electricity for the RIWINDS project. Regional legislation is in effect (the Regional Greenhouse Gas Initiative, or RGGI) and national legislation has been proposed that requires power plants to purchase carbon allowances for every ton of carbon emitted. Allowances are originally auctioned by the government and then can be traded on secondary markets among firms that have too many or too few allowances to cover their carbon emissions. The allowances contribute to electricity prices because they are essentially an added cost for all fossil fuel generators, and therefore those generators must bid higher prices into the competitive market. Ultimately, this raises the clearing price, and will therefore increase the electricity revenue renewable energy generators receive, since they do not emit carbon.

The amount the carbon market will raise electricity prices depends on the market price of allowances and the amount of carbon emitted by price-setting generators. According to the New England ISO, which tracks generator's emissions, the most recent calculated marginal emission rate (2006) was 993 pounds of carbon per MWh.[63] Carbon allowances are measured in short tons, which are 2000 pounds, therefore marginal generators, those that set the electricity price, will have to purchase approximately one carbon allowance for every 2 MWh. This information along with carbon allowance price projections will inform the 'carbon adder' added onto future electricity prices in the Chapter 5 analysis. This 'carbon adder' is additive to current electricity projections because the RGGI did not begin until 2009, and the electricity projections in this thesis are based on natural gas forecasts and do not take into account the emerging carbon market.

3.3.1 Carbon Adder Analysis

As described in Chapter 2, the emerging carbon market will have an effect on electricity prices and therefore the revenue earned by the proposed offshore wind farm. The amount added to the projected electricity price equals (\$/ton CO_2) * (993 lbs CO_2/MWh of marginal generation[64]) / (2000 lbs/ton). Price influences and auction results are described below, and carbon price projections have been adapted from a recent PJM ISO study, *Potential Effects of Proposed Climate Change Policies on PJM's Energy Market*, released January 2009.

Currently, the only carbon market affecting renewable generators in New England is RGGI, however, if a national carbon cap and trade regime is established, as is increasingly expected, New England generators will be affected by the national carbon allowance prices. Therefore, RGGI and national carbon price projections are relevant for the proposed Rhode Island offshore wind farm. In addition, the RGGI prices are significantly influenced by industry perception of the likelihood of the RGGI allowances being accepted for compliance in a future national cap and trade system.[65]

[63] "2006 New England Marginal Emission Rate Analysis," ISO New England, Sept 2008.
[64] "2006 New England Marginal Emission Rate Analysis," ISO New England, Sept 2008.
[65] Point Carbon. *Carbon Market North America.* Vol 4, Issue 9. 6 Mar 2009. http://www.pointcarbon.com/news/cmna/. 2.

The main factors that influence the price per carbon allowance are supply, demand, the industry perception of this balance, and legislative price control mechanisms. The supply of carbon allowances is limited by the emissions cap in the cap and trade legislation, and the demand is determined by regulated entities' emissions. Carbon allowance supply can be flexible if offsets, which are documented emission reductions that firms can buy in lieu of allowances, are allowed for compliance. Carbon allowances are issued by the government whereas carbon offsets are emission reductions that can be created and sold by participants in non-regulated but carbon emitting sectors, such as agriculture or heating. The extent to which national and international offsets will be counted towards US targets will have a significant effect on national allowance prices since that will affect the supply of carbon reduction strategies for firms. Finally, legislative price control mechanisms will affect the allowance prices, such as price floors and ceilings, banking and borrowing, or reserve allowances released when the market allowance price passes an established threshold.

RGGI legislation includes several price mechanisms and defines the role of offsets. In RGGI, there is a price floor for the allowances set at \$1.82/ton CO_2, and price alleviation mechanisms at \$7 and \$10/ton, which allow increased levels of carbon offsets to meet carbon reduction goals. Carbon offsets could alleviate carbon allowance supply shortages up to the amount they are permitted by legislation, which under RGGI is 3.3% when the allowance price is at or below \$7, 5% between \$7 and \$10, and 10% over \$10/ton. There is no price ceiling for RGGI.[66]

Forward market trades indicated a positive expectation that RGGI allowances would be grandfathered in to a national cap and trade regime. Allowances traded between \$7.00 and \$8.50 before the first RGGI auction in September 2008.[67] The prices likely reflect a hopeful attitude with respect to the Lieberman-Warner bill proposed in 2008 that specifically allowed grandfathering of RGGI permits into the national carbon regime. Belief that a carbon market regime with RGGI allowance grandfathering would be established in the next few years could affect the RGGI price as follows: If any domestic firm believes a national carbon regime is 80% likely to pass in the next few years, and expects the price per ton of carbon to be \$10 or more, purchasing RGGI allowances for any price under 0.8 * \$10 is a wise investment.

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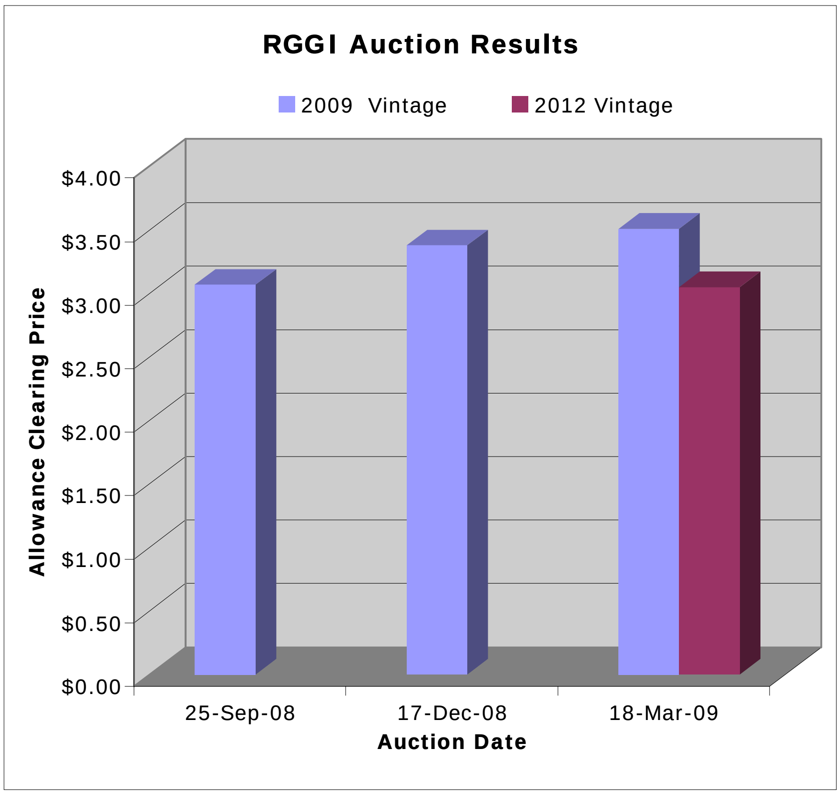
[66] DeLucia, Libby. "RGGI Workshop: NECA June 19th, 2008 Conference Summary." 28 July 2008. Framingham, MA. 6.
[67] DeLucia, "RGGI Workshop…" 9.

The actual auction clearing prices in the three auctions to date have been between $3.07 and $3.51/ton CO_2.[68] This is well below the forward market trades and well above the RGGI price floor. The price is likely above the price floor despite a clear over-allocation of permits[69] due to continued speculation that RGGI allowances will be grandfathered. Voluntary interest in allowances could have also boosted demand, but auction results have showed individual and environmental group participation to be negligible compared to that of power companies and financial firms.[70]

Figure 8: RGGI Auction Results



Two recent studies were researched for carbon allowance price forecasts. These were a PJM study (2009): *Potential Effects of Proposed Climate Change Policies on PJM's Energy Market*, and a Synapse report (2008): *CO_2 Price Forecasts*. The PJM study reviews three major carbon regime bills of the 110th Congress (2008), the Lieberman/McCain Bill (S.280), the Bingaman/Specter Bill (S.1766)

[68] Regional Greenhouse Gas Initiative, Inc. " States Release Results of Third Auction…" 1.
[69] Point Carbon. *Carbon Market North America.* Vol 4, Issue 10. 13 Mar 2009. http://www.pointcarbon.com/news/cmna/. 2.
[70] Regional Greenhouse Gas Initiative, Inc. " States Release Results of Third Auction for RGGI CO2 Allowances." www.rggi.org. 9.

and the Lieberman/Warner Bill (S.2191).[71] The study used in-house, EPA and EIA analyses to project the impact of these bills on wholesale electricity prices in the PJM region, which is primarily the Mid-Atlantic. It includes sensitivity analyses for offset allowances, other price mechanisms, natural gas prices, and renewable energy, nuclear and clean coal availability.[72] The price projections for carbon allowances in 2013 are given in the table below. It is likely that the projected PJM wholesale price impacts are slightly higher than they would be for New England because PJM relies more heavily on coal. The un-weighted average of the PJM projections is $28.75/short ton CO_2 in 2013.

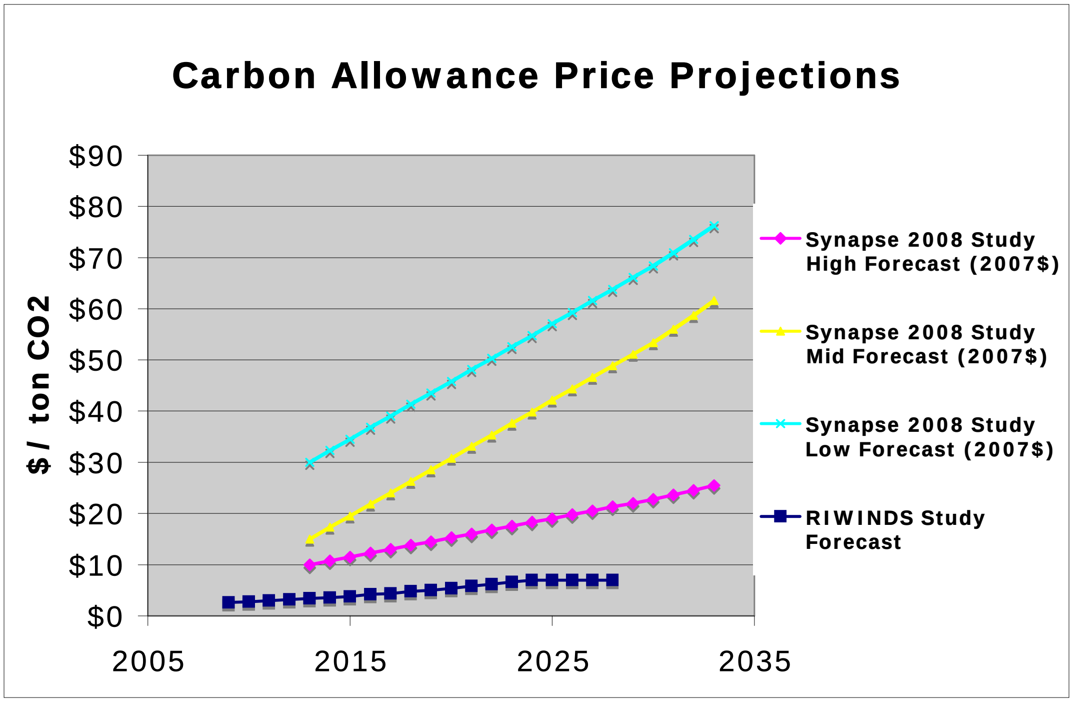
Table 3: Legislative Analyses and Corresponding PJM 2013 Scenarios

Legislation and Analysis Assumptions	Closest Corresponding PJM 2013 Scenario
Lieberman/McCain, core assumptions	$10/short ton CO_2, Base gas
Lieberman/McCain, no offsets available	$40/short ton CO_2, Base gas
Bingaman/Specter core assumptions	$10/short ton CO_2, Base gas
Bingaman/Specter, no Technology Accelerator Payment (safety valve price)	$25/short ton CO_2, Base gas
Lieberman/Warner, core assumptions	$20/short ton CO_2, Base gas
Lieberman/Warner, limited availability or high cost new nuclear, renewable and CCS	$25/short ton CO_2, Base gas
Lieberman/Warner, no international offsets, domestic offset allowed	$40/short ton CO_2, High gas
Lieberman/Warner, no offsets of any type	$60/short ton CO_2, High gas

The Synapse *CO_2 Price Forecasts* determines a low, mid and high CO_2 allowance price from 2013 to 2030. These are shown in the graph below compared to the RIWINDS CO_2 allowance price projections. The price projections were based on a political overview of legislation proposed in the 110th Congress, publicly available models of proposed national carbon market legislation, and CO_2 prices used by utilities and utility regulatory commissions for planning purposes.[73] Because the Synapse report includes price predictions through 2030 rather than only for 2013 as the PJM study, the mid-range Synapse CO_2 allowance price forecast is used for the purposes of this thesis. To extrapolate the forecast through the assumed life of the RIWINDS offshore wind project, I have used an average of the growth rate in prices from the last five years of the mid forecast (2026-2030).

[71] PJM. *Potential Effects of Proposed Climate Change Policies on PJM's Energy Market.* 23 Jan 2009. www.pjm.com/Media/documents/reports/20090127-carbon-emissions-whitepaper.pdf. 1.
[72] PJM 22.
[73] Synapse Energy Economics, Inc. "Synapse 2008 CO_2 Price Forecasts." July 2008. http://www.synapse-energy.com/Downloads/SynapsePaper.2008-07.0.2008-Carbon-Paper.A0020.pdf 4.

Figure 9: CO_2 Allowance Price Projections[74]



3.4 Capacity

Capacity payments are the last direct revenue stream applicable to the RIWINDS project. The ISO has to ensure that enough generators are available to maintain a certain degree of system reliability, so they have developed a capacity market to incentivize sufficient generator availability in the future, called the Forward Capacity Market (FCM).[75] FCM auctions are held for existing or planned generators who commit capacity availability in the future in exchange for compensation that is intended to cover the fixed costs of a generator's existence, whereas wholesale prices are intended to cover the variable costs of generation.[76] This is not ideally structured for wind projects since they cannot control the exact time of generation, and therefore cannot commit capacity availability in the same way as fuel-based generators. Therefore, intermittent generator's capacity is derated, or lowered in value since it cannot produce energy on demand. In addition, wind farms have almost entirely fixed costs since their 'fuel' is free.

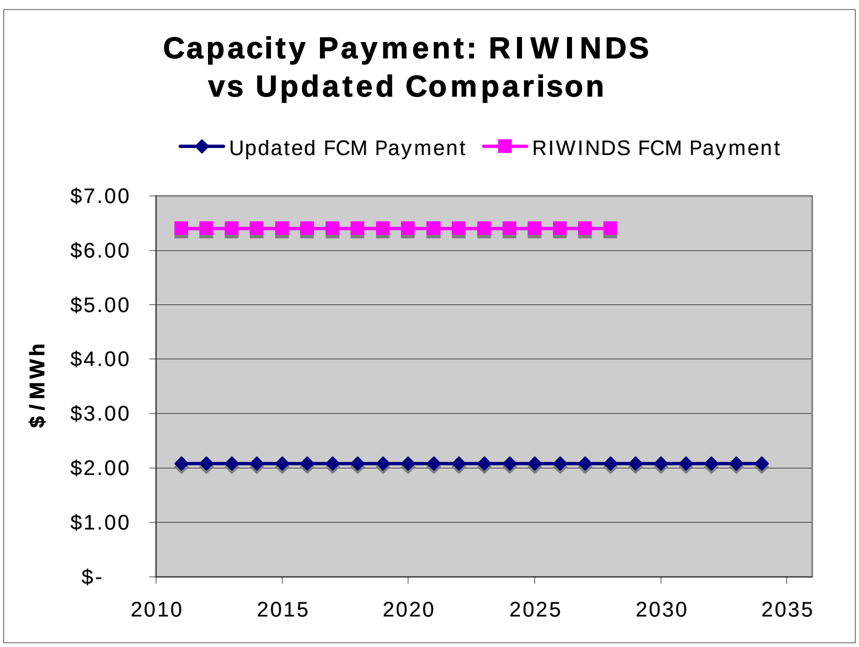
[74] Synapse Energy Economics 16.
[75] ISO New England. "Capacity Markets." 4 Mar. 2009, http://www.iso-ne.com/nwsiss/grid_mkts/how_mkts_wrk/cap_mkt/index.html.
[76] ISO New England. "Capacity Markets."

Capacity payments will be incorporated into the final analysis, although they are relatively insignificant to the needed revenue stream due to intermittent generator derating.

3.4.1 Capacity Payments

The forward capacity market will pay a small amount to qualifying wind generators. The most recent clearing price was $3.60/kW*month for the 2011-2012 capacity auction.[77] (Capacity auctions are held three years before the relevant payment period.) Assuming that wind generators typically receive payment for 15% of their nameplate capacity due to intermittency and reliability requirement, this amounts to $2.4 million per year for the proposed offshore wind project. This would amount to $1.85/MWh in 2011 if the project had participated and cleared the 2011-2012 capacity auction which was held in 2008. The RIWINDS study projected the forward capacity clearing price would be $7/kW*month, and the previous and only other clearing price (2010-2011) was $4.50/kW*month. Without further information it is difficult to predict what the long-term trend will be for this market. Therefore, I have taken the average of the two auctions to date and added inflation at 1% for the relevant time period. The RIWINDS capacity payments are compared to those used in this report in the figure below.

Figure 10: Capacity Payment: RIWINDS vs Updated Projection



[77] ISO New England. "Forward Capacity Market Auction (FCA_2011_2012) Result Report." 16 Dec 2008. 2.

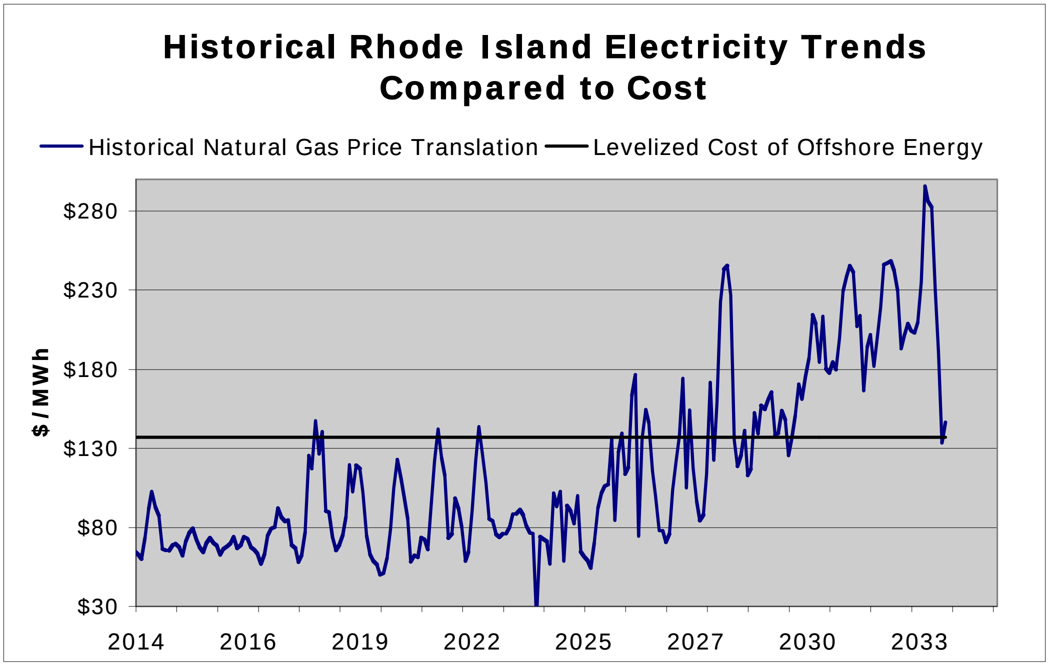
3.5 Hedge Value

As mentioned, a significant source of uncertainty over the market value of the wind energy stems from fossil fuel market volatility. Figure 11 shows actual natural gas prices from 1989 to 2009 that have been transposed to electricity prices for the lifetime of the proposed offshore wind project to give a sense of potential volatility in natural gas futures and therefore electricity price forecasts.[*] In this figure, the electricity price spikes above the cost of the offshore wind energy six times in the first twelve years of the project's operation before staying well above the offshore wind cost for the majority of the last eight years of the project. Another point of comparison was the significant rise in Standard Offer Service rates in Rhode Island between 1997 and 2008. In this time, not accounting for inflation, they more than quadrupled, from $0.028/kWh in 1997 to $0.124/kWh in 2008.

For many firms, certainty in electricity prices is very valuable, lowering exposure to markets that could drive market electricity prices twice as high as the known cost of the wind energy. Periods of exorbitant energy costs could be very damaging to firms, particularly those where energy costs are a particularly large fraction of their expenses. Although it is beyond the scope of this research to quantify the value of certainty to different energy purchasers, the concept is demonstrated by Figure 11 and merits further study as the economic feasibility of the offshore wind project is determined.

[*] To transpose the historical natural gas prices to future electricity prices, I found the ratio of the natural gas future for January 2014 to the historical price for January 1989, 1.956. I multiplied all of the historic natural gas prices by this ratio and then used the same formula used to predict electricity futures from natural gas futures to convert the extrapolated historic natural gas prices to future electricity prices.

Figure 11: Value of Hedge: Historical Natural Gas Trends Extrapolated to Future Electricity



3.6 Summary

This chapter summarizes the revenue streams of the RIWINDS project. In Chapter 6 these are taken in context with the costs and values of the externalities to shed light on the project's financial feasibility. The revenue streams are described generally, to give an understanding of the different markets, legislation and uncertainty that will influence the revenue of the potential project. The quantified estimates for each of the four revenue streams will all be affected by many future uncertainties, giving a range of likely values for the cumulative revenue streams for the project, similar to that given for CO_2 allowance values from the Synapse report. Although this thesis does not predict high and low ranges for all four revenue streams, the volatility shown in Section 3.5 also speaks to this, and it is an important factor to keep in consideration.

4 **Emissions Impact**

The proposed RIWINDS project would have positive air quality impacts on Rhode Island and the region by helping to reduce emissions from electric generation. This chapter discusses the avoided emissions of several pollutants, methods for determining the quantity of avoided emissions, and an avoided emissions calculation for the RIWINDS project based on those methods. Subsequently, there is a discussion of the impacts of the avoided emissions, with a focus on global warming and health impacts, and methods for economically quantifying health impacts.

Electricity generation from the RIWINDS project would create no emissions after manufacturing and transportation to the project site, excluding negligible amounts from transportation to and from the wind turbines for maintenance. When the wind farm generates electricity, it would reduce the need for other electric plants to operate, displacing their emissions if the plants are powered by fossil fuels. Fossil fuel generators emit many pollutants in varying concentrations depending on the fuel and combustion technology. These pollutants include carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO), and others, with each pollutant impacting biologic systems.

Carbon dioxide is the primary anthropogenic greenhouse gas responsible for global warming, along with nitrous oxide (N_2O) and methane, a volatile organic compound, whose effects are less significant than carbon dioxide's due to lower concentrations in the atmosphere.[78] Particulate matter causes respiratory problems including asthma and chronic bronchitis, and can lead to premature death[79]. Volatile organic compounds include known carcinogens, greenhouse gases, and are precursors to ozone formation in the lower atmosphere, where it causes adverse health effects and damages crops. Sulfur dioxide and nitrogen oxides contribute to acid rain and respiratory ailments through fine particle formation (sulfates and nitrates).[80] Finally, carbon monoxide at low and moderate levels, as is applicable for power plant emissions, inhibits oxygen uptake by the blood, causing headaches, dizziness, and other symptoms as severe as impaired vision and brain function.[81]

[78] "Climate Change 2007: Summary for Policy Makers." Intergovernmental Panel on Climate Change, Nov 2007. http://www.ipcc.ch/ipccreports/ar4-syr.htm, 5.
[79] Levy et al 2000
[80] "Acid Rain Program 2007 Progress Report." U.S. Environmental Protection Agency. January 2009. http://www.epa.gov/airmarkets/progress/docs/2007-ARP-Report.pdf, 3.
[81] "Carbon Monoxide." US Environmental Protection Agency, http://www.epa.gov/iaq/co.html#Health%20Effects%20Associated%20with%20Carbon%20Monoxide.

4.1 Avoided Emissions & Marginal Emission Rates

Determining which electric generation would be displaced by the RIWINDS project is a key aspect to forecasting the emission effects of the offshore wind farm. This is determined by the structure and generation mix of the Rhode Island and New England electricity market.

Emitting electricity generators in the New England market are considered either baseload or marginal resources depending on their characteristics.[82] Baseload generators tend to have the lowest variable costs—i.e. use the cheapest fuel—and are not meant to ramp up or down to follow load. The emitting baseload generators in New England are coal plants,[83] which account for 9% of regional capacity.[84] Nuclear, hydroelectric and some landfill gas plants are also baseload generators, however they are non-emitting. Marginal generators are the lowest cost resources for providing variable output, and they are mainly natural gas and oil generators. Although their variable costs (fuel costs) are higher per MWh than those of baseload generators, they are effective at load following, meaning they can efficiently alter their production to meet changing demand. In New England, natural gas and oil generators make up 53% of regional capacity.[85]

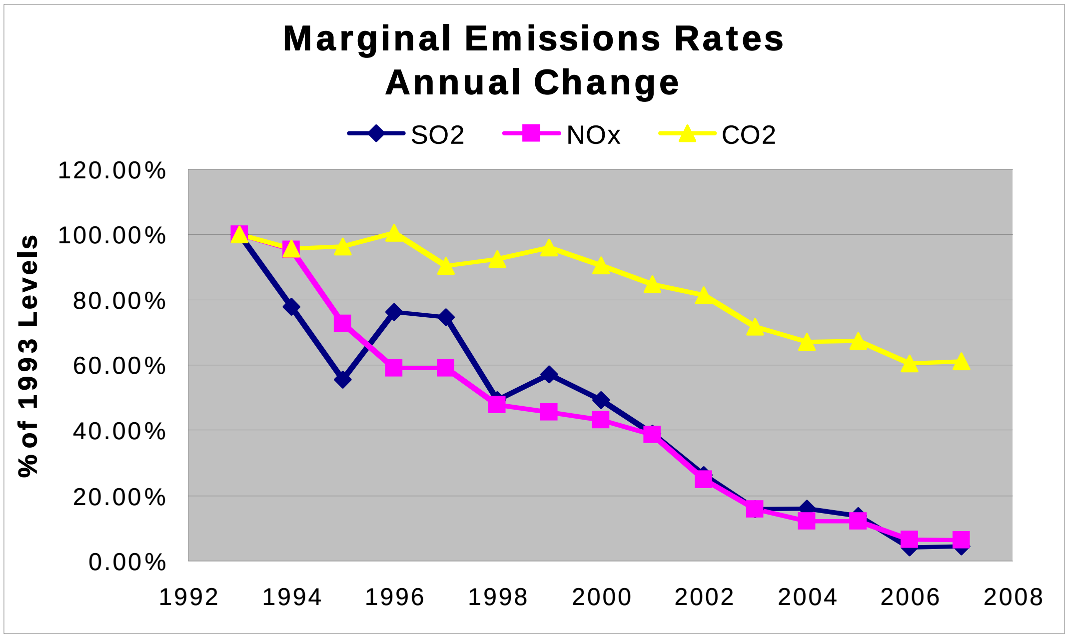
Wind, along with other renewable resources, is an intermittent generator because wind speeds cannot be controlled or precisely predicted. Marginal generators alter their production, thereby effecting their emissions, to compensate for intermittent renewable resources. Therefore, marginal generator's emissions would be avoided when the RIWINDS project generated electricity. To calculate the displaced emissions from the potential project, I have adapted methods used in environmental impact statements for Cape Wind. In these studies, emission rates from marginal generators are used to forecast the avoided emissions due to the offshore wind project.

Marginal emission rates, given in tons of pollutants per MWh, are published in annual reports by ISO New England. Marginal Emission Rate Analyses focus on three pollutants, CO_2, SO_2 and NO_x, and they are used to calculate the emission impacts of renewable generators and utility energy efficiency programs, known as demand side management programs.[86] The ISO collects generator emissions data from all of the marginal generators in New England to determine the average marginal

[82] Saarela, Hevle, "2005 Marginal Emissions Analysis," ISO New England. June 5 2007. http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/mtrls/2007/jun52007/2005_marginal_emissions_analysis.pdf, 9.
[83] Saarela "2005 Marginal Emissions Analysis" 9.
[84] George, Ann. "ISO New England Renewable Initiatives." Northeast Energy & Commerce Association, Mar 5 2009. http://www.necanews.org/dev/index.php?go=documents, 4.
[85] George, Anne. "ISO New England Renewable Initiatives." 4.
[86] Saarela, Hevle, "2005 Marginal Emissions Analysis," 3-4.

emission rates for that year. The reports average emissions for each state's instate generators, including averages from on and off-peak hours, and for ozone and non-ozone months for NO_x, which contribute to ozone formation.

Figure 12: Marginal Emission Rates' Annual Change



Marginal emission rates changed greatly from the beginning of the analyses through 2006.[87] Rapid significant changes in the marginal emissions rates, such as the 70% decrease in sulfur dioxide emission rates from 2005 to 2006,[88] impact the accuracy of projected emissions impacts of renewables. Therefore, estimations of the avoided emissions for the life of the Cape Wind project using 2000 marginal emission rates are inaccurate in light of current data, as would be an analysis of the RIWINDS Wind project unless an emission rate trend can be established and projected into the future. However, these rate changes can be largely attributed to specific legislation and a recent significant shift in the New England generation mix. Based on this analysis, marginal emissions rates are not expected to continue to change as dramatically in the future although some initiatives will continue to catalyze cleaner electricity generation on the whole, such as by encouraging renewable development and strengthening controls on coal plant generation.

[87] Saarela, Helve. "2007 Marginal Emissions Analysis," ISO New England. Jan 22 2009. http://www.iso-ne.com/committees/comm_wkgrps/relblty_comm/pwrsuppln_comm/mtrls/2009/jan22200, 8.
[88] Saarela, Helve. "2007 Marginal Emissions Analysis," 8.

Under the Clean Air Act of 1990, the EPA implemented the Acid Rain Program, which set strict caps on SO_2 and NO_x emissions and began in 1995.[89] These regulations mainly impacted coal generators, since coal is the most polluting fossil fuel. However, it also had an impact on the marginal generator's mix of oil and natural gas plants because oil emits significantly more than natural gas when combusted.[90] Additional EPA programs have been laid out in the past few years, including the Clean Air Interstate Rule and the NO_x Budget Trading Program, that extend the coverage of the Clean Air Act, and hence add to the pressure to use more natural gas on the margin rather than more heavily SO_2 and NO_x emitting oil.[91]

Combined cycle technology developments for natural gas plants contributed greatly to the significant shift towards natural gas for marginal generators. Combined cycle natural gas plants are much more efficient than older technologies for natural gas plants.[92] The technology allowed increased electricity production for lower cost and with lower pollutants at a time when it was clear that pollutants were going to cost generators money into the future. In the 1990's and 2000's, combined cycle plants were constructed in waves across the US, making up as much as 95% of the new generation in 2000, and natural gas is predicted to continue increasing over the next twenty years.[93] In New England, 91% of the added capacity between 1999 and 2006 was combined cycle natural gas plants.[94] Currently, 99% of the Rhode Island capacity and 37% of the New England capacity is from combined cycle natural gas.[95]

The effect of the recent boom in combined cycle natural gas development is that the marginal emissions rates are currently largely determined by natural gas emissions rates. Since the majority of the marginal generation currently comes from combined cycle natural gas plants, emissions rates should not drop as rapidly in the future. Going forward, the marginal emission rates will be primarily affected by relative changes in the prices of natural gas and oil since many natural gas generators can also be run with oil. Therefore, at times when oil is cheaper than natural gas in the future, marginal emission rates may increase as some plant operators chose to purchase oil. On the other hand, tightening emissions standards may discourage this fuel substitution.

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[89] "Acid Rain Program," 3.
[90] *Annual Energy Review 2005.* Energy Information Administration. 412. Dec. 12, 2006. <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec13_1.pdf>
[91] "Acid Rain Program," 2.
[92] "Electric Generation Using Natural Gas," NaturalGas.org. http://www.naturalgas.org/overview/uses_eletrical.asp
[93] "Electric Generation Using Natural Gas."
[94] "2006 New England Marginal Emission Rate Analysis," ISO New England, Sept 2008, 12.
[95] "2006 New England Marginal Emission Rate Analysis," 12.

Given this understanding of the overall electricity mix trends in New England, it is reasonable to expect that emissions rates will be more steady into the future than they were in the 1990's and early 2000s. This is supported by the minimal change in rates between 2006 and 2007 visible in Figure 3. Based on this evidence, I can have significantly more confidence in avoided emissions calculations based on 2007 marginal emission rates than I could have several years earlier, when natural gas plants were still coming on-line rapidly.

4.2 Avoided Emissions Calculations

This thesis uses the most recent marginal emission rate and the predicted output to forecast the avoided emissions from the RIWINDS project. As described, the project must meet or exceed 1.3 million MWh/yr of output according to the RFP.[96] The 2007 marginal emissions rates of SO_2, NO_x and CO_2 and the avoided emissions are given in the table below.

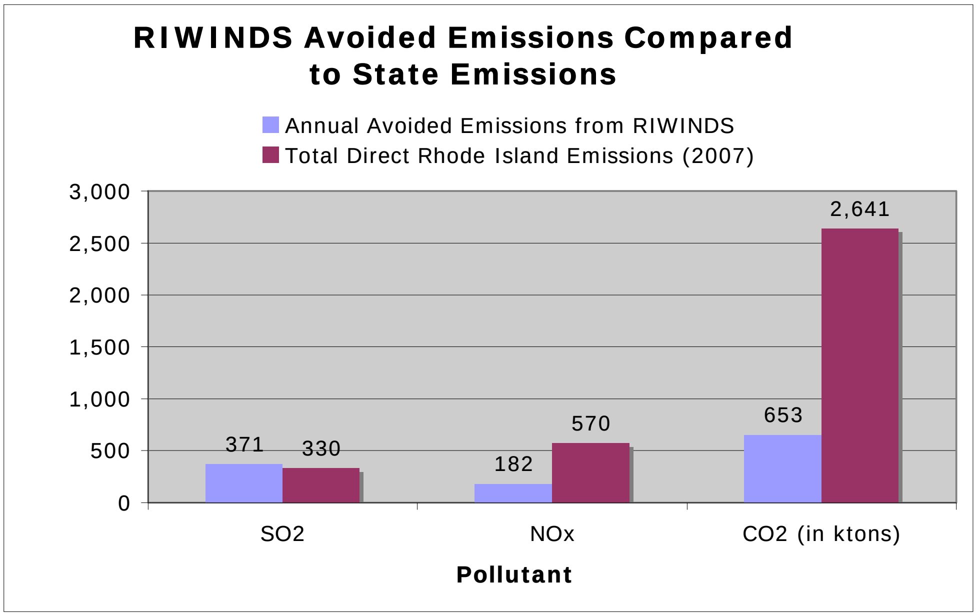
Table 4: RIWINDS Project Emissions Impact[97]

	Units	**SO_2**	**NO_x**	**CO_2**
2007 Marginal Emissions Rates	*lbs/MWh*	0.57	0.28	1004
Annual Avoided Emissions*	*lbs*	741,000	364,000	1,305,200,000
	tons	371	182	652,600
Lifespan Avoided Emissions	*tons*	7,410	3,640	13,052,000
% of Rhode Island Electric Emissions	*%*	112.3%	31.9%	24.7%
% of New England Electric Emissions	*%*	0.34%	0.52%	1.10%

**Annual Generation: 1,300,000 MWh; Lifespan: 20 yrs*

[96] RFP 4.
[97] Saarela, Helve. "2007 Marginal Emissions Analysis."

Figure 13: RIWINDS Avoided Emissions: Comparison to Total Rhode Island Emissions



4.3 Global Warming Impact

The avoided emissions of CO_2 represent an important step towards the goals detailed in the proposed Rhode Island Global Warming Solutions Act of 2008 and the Energy Independence and Climate Solutions Act of 2009, although the displaced emissions will not necessarily all be within Rhode Island. These acts, neither of which has passed, aim to meet the emission levels promoted by the scientific community to avoid catastrophic and irreparable damage, which are to achieve an 80% reduction in greenhouse gas emissions from 1990 levels by 2050.[98] The 2009 legislation specifies that indirect and direct emissions will be counted under the bill from all significantly contributing sectors.[99]

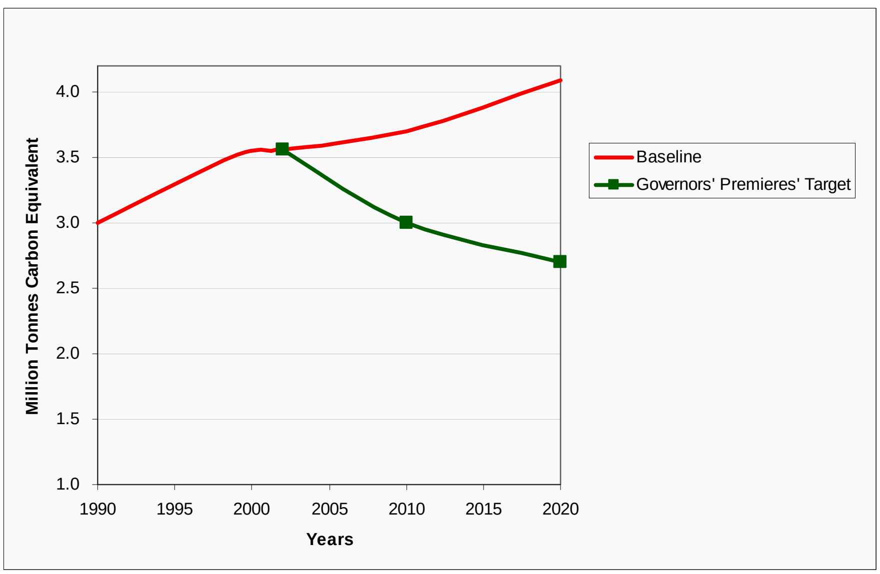
The avoided emissions can be used to estimate the impact of the RIWINDS project on the Climate Solutions Act goals. Electricity use in Rhode Island creates indirect and direct emissions since some of the electricity consumed in the state is produced within the state—5,967,725 MWh or 76.5% (2006 data),[100] and the remaining 23.5% is imported. The direct electricity emissions come primarily from natural gas, with other direct emission in Rhode Island coming from natural gas and petroleum

[98] "Rhode Island Energy Independence and Climate Solutions Act," State of Rhode Island General Assembly, H5706, 26 Feb 2009, 5.
[99] "Rhode Island Energy Independence and Climate Solutions Act," 4.
[100] EIA. "Rhode Island Electricity Profile." 13 Mar 2009. http://www.eia.doe.gov/cneaf/electricity/st_profiles/rhode_island.html

for heating, and petroleum for transportation. In total, Rhode Island's direct CO_2 emissions were 1,100,000 tons of in the most recent year studied, 2005.[101] Unfortunately, an inventory of the state's direct *and* indirect emissions is not currently available, which is necessary to track progress towards the Climate Solutions Act goals. Therefore, the following estimate of what percentage of the state's CO_2 emissions the RIWINDS project would displace is too high since indirect emissions are not taken into account.

In 2005, 25% of the state's direct CO_2 emissions came from electricity.[102*] Using the calculation in the previous section, the RIWINDS project would reduce annual electricity CO_2 emissions by approximately 25%, which would be about 6.2% of Rhode Island's overall direct CO_2 emissions, assuming the total emissions from Rhode Island and the marginal emission rates stay in a similar proportions. Compared to the Climate Solution's Act baseline, 1990 emissions, the reduction is slightly more significant, at 7.5%, however this should be understood from this perspective that 2005 emissions levels are 128% of 1990 levels.[103]

Figure 14: Baseline Emissions Compared to Greenhouse Gas Action Plan Target



[101] "State Energy Profiles: Rhode Island." Energy Information Administration, 5 Mar 2009, http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=RI.
[102] Energy Information Administration, "Table 1: 2005 State Emissions By Fuel," http://www.eia.doe.gov/environment.html.
[*] This was calculated using the total RI greenhouse gas emissions found in the EIA Table for 2005, and Rhode Island's electricity CO2 emissions given in the 2005 Marginal Emission Analysis for 2005 (available: http://www.iso-ne.com/genrtion_resrcs/reports/emission/2005_mea_report.pdf, p 23)
[103] Energy Information Administration, "Table 3: State Emissions By Year," http://www.eia.doe.gov/environment.html.

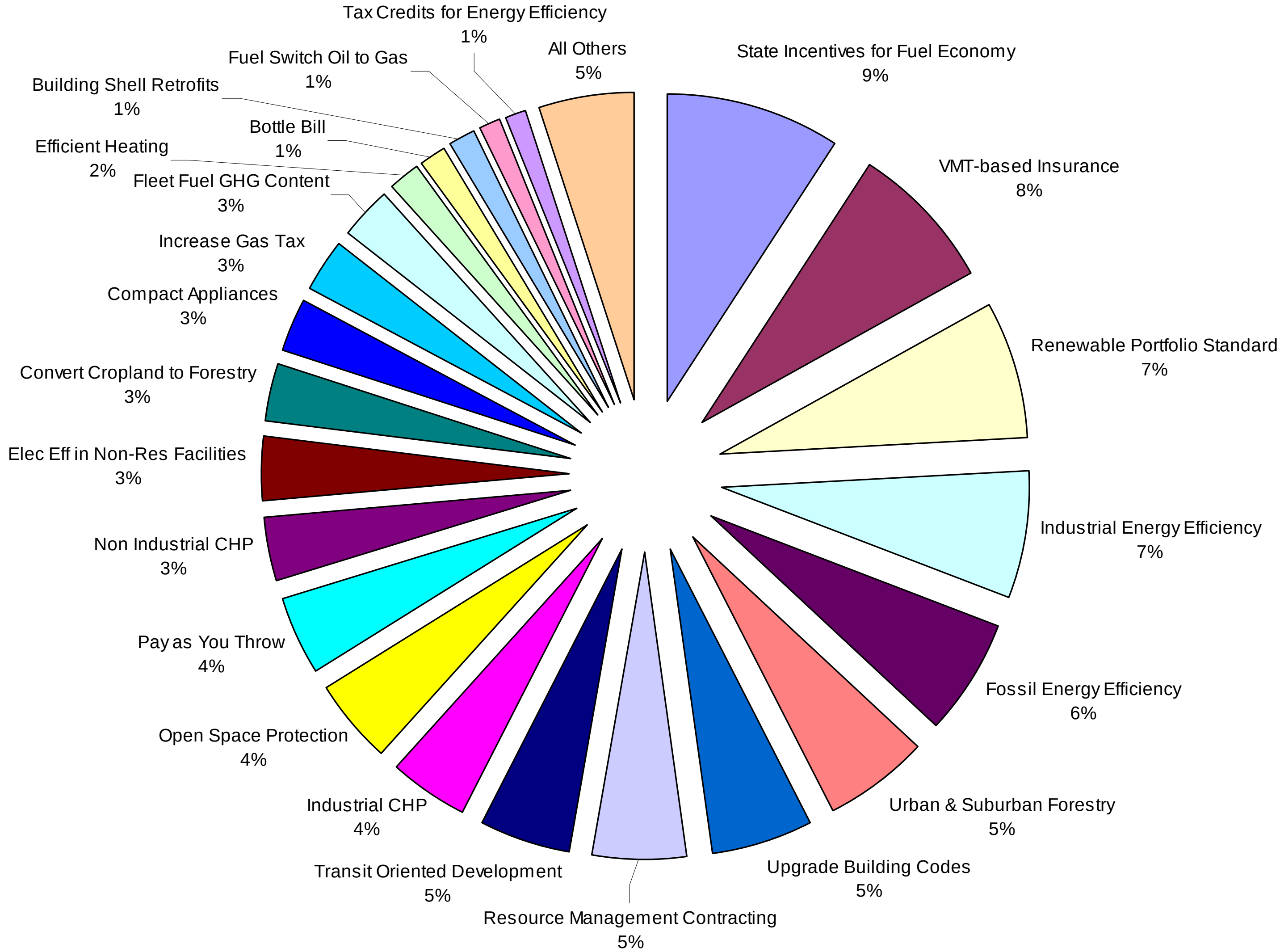
4.3.1 Discussion

It is generally understood that there is no ‘silver bullet’ for climate change mitigation, and that many strategies must be aggressively employed to achieve the scientifically promoted greenhouse gas levels. In 2002, the Rhode Island Greenhouse Gas Stakeholder Process released its Action Plan to meet emissions goals of 1990 levels by 2010, 10% below those by 2020, and ultimately 75% below 1990 levels.[104] The plan includes 52 in-state policies and programs that should be implemented to meet these targets, spanning buildings and facilities, transportation, land use, energy supply and solid waste. In total, these strategies were predicted to have a cumulative economic benefit to the state of $700 million.[105]

Each program and policy is listed with a target greenhouse gas emission savings expressed in tons of carbon equivalents, and the program with the largest predicted impact is the Renewable Energy Standard. As described in Chapter 3, the Renewable Energy Standard created the primary demand that drives the current REC market, and its main purpose is to promote renewable energy development, similar to the RIWINDS program. Specifically, the RPS is estimated to save 140,000 metric tons of carbon equivalents (MTCE) annually by 2020.[106] The avoided emissions for the offshore wind project calculated in the last section, 652,600 tons per year, are given in carbon dioxide, and when converted to tons of carbon equivalents[*] equal 177,982 tons per year.

[104] Rhode Island Greenhouse Gas Stakeholder Process. “Rhode Island Greenhouse Gas Action Plan.” Raab Associates, Tellus Institute. 15 July 2002. 3.
[105] Rhode Island Greenhouse Gas Stakeholder Process 7.
[106] Rhode Island Greenhouse Gas Stakeholder Process 5.
[*] The atomic weight of carbon is 12 and that of oxygen is 16, making the molecular weight of CO2 44. To convert tons of CO2 to tons of carbon, multiply by (12/44).

Figure 15: Rhode Island Greenhouse Gas Action Plan Strategies [107]

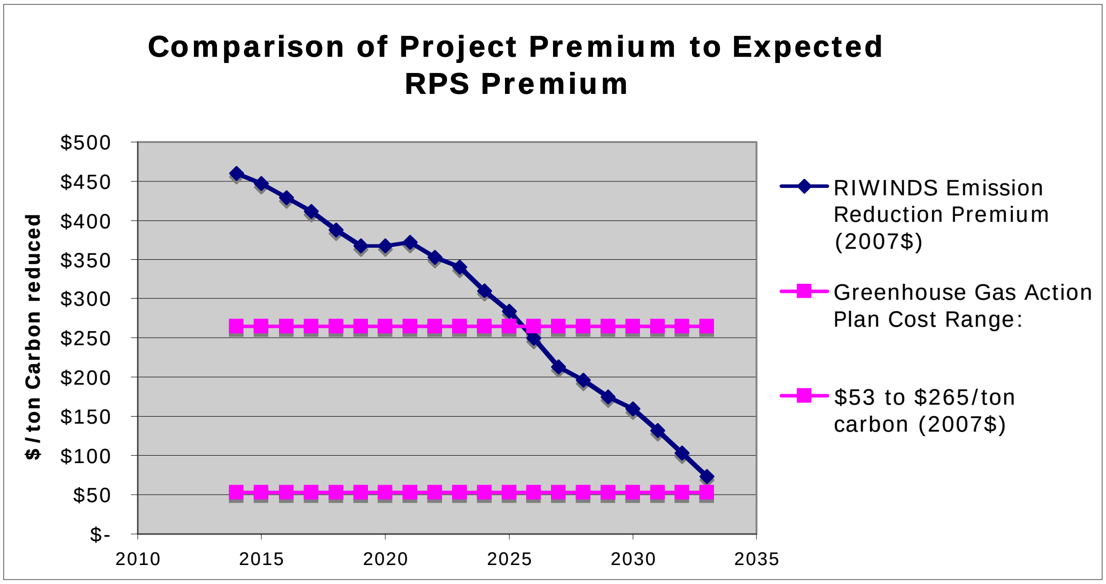


Therefore, the RIWINDS offshore project would exceed the target of greenhouse gas reductions from renewable energy. As mentioned, this would represent the renewable energy part of a multi-pronged strategy expected to be a net economic gain to the state, mainly in the form of avoided energy costs and pollutants.[108] The RPS portion however, was expected to cost between

107 Rhode Island Greenhouse Gas Stakeholder Process 37.
108 Rhode Island Greenhouse Gas Stakeholder Process 7.

$52.90 and $264.50 per ton of carbon reduced,* but the premium for carbon reductions** from the offshore wind project would be above that range for the majority of the project, as is shown in the graph below.[109]

Figure 16: Carbon Reduction Premium Compared to RI GHG Action Plan Range



4.4 Health Impacts

The avoided emissions also represent savings in health costs, with SO_2 and NO_x in particular having significant health impacts. SO_2 and NO_x react in the atmosphere to form sulfates (SO_4) and nitrates (NO_3 and HNO_3), which are known as secondary particulates.[110] In a study by the Harvard School of Public Health (Levy et al 2000) on the health impacts of coal power plants in Massachusetts* that considered SO_2, NO_x and particulate matter emissions, the secondary particles from sulfates and nitrates were responsible for 77% to 81% of the premature deaths associated with the emissions

* The Action Plan gave a range of $46 to $230. Presumably this was in 2002$, so I have taken inflation into account to translate the values into 2007$ because all monetary values in the analyses in this thesis are in 2007$. (Inflation 2002 to 2007=1.15. Source: http://data.bls.gov/cgi-bin/cpicalc.pl, Accessed May 8 2009.

** "Premium" indicates the amount of extra cost over what the project would be reimbursed from other revenue and value streams. In this case, it means the total cost of the energy minus revenue streams (electricity and capacity) and the health savings per MWh. RECs are not included in the revenue for this analysis since they are meant to represent the environmental attributes of renewable energy and including them would be redundant.

[109] Rhode Island Greenhouse Gas Stakeholder Process 31.

[110] Levy, Jonathan; Spengler, John. "Estimated Public Health Impacts of Criteria Pollutant Air Emissions from the Salem and Brayton Point Power Plants." May 2000. Harvard School of Public Health. 15.

* Brayton Point, 25 miles south of Boston, and Salem Harbor, 15 miles north of Boston.

studied.[111] Of the secondary particle deaths, 80% to 85% were from sulfates with the remainder from nitrates.[112] Out of all the public health effects taken into account in the study, which ranged from respiratory symptoms to premature death, their economic valuation method showed that 93% of the impacts by cost were from premature deaths, with another 4% from chronic bronchitis.[113]

An analysis based on an earlier study by the same public health scientists shows the value of the RIWINDS avoided emissions would be $3.7 million per year, or $2.85 per MWh. This scenario is drawn from an estimate by Levy et al that a sample natural gas and distillate oil cogenerator in Boston causes 0.9 premature deaths per year using long-term mortality studies.[114] This sample plant emitted 333 tons of SO_2 in the year data was collected for the analysis,[115] which is equivalent to 90% of the projected avoided SO_2 emissions due to the RIWINDS project. Since estimates conclude that the primary health savings come from avoided sulfates as described from the Levy (2000) study, the approximate public health value of the RIWINDS plant could be represented by the avoidance of 1.11 x 0.9 = 1 premature death per year. Using the EPA value for a life as $3.7million, this represents a levelized savings of $2.85/MWh.

Further, the health estimates used in the Army Corps of Engineers Draft Environmental Statement for Cape Wind based on Levy (2000) and (2002) studies projected that the Cape Wind project would save $53.1 million per year in avoided health costs, primarily from an estimated 12 avoided premature deaths per year from all avoided emissions at the revised EPA statistical life value of $3.7 million.[116] In a letter to the Delaware Public Utilities Commission, Dr. Levy and Willett Kempton, a Professor at the University of Delaware frequently published for offshore wind articles, describe how this analysis can be applied to the proposed Delaware offshore wind project. They suggest two relevant multipliers, one for the relative capacity of the projects, and one for the regulatory caps on SO_2 emissions, and assume that the Delaware project will offset nearby fossil fuel generators as they did in the Cape Wind analysis. In Delaware, Levy and Kempton assume that a nearby coal plant's generation will be displaced, similar to the Cape Wind analysis where Levy assumed two

[111] Levy, Jonathan; Spengler, John. 2000 22.
[112] Levy, Jonathan; Spengler, John. 2000 22.
[113] Levy, Jonathan; Spengler, John. 2000 24.
[114] Levy, Jonathan; Spengler, John. 2000 10.
[115] "Development of a New Damage Function…" 4366.
[116] Army Corps of Engineers. "Draft Environmental Impact Statement/Environmental Impact Report." 2004. Tables 5.16-6- Estimated Health Effect Offsets from Proposed Wind Park Extrapolated from Levy et al (2000) and Levy and Spengler (2002).

nearby coal plant's generation would be displaced, that of Brayton Point and Salem Harbor generators.[117]

These same assumptions and multipliers can be applied to the Rhode Island RIWINDS project. At 454 MW, the Cape Wind project is 24% larger than the RIWINDS project (367MW), or the RIWINDS project has 0.808 of the capacity of Cape Wind. SO_2 is regulated in New England by the Clean Air Act, and in 2007, the region met and exceeded the Acid Rain Program's long-term emissions cap of 8.95 million tons, emitting 8.9 million tons. Since the regional cap has already been met, SO_2 emissions presumably will not continue to drop due to the legislation, therefore the reductions of SO_2 do not need to be discounted. This means that each emission reduction represents an incremental health benefit, although not a commodity that is valuable due to Acid Rain legislation.

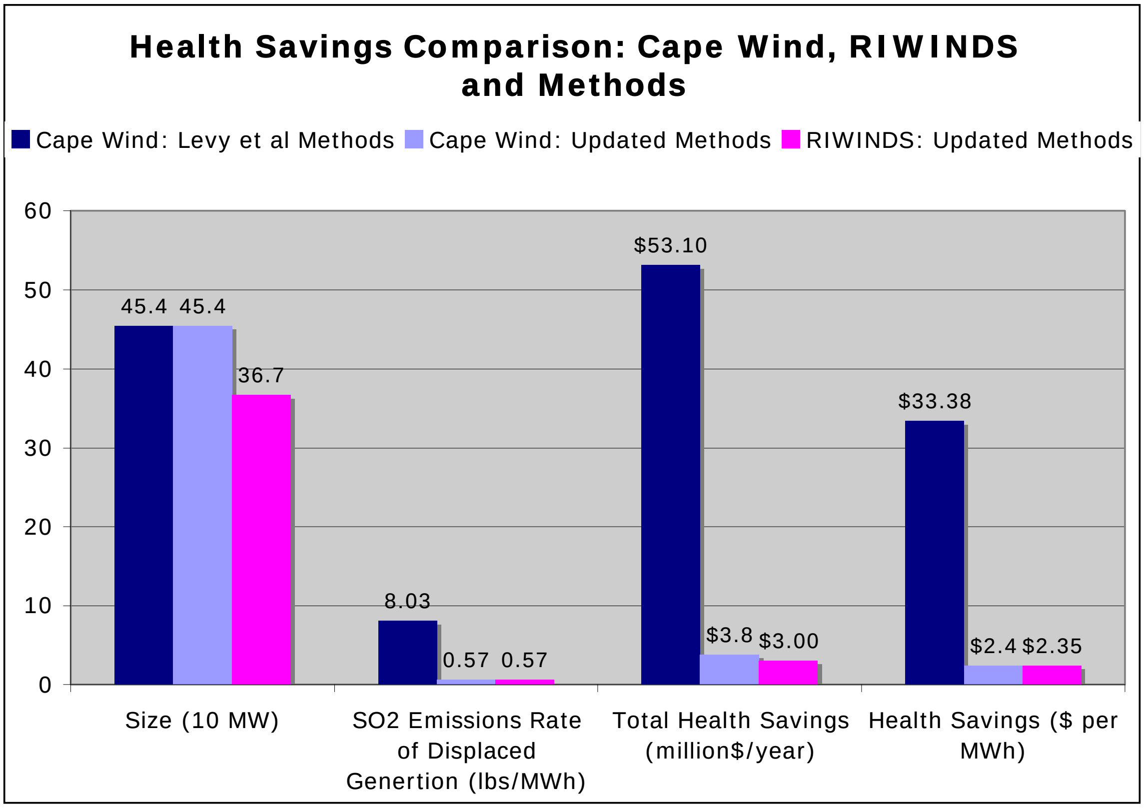
Finally, the RIWINDS project is expected to displace marginal generation rather than generation from coal plants, because of the intermittency of the project. Based on this assumption, which differs critically from that used in the Cape Wind analysis, offset SO_2 emissions per MWh are 0.57 lbs, rather than the approximately 8lbs per MWh emitted by Brayton Point and Salem Harbor in a 2004 study.[118] The multiplier for avoided SO_2 emissions is then 0.071, and final RIWINDS project multiplier is: (367MW/454MW) * (0.57lbs SO_2/MWh/ 8.03lbs SO_2/MWh) = 0.808 * 0.071 = 0.057.

Since these are the steps Levy and Kempton took in their letter to the Delaware PUC to apply the Cape Wind public health benefit analysis to the Delaware offshore wind project, the RIWINDS multiplier above can be used to estimate public health benefits, which are 0.057 x $53.1 million/yr = $3.0 million per year. As explained for the other estimates, this equals a levelized value of $3 million/1.3million MWh=$2.35MWh.

[117] Kempton, Willett; Levy, Jonathan. Letter to Delaware Public Utilities Commission on the Public Health Impacts of Cape Wind and the Proposed Delaware Integrated Resource Plan. 3 May 2007. Available: www.ocean.udel.edu/Windpower/DE-Qs/IRP-KempLevy-Health.pdf

[118] U.S. Environmental Protection Agency, Emissions and Generation Resource Integrated Database, 2007, www.epa.gov/cleanenergy/egrid/index.htm.

Figure 17: Health Savings Comparison: Cape Wind, RIWINDS & Methods



4.4.1 Discussion

As mentioned, a critical assumption in the Cape Wind analysis and the method for applying that study to other offshore projects is that generation will be displaced from nearby fossil fuel generators, without taking into account marginal and baseload characteristics. The following is an excerpt from the Levy and Kempton letter describing their recommended approach:

> …Examine the emissions from specific nearby power plants, the ones more likely to be turned down when new clean energy comes on the electric grid…Such an approach has been used for the proposed Cape Wind project off Cape Cod. In that case, two nearby power plants were examined (Salem Harbor and Brayton Point). …[An] identical to the approach that could be applied in principle to power plants in and around Delaware.[119]

While Brayton Point, the closer of the two coal plants (Salem Harbor is 80 miles from Providence), is only 15 miles from Providence, and not accounting for the much lower marginal emission rate would indicate significantly higher health impacts of the RIWINDS project, a deeper understanding of Brayton Point's generating characteristics shows that its coal emissions are unlikely to be mitigated by

[119] Kempton, Willett; Levy, Jonathan. Letter 2.

nearby wind farms.

Brayton Point is New England's largest coal generator at 1,600MW nameplate capacity.[120] It is comprised of four generating units, three of which can run on coal or natural gas, and one of which, 475MW, can run on residual oil or natural gas.[121] These are two of the primary fuels generally used in marginal generators, and it is likely that this unit would, if any in the plant, be most able to be load following. If this is the case, the marginal emission rates would be more accurate to use for displacement than the emission rates for the entire plant.

As was explained in section 3.1, intermittent renewables displace marginal generators in nearly all cases because of plant abilities to ramp up and down production. In some specific cases, there may be significant load pockets near large coal generators where transmission lines to the load pocket are congested enough that the demand is preferentially met by nearby generation rather than the economically optimal generation. This means some coal generators could be forced to be load following, and therefore could be displaced by the introduction of intermittent renewables. However, due to physical characteristics of many baseload generators, this is likely to result in 'dumped' or wasted energy if it is truly uneconomical to ramp the production up or down, or if the plant is required to maintain a certain level of operation for emissions standards purposes.[122]

Given the Brayton Point generating units and fuels and its characteristics as a baseload generator, even if it is affected by the RIWINDS project due to a specific Rhode Island load pocket and limited transmission, it is likely to either respond similarly to a marginal generator with its oil and gas unit, or not have the ability to respond at all. Therefore, substituting marginal emission rates for the Brayton Point and Salem Harbor emission rates most likely provides a more accurate public health benefit estimate than not taking that into account, as Levy and Kempton recommended for the proposed Delaware project.

Therefore, the public health estimates proposed above, $2.85 and $2.35 per MWh of the RIWINDS project will be used, rather than one up to 16 times higher based on the Levy and Kempton methods. The difference between these two estimates is negligible among the other values of the RIWINDS generation, and the average, $2.60/MWh will be used in the final analysis in Chapter 6.

Finally, this estimate only includes premature death impacts from SO_2 emissions and secondary

[120] Energy Information Administration, "Existing Generating Units in the United States by State, Company and Plant, 2005," http://www.eia.doe.gov/environment.html.
[121] Energy Information Administration, "Existing Generating Units…"
[122] Rathbun, Mark. "Making Wind Part of the Solution." AWEA WindPower 2008 Conference. Austin TX. http://www.awea.org/utility/pdf/Rathbun.pdf, 22.

sulfate formation. While SO_2 is the pollutant with the highest health impacts and premature death translates to the highest economic value, there will be other health benefits from the offshore wind farm from avoided NO_x and other pollutants.

4.5 Summary

The emission reductions from the proposed offshore wind farm would bring important socio-economic benefits, particularly with regards to global warming mitigation and health care. The project is forecasted to reduce Rhode Islands CO_2 emissions by 652,000 tons per year, and 13,052,000 tons over the lifetime of the project. This represents 6% of the state's annual carbon emissions, which is significant not only in the emerging carbon market, but also with respect to the legislative goals outlined in the Global Warming and Climate Solutions Acts of 2008 and 2009 to reduce greenhouse gas emissions to 80% less than 1990 levels by 2050. In addition, this meets and exceeds the renewable energy quota of greenhouse gas reductions outlined in the Rhode Island Greenhouse Gas Action Plan.

The project will also provide health benefits to the state by displacing polluting, and specifically SO_2 emitting fossil fuel electricity that will prevent one premature death per year. In addition, many other positive health impacts will result, such as fewer cases of respiratory symptoms and chronic bronchitis. These too will lower health care costs for Rhode Island families at a time when many communities are suffering from increasing unemployment and rising health care costs.

5 Long-term Contracts

A guaranteed revenue stream that is adequate to cover construction, operation, maintenance and financing costs is key to the continued progress of the RIWINDS proposed project. Renewable energy projects in the US have often used long-term contracts to secure a revenue stream that was adequate to cover financing for the project. Similarly, some European countries offer feed-in tariffs for the same purpose, and this structure is being considered in the US. Other renewable energy projects, known as merchant or partially-merchant plants, did not procure long-term contracts for their energy. However, since electricity prices have fallen and capital costs have risen, this option is generally too risky for plants currently being developed.

Based on legislative history, a long-term contract with Rhode Island’s primary utility, National Grid, is the most likely offtake agreement for the RIWINDS project. Without one of these long-term revenues, the large upfront investment in capital for the project will be too risky for financers, jeopardizing the state’s ability to meet the RIWINDS goal of 15% of the state’s electricity generated by wind.

5.1 Long-term revenue options:

The RIWINDS project is a non-utility power producer, specifically an Independent Power Producer, which is a facility that generates electricity but is not authorized to provide electricity distribution services to end use customers.[123] Independent Power Producers sell electricity on the wholesale market[124] and sometimes establish long-term contracts with utilities, known as Power Purchase Agreements, to secure a revenue stream.[125] Power Purchase Agreements (PPAs) and long-term contracts are more prevalent in vertically integrated electricity markets, however in the restructured New England market, they are very rare.

PPAs are critical to renewable energy project’s development because otherwise there is no guarantee of a revenue stream and investors have little information to determine the project’s profitability, and are particularly critical for financing given the current economic crisis. While some

[123] Energy Information Administration "Electricity Power Industry Overview" 16 Feb. 2009 <http://www.eia.doe.gov/cneaf/electricity/page/prim2/toc2.html>.
[124] EIA.
[125] Lam, Patrick T I, "A sectoral review of risks associated with major infrastructure projects" International Journal of Project Management 17 (1999): 84.

renewable energy projects receive financial backing before they have a PPA, the enormous upfront capital investment needed for offshore wind makes it far too risky for investors without a PPA.

PPAs or similar contracts can take several forms, three of which are possible for the RIWINDS project. They can be government mandated through feed-in tariff legislation, government mandated through long-term contracting legislation, or the government can be the direct offtaker. A utility could also enter into a long-term contract of its own accord, particularly in Rhode Island to meet its RES requirements of purchasing an increasing percentage of RECs. However, the proposed offshore wind project is too large to be able to be financed with a PPA for only the amount of renewable energy demanded by the Rhode Island RES, so this fourth option is less feasible.

5.1.1 Feed-in Tariffs

As mentioned in the chapter introduction, feed-in tariffs are a policy mechanism used widely in Europe that displace the need for PPAs since they also guarantee long-term revenue streams.[126] Feed-in tariff (FIT) legislation requires utilities to purchase energy from renewable generators for a price that secures economic feasibility for the project.[127] The prices offered for renewable projects are technology specific, with wind and biomass projects receiving prices near market wholesale rates while photovoltaic projects can receive as much as ten times more in proposed state legislation in the US.[128] To protect electric customers from exorbitant electricity rates and project failures, FIT legislation can include price ranges and extend the policy only to commercially proven technologies.[129]

Federal FIT legislation has been proposed in the US along with state legislation in six states, including Rhode Island.[130] In the 2008 legislative session, H7616, the "Rhode Island Renewable Energy Sources Act," which would guarantee all renewable electricity generators in Rhode Island a power purchase agreement for twenty years at a rate where the generator would earn ten to thirty

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[126] Rickerson, Wilson "Feed-In Tariffs in the US: A Policy Update" California Feed-In Tariff Design and Policy Options CEC Staff Workshop, 1 Dec. 2008, www.energy.ca.gov/portfolio/documents/2008-12-01_workshop/presentations/Wilson_Rickerson.PDF 2.
[127] Rhode Island Legislature, House, By Raymond J. Sullivan Jr, J. Patrick O'Neill, David A. Segal, Arthur Handy, and Thomas Winfieldm, 2008 Session, H7616, 26 Feb. 2008, The State of Rhode Island General Assembly, 17 Feb. 2009 <http://www.rilin.state.ri.us/billtext08/housetext08/h7616.pdf> , 1-2.
[128] Rickerson 7.
[129] Rhode Island Legislature H7616 3.
[130] Rickerson 6.

percent profit, was proposes.[131] This bill stalled in the House after critical components were incorporated into the long-term contracting and net metering bills that were expected to become law;[132] however, the long-term contracting bill was vetoed by the governor,[133] and the net metering bill does not affect generators with over 3.5MW of capacity.[134] Experts on FITs expect that with the uncertainty around renewable energy tax incentives due to the current financial crisis, FITs may gain support as an effective mechanism for providing investor security.[135]

5.1.2 Power Purchase Agreement (PPA) with a Utility

A Power Purchase Agreement (PPA) is a contract between a power provider and a power purchaser. It ensures a regular income stream for the provider and includes significant long-term financial obligations for the purchaser, and, when executed properly, risk management in stabilizing the costs of wholesale electricity compared to sources based on fluctuating fossil sources.[136,137] PPAs define the rights and obligations of investors, and distribute the risks and benefits of the project among the provider, purchaser, and end-use customers.[138] Often, governments regulate PPAs, setting a maximum rate of return on contracts to minimize customer costs.[139] PPAs can be a long-term contract for only electricity, only RECs, or for 'bundled' attributes of RECs and electricity.[140] They are complicated, technical contracts, particularly when signed before commercial operation, that detail the outcomes of all negotiations, including transmissions upgrades, construction delays, unforeseen events and other issues.[141]

Offtakers for industrial sized renewable projects are usually utilities because they have the creditworthiness and load certainty to accommodate long-term contracts. National Grid, the Block

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[131] Rhode Island Legislature, House, By Raymond J. Sullivan Jr, J. Patrick O'Neill, David A. Segal, Arthur Handy, and Thomas Winfield, 2008 Session, H7616, 26 Feb. 2008, The State of Rhode Island General Assembly, 17 Feb. 2009 <http://www.rilin.state.ri.us/billtext08/housetext08/h7616.pdf> , 1-2.
[132] Sustainable Energy Advantage "Feed-in Tariff legislation on hold" New England Renewable Energy 'Eyes & Ears' Update, Vol 1, Issue 10 (20 June 2008): 13.
[133] Montalbano, Joseph A, "Governor's veto of renewable energy bill sets state back," Rhode Island General Assembly, Legislative Press & Information Bureau, 17 Feb. 2009 <http://www.rilin.state.ri.us/news/renewableenergyoped.asp>.
[134] Sustainable Energy Advantage "Net Metering bill passes both chambers" New England Renewable Energy 'Eyes & Ears' Update, Vol 1, Issue 10 (20 June 2008): 14.
[135] Rickerson 14.
[136] Lam 84.
[137] Bosshard 1.
[138] Bosshard, Peter (2002): Private Gain, Public Risk? http://irn.org/programs/bujagali/bujagalippa-background.pdf , 15 Feb 2009, 1.
[139] Lam 84.
[140] Windustry 4, 6
[141] Windustry 1-6

Island Power Utility, and the Pascoag Utility are the three utilities that operate in Rhode Island, with the Pascoag and Block Island utilities serving their small namesake communities and National Grid serving the vast majority of the state.[142] Because the proposed project is around 370MW and wind is an intermittent resource, National Grid is the only practical offtaker of the three. Such a large wind project must be connected to an extensive grid system to minimize the reliability impacts of its intermittency. Natural gas generators are often coupled with wind to minimize the effects of intermittency because they can alter their generation to compensate for changes in wind generation.[143]

State utility boards or specially created entities can also enter into PPAs with Independent Power Producers.[144] Recent dockets and legislation have proposed the creation of these offtakers, and although that could accomplish the RIWINDS goal, it currently seems that a PPA with National Grid is more probable.

5.1.3 PPA with State Entity: Power Authority Bill

In the 2007 and 2008 legislative sessions, Rhode Island Power Authority bills were introduced[145] to establish a public corporation authorized to enter into any long-term contracts deemed necessary for cost-effective renewable energy development.[146] The Power Authority was proposed by Governor Carcieri to enable the development of an RIWINDS offshore wind farm, which he estimated could cost between $0.9 and $1.9 billion.[147] The Power Authority would be a state corporation that is legally distinct from the state, and it could take on debt, enter into contracts, and invest in property.[148] The Authority would have to resell the electricity to a load-serving entity, such as a utility, and therefore it would take on the risk that the sales price for the electricity was less than the purchase price. In addition, it would be responsible for ensuring that Rhode Islanders are the primary

[142] "Regulated Utilities." Rhode Island Public Utilities Commission. 17 Feb. 2009 <http://www.ripuc.org/utilityinfo/regulated.html>.
[143] Pavlak, Alex. "The Economic Value of Wind Energy." The Electricity Journal 21 (2008): 46-50.
[144] Lam 84.
[145] Sustainable Energy Advantage, "Power Authority Bill to be resubmitted" New England Renewable Energy 'Eyes & Ears,' Issue 1 Vol 7 (2007): 10.
[146] Rhode Island Legislature, Senate, By Algiere, J Montalbano, Walaska, Sosnowski, and Bates, 2007 Session, S943, 26 Apr. 2007, The State of Rhode Island General Assembly, 19 Feb. 2009 < http://www.rilin.state.ri.us/billtext07/senatetext07/s0943aaa.pdf> , 11-14.
[147] Barmann, Tim, "Power Authority Bill being considered again," Providence Journal, Biz Blog, 19 Mar 2008, http://bizblog.projo.com/2008/03/power-authority.html 19 Feb 2009.
[148] Rhode Island Legislature, S943 15.

beneficiaries of the electricity,[149] which could mean concentrating the associated job creation and investment in Rhode Island.

The first Power Authority Bill, S943, was passed in the Senate in 2007, but was held for further research in the House.[150] In 2008 it was reintroduced as S2600, but lost support because its proponents expected the main objectives to be accomplished by the long-term contracting bill, which was vetoed by the Governor.[151] Since the long-term contracting bill has been reintroduced in 2009 and it had wide support in the legislature and from the Office of Energy Resources last spring, it is expected that interest in the Power Authority will wane in favor of direct mandates for National Grid to enter into long-term contracts with renewables.

5.2 Long-term Contracting with National Grid

5.2.1 National Grid Perspective on RIWINDS Long-term Contract

National Grid is an international investor-owned electricity and gas company that delivers to customers in the United Kingdom and the northeastern US. In the US, it serves six million customers and operates primarily as an independent transmissions company, although it also owns 4,000 MW of electricity generation and imports and stores liquid natural gas among other electricity and gas related business operations.[152] With respect to electricity, the company's primary goal is to provide low-cost and reliable delivery, which largely defines its stance on the RIWINDS project.[153]

National Grid outlines its general perspective on wind development in its 2006 Transmission and Wind Energy report.[154] To address reliability issues, Grid urges better use and development of wind forecasting technology. Grid also advocates regional stakeholder involvement in long-term transmission planning and policy. Meanwhile, it acknowledges the economic and reliability benefits from mixed generation assets, where wind plays an important role, and the need to provide transmission access to renewables.[155]

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[149] Office of the Governor, "Carcieri Proposes Creation of New Rhode Island Power Authority," 2 May 2007, http://www.ri.gov/GOVERNOR/view.php?id=4063 19 Feb 2009.
[150] Sustainable Energy Advantage Eyes & Ears Vol 7 10.
[151] DeLucia, Libby, "Power Authority Bill Stalls," Sustainable Energy Advantage, New England Renewable Energy 'Eyes & Ears' Update, Vol 1, Issue 10 (20 June 2008): 14.
[152] National Grid, "About Us" http://www.nationalgrid.com/corporate/About+us 15 Feb 2009.
[153] National Grid, Transmission and Wind Energy, 2006, 15 Feb. 2009 http://www.nationalgridus.com/transmission/c3-3_documents.asp, 1.
[154] National Grid, Transmission and Wind Energy 1-3.
[155] National Grid, Transmission and Wind Energy 1-3.

However, the utility is reluctant to enter into long-term contracts. At a recent Procurement Planning meeting, National Grid members asserted that long-term contracts are seen as risky and as a form of undesirable debt, therefore entering into them can raise its cost of financing. Since it is a regulated entity and all of its regulator-approved costs are recoverable, there is debate on whether this position is accurate. National Grid generally procures power for its main retail product, Standard Offer Service (SOS), through three to six month load-following contracts, with the upper limit being two years.[156] Long-term renewable energy contracts represent a major departure from this practice, being ten to twenty years, and the generators are not load following. To date, National Grid has been more comfortable fulfilling its renewable energy obligations through short term REC purchases than entertaining the idea of long-term energy contracts.

Through political negotiations further described in Section 5.2.2 National Grid has identified characteristics that would help change its attitude toward long-term renewable contracts. The utility was in support of the long-term contracting legislation described in the next section that gave it a 3% incentive for long-term contracting. Perhaps because utilities rates are closely regulated by the PUC to maximize customer benefits by keeping rates low, this incentive represents a rare opportunity for National Grid to increase its profitability.

In addition, National Grid would be more amenable towards renewable energy long-term contracts if its distribution customers rather than only its SOS customers would bear the costs or savings of the contract. As described, National Grid provides many distinct electric services, including power procurement and retail for customers (SOS), and distribution services through its transmission lines. There are fewer transmission operating companies than power procurement and retail companies, and National Grid has more distribution customers than SOS customers.

Because New England has a deregulated electricity market, customers can choose which company they want to supply their electricity. This choice is typically based on the cost electricity, and the RIWINDS electricity is likely to be more costly than other options in the short term. If National Grid had to pass the costs or savings of the RIWINDS contract on to its SOS customers, it could potentially lose some customers to supply competitors that were not obligated to enter into such long-term renewable energy contracts. This could become a positive-feedback cycle as extra costs were then spread among fewer customers, thereby increasing per customer and more were motivated to switch electricity providers.

[156] National Grid. "RIPUC Technical Session: Standard Offer Service Supply Procurement." 19 February 2009. 3.

On the other hand, if National Grid were allowed to pass along financial impacts from the RIWINDS contract to its distribution customers, a wide spread of the financial burdens or benefits would be assured. Also, National Grid would be at lower risk of losing customers since customers would have to relocate outside of National Grid's transmission jurisdiction to terminate their distribution service.

However, this rationale is controversial for several reasons. First, in Rhode Island, the existence of other options for residential customers is extremely limited, as exemplified by 99.8% of residential customers purchasing electric supply from National Grid.[157] Second, there are issues with passing cost on to distribution customers as well. For these reasons, which are beyond this scope of this thesis to discuss fully, there is significant disagreement as to whether it is preferable to have costs passed through to SOS, or supply customers, or distribution customers.

5.2.2 Legislative History

Renewable energy long-term contracting with utilities has had a long legislative history in Rhode Island. It was first discussed as part of the Renewable Energy Standard (RES) that requires electricity providers to provide 16% renewable energy by 2020, which became law in Rhode Island in 2004. In the original language of the bill, a percentage of the required renewable energy in the RES had to be procured through long-term contracts for renewable energy and RECs, rather than purchasing RECs on the short-term market. However, the long-term contracting language was taken out of the bill just before it passed.[158]

Lacking this specific directive for long-term contracts, the Public Utilities Commission (PUC) was in a position to interpret the intent of the law with regard to renewable energy contracting. After filings from environmentalists and developers in favor of long-term contracting mandates, (and National Grid against,) the PUC ruled that long-term contracts must be part of the utilities compliance with the RES. The explicit purpose of the RES legislation is "to protect public health and the environment and to promote the general welfare."[159] A message from the legislature to the PUC also states that it is "a policy to encourage investment in renewable energy supply."[160] Specifically, Rule 8.3 of the PUC's *Rules and Regulations Governing the Implementation of a Renewable Energy*

[157] Jerry Elmer, "Statement of Conservation Law Foundation re: National Grid Electric Standard Offer Service Docket," 14 Jan 2009, 6.
[158] Jerry Elmer, Conservation Law Foundation, Staff Attorney, Personal Interview by Libby DeLucia, 19 Feb 2009.
[159] R. I. General Laws, § 39-26-1(e).
[160] R. I. Public Utilities Commission. "Report on Final Rules." Docket # 3659. 28 Dec 2005. 9-10.

Standard states that electric distribution company's Renewable Energy Procurement Plan "shall contain [the utility's] procedure for procuring its target percentage of eligible renewable energy…including long-term contracts which shall be made part of the Obligated Distribution Company's portfolio."[161]

Despite this rule which all stakeholders acknowledged mandates long-term contracts for renewable energy, National Grid has not included long-term contracts in its RES procurement plans. Since Rule 8.3 was promulgated in December 2005, National Grid has filed three RES procurement plans. [162] At each of these filings, environmental groups and developers, including Conservation Law Foundation, Cape Wind Associates and Bluewater Wind, have contested the plans for non-compliance with Rule 8.3. In each case, the PUC approved the one-year RES procurement plans, ruling that long-term contracting will be enforced when National Grid submits a new procurement plan for its primary electricity product, SOS, in 2009.[163] 99% of National Grid's residential customers and 94% of its small and medium commercial and industrial customers use the SOS.[164]

Realizing the importance of resolving renewable long-term contracting, the PUC ordered the creation of a stakeholder group to try to develop a solution that would satisfy multiple parties, including National Grid, renewable energy developers, and environmental parties. In the 2008 legislative session, this working group produced a long-term contracting bill that passed the House and Senate with overwhelming support, as H7916 and S2849, respectively. However, Governor Carcieri vetoed it after the session ended.

The Governor cited three reasons for his decision: an incentive for National Grid to enter into long-term contracts, lack of a mandate that the projects be in-state, and a 5MW solar carve out.[165] Each of these issues remains critical to the debate over long-term contracting in Rhode Island. First, the legislation included a 3% incentive for the 90MW of renewables National Grid was ordered to contract with. That would have given the utility an increased marginal profit on distributed electricity from a long-term contract, similar to Massachusetts legislation that gave utilities a 4% incentive. This statute was contested by some stakeholders because, as a regulated entity, if contracts were approved

[161] Available < http://www.ripuc.org/rulesregs/commrules/RESRules(7-25-07).pdf> 19.
[162] Elmer "Statement of Conservation Law Foundation re: National Grid Standard Offer Service Docket," 5.
[163] Elmer "Statement of Conservation Law Foundation re: National Grid Standard Offer Service Docket," 5.
[164] Elmer "Statement of Conservation Law Foundation re: National Grid Standard Offer Service Docket," 6.
[165] Conservation Law Foundation. "CLF Fact Sheet: Governor Carcieri's Veto of Long-Term Contracting Bill for Renewable Energy." Press release. Providence, RI. June 2008, 2.

by the PUC, National Grid would be taking on negligible risk in entering into a long-term contract.[166] In addition, Commissioner Germani of the PUC noted that the PUC is charged with setting fair rates for regulated entities and customers, rather than the legislature.[167]

Conversely, some professionals believe that the incentive is a crucial part to successful long-term contracting legislation. It is possible that utilities are so opposed to long-term contracts with renewables that they will consciously choose projects to contract with that they believe will fail, thereby negating the contract. If this is the case, long-term contracting legislation without a utility incentive may lead to a string of RFPs that never result in operation projects. Then, the 3% incentive on energy delivered from long-term renewable contracts could be critical to motivating National Grid to support the most viable renewable energy projects, resulting in the most renewable development.

Second, the Governor vetoed the bill because it endorsed projects that would directly benefit Rhode Island economically, rather than having to be located within the state. Proponents of the bill argued that this phrasing could encourage near-by developments, such as Cape Wind, to locate manufacturing or construction jobs in Rhode Island to obtain eligibility for long-term contracts in Rhode Island.[168]

Finally, the long-term contracting bill included a specific mandate that 5MW of the 90MW of mandated renewable generation be from solar technology. According to the legislation, National Grid would have had four years to contract with ‘commercially reasonable’, as defined by the PUC, solar projects under development. The Governor disliked the preferential treatment for this technology, perhaps reasoning that it is not in Rhode Island’s best interest to force its rate-payers to sponsor a technology that produces expensive electricity, even among other renewable technologies, and for which the necessary natural resource, sunlight, is not particularly strong in Rhode Island.

[166] Sustainable Energy Advantage, “Long-term contracting Standards bill passed House and Senate,” Sustainable Energy Advantage, New England Renewable Energy 'Eyes & Ears' Update, Vol 1, Issue 10 (20 June 2008): 12.
[167] Public Utility Commission meeting, Feb 20, 2009. “National Grid Standard Offer Service Procurement Plan.”
[168] CLF Fact Sheet 2.

Figure 18: Relative Costs of Constructing Electricity Capacity by Power Type (2007)[169]

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

On the other hand, solar technology costs are falling and it would offer cost and risk diversification, which are key to developing long-term energy independence with a stable energy supply. In addition, solar plants often complement wind projects well since they tend to generate the most energy when wind is weak in the middle of the day. In fact, solar is an important peak load following resource since annual peak load falls on hot summer days when solar plants would maximize their generation. Lastly, solar energy could create local installation jobs.

Proponents of long-term contracting for renewables are still working to see that National Grid will comply. The Long-term Contracting bill was re-introduced in the legislature as S111 and H5002 in 2009. Also, the PUC rejected National Grid's 2010 SOS and Renewable Energy Supply procurement plan on the basis of their non-compliance with Rule 8.3 mentioned above.[170] At a preliminary hearing for the SOS plan on February 20, 2009, the utility stated that they had not prepared a renewable energy procurement plan and that they would not be able to provide one by the March 2nd filing date. State Energy Office Commissioner Dzykewicz and Commissioners of the PUC expressed their disappointment at the meeting that National Grid had again failed to comply with the PUC Rules. PUC Rules.

National Grid's argument for why they have not yet entered into long-term contracts for renewables is based on the distinction between the SOS legislation and the Renewable Energy Standard legislation. These are separate in Rhode Island General Law: 39-1-27.7 & 27.8 addresses

[169] Ken Choate. Available: http://solarsmorg.blogspot.com/2009/03/secretary-of-energy-steven-chu-lays-out.html May 6, 2009.
[170] R. I. Public Utilities Commission. "Order Rejecting National Grid's Proposed Procurement Plans." Docket No. 4041. Mar 18, 2009. 1.

least cost procurement and SOS procurement, while 39-26-4 is the Renewable Energy Act. The Least Cost Procurement act states that utilities must supply electricity in an "optimally cost-effective, reliable, prudent and environmentally responsible" way.[171] Statute §39-1-27.8 regarding electricity supply dictates that supply procurement plans be "consistent with the purposes of least-cost procurement."[172] Although neither of these sections of the law mention renewable energy, some argue that a long-term contract with a wind generator fits the definition of prudent in the Least Cost Procurement act since if offers price stability, and potential customer savings in the latter part of the contract since fossil fuel prices are volatile and generally increasing.

5.3 Analysis of Long-term Contracting Options

Of the three long-term contract mechanisms that have been proposed in the Rhode Island legislature—Feed-in-Tariffs, Power Authority, and long-term contracting with National Grid, the latter appears most likely to come to fruition. The Long-term Contracting bill was the only one that was re-introduced in 2009, and it passed with significant majority at the end of the 2008 legislative session in both the House and Senate. The issues identified by the Governor in support of his veto are being further negotiated, and more importantly, the bill had enough support in the legislature in 2008 that it could have over-ridden the Governor's veto if the veto had not come after the session ended. It is also possible that long-term contracting could be enforced by regulatory action, such as the PUC's decision to reject National Grid's Renewable Energy Supply procurement plan.

Several issues still need to be resolved for long-term contracting, however it is enforce. One is which customers should bear the costs of the contracts. As described, spreading costs or savings among a wider customer base, the distribution customers, would lower the risk exposure per customer. It would also mitigate opposition National Grid would likely mount for potentially losing supply customers to competitors. However, there are arguments against spreading the costs among distribution customers as well.

Another key issue is the incentive that was included in the 2008 long-term contracting bill. The smoothness with which any long-term renewable energy contracts are entered into and the success of the renewable projects could be greatly affected by the utility's attitude towards the contract. National Grid's attitude appears to be negative without the incentive due to the above-market cost and

[171] Rhode Island General Law: System reliability and least-cost procurement, § 39-1-27.7.
[172] Rhode Island General Law: Supply procurement portfolio, § 39-1-27.8.

intermittency of many renewables, and its preference for three to six month supply procurement contracts. The 2008 long-term contracting bill, which included the 3% incentive for distributed energy from long-term renewable energy contracts, did have National Grid's support. Here the distinction of distributed energy is important since this means National Grid will only receive the incentive if the project it enters into a long-term contract with is successfully developed. On the other hand, despite the benefits of National Grid's support for renewable energy development, the incentive would raise electricity rates for customers.

Finally, the impact of a long-term renewable energy contracting bill on the RIWINDS project will depend on the amount of energy or capacity that National Grid is willing to contract with and the RIWINDS financer's perception of risk. If National Grid is required to enter into a long-term contract for at least 90MW of renewable energy capacity, as is detailed in a current long-term contracting bill, H5002, this would only be about 60% of the RIWINDS project since its capacity would be around 150MW. Depending on the risk appetite or aversion of potential financers, this may not be sufficient revenue guarantee for them to fund the project.

5.4 Summary

In summary, there have been several mechanisms proposed to support long-term contracting with renewables in Rhode Island, and a long-term contracting bill in 2008 that was reintroduced in 2009 passed the legislature with overwhelming support. National Grid supported this bill, largely because of a 3% incentive for distributed energy from such a long-term contract. However, without this incentive, National Grid been opposed renewable energy long-term contracting. Along with this incentive, important factors to be considered in the contract structure are what set of customers will bear the costs or savings from the contract (distribution or generation supply customers), and whether the legislative mandates for renewable energy capacity under long-term contracts are sufficient to attract financers to the RIWINDS project.

6 Synthesis & Recommendations

This chapter provides a final synthesis of the costs, revenues, socio-economic benefits, political issues and risks relevant to long-term contracting with the proposed offshore wind farm in Rhode Island. Based on this comprehensive analysis of the costs and benefits, it recommends a strategy for further study to determine whether entering into a long-term contract with the development will be beneficial to Rhode Islanders.

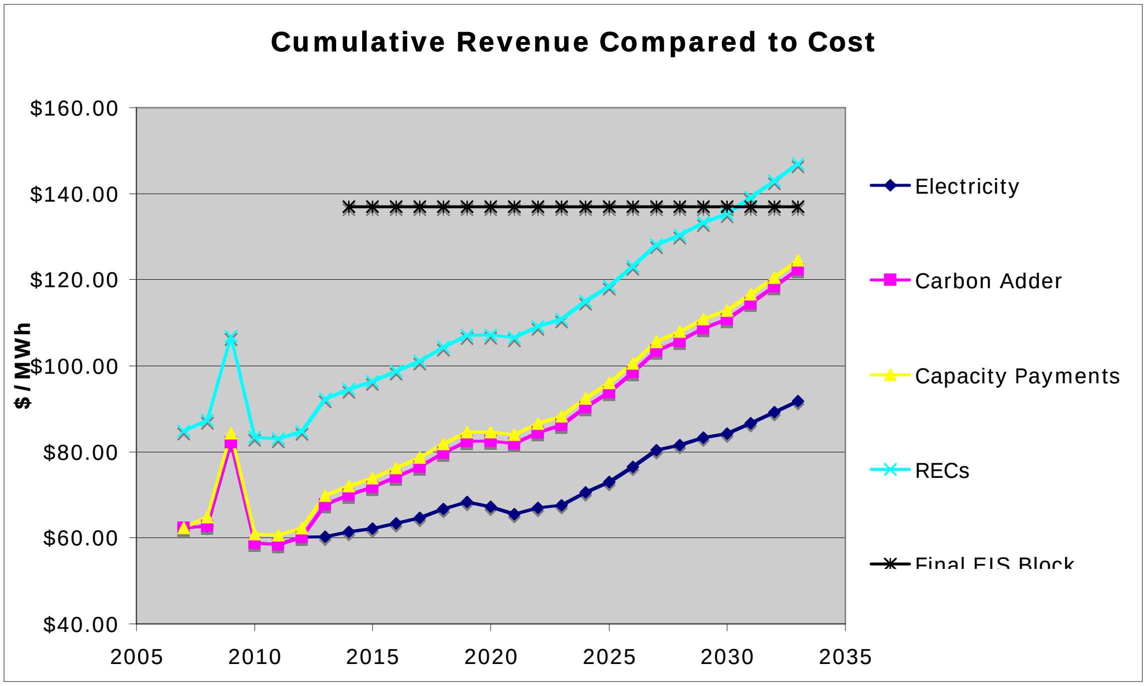
First, the chapter compares the cumulative revenue streams analyzed in Chapter 3—energy, capacity, REC and carbon revenues, to the cost estimates in Chapter 2. Next, the health and global warming and hedge socio-economic values of the wind farm from Chapter 4 are incorporated into the analysis to provide a holistic understanding of the true societal costs and benefits analyzed in this thesis. Finally, the need for further quantification of externalities and frequent updates to market projections is discussed along with the implications for a long-term contracting.

6.1 Cost & Revenue Comparison

To portray the complete cost and revenue analysis of the proposed Rhode Island offshore wind project, the revenue streams quantified in Chapter 3 are compared to the cost projections described in Chapter 2. As mentioned, there are many uncertainties surrounding both the costs and revenues of the proposed project. These are due to emerging renewable energy technologies, developments, policies, and the value and price of electricity in the future. The quantified cash flows presented represent a thorough analysis of the best data publicly available at the time of this study under one set of assumptions.

Figure 19 shows the cumulative revenue streams quantified in Chapter 3 with the RIWINDS cost projection for comparison purposes. The total revenue exceeds the levelized cost of the energy in 2031.

Figure 19: Cumulative Revenue Streams for Proposed Rhode Island Offshore Wind Project



6.2 Externality Discussion: Global Warming & Health Impacts

As described in Chapter 4, the proposed offshore wind project would have externalities with positive socio-economic value, in particular for health, global warming, and price stability.

The avoided health costs result primarily from avoided premature deaths due to displaced SO_2 emissions. The generators displaced would be marginal generators rather than baseload coal plants as assumed in the Levy et al. (2002) Cape Wind health savings evaluations. Adapting the Levy et al. study with this assumption for the RIWINDS project results in a levelized avoided health costs value of $2.35/MWh, as is described fully in Section 3.4. The average between this value and that using the other method described in Chapter 3 is $2.60/MWh, which is the amount used in this analysis. Figure 21 below shows the magnitude of the health savings is 2% of the levelized cost of the energy.

Figure 20: Health Savings: Cumulative Value of RIWINDS Energy

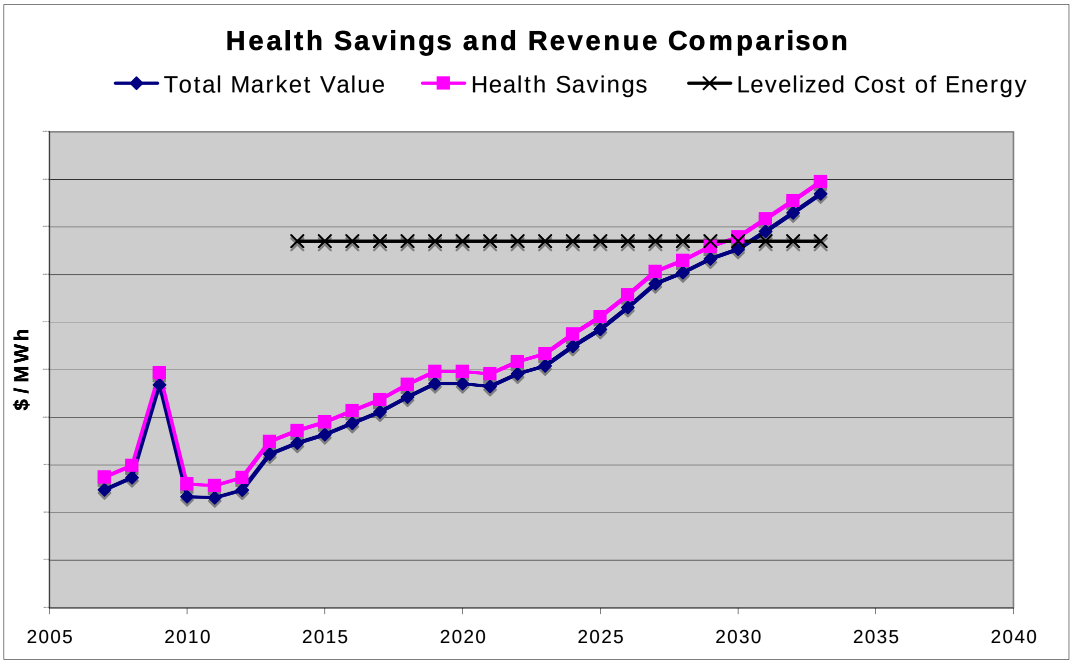
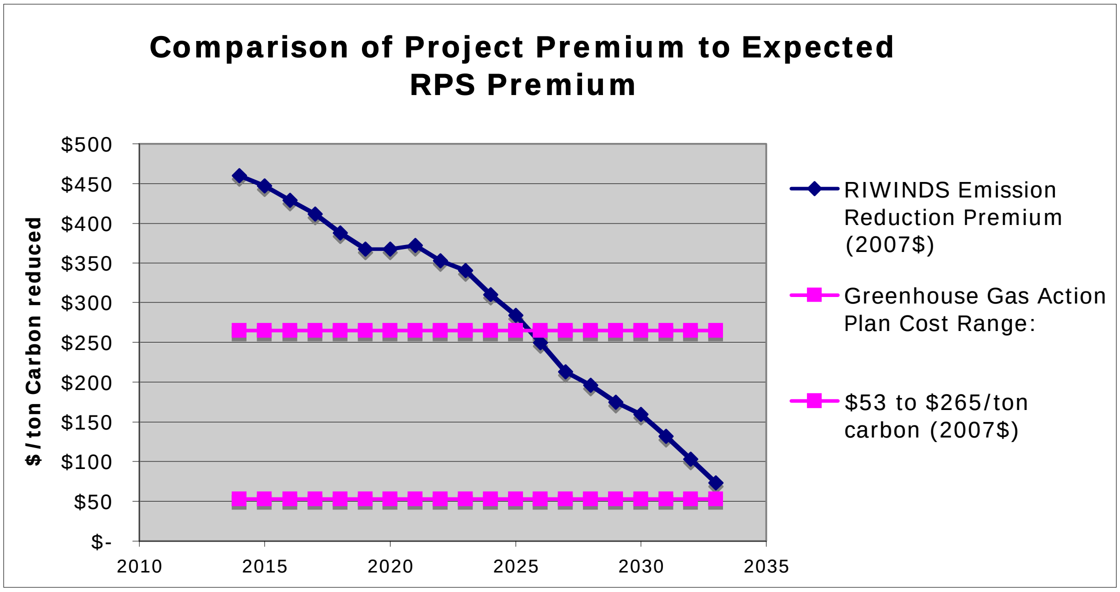


Figure 22 shows the global warming mitigation premium and how it fits in with the Rhode Island Greenhouse Gas Action Plan. The expected carbon reductions from the RI RES in the Greenhouse Gas Action Plan are 2020 are 140,000 metric tons annually at a cost of $53 to $265 per ton. The proposed offshore wind project would offset 177,982 tons of carbon per year, 27% higher than the Action Plan goal assuming all of the RECs are paid for in Rhode Island rather than sold to out-of-state utilities.

The cost of carbon reductions per ton is given by the renewable energy premium above other values. Therefore, the value of electricity (including the carbon adder), capacity payments and health care savings can be subtracted from the levelized cost of the RIWINDS energy to find the premium cost for carbon emission reductions. Because energy prices are projected to increase over the lifetime of the project, this premium decreases over time. The graph below shows the range of costs given in the Greenhouse Gas Action Plan, $46 to $230 per ton of carbon reduced, the annual carbon reduction premium of the RIWINDS project.

As is evident from the graph, the RIWINDS premium drops steadily between 2014 and 2033, mainly because natural gas and therefore electricity prices are expected to rise and the cost of the energy remains constant. In 2026, the RIWINDS premium dips below the upper range of the Action Plan projections, and it ends in 2033 near the lower range value, at $73.32.

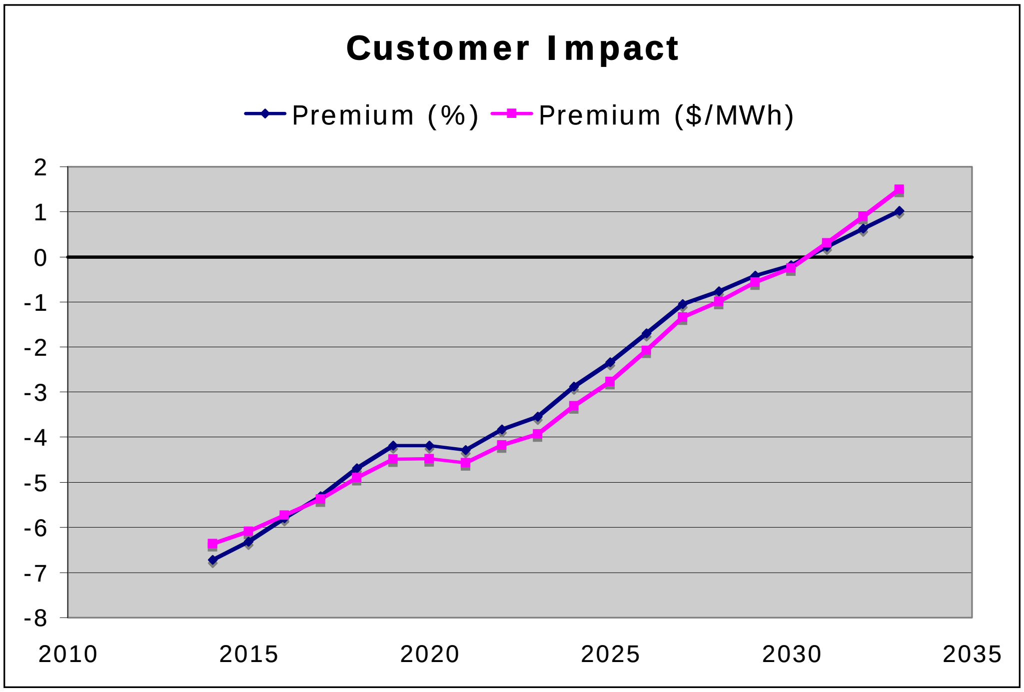
Figure 21: Global Warming Externality: Premium for Carbon Reductions from RIWINDS Energy



6.3 Long-term Contracting Synthesis & Recommendations

In Section 6.1, the levelized cost of the RIWINDS energy is compared to projected market values. The financial impact on customers of long-term contracting with the project at the price $137/MWh for energy, RECs and capacity would be the premium or savings of that price relative to the market value of the attributes multiplied by the percentage of the customer's energy that it represented. Assuming customers buy 15% offshore wind energy because that is the project's goal, the financial impacts of the project would be to raise customer prices by $0.006/kWh, or 6% at the beginning of the project, and lower customer prices by $0.0015/kWh, or 1% at the end of the project. The premium or savings to customers caused by the project in both $/MWh and percentage are shown in Figure 22. Another metric to consider for evaluating the feasibility of the project based on this analysis is its Net Present Value. Given a 10% discount rate, the project shows a negative Net Present Value of $171 million in 2007 dollars.

Figure 22: Rhode Island Customer Cost/Savings Due to Offshore Wind Project



This analysis shows that the proposed offshore wind project will increase electricity prices by up to 6%, although this will decrease and eventually become savings over the lifetime of the project, and have a net cost of $171 million assuming a discount rate of 10%. Despite this conclusion to the analysis, further research could still indicate that the project is a wise investment for Rhode Island. As mentioned in section 3.5, this analysis does not quantify the value of the wind energy as a hedge against fluctuating electricity prices, but does point to its potentially significant impact (Figure 11: Value of Hedge). In addition, the project is expected to have large economic development impacts. A recent report for NYSERDA by KEMA calculated that wind development from New York's first three renewable energy solicitations had an average positive direct economic impact of $23.92/MWh. If the same were true for the proposed RIWINDS project, this would increase the value of its energy by up to 20%. Lastly, the environmental impacts of the project, other than global warming, are not fully discussed here and are likely to be positive.

The cost-benefit scenario given here is uncertain. The market value forecasts and the cost estimate are subject to change over the lifetime of the project and the next few years respectively. As the development moves forwards, high and low cases for cost and market value should be established, and the base case (given here) should be updated with the most current information.

If due to updated forecasts and further incorporation of the value of wind energy externalities, the value of the RIWINDS energy is found to be above the estimated levelized cost of developing the offshore wind project, a long-term contract with the RIWINDS project is advisable for National Grid and Rhode Island electricity customers. As discussed in Section 5.3, several decisions remain about the structure of the potential long-term contract. These include whether it should spread the costs and savings over National Grid's distribution or SOS customers, if the 3% incentive should be included to encourage National Grid to support the project or if that will an unnecessary price increase for rate payers, and what the magnitude of the mandated long-term renewable energy contract should be to sufficiently increase the project's ability to obtain financing.

6.4 Conclusion

Based on a current analysis of the costs and benefits of the proposed RIWINDS offshore wind farm, the project would increase customer electricity rates by 6% beginning in 2014, and reduce rates by 1% at the end of its expected lifetime in 2033. Further research that quantifies more externalities of offshore wind energy and alternatives may show that Rhode Island electricity customers would benefit from a long-term contract between National Grid and the proposed RIWINDS offshore wind project. The project would provide health benefits and savings, and the global warming mitigation effect of the project would be a significant strategy towards meeting imperative emission reduction targets.

Global warming is one of the largest global challenges of the present and future. Natural resource endowment and political initiatives have placed the RIWINDS project at the forefront of US offshore wind development. Rhode Island has the opportunity to contribute importantly to its mitigation, meanwhile benefiting Rhode Islanders financially and physically through the RIWINDS project. The success of the long-term contract necessary for RIWINDS offshore development depends of the understanding of the costs and benefits of the project by key decisions makers. This great opportunity should not be missed for lack of information about the impacts of offshore wind.

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