2010

New York State Wind Energy Study Final Report


Source: Milian, Chris; www.photosfromonhigh.com

Submitted by:

Christina Hoerig

Kimballe Campbell

Daniel Grew

Nicole Gumbs

Happiness Munedzimwe

Sandeep George

Jun Wan

Timothy Komsa

Karl Smolenski

Tyler Coatney

Cornell University

Table of Contents

List of Figures

List of Tables

1 Executive Summary

New York State faces many economic, environmental and political pressures to develop new sources of clean electricity. According to one study, the current demand for electricity will increase nearly 20% over the next decade. Even with the implementation of efficiency standards, demand will still increase by 10% (NY ISO, 2010). New York State currently generates the bulk of its electricity from the combustion of carbon based fuels which produce a staggering amount of greenhouse gas. The state also imports nearly all of these fuels as well as being a direct electricity importer from other countries and states. For these reasons it is crucial for the state to develop internal sources of clean electricity.

While New York may not have the greatest total wind potential in the US, the pressure of high electricity prices and demand make wind energy an attractive development option. Out of all alternative electricity sources, land-based wind provides the largest opportunity for economical development at this time. The first commercial wind farm in the state was put online in 2000 and nearly 2000MW of capacity has been installed in the past decade. Many wind energy projects have been put on hold in the past few years due to the overall economic downturn as well as falling electricity sale prices. However if enough incentives and funding becomes available for all schedule projects, New York could see its installed capacity quadruple in the next decade.

An important basis for renewable energy goals in New York State was the Renewable Energy Portfolio Standard (RPS). This included a clean energy goal of ’45 by ’15. 30 % of energy demand for New York State would be from renewable energy sources and 15 % of the energy demand would be reduced through energy efficiency. In regards to renewable energy sources, biomass, landfill gas, and hydropower are projected to be profitable. Large wind energy projects would be the next logical clean energy source to pursue since they have the smallest price premium. This price premium can potentially be bridged through federal incentives such as the Production Tax Credit (PTC) that offers 2.1 cents per kWh for a ten year period or the Investment Tax Credit (ITC) that provides 30 % of the project’s qualifying costs within the first year of production. Through an analysis of the amount of wind energy generation through 2014, it is expected that New York State will receive $708,246,000 through incentives.

Additionally, this study analyzed the probability of actually meeting the RPS goal set for 2015 by considering the growth of various renewable sources of electricity in New York State including Wind Energy. The various renewable sources were assumed to follow various probability distributions, and the sum of the total electricity that would be produced from these sources was compared against 30% of the projected electricity demand for 2015.

Though there are 7000MW of Wind Farm applications in the pipeline, it was assumed that on average, there was a higher chance of 25% of those Wind Farms becoming operational by 2015. From the simulation results it was concluded that there is a 65% probability of achieving the RPS target. The upcoming Champlain Hudson Hydro Project in Canada was found to be the most critical in meeting the RPS target. Wind Energy was found to be the next most critical factor in achieving the RPS target and thus reiterates the fact that the growth of Wind Energy in New York State is critical to the State's future renewable electricity demand.

Furthermore, this study took a look at the potential of Offshore wind farms for New York State. The Long Island-New York City Offshore Wind Collaborative was found to be a promising source of significant wind energy for the state providing as much as 700MW of clean electricity to the state while reducing transmission losses due to its proximity to New York City. Offshore wind is stronger than onshore wind and wind speeds are greater in the morning and reduced at night thereby being able to produce electricity in-phase with the demand; unlike the wind pattern observed for onshore wind farms. The recent federal approval for the construction of the Cape Wind project off the coast of Massachusetts which will be the first Offshore wind project in the US can be seen as a positive sign for more Offshore initiatives.

Finally, this study includes a feasibility assessment of the proposed Black Oak Wind Farm in Enfield, New York. The proposal includes the installation of approximately twenty 2.5MW wind turbines for a total installed capacity of 50MW. A meteorological tower was previously installed on site and its data for a full year was analyzed to determine the wind speed distribution at different heights. The data was validated based on its close fit with the typical wind distribution for the site’s average speed as predicted by the Weibull distribution. The average wind speed for the site was found to be 5.48 m/s, 5.82 m/s and 6.11 m/s at the heights 40m, 50m and 58.2m respectively. The extrapolated average wind speed for the proposed hub height of 80m was 6.51 m/s. The corresponding expected net power output at the 80m hub height is 120.2 GWh/yr with a capacity factor of 27.4% and estimated losses of 10%. The economic analysis confirms that this is a valuable investment with a Net Present Value of $14,681,527, discount rate of 7% over 20 years and at an initial capital investment of 40% equity and 60% debt. The levelized cost for this investment option was found to be $0.068. This is further confirmed with a Net Present Value of $10,065,909, discount rate of 9.5% over 20 years and at an initial capital investment of 40% equity and 60% debt. The levelized cost for this investment option was found to be $0.071. Based on these findings, the wind farm could supply the full needs of the Enfield community based on an expected consumption per household of 5000 kWh/year.

2 Introduction

Residents in New York State face a number of energy and environmental challenges that impact many facets of their lives. Major issues include high energy costs, continued reliance on imported fuels and the effects of climate change. The steady increase of gross energy consumption and its cost of generation will prove to only magnify these current problems. New York's landscape and geographic location make it a top candidate for exploiting wind energy in expanding its generation capacity. Harnessing the state's wind resources is a forward-thinking and cost-effective way of culturing environmental responsibility, lowering energy costs and increasing energy security and independence.

New York State has the third largest population in the United States at approximately 19.5 million (US Census Bureau), with 8.4 million (New York City Department of City Planning) in New York City alone. Given this large population, the state has a great demand for energy sources. In 2007 New York produced 873 trillion Btu of total energy (including electricity generation), only 1.2% of the nation's total. During the same period the state consumed 4,064 trillion Btu, equaling a 4% share of national consumption and was the highest in the US. The foregoing figures pertain to energy in all forms. Electricity accounts for about 37% of the state's yearly usage at 1490.7 Trillion BTUs (DOE Energy Information Administration). As a result of high demand, the New York prices of petroleum derivatives, natural gas, coal and electricity are all consistently higher than the national average. New York, like much of the Northeast, is also vulnerable to fuel oil shortages and the resultant price spikes during winter months. New York has also been the victim of a number of major electricity outages, the largest of which affected an estimated 55 million people in August of 2003. Lacking its own substantial sources of petroleum, natural gas and other fossil fuels, New York relies heavily on importing these resources from other states and abroad.

New York State already produces a large amount of electricity through alternative and renewable resources. Several powerful rivers, including the Niagara and the Hudson, provide New York with some of the greatest hydropower resources in the US. But it is wind power that may have the highest potential for growth. New York's Catskill and Adirondack regions are examples of areas prime for wind development. In 2004, New York adopted the Renewable Portfolio Standard (RPS). The main objective of RPS is to increase the amount of energy produced by renewable resources to 25 % by 2013, which calls for greater energy efficiency while using renewable sources to support 30 % of the state's energy demand (NY State Energy Planning Board, 2009). In just two years (2006-2008) New York already doubled its wind energy capacity. Wind energy can therefore play a major role in meeting the RPS requirements.

Our report begins by examining the current energy supply and demand in New York State. This initial research will inform the development of a medium to long-term energy plan. Additionally, the information will provide some background for and depict the motivation behind the development of wind energy in the region. A preliminary review reveals that New York State currently produces most of its energy from natural gas and nuclear power plants. Other renewable sources also play a major role in both energy and electricity production, the bulk of which comes from hydroelectric plants near the Great Lakes. While the region's Adirondack and Catskill mountain ranges provide a high potential for wind energy generation, wind currently makes up only a small fraction of its energy portfolio. Identifying the current sources, which supply the state with energy, as well as the current demand for these resources, will lay a foundation for future energy planning. Since New York State has several densely populated regions, particular attention will be paid to the geographic distribution of the energy resources and their use. Knowing the regions of high demand and sufficient wind capability will help identify prime locations for wind development. A demand portrait of domestic versus industrial electricity usage will also be integral the analysis. The background research will round up with a brief look into the capabilities for wind as it relates to future demand, thus setting the stage for a more detailed analysis of current state NY wind resources.

New York State currently has a number of wind farms in operation, various other sites under development, and still others with the potential for development but no plans in place at present. By 2013, 25% of all power in the state is to come from renewable energy sources according to the New York Renewable Portfolio Standard (NYSERDA). Wind energy will play a critical role in reaching this target. This project will therefore assess the current geographic distribution of wind around the state and also forecast at different time points in the future how much wind might be developed, and what fraction of the demand for carbon-free electricity might come from wind. In addition, because of the population structure and the pocket-distribution of landside wind resources, a brief foray into offshore wind in both the Great Lakes and the Atlantic will be made.

Finally, our report will examine a specific instance of the realization of Wind Energy in New York State as a representative case study for the principles and factors alluded to in the preceding paragraphs. Our chosen site, Enfield Wind's Black Oak Wind Farm in the Town of Enfield, NY is particularly convenient because of its close proximity to Cornell University. Enfield Wind is still in the planning stages, though real estate has been secured, and has featured an onsite meteorological tower that has been taking wind speed data at 40, 50, and 60 meters elevation since 2006. This data has been made data available to us by the attendant engineer and will constitute the heart of our feasibility evaluation. Enfield Wind developer, John Rancich, has proposed a farm with about 20 tri-bladed, 425-ft wind turbines at an operational rating of 2.5–3 MW each. The total rated capacity of the site would therefore be 50-60 MW, which, at a capacity factor of 27% (typical for wind farms in this region), would produce an average output of 15-20 MW, and is intended to be sufficient for the residential needs of the entire Tompkins County, NY. The project would have a net cost of $120 million raised through private and public funds, and would be complete with a "substation, collection system, pad-mounted transformers and compacted gravel service road, on a project area spread over 925 acres (Henbest, 2008)." This analysis will examine all nominal figures of power production and financials. There have been mixed reactions from the community leading to the passing of a local Town of Enfield Wind Ordinance in early 2009. Overall, Black Oak Wind Farm is highly illustrative of typical socio-demographic, meteorological, technological and economic parameters of Wind Energy realization in New York State. Our examination focuses on the meteorological and economic factors, as these are highly determinative.

Goals and Objectives

In order to put the potential of wind power generated electricity into perspective an overview of energy sources and breakdown of demand in New York State was developed, focusing on electricity demand and suppliers. Other energy sources and consumption were reviewed in general terms. A list of the sources within NYS was developed with their location, type (coal, hydro, wind, etc.) and production capacity. A map and list of wind energy producers was developed along with a look at the capacity for further expansion of wind energy generation in the state. Finally data was compiled for current energy demand in NYS with geographic distribution if available.

Following the background research on the current wind energy capacity for NYS, a medium to long-term wind energy plan was proposed. One of the objectives for this section of the report was to identify sites with greatest potential for wind energy production. Within the model, we included the wind farms which are currently operating or under development. Based on this analysis, a time scale assessment of how wind energy production can be integrated into the standard electric grid was made and used to determine what fraction of carbon-free electricity could come from wind. Additionally, the potential and feasibility of offshore wind farms and how they could supplement onshore wind energy was investigated.

Lastly, a case study of wind application for Enfield site was conducted. This includes an estimate of the average wind speed available and its associated statistical distribution. This was used to determine the physical resource available at the site as a measure of the estimated annual output of electricity (in kWh). These calculations were based on a representative power curve for a state-of-the art wind turbine at a desired rating of 2.5 MW.

This information as well as the approximate cost of the representative wind turbines were used to do an investment analysis using conventional cash-flow analysis and engineering economics, with attendant incentives from the Federal and State governments.

3 New York State Present Energy Supply/Demand

3.1 New York Energy Background

New York imports virtually all of the fuels it uses to produce electricity as well as directly importing electricity from neighboring states and Canada. New York has very minor domestic supplies of oil and natural gas (setting aside the reserves contained in the Marcellus Shale beds.) New York ranks 26th in the nation in production of oil, supplying 28 thousand barrels of oil a year compared with Texas (ranked 1st) which produces 32 million barrels. (DOE Energy Information Administration) New York ranks 22nd in the nation in production of natural gas, producing 50 billion cu. ft. compared with the 7 trillion cu. ft. produced by 1st ranked Texas. No coal is mined in New York. The state does have large supplies of hydroelectric power primarily on the Niagara River. New York also has three nuclear power plants with a total of six reactors. The 2008 power generation by source can be seen in Figure 1 and Figure 2 shows generation capacity by source.

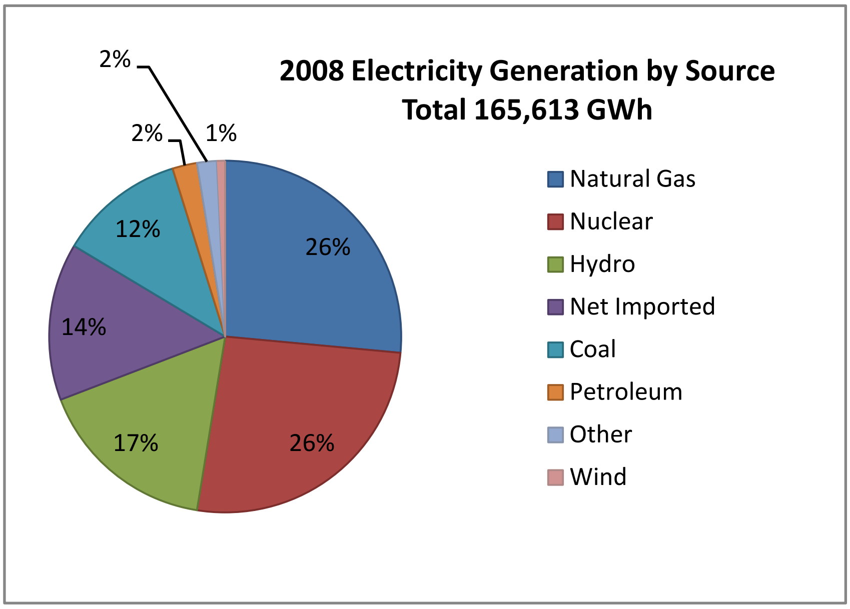


Figure 1: New York State Electricity Generation by Source, 2008

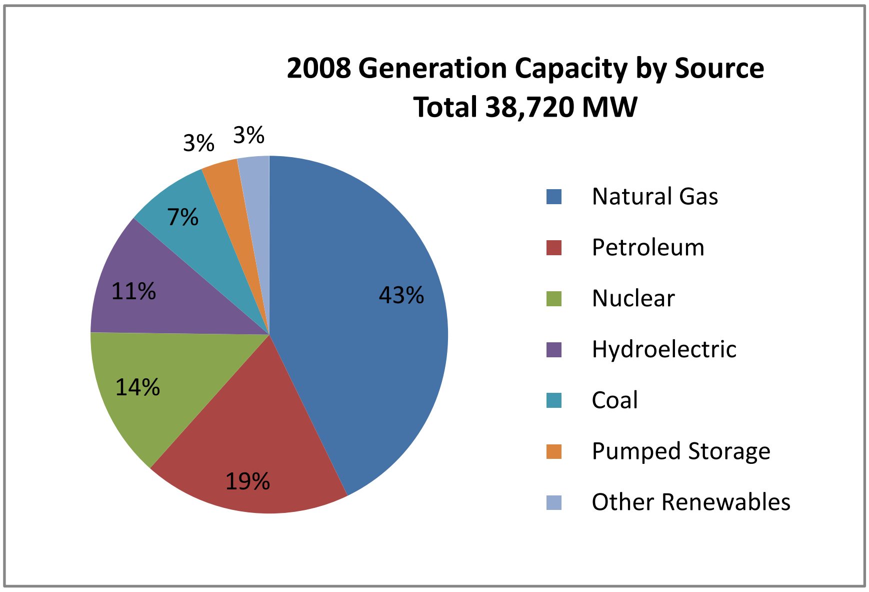


Figure 2: New York State Electricity Geneartion Capacity by Source, 2008

Developing local energy resources would be a benefit to the state in terms of energy independence and security since it is so reliant on fuel imports. Given that the bulk of the state's hydroelectric resources have already been utilized, wind is the natural resource with the most potential for development.

When compared with other states in terms of wind power potential New York ranks 15th. A 1991 wind power study predicted a theoretical potential of 62 billion kWh/yr of electric power, which is quite low compared with the Plains states which in general have an average potential of over 500 billion kW-hr/yr each ((Pacific Northwest Laboratory, 1991). North Dakota has the highest potential in the nation, 1200 billion kW-hr/yr, which could provide one quarter of the nation's electricity if sufficient transmission capacity was available. The US Midwest is indeed the "Saudi Arabia" of wind power. While NY can't match the mid-west's wind potential, wind power could be a useful part of a portfolio of alternative energy resources to help the state meet its long-term goals.

While New York's capacity may not be as large as the Midwest's its post-transmission retail electricity costs are the third highest in the nation at 17 Cents/kW-Hr. This allows high cost wind energy to be more acceptable when compared with conventional sources (DOE Energy Information Administration). New York is also remarkably energy efficient and ranks 49th in per capita energy consumption, primarily due to the urbanized New York City Metropolitan area. This low per capita consumption is also reflected in the fact that NY emits (only) 47million metric tons of C02 from its electricity industry which is 20th in the nation while the population of the state is third.

Appendix A-1 shows non-wind renewable energy projects in the NYISO interconnection queue.

3.2 Current NYS Wind Power

Utility scale wind power in New York State started with the installation of the 11.5 MW Madison Wind Farm in 2000 and has grown steadily since. As of the start of 2010 there is 1275 MW of installed faceplate capacity, which is the capacity of the turbines if running at full power, at 14 sites in upstate NY. There are another four wind farms scheduled for completion in 2010, bringing the total capacity to 1475MW. Figure 3 shows the growth of wind power capacity over the past 10 years. Until the recent period of economic downturn there was significant interest in adding further capacity.

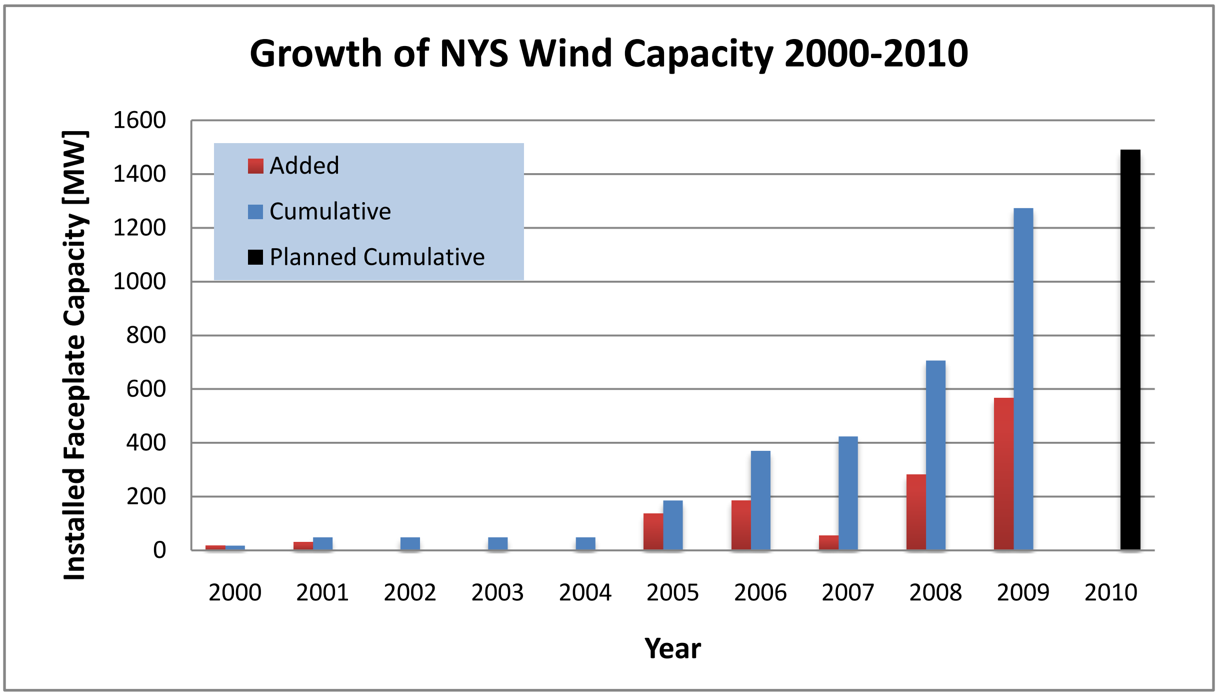


Figure 3: Wind Power Capacity Growth in NY from 2000 - 2010

A quasi government agency, the NY Independent Systems Operator (NY ISO) maintains a connection application queue for all projects that require a connection to New York State's electrical grid. Projects remain in the queue until they have been constructed and tests show that they meet all requirements for connection to the grid.

In April 2009 there was 9200 MW of planned wind projects in the interconnect queue, but this had dropped to 7000 MW as of March 2010. A few of these projects were cancelled because multiple companies were competing for projects at the same site, but others appear to have been canceled due to lack of funding or profit potential. Existence of a project in the queue does not mean that it will be built and forecasting how many of these projects will actually be built was a critical part of this project. On the other hand, any project that intends to be online in the near future should be found there. Black Oak Wind, subject of our case study, holds position 346 in the queue and its application process was started in June 2009. There are other projects awaiting approval which date back as far as 2002. Projects that are not found in the interconnect queue should probably be treated as proposal only. Judging from the project initiation dates in the queue, these projects take 3-5 years from application to final approval.

3.3 Near Term Growth of New York State Wind Power

One possible method to determine the future production capacity of wind power in New York would be to develop a heuristic that accounts for the available area with wind velocity above a minimum threshold and the fraction of this area that could be built (based on population density, land usage, etc.). Using a typical turbine and the area required for each turbine, one could calculate the total output possible. For the very long term this method may be appropriate. One could imagine that wind farms become very common and each small town in the windier areas would have its own local wind farm for electricity generation instead of relying on large remote conventional power plants.

This was not the approach taken, however. Growth was projected based on what fraction of the NY ISO queue could reasonably come online in the near future. In order to allow further analysis by other team members a 25% success rate was used, as shown in Figure 4. While perhaps conservative, this forecast still requires that the statewide capacity more than double in the next 5 years.

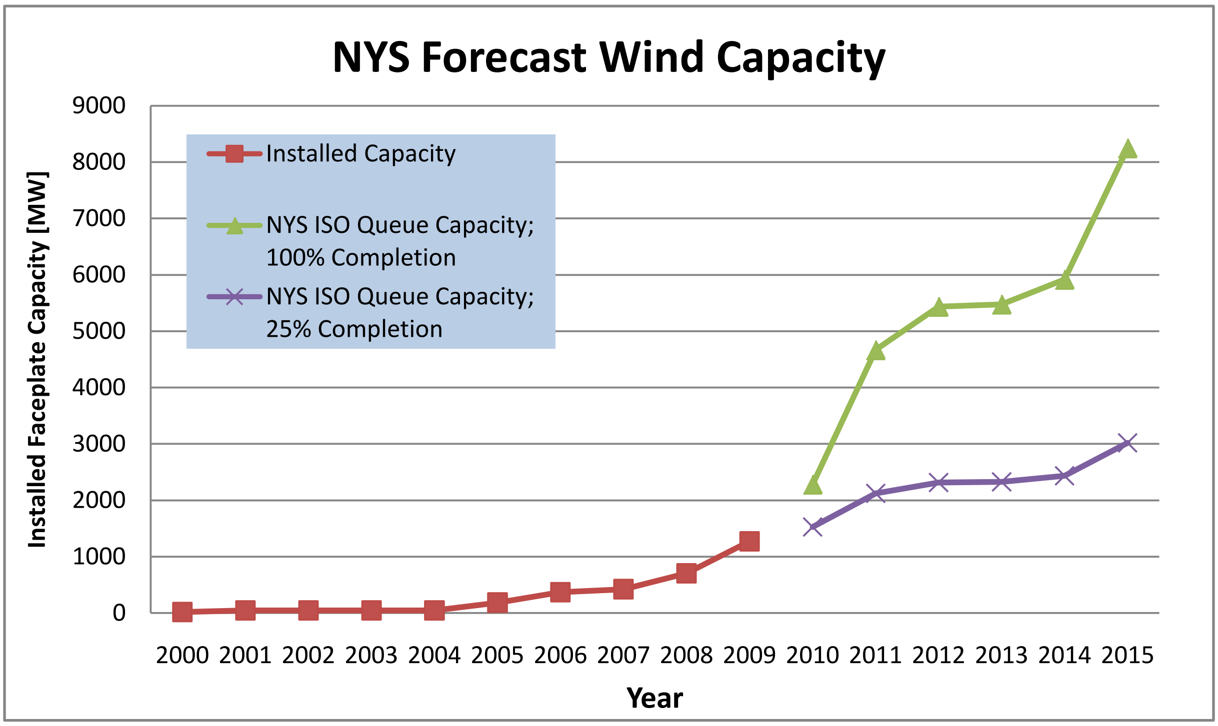


Figure 4: Conservative Growth of Wind Capacity: NYS ISO Queue Capacity vs. 25% Completion

The adoption of novel technologies often takes the form of an S-Curve. Initially adoption is slow because the technology is expensive, challenging, or exotic, but as the promise of the technology becomes more widely apparent its adoption becomes more rapid. During the rapid adoption period, the growth becomes nearly exponential until it flattens once again it is limited by demand or resources, which in the case of wind, is high wind velocity areas available to develop. New York is still very early in the growth of wind power and if funding for incentives and financing are available one may expect very rapid growth in the next ten years as shown in Figure 5. An exponential curve was best fit by the method of least squares to the wind capacity data from 2000 through 2009 and projected through 2015. This forecast compares well with a complete build out of all projects in the NY ISO queue which would give a total capacity of around 10 GW by 2015, but should be considered an upper bound.

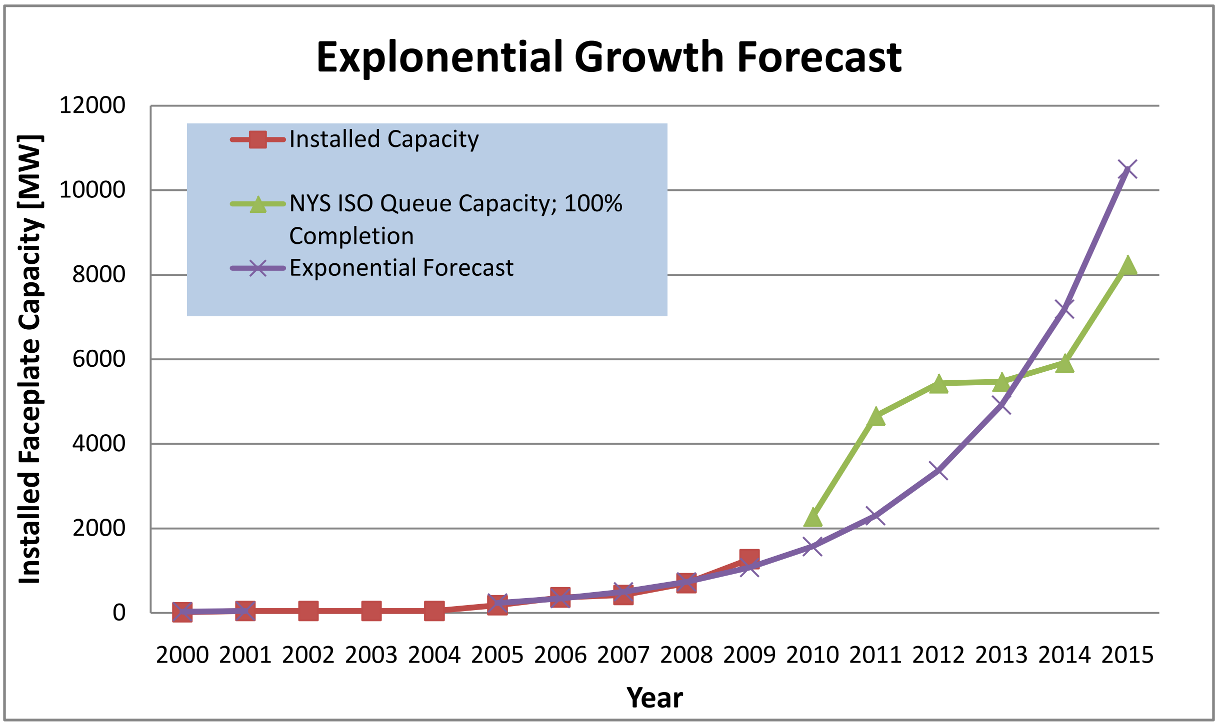


Figure 5: Exponential Growth of Wind Capacity

3.4 Progress of Other Renewables in New York State

Since the NY ISO queue contains ALL projects interested in connection to the grid, the potential for other alternative energy projects was compared with wind projects. As of March 2010, only 200MW of alternative energy projects are in the queue paling in comparison to the potential growth for wind power. These alternative projects are of four types: upgrades to existing hydroelectric plants, generators powered by methane from landfills, wood fired steam generators, and one large scale solar project (32MW).

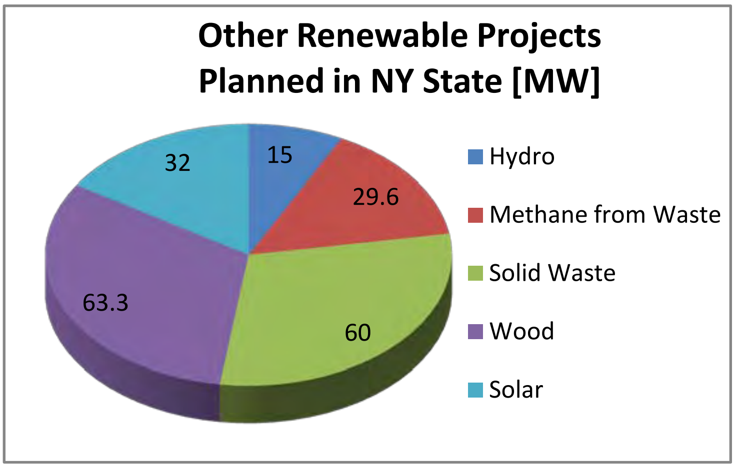


Figure 6: Other Renewable Projects Proposed for NY State

3.5 Power Demand in Tompkins County

Ithaca is the largest city in and contains the bulk of the population in Tompkins County. Tompkins County is part of the NY ISO central grid region for which detailed historical electricity demand data is available from their online database (NY ISO). Data for Tompkins Country is not directly available but was scaled from central region overall data by treating consumption as a constant per capita in the region. This assumption was used though it may not hold if there are large differences from country to county in terms of industrial power consumption. The population of all counties in the region was determined and the consumption scaled accordingly using the most recent 2000 census data. This gives a rough average Tompkins County load of 140 MW for the full year 2009. This is equivalent to 1.26 billion MW-hr/yr.

Tompkins County has a population of 102,000 and 39770 households from 2008 US census data (US Census Bureau) and an average household consumption of 5974 kW-hr/year. This leads to residential consumption in Tompkins County of 237,589 MW-hr/year, see table 19.

Based on New York state data, residential electrical usage is 40.6% of the total, commercial is 42.4% with industrial consumption the rest at 17% (Energy Information Administration, 2006). 40.2% of the total county consumption is 0.51 billion MW-hr/yr, not completely consistent with the number above. Because New York State is highly urbanized, we suspect that its average residential consumption is skewed by low consumption in urban areas. Tompkins County being relatively more rural may have higher per household consumption than the New York State average. Further the consumption split between residential, commercial, and industrial may not hold well for Tompkins County due to the unknown effect of two relatively large college campuses. These two methods of calculating residential consumption may be closer than our quick estimates here.

This load is not constant over the course of the day as shown in Figure 7. Electrical load is lowest in the early hours of the morning, when most people are sleeping, then plateaus for business hours of midday, then normally there is a minor peak between 17:00 and 20:00 when most people are returning home to eat dinner.

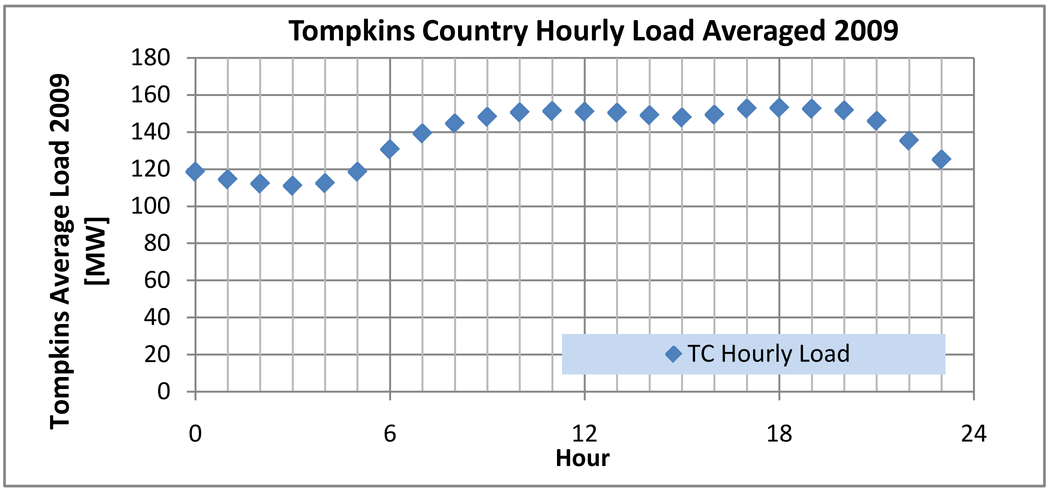


Figure 7: Tompkins County hourly load averaged for 2009

The hourly load pattern changes with the season because of changing lighting and air conditioning demands. Looking at the load over the course of the year 2009 averaged by week in Figure 8, we see that there are peaks at the hottest and coldest points of the year, mid January and mid august respectively. Year to year the exact week would most likely change but the pattern should be roughly similar.

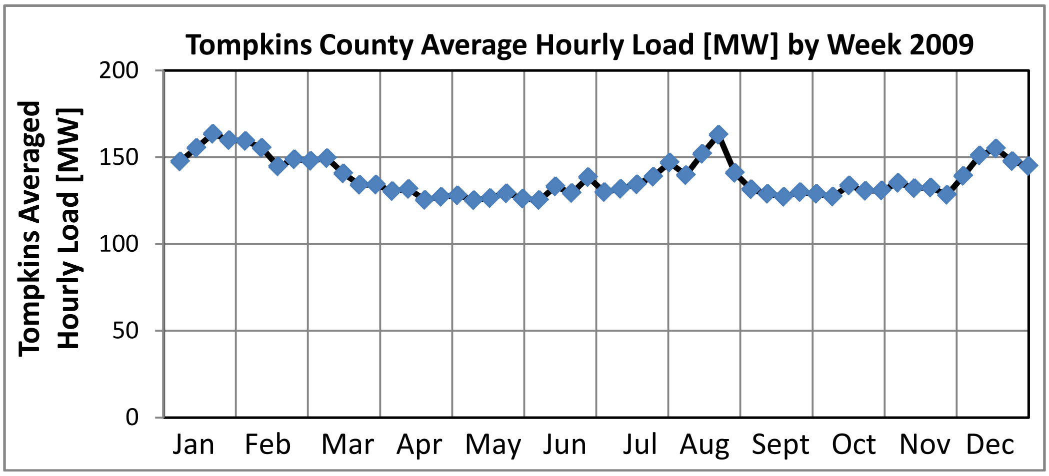


Figure 8: Tompkins County Load Averaged by Week for 2009

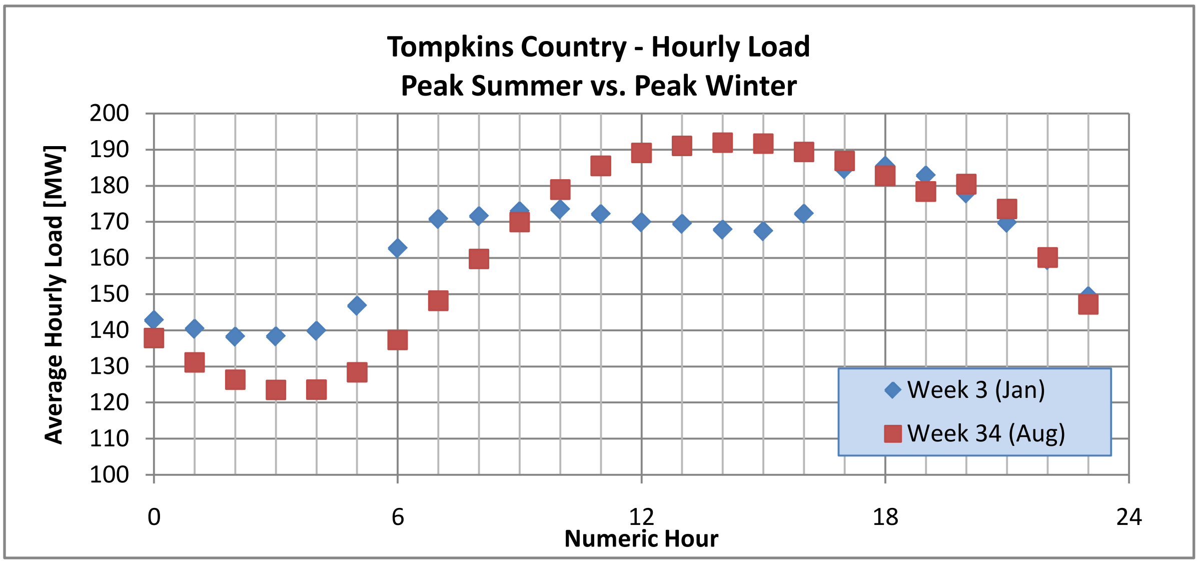


Figure 9: Peak Summer and Winter Load by Hour

As shown in Figure 9 the peak winter and summer hourly loads differ somewhat. Winter, the blue data points, is consistent with the pattern described above for the yearly average except higher due to the higher heating and lighting demands in winter. Note that electric heat is rare in New York State, but that most home heating does depend on electrical pumps or blowers. Summer, the red data points, is driven by the need for air conditioning and is sinusoidal with the peak occurring at the hottest point of the afternoon. Wind is a highly variable resource and changes not only with season but by the hour of the day.

4 New York State Future

4.1 Renewable Portfolio Standard

4.1.1 Overview

In 2004, the Renewable Portfolio Standard (RPS) was adopted with the clean energy goal of ’45 by ’15. This plan would meet 45% of the energy demand in New York State through renewable energy sources and energy efficiency by 2015. Of the 45%, 30% would come from renewable energy and 15% from energy efficiency. (NY State Energy Planning Board, 2009)

4.1.2 RPS Implementation

Energy Contributors for the RPS goal include baseline resources for the New York State, the NYSERDA administrated RPS program, Executive Order 111, the Long Island Power Authority, and the voluntary market. Mainly of these contributors also receive contributions from the New York Power Authority (NYPA). New York’s current baseline resources will cover approximately 69 % of the RPS goal and predominantly include hydropower sources as well as a few biomass facilities.

NYSERDA’s RPS program is a two-tier procurement program with both a main or large-scale generators tier and customer-sited tier. Funds for this program are obtained through a systems benefit charge (SBC) from retail electric consumers. 98% of the RPS program resources will be met through the medium to large-scale projects of the main tier; where as the remaining 2 % will be obtained through the customer-site tier. Projects included in the main tier are mainly the biomass portion of co-fired coal plants, large wind projects, and repowered hydropower plants. The customer-sited tier includes solar photo voltaic cells, fuel cells, anaerobic digesters, and small wind turbine projects.

Executive Order 111 involves a purchasing renewable energy to met 10% of the required energy demand for buildings of state agencies and entities. This order also incorporates an energy efficiency component in which these state buildings and entities will become 35 % more energy efficient based on 1990 energy demand levels.

The Long Island Power Authority (LIPA) has a Clean Energy Initiative (CEI) as well as Electric Generation efforts that will contribute to RPS goals. The CEI was a ten-year program starting in 1999 and ending in 2008, which promoted clean energy technologies and energy efficiency. It provided approximately $335 million in rebates for promoted technologies and efficiency efforts. Regarding electric generation LIPA has issued Requests for Proposals

(RFPs) for renewable energy generation credits and projects. Some of these RFPs include a 10-year supply of renewable energy and renewable energy credits in 2007, and evaluating a 350 MW offshore wind project called the New York City Offshore Wind Collaborative. LIPA is also making progress in entering a Power Purchase Agreement (PPA) for solar energy.

Finally, there is the voluntary consumer market. This involves the purchase of premium green energy by retail customers. Renewable energy credits are the prime source of voluntary consumer market transactions. It is anticipated that 4% of the RPS goal will be met through the voluntary market. (NY State Energy Planning Board, 2009) (American Wind Energy Association (AWEA), 1996-2010)

Specifically for Upstate New York, there is a wind energy option made possible by a collaboration between New York State Electric & Gas (NYSEG) and Community Energy. Fenner Wind Farm, located 40 miles south east of Syracuse, would supply 30 MW of wind energy for this option. This premium green energy source is offered in 100 kWh blocks with cost $2.50 each which would be added to a customer's regular electricity bill. Interested customers are required to purchase a minimum of 2 blocks per month, but are limited to a maximum of 6 blocks for a total upper limit of 600 kWh each month. A minimum of 200 kWh per month would offset CO2 emissions equivalent to driving 2,194 miles or planting 1 acre of trees.Purchased wind energy would be delivered to the New York power grid on behalf of the customer. (US Department of Energy, 2008) (NYSEG) (NYSEG)

4.1.3 Levelized Costs and Revenues for Wind Technology

Costs and potential revenues, while not the main determinant of which technologies will be developed further, do factor into whether or not a option will be considered. Among renewable technologies in New York, currently biomass, hydro upgrades, and landfill gas are profitable. Large-scale wind projects are the renewable energy source with the smallest price premium to be bridged among the sources with cost higher than revenue. A price premium is seen in a situation where cost is greater than revenue. The difference between cost and revenue represents the price premium for the resource to be deemed economic.

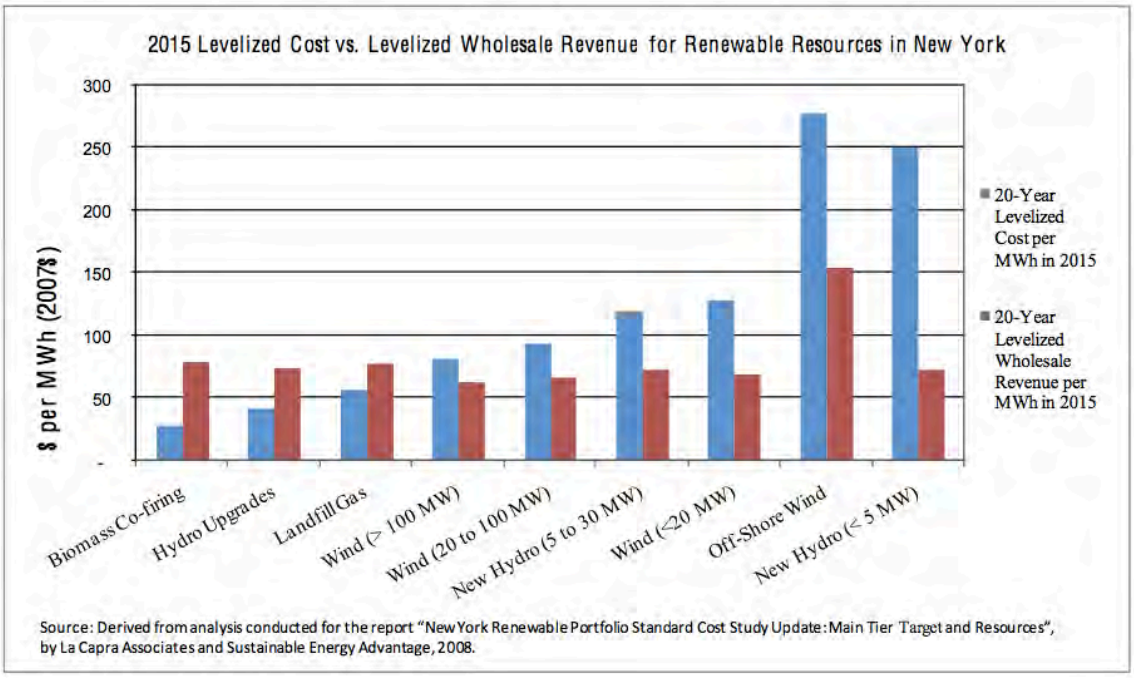


Figure 10: Levelized Wholesale Revenue for Renewable Resources in New York

In the above graph, the red bars represent revenues whereas the blue bars represent costs. Both cost and revenue have been levelized over a 20-year period per MWh. Since these projects require the smallest price premium amongst renewable sources, wind energy is expected to see significant development under the RPS Plan. It is though that this gap between cost and revenue can be bridged through incentives. (New York State Energy Planning Board, 2009)

4.1.4 Wind Energy Incentives

For wind energy, major incentives come through the federal government, although some are available at the state level through the Database of State Incentives for Renewables & Efficiency (DSIRE). (US Department of Energy, 1995-2010) Our focus will be on federal incentives, which includes two main incentives: Production Tax Credit (PTC) and Investment Tax Credit (ITC). Only one of these options can be chosen per project.

The Production Tax Credit incentive provides 2.1 cents per kWh for the first ten years of operation. This incentive was originally developed under the Energy Policy Act of 1992. Since then it has undergone a few short-term extensions with the most recent being through the American Recovery and Reinvestment Act, which extends the incentive benefits to the end of 2012. (New York State Energy Research and Development, 2010) There is also the Investment Tax Credit incentive that provides 30% of the project's qualifying costs in the form of a grant. This money is paid in the first year of operation. Like the PTC, the ITC is also available for all wind farms in service before 2013. (American Wind Energy Association (AWEA), 1996-2010)

4.1.5 Analysis of Incentive Money Expected by 2015

Currently, 7000 MW capacity of wind energy is in the pipeline to be in operation by 2015. Through our analysis, we made a conservative estimate that 25% of this capacity, equivalent to 1750 MW, will actually be available by 2015.

Using a capacity factor of 0.22, we can then convert this conservative estimate of 1750 MW to a generation amount of 385 MW per hour. We then convert this to a yearly amount by multiplying by the hours in a year to get an annual generation amount of 3,372,600 MW.

To calculate the amount gained by incentives we convert the annual generation to kilowatt-hours by multiplying by 1000. We estimated the amount to be gained from incentives by using the production tax credit and multiplying the annual generation in kilowatt-hours by 2.1 cents. This amount is then multiplied across ten years to get an amount of $708,246,000 for wind incentives for projects in the pipeline by 2015.

4.2 Current Renewable Energy Composition

Currently 21% of New York State's electricity is generated from renewable sources of energy (NY ISO, 2009). Appendix A-2 and A-3 shows the composition of the various renewable sources of energy. The table below shows the capacity and electricity generated from the various renewable sources.

Source	Capacity (MW)	*Capacity Factor	Electricity Generated (GWh)
Hydro-electricity	4,300	68%	25,874
Wind	425	34%	1,282
Others (Bio, Landfill Gas, wood)	360	95%	2,996

Table 1: Capacity and Electricity for Various Renewable Sources

* Average capacity factor of various renewable sources of energy calculated by comparing the electricity generated against the installed capacity

Hydro-Electricity is the largest source of renewable energy, which makes up 86% of the total renewable electricity generated in the state while Wind makes up only 4%. The other renewable sources such as Bio, Landfill gas and wood, account for the remaining renewable sources. Solar energy is used currently in households for domestic purposes but is not used commercially to supply electricity to New York State's Grid.

4.3 Current Wind Farms

Name	Location	Capacity (MW)
Allegany Windpark	Centerville, NY	82.5
Allegany Windpark II	Rushford, NY	18
AltonaWindpark	Altona, NY	97.5
Ball Hill Windpark	Chautauqua, NY	94.5
BellmontWindpark	Bellmont, NY	21
Bliss Windpark	Bliss and Eagle, NY	100.5
ChateaugayWindpark	Chateagay, NY	106.5
Clinton Windpark	Clinton, NY	100.5
Cohocton Wind	Cohocton, NY	125
EllenburgWindpark	Ellenburg, NY	81
FennerWindpower Project	Cazenovia, NY	30
High Sheldon Energy	Sheldon, NY	112.5
Madison Wind Farm	Madison County, NY	11.55
Maple Ridge 2005	Lewis County, NY	136.95
Maple Ridge 2006	Lewis County, NY	61.05
Maple Ridge 1A	Lewis County, NY	33
Maple Ridge II	Lewis County, NY	90.75
Munnsville	Munnsville, NY	34.5
Steel Winds I	Lackawana, NY	20
Wethersfield Windpark	Wethersfield, NY	126
Wethersfield Wind Power	Wyoming County	6.6
	TOTAL CAPACITY	**1490 MW**

Table 2: Current 21 Windfarms in New York State

Currently there are 21 wind farms built in New York State. Combined, they have a capacity of 1490 MW; however, 4 of the smaller wind farms are not operational. The non-operational wind farms are: Allegany I, Allegany II, Ball Hill, and Bellmont Wind Parks. Table 2 gives a list of these 21 wind farms.

The locations of these wind farms are strategically put in locations of high average wind speeds in order to return a high capacity factor. Below is a map of the average wind speeds in New York State and each black star represents a completed wind farm. (Figure 11)

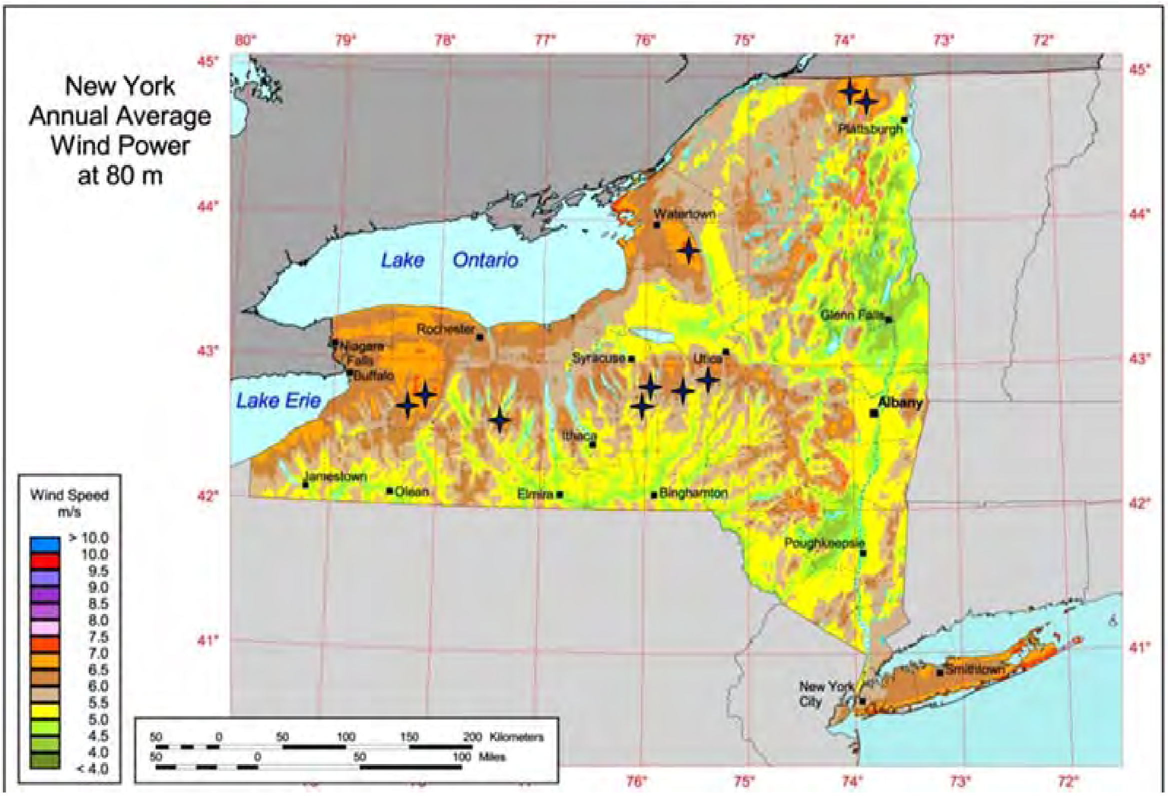


Figure 11: Wind Distribution Map with Current Wind Farms
Source: (AWS, 2007)

As is shown above, the areas of highest average wind speeds are around the Great Lakes, the Finger Lakes and on Long Island. These areas average around 6.5 m/s, which have proven to be adequate for the installation of wind turbines. There is still a large amount of available land that has great wind potential. The availability of wind in New York State and the huge energy demands of New York City mean that New York State is a great candidate for the addition of new wind farms.

4.4 Proposed Wind Farms

Determining the number of proposed wind farms and their expected capacity is quite a difficult task for a couple of reasons. There are many stages in becoming a wind farm and one must choose a specific stage in development where it is decided that a wind farm is officially 'proposed'. Also, the number of turbines at a proposed wind farm is subject to change far along in the process. Assuming that a proposed wind farm means that the necessary paperwork has been completed and the expected year of operation is 2015, a list of proposed wind farms is shown below.

Name	Location	Capacity (MW)
Adirondack Wind Park	Warren Co.	27
Allegany Project	Cattaraugus Co.	80
Howard Project	Howard, NY	63
Gateway Wind	Schenectady Co, NY	79
Rensselaer Wind	Rensselaer Co., NY	60
EcoGenPrattsburgh	Prattsburgh, NY	79.5
Steel Winds II	Lackawana, NY	18
Arkwright Summit	Arkwright, NY	79
Alabama Ledge	Genesee Co	80
Dairy Hills	Perry	80
Jericho Rise	Chateaugay, NY	79
Marble River	Clinton / Ellenburg, NY	200
Jordanville	Jordanville, NY	80
Moresville	Roxbury, NY	
Ripley Westfield	Chautauqua Co. NY	
Roaring Brook	Martinsburg, NY	78
St. Lawrence Wing	Cape Vincent, NY	136
Benton	Benton, NY	37.5
West Hill	Madison Co., NY	37.5
Plum Island	Offshore	
LI/NYC Offshore	Offshore	350/700
	TOTAL	**1994 MW**

Table 3: Proposed Wind Farms

If these wind farms are all completed, they will add 1994 MW of capacity to New York State. However, if one counts all of the wind farms that have expressed interest in becoming operational by 2015, it is possible that an extra 7000 MW of capacity will be added. Using the same map of New York State from above (Figure 11), red stars indicate the location of the proposed wind farms. (Figure 12)

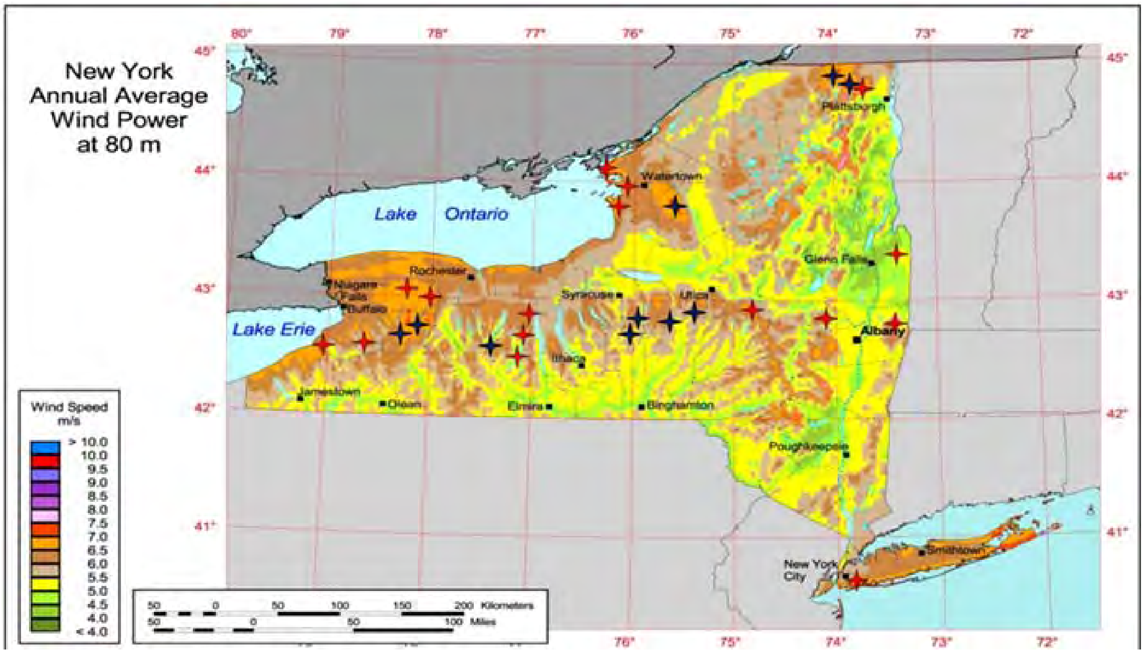


Figure 12: Proposed Wind Farms
Source: (AWS, 2007)

As expected, these wind farms are also in areas of high average wind speeds.

4.5 Forecast for 2015 Renewable Energy Including Other Sources Besides Wind

In order to accurately predict the total amount of renewable energy in New York State by 2015, a forecast for each renewable energy source is needed. Only the significant renewable energy sources are considered. They are wind, landfill gas, solar, biodiesel and wood. Based on a study conducted by NYSERDA, biodiesel should produce roughly 660 GWh of energy by 2015 (NYSERDA, 2003). Using a forecast model based on the average rate of growth over a four-year period, landfill gas should produce roughly 1970 GWh by 2015 and wood should produce 490 GWh (DOE Energy Information Administration, 2003-2007)NYSEIA has a goal of 2,000 MW of solar energy in New York State by 2020 (NYSEIA, 2010). Assuming that 30% of this goal will be met by 2015, solar should produce roughly 710 GWh. A pie chart showing the breakdown of production of all renewable sources by 2015 is displayed below. (Figure 13)

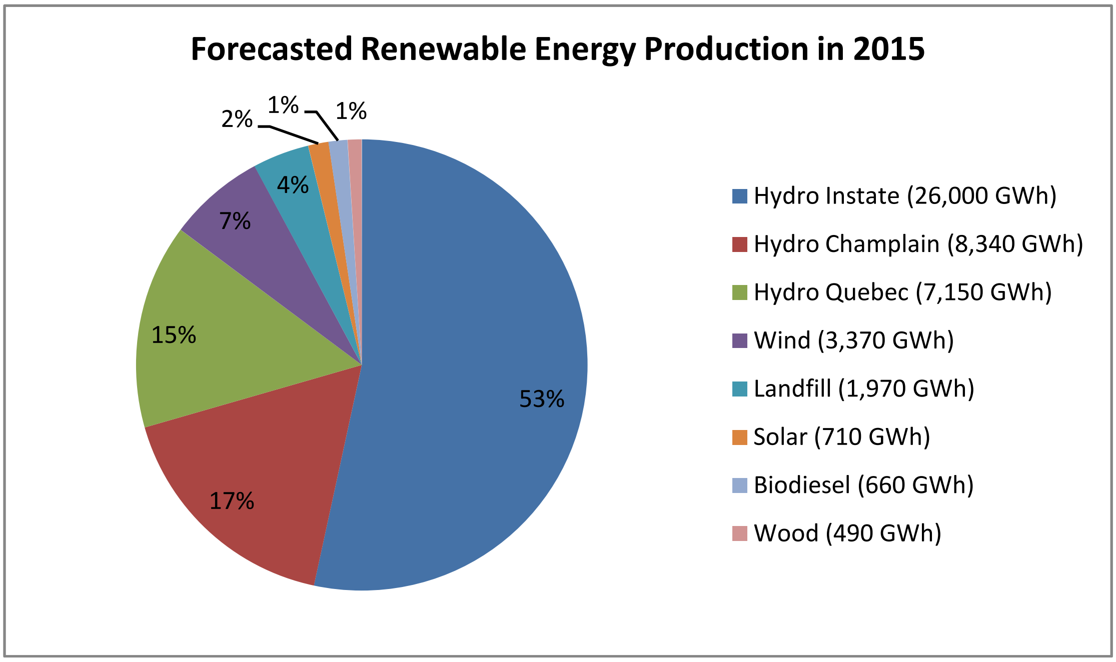


Figure 13: Forecast for Renewable Energy Production for 2015

4.6 Simulating probability of achieving RPS target

In order to determine the probability of achieving the RPS target of 30% of the electricity supply being generated from renewable sources, a Monte Carlo simulation was performed. The various renewable sources were assumed to follow various probability distributions, and the sum of the total electricity produced from these sources was compared against 30% of the projected electricity sales for 2015.

Note that there has historically been a difference of 20,000 GWh between the Electricity generated and the electricity that has been sold (NYSERDA, 2009); and in the simulation, the target is 30% of the electricity sold and not electricity generated. This is in line with the RPS calculations conducted by NYISO (NY ISO, 2009). This difference can be attributed to the losses during transmission, local consumption of electricity at the site of generation or electriticty generated privately by certain industrial units such as paper mills that do not supply electricity to the New York State grid.

4.6.1 Wind Energy Projection

Though New York State has applications for wind farms that amount to 7000MW of capacity, the approval process has been sporadic as mentioned earlier. It is assumed that 25% of the 7000MW or 1750MW of additional capacity would be operational by 2015, however there is also a chance that, federal policies shift and that all of the 7000MW get approved and become operational. Therefore, the percentage of the total wind capacity becoming operational was assumed to follow a custom probability distribution (Appendix A-4).

Percentage of projected 7000MW of Wind Capacity becoming operational by 2015	Probability
0.00	0.03
0.05	0.03
0.10	0.05
0.15	0.05
0.20	0.10
0.25	0.40
0.30	0.10
0.40	0.08
0.50	0.05
0.60	0.03
0.70	0.03
0.80	0.03
0.90	0.03
1.00	0.03

Table 4: Probability of Wind Capacity Becoming Operational by 2015

A capacity factor of 22% was assumed to convert the predicted capacity to electricity generated based on NYSERDA Annual reports 2003-2007 (DOE Energy Information Administration, 2003-2007).

4.6.2 In-State Hydro-Electricity Projection

New York State currently uses all of its available Hydro-Electricity. Therefore, the simulation assumes that the total hydro electricity produced in state will be more or less the total electricity that is produced today. The simulation considers the instate hydro-electricity generation to be a normal distribution (Appendix A-5).

Normal Distribution	
Mean	26,000.00
Std. Dev.	500.00

4.6.3 Hydro-Quebec Import Projection

Hydro-Quebec is a government-owned utility conglomerate of 60 hydroelectric plants located in Quebec, Canada. These plants have a total production capacity of 36,810MW of installed capacity. Hydro-Quebec typically sells part of its surplus electricity to the US through long-term contracts with neighboring states. With 22% of its 2009 profits coming from US exports, Hydro-Quebec has a strong interest in maintaining and increasing its export capabilities. (Hydro-Queubec Annual Report, 2009) This includes investment in a new export-focused generation plant on the La Romaine River and the installation of an additional 1200MW transmission line.

1099 GWh/year of hydro-electricity is currently imported from Quebec, Canada.. The transmission cap for 2010 is fixed at 1200 GWh/year though there is a capacity for a maximum of 1600 GWh/year. The simulation conservatively assumes that the import from Quebec will not change much at 2010 and assigns a normal distribution to the total electricity imported from Hydro-Quebec (Appendix A-6).

Normal Distribution	
Mean	1,099.00
Std. Dev.	120.00

Table 5: Normal Distribution of Total Electricity Imported from Hydro Quebec

4.6.4 Champlain Hudson Power Express Project

Critical to meeting the Renewable Portfolio Standard goal for renewable energy is the Champlain Hudson Power Express Project. This project would transfer 2000 MW of renewable energy, in the form of mainly hydropower and some wind energy, from Canada into New York and Connecticut. It is a transmission project which uses a High Voltage direct current (HVdc) cable that is 5 inches in diameter. The transmission line would stretch from the U.S.-Canadian border to New York and parts of Southern New England. It would be placed underground and in waterways to preserve natural views and pose minimal impact on the environment. If this project is completed it would be one of the largest investments in New York State history at a cost of $3.8 billion. (Transmission Developers Inc., 2010)

Figure 14: Champlain Hudson Power Express Proposed Transmission Route
Source: (Transmission Developers Inc., 2010)

The project is scheduled to be operational by 2015. Given the uncertainty, the simulation assumes a custom distribution with a 60% probability that the project is operational and contributes 1400MW of capacity to New York State and a 40% probability that the project fails to come online (Appendix A-7).

Custom Probability Distribution	
Value	**Probability**
0.00 MW	0.40
1,400.00 MW	0.60

Table 6: Projected scenarios for the Champlain Hudson Output

4.6.5 Solar Energy Projection

Though solar energy is not used to supply electricity to the New York State Electrcity grid (Energy Information Administration (EIA), 2007), it is projected to generate as much as 710 GWh in 2015 (NYSEIA, 2010). In the simulation, the electricity generated from solar energy is assumed to be normally distributed (Appendix A-8).

Normal Distribution	
Mean	709.56 GWh
Std. Dev.	150.00 GWh

Table 7: Electricity generated from Solar Energy

4.6.6 Other renewable sources

Output from other renewable sources such as landfill, biodiesel and wood is not expected to grow significantly and the model conservatively assumes the electricity generated to be the same as it is generated currently. The simulation assumes that the electricity generation from these sources to be normally distributed (Appendix A-9, A-10 and A-11).

4.6.6.1 Landfill Gas

Normal Distribution	
Mean	1,970
Std. Dev.	197

Table 8: Electricity generated from Landfill Gas

4.6.6.2 Biodiesel

Normal Distribution	
Mean	657.00
Std. Dev.	65.70

Table 9: Electricity generated from Biodiesel

4.6.6.3 Wood

Normal Distribution	
Mean	490.00
Std. Dev.	50.00

Table 10: Electricity generated from Wood

4.6.7 Simulation Results

The cumulative probability distribution below generated from 2000 trials of the Monte Carlo simulation using Oracle Crystall Ball, shows that there is a 65% probability that the RPS target is met and a 45% chance that New York State falls short of its target.

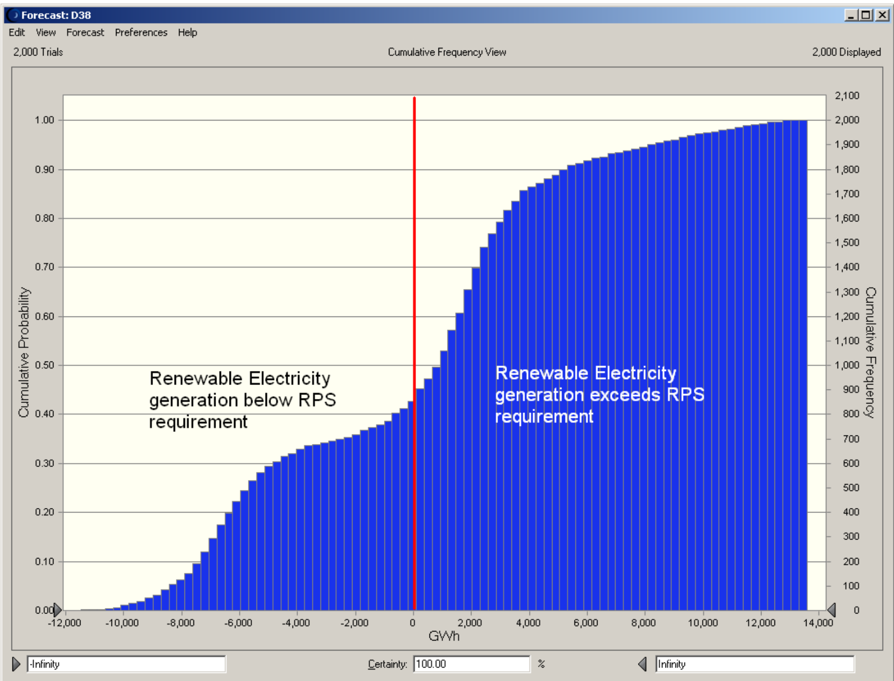


Figure 15: CDF Showing Probability of Achieving RPS Target

4.6.8 Sensitivity Analysis

Given that there is some uncertainty about the achievement of the RPS target, a sensitivity analysis was conducted on the simulation model using the sensitivity tool available in Oracle Crystall Ball.

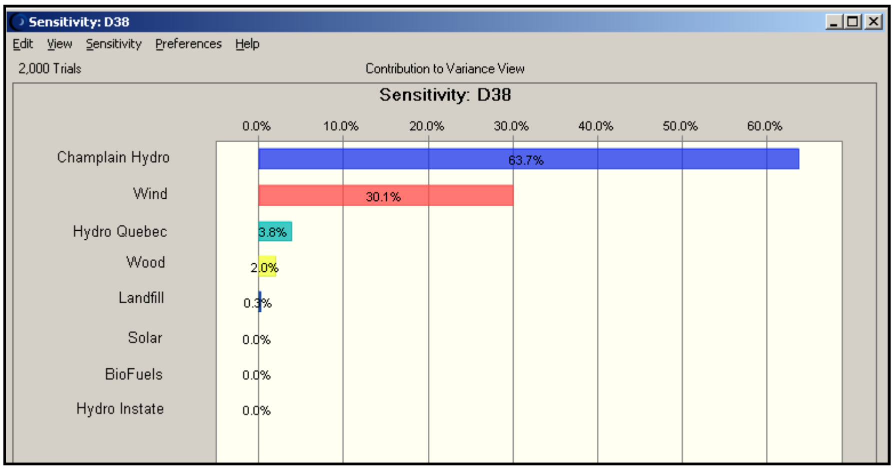


Figure 16: Sensitivity Analysis of RPS Simulation

The Pareto view above, ranks the importance of the various sources of renewable electricity and illustrates their impact on electricity generation.From the sensitivity output, the following are the findings;

1. The analysis shows that the Champlain Hudson Project impacts the realization of the RPS target as much as 63% or in other words, the Champlain project varies the amount of the total electricity generated in 2015 as much as 63%. Therefore, the Champlain Project is critical to meeting the RPS goal
2. The Growth of Wind Energy has a 30% impact on the total electricity generated in 2015.
3. The impact of the other sources, do not really impact the attainment of the RPS target.

Therefore, Wind plays an important role in New York State's Future Electricity. Another point to note is that, in the event that in 2015, New York State fails to meet the RPS target, the RPS is not considered a failure if significant improvements with regards to dependence on renewable sources of electricity are made.

4.7 Offshore Wind Energy

4.7.1 Overview

The development of offshore wind energy has taken place almost exclusively in European waters since the early 1990s. More than 800 wind turbines spin off the coasts of Denmark, Britain and seven other European countries totaling 2063 MW of installed capacity. In 2009, 582 MW of offshore wind were installed in the European Union, up 56% on the previous year, and it is expected that another 1,000 MW offshore wind will be installed in 2010. By 2020, the EU predicts offshore wind energy capacity will reach 40,000 MW. The success of offshore wind energy in Europe has become a model that many countries outside the EU are trying to replicate. For example, in China, the first offshore wind farm, a 102 MW venture near Shanghai, is expected to come online in May 2010. (AWS Truewind, 2010)

Despite significant efforts to develop offshore wind project in the North America, there are no projects in operation. However, America's first offshore wind project looks very promising as U.S. Secretary of the Interior Ken Salazar approved the construction of the Cape Wind project off the coast of Massachusetts on April 28, 2010. In addition to the Cape Wind project, British Columbia, Delaware, New York, Ohio, Ontario, Rhode Island, and Texas are working to develop offshore wind energy.

New York's most prominent offshore wind project is being developed by the Long Island-New York City Offshore Wind Collaborative. The project is only in its planning stage but construction is expected to take place between 2014 and 2016. The next section of this report provides an overview of this project and the available turbine technologies, foundation designs and costs for offshore wind development.

4.7.2 Long Island - New York City Offshore Wind Collaborative

The Long Island-New York City Offshore Wind Collaborative is a coalition of utilities, State and New York City agencies seeking to obtain power from an offshore wind energy facility in the Atlantic Ocean off of Rockaway Peninsula, Long Island. The Collaborative has determined the offshore wind facility would have an initial capacity of up to 350 MW as filed with the New York Independent System Operator. Depending on the success of this initial phase, the Collaborative may consider another project increment to bring the total project to 700 MW. A 350 MW wind facility operating at 30% capacity factor would generate about 920,000 MWh per year, enough energy for over 250,000 homes. (Collaborative, 2009)

4.7.3 Advantages of an Offshore Wind Facility

Offshore wind power appears to be one of the most favorable renewable resources that could provide a significant amount of clean energy to consumers in NYC and LI. While the initial investment required of an offshore wind energy project is approximately twice as much per megawatt than for a land based project, offshore wind provides various advantages over land based wind. First, a New York City - Long Island area wind project warrants an offshore location due to the sheer size and number of wind turbines necessary to supply a substantial amount of cost effective, clean energy. Second, the proximity of an offshore facility in comparison to remote land based locations helps reduce transmission losses in delivering energy to NYC. Third, offshore wind generally gets stronger, more consistently available than land based wind. Unlike land-based wind which tends to drop off during the hottest part of a summer day, which is precisely the time that Con Edison and LIPA customers use the most electric, offshore wind generally get stronger. Therefore, the offshore facility's power output will be strategic in supplying NYC's electricity load.

4.7.3.1.1 Location and Site Specs

As shown in the map below, the proposed location for the offshore project is located 13 miles off of Long Island's Rockaway Peninsula and encompasses a total area of 57 square nautical miles (196 sq km). The annual average wind speed for this site is approximately 8.5 m/s at 90 m and the water depths range between 18m and 37m (60-120 ft). (Collaborative, 2009)

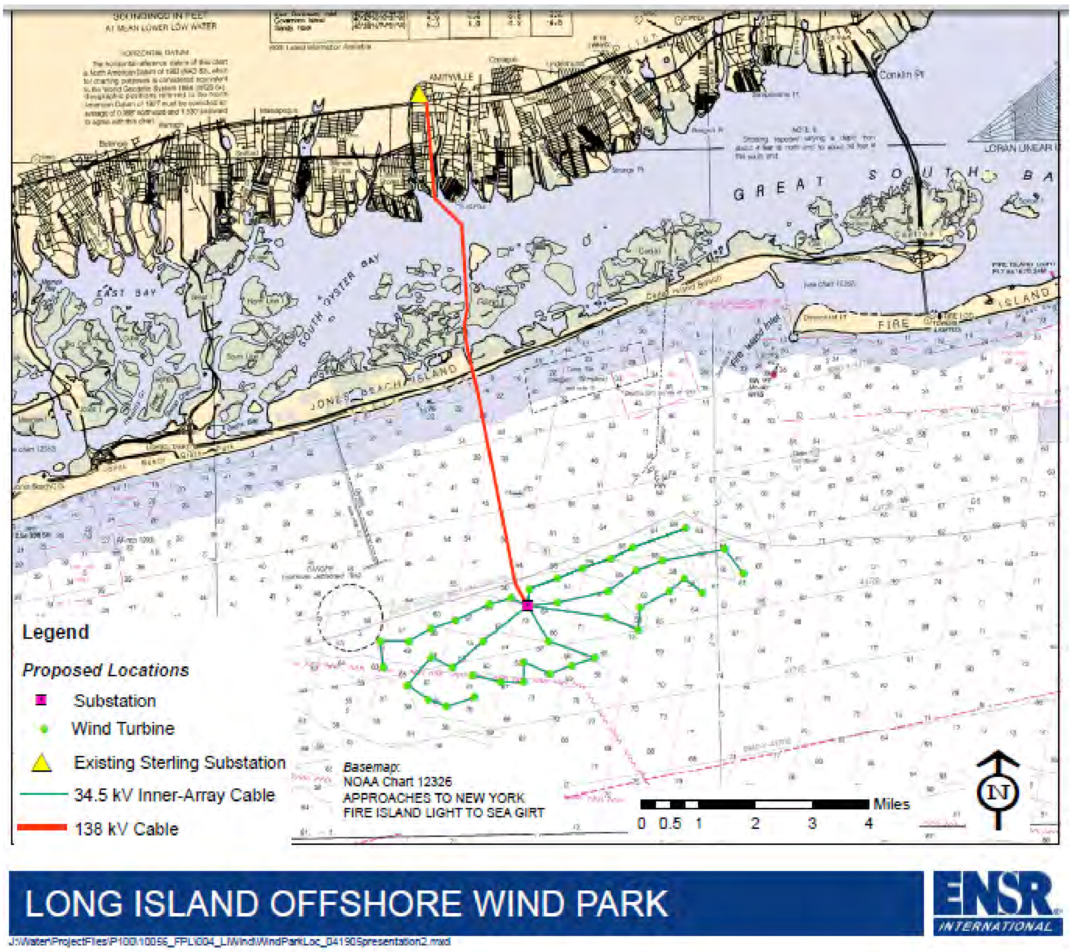


Figure 17: Long Island Offshore Wind Park
Source: (Collaborative, 2009)

The Collaborative will have to account for various factors in designing the layout of the wind park. The design of the park layout should aim to minimize turbine flow disturbances as well any environmental or aesthetic impacts that may affect existing use of this area such as vessel traffic, air space usage, etc. To minimize the turbulence or wakes created by wind turbines, the distance between turbines aligned in rows should be at least five to ten rotor diameters, and spacing between rows should be between seven and twelve rotor diameters. (Truewind, Offshore Wind Technology Overview (For the Long Island - New York City Offshore Wind Collaborative), 2009)

The power generated from each turbine will be collected at an offshore substation; from where it will be transferred using high voltage submarine lines back to shore. The offshore substation is sized with the appropriate power rating for the project capacity, and steps the line voltage up from the collection system voltage to a higher voltage level, which is usually that of the point of interconnection. This allows for all the power generated by the farm to flow back to the mainland on higher voltage lines, which minimizes the electrical line loss and increases the overall electrical efficiency.

Transmission lines back to shore are specified at an appropriate voltage and power rating. The size of these cables is dependent on the project's capacity and the amount of power that will be transmitted to the shore, as shown in the table below. As you can see, the initial 350MW project will require at least 345 kV line voltage.

Project Size	Minimum Line Voltage (AC)
35 MW	69 kV
70 MW	35 kV
135 MW	115 kV
160 MW	138 kV
210 MW	161 kV
300 MW	230 kV
1000 MW	345 kV
2000 MW	500 kV

Table 11: Required Line Voltage for Various Project Sizes
Source: (Truewind, Offshore Wind Technology Overview (For the Long Island - New York City Offshore Wind Collaborative), 2009)

High voltage underwater transmission cabling is an important design and contracting consideration during the offshore wind development process. The specialized installation vessels are relatively rare, costly and in high demand. These factors contribute to an installed cost for underwater transmission of around two to three times more than an equivalent voltage on land transmission.

The onshore interconnection points supply power to the Long Island Power Authority (LIPA) and Con Edison transmission systems. The initial 350 MW power installation is optimal for simplicity and cost as the existing station in Northern Queens combined with a connection to the LIPA transmission system in the Rockaways would suffice for this project size. The expansion of the project to 700 MW would require additional investments to increase the electrical capacity of the Con Edison and LIPA transmissions systems near Eastern Queens.

4.7.4 Offshore Wind Turbine Technology

Early offshore installations consisted of wind turbines primarily under 1 MW, which was the common turbine size for land based projects at the time. Vestas and Siemens, the most prominent offshore wind turbine suppliers, were the first suppliers to offer offshore technology in 2000 and 2003, respectively. To date, Vestas' V80 2 MW and V90 3 MW models have been installed predominantly throughout Europe, as have Siemens' 2.3 MW and 3.6 MW models. (Truewind, Offshore Wind Technology Overview (For the Long Island - New York City Offshore Wind Collaborative), 2009) In recent years, BARD Engineering, Multibrid, and REpower have begun manufacturing offshore turbine with rating up to 5 MW with 90 meter or greater hub height. These turbines have been designed more specifically for offshore applications, as exhibited by their greater rated capacity and offshore-specific design features such as enhanced corrosion protection and climate control systems for the nacelle and other sensitive components.

4.7.5 Foundations

One of the primary drivers of a project's overall cost is the level of sophistication in a project's foundation technology. The design of a project's foundation technology is a function of various factors including maximum wind speed, water depth, wave heights, currents, and soil properties. While the industry has historically relied primarily on monopile and gravity-based foundations, the increasing number of planned projects in deeper water has motivated research and pilot installations for more complex multimember designs with broader bases and larger footprints, such as jackets, tripods, and tripiles, to accommodate water depths exceeding 20 to 30 meters. Much of the deep water technology used for wind projects has been adopted from the offshore oil and gas industry. Based on the water depths (18-37 m) and wave conditions of the proposed offshore Long Island project area, it is likely that one of these multi-member larger footprint designs will be selected.

4.7.5.1 Shallow Water Foundations (Monopile Foundation & Gravity Base)

The monopile is the most common foundation type due to its lower cost, simplicity, and appropriateness for shallow waters less than twenty meters. The design is a long hollow steel pole that extends from below the seabed to the base of the turbine. Generally, this technology does not require any preparation of the seabed and is installed by drilling or driving the structure into the ocean floor to depths up to forty meters.

An alternative to the monopile foundation is the gravity base foundation. While in the past the gravity foundation has been used in water depths primarily up to fifteen meters; it is now being installed at depths of up to 30 meters. This technology relies on a wide footprint and massive weight to counter the forces exerted on the turbine from the wind and waves. These structures can weigh over 7,000 tons. The gravity foundation rests on top of the ocean floor; therefore it often requires significant site preparation including dredging, filling, leveling, and scour protection. These structures are constructed almost entirely on shore of welded steel and concrete. The countrsuction is a relatively economical process, and once complete, the structures are floated out to the site, sunk, and filled with ballast to increase their resistance to the environmental loads.

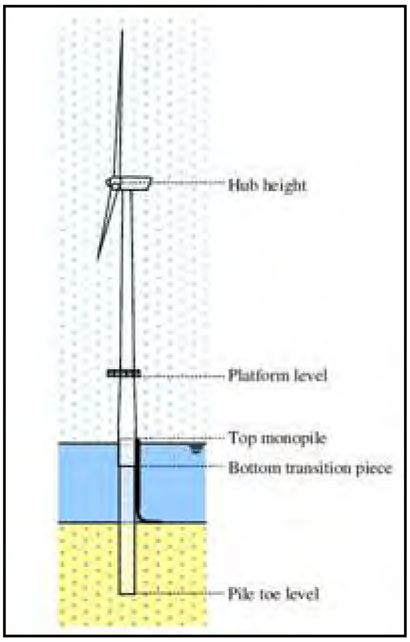


Figure 18: Monopile Foundation & Gravity Base Foundation
Source: (Truewind, Offshore Wind Technology Overview (For the Long Island - New York City Offshore Wind Collaborative), 2009)

4.7.5.2 Jacket, Tripod and Tripile Foundations

The jacket foundation is an application of designs commonly employed by the oil and gas industry for offshore structures. The four-sided, A-shaped truss-like lattice can support a five megawatt wind turbines in water depths over forty meters. The legs of the jacket are set on the seabed and a pile is driven in at each of the four feet to secure the structure. This foundation has a wider cross-section than the monopile, strengthening it against momentary loads from the wind and waves. Once manufacturing and deployment practices can be scaled up to economically meet the needs of large projects, these foundations will likely become the predominant deeper water foundation type.

For deep water installations, the tripod foundation adapts the monopile design by expanding its footprint. The three legs of the structure support a central cylindrical section that connects to the wind turbine's base. Like the jacket foundation, the legs are pinned to the seabed with piles to secure the structure. Tripod foundations are relatively complex and time consuming to manufacture, and also are more massive than jackets.

The tripile foundation is adaption of the monopole foundation that replaces the single pole with three piles that are driven into the seabed. They are connected just above the water's surface to a transition piece at the tower's base. The increased strength and wider footprint created by the three piles is expected to allow for turbine installation in water up to fifty meters in depth. The triple design is easily adaptable to a variety of bottom - type conditions, as each of the piles can be manufactured appropriately to match site - specific conditions.

Figure 19: Jacket, Tripod and Tripile Foundations
Source: (Truewind, Offshore Wind Technology Overview (For the Long Island - New York City Offshore Wind Collaborative), 2009)

4.7.5.3 Suction Bucket Alternative to Piles

Suction bucket foundations could be applied to any of the foundation types previously described as an alternative to driving piles deep into the seabed. While a significant failure occurred with this technology in 2007, further research is being conducted to improve this technology. Rather than driving the narrow piles into the seabed, bucket foundations employ a wider based cylinder that is vacuum-suctioned into position under the seabed. Depending on soil conditions encountered at a site, the suction bucket alternative may be preferable to deep, slender piles for economic reasons and for ease of installation.

4.7.5.4 Floating Offshore Wind Technology

Floating offshore wind power is not a mature technology yet, and the economic feasibility is not completely understood in comparison with shallow-water offshore wind technologies. For deepwater wind turbines, a floating structure needs to provide enough buoyancy to support the weight of the turbine and to restrain pitch, roll and heave motions caused by waves and wind. The world's first deep-water floating turbine was installed in the North Seas, 10 km off of Norway. This 2.3 MW turbine is 65 meters high and supports rotors 80 meters in diameter. The 5,300 ton structure floats 220 meters above the ocean floor and is attached to the seabed by a three-point mooring spread. The project was inaugurated in the summer of 2009 and the total project costs were approximately $62M. The turbine is expected to produce 9 GWh of electricity annually. (NewTechnologyMagazine, 2009)

Figure 20: Hywind Floating Turbine
Source: (NewTechnologyMagazine, 2009)

4.7.6 Offshore Project Costs

Offshore wind energy projects cost approximately twice as much per megawatt than land-based projects. The costs of an offshore project can be expected to be in the range of $3.4 to $5.8 million per megawatt (i.e. Mean of $4.6 million per MW ± 26%). (AWS Truewind, 2010) This range of expected investment requirements for an offshore project is based on the total project costs published for twenty five projects, eighteen of which have been commissioned or under construction in Europe or China, and seven projects which are due to be commissioned between 2010 and 2012. (See A-12) Based on this data, the total investment costs for a 350 MW offshore wind project for Long Island - New York City can be expected to range between $1.2B and $2B.

The major factors that drive the cost for offshore projects above land-based project are caused by the greater investments required for offshore turbine foundations, advanced installation processes, specialized turbine equipment, and higher developments costs associated with project planning. The figure below shows the percentage breakdown of the costs for offshore and onshore projects. As you can see, turbines make up a much smaller percentage of the overall cost for an offshore project compared to an onshore project.

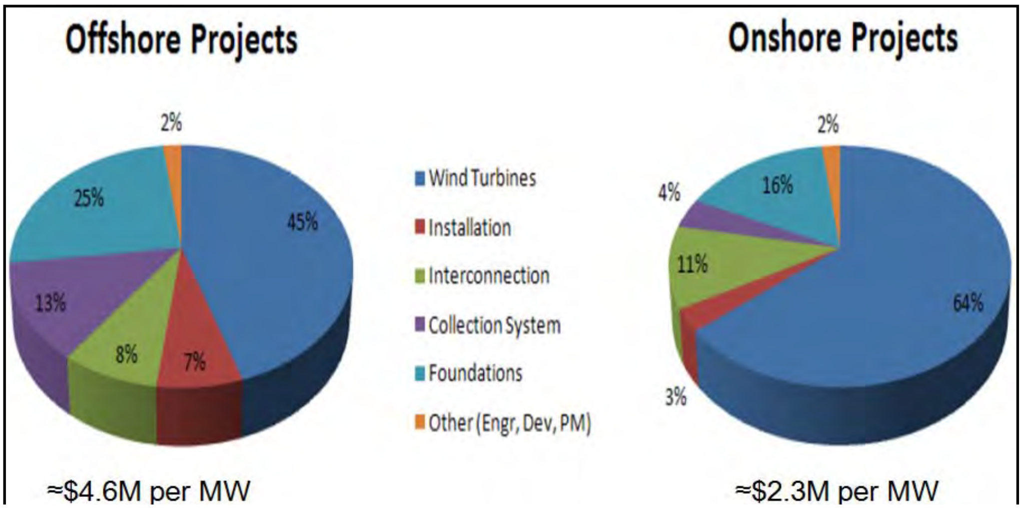


Figure 21: Offshore and Onshore Percentage Cost Breakdown
Source: (AWS Truewind, 2010)

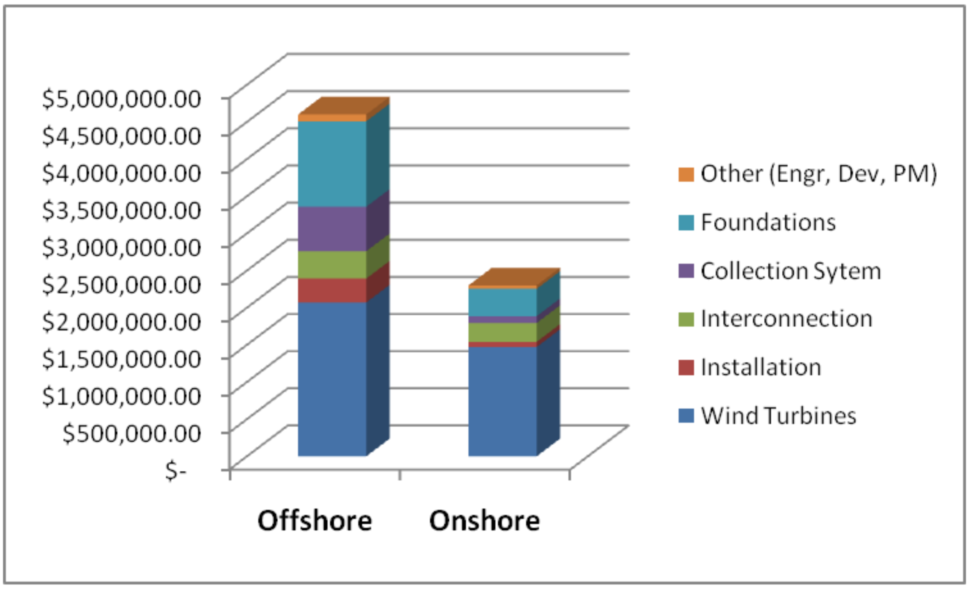


Figure 22: Offshore and Onshore Cost Breakdown
Source: (AWS Truewind, 2010)

4.7.7 Potential for Wind Power Development of the Great Lakes Region

The Great Lakes offer great potential for development with their high and consistent wind velocities. The NY Power Authority has published a Great Lake offshore site study which accounts for a large number of factors (bird migration, shipping lanes, water depth, visual impact, grid connection, etc.) in optimizing the possible locations for future wind farms. This report claims that there is a potential capacity of 1950 to 3900 MW in Lake Erie, and 1575 to 3170 MW capacity in Lake Ontario in the areas A-J indicated in the figure in Appendix A-13 (Truewind, Great Lakes Offshore Wind Power Project, 2010) The available area within the borders of New York State (dashed line) in Lake Ontario is significantly larger than Lake Erie, but the depth of the lake is deeper making offshore construction more difficult. For comparison, Lake Erie has an average depth of 19m, while Lake Ontario has a depth of 86m. If deep water construction techniques or floating and moored turbines became available, Lake Ontario's capacity would be substantially larger. Currently NYPA is seeking, through a commercial request for proposals, industrial partners for a 120-500MW farm in Lake Erie. (Truewind, Great Lakes Offshore Wind Power Project, 2010)

5 Enfield Case Study

5.1 Overview

The following case study is on Enfield Wind Company's proposed Black Oak Wind Farm in the Town of Enfield, NY. The developer, John Rancich, has proposed a farm with about 20 tri-bladed wind turbines at an operational rating of 2.5 MW each and has suggested that the site would operate at an average of 35-50 MW aggregate output, sufficient for the residential needs of the entire Tompkins County, NY. These assumptions, as well as the cost dynamics are examined in subsequent portions of this report. To date the project is in the capping stages of planning, with real estate having been secured, and with a three-year history of on-site meteorological studies. Since 2006, an independent contract engineer has been collecting wind data at 40m, 50m, and 58.2m elevation at ten-minute intervals. The first year data from that pool has been made available to us for the purpose of analysis. The project is anticipated to have a net cost of about $120 Million privately and publicly raised funds, and would be complete with a "substation, collection system, pad-mounted transformers and compacted gravel service road, on a project area spread over 925 acres (Henbest, 2008)." We examine all nominal power and cost figures in this case study.

There has been mixed reactions from the community leading to the passing of a local wind regulation ordinance in early 2009 known as The Town of Enfield Wind Energy Facilities Law. The overall tone of the law is against the proliferation of wind farms, and reflects the strong communal opposition that the proposal has faced. Black Oak Wind Farm is particularly illustrative of typical socio-demographic, meteorological, technological and economic parameters of Wind Energy realization in New York State. This study, however, primarily examines the economic feasibility of Black Oak Wind Farm, and uses statistical, conventional economic and financial analyses as tools to that end. Construction is planned to begin in 2010, barring the approval of town administration.

Choice of site: Black Oak Wind Farm in Enfield, NY is a relatively high wind velocity location, with a consistent direction of blow. These two qualities are usually highly correlated with high electricity output from a wind turbine. In addition, there are no intervening natural or man-made structures to disrupt the pattern of wind-flow. The real estate is not particularly expensive as the location is neither residential nor near a business district and also because the climatic pattern on the Enfield peak is not conducive to serious commercial agriculture. Finally, as is typical of most wind farms, Black Oak is located near a high-volt transmission line. In this case, this is particularly convenient because the transmission line has a capacity of 115kV and does not need to be expanded to cater for Black Oak's output once it goes online. Below is a wind resource map for the proposed turbine locations, courtesy of Enfield Wind.

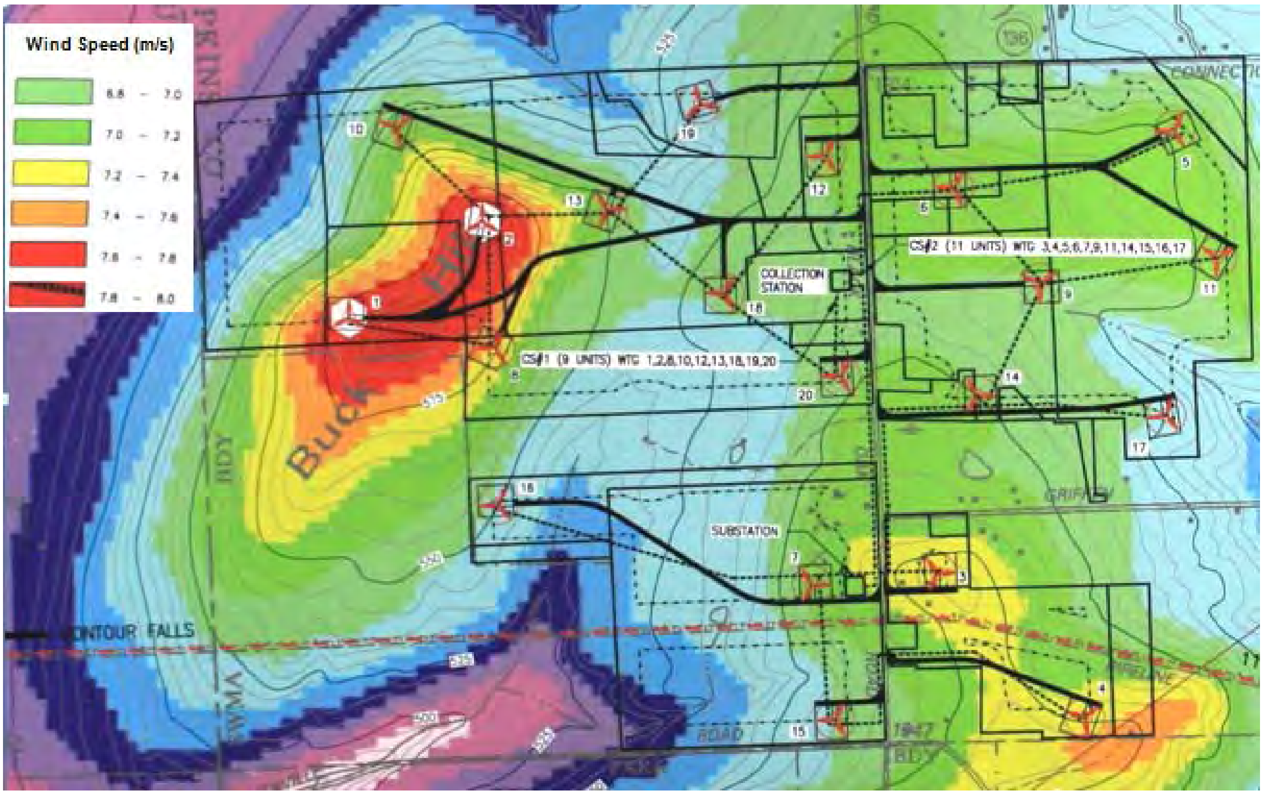


Figure 23: Wind Resource Map of Enfield Town at Black Oak Wind Farm.

The shown wind speeds are at 80m, which is the proposed hub-height for the turbines. Most turbines will be located in the green, open plateau area where the wind speed varies around 6 and 7 m/s. It goes up to 8m/s for the area between peaks of Buck Hill. The red "stars" in Figure 23 show the proposed turbine locations. The meteorological tower at the Enfield site was commissioned in November 2006. Its structure includes a total of six anemometers, two each at the heights 40m, 50m and 58.2m. It also includes a temperature sensor, voltmeter and two wind vanes at 39m and 57m respectively.

5.2 The Approach to Analysis

The following figure summarizes the approach of our analysis:

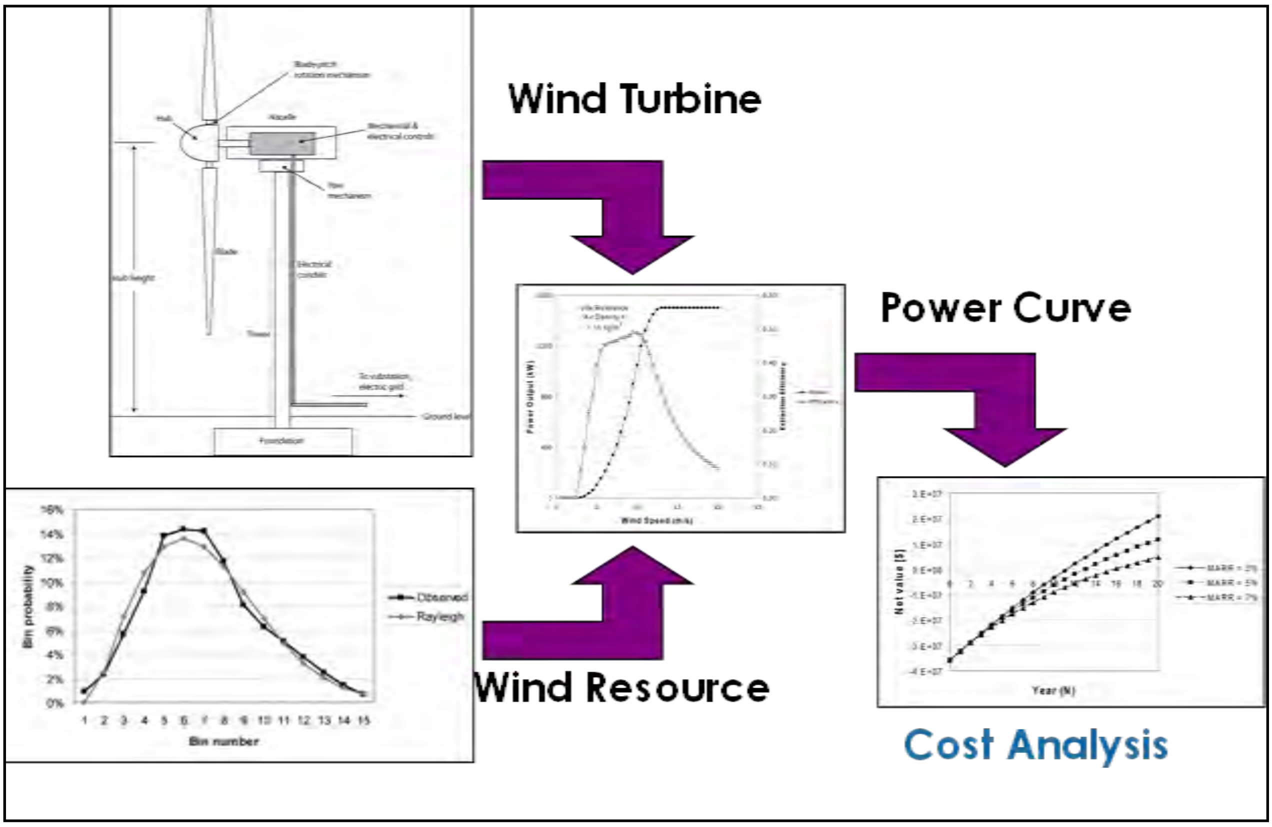


Figure 24: The Approach to Analysis
Adapted from: (Vanek, 2010)

Firstly, the data for the pair of anemometers was scrutinized and compared for errors or large discrepancies. The data was further validated by deleting outliers and comparing the distribution of the data to that of a typical wind speed distribution as predicted by the Weibull Distribution. After verifying the data, it was evaluated to determine the average wind speeds at the different heights and a linear extrapolation was done to determine the expected wind speed at the proposed turbine hub height of 80m. The wind resources available were then fitted to a typical 2.5 MW power curve and the expected power output and corresponding capacity factor was estimated. The expected power output was used to conduct an investment analysis on the proposed investment using the Net Present Value method and the levelized cost of the investment was determined. These were then used to evaluate the feasibility of the proposed project. The following sections provide additional details for each of the steps of the analysis.

5.3 Data Validation

As mentioned in the opening section of this case study, we were supplied with Black OakFarm's raw wind dynamics measurements for the given year. Before pursuing statistical analysis of the data we examined its validity. Validation was a two step process; first an outlier analysis to determine the conformity of the measurements to known upper bounds for

Enfield Town's wind profile and then, more rigorously, an examination of the consistency within the measurements (since there was built-in redundancy in the data). These two procedures and their results follow.

5.3.1 Outlier Analysis

We assumed an upper-bound for wind speeds in Enfield Town of below 40m/s, based on the State's climatic pattern. We then compared the highest speed measurements in our year's worth of data with this asymptotic value. The table below shows the upper wind speed measurements for each of Black Oak's meteorological tower's six anemometers. As can be seen, the highest measured speed of 33.23 m/s is within the assumed bounds and suggests the absence of systematic scaling errors. Furthermore, the general agreement of these simultaneous measurements further validates the data. This "agreement of measurements" is examined in more depth in the next section.

Anemometer 1	Anemometer 2	Anemometer 3	Anemometer 4	Anemometer 5	Anemometer 6
Top Five Wind Speeds	Top Five Wind Speeds	Top Five Wind Speeds	Top Five Wind Speeds	Top Five Wind Speeds	Top Five Wind Speeds
32.1 m/s	**32.88 m/s**	**32.88 m/s**	**32.44 m/s**	**32.88 m/s**	**33.23 m/s**
31.75 m/s	31.75 m/s	31.33 m/s	32.1 m/s	30.92 m/s	31.33 m/s
29.38 m/s	29.78 m/s	29.78 m/s	30.59 m/s	28.68 m/s	30.59 m/s
29.38 m/s	29.78 m/s	29.38 m/s	30.18 m/s	28.3 m/s	27.93 m/s
28.68 m/s	29.38 m/s	29.07 m/s	29.38 m/s	27.12 m/s	27.48 m/s

Table 12: Highest measured wind speeds from Enfield Wind

5.3.2 Redundancy Analysis

As mentioned earlier, Enfield Wind erected a meteorological tower with, among other instruments, two cup-anemometers at each of heights of 40m, 50m and 58.2m to form a twice-redundant speed data collection system. Nominally, the speed measurements should be identical for any given instance of sampling. In reality, instrument precision limits will lead to differences beyond certain significant levels. Assuming anemometers are redundant, that is they are of the same accuracy and precision, there should be minimal difference between the annual average difference and the instantaneous difference in measurement across each pair. This section examines this assumption.

Differences in measurement were normalized by the average of the absolute differences for that height for the entire data set. Stated mathematically:

$$\Delta = \frac{(A_1 - A_2)}{\sum \frac{|A_1 - A_2|}{n}}$$

Equation 1: Normalized difference in instantaneous wind speed measurements for an anemometer pair. A_i= Speed Reading on Anemometer i, n= sample size=52,181.

As indicated in the caption $\mathbf{A_1 - A_2}$ is the difference in the instantaneous velocity measurement for each of the coupled anemometer at a given height, and **n** is the total number of instantaneous measurements (n = 52,181). Using this relation for differences arising from just noise, the normalized difference,Δ, should be mostly about -1 and 1, and should have a random polarity meaning that neither of the anemometers is consistently upwardly biased with respect to the other. The expected distribution around unity is because instantaneous variation should be approximately equal to the average absolute variation for the year, ignoring polarity. The table below summarizes the results from this analysis.

Overall Difference Statistics

$\Delta= \frac{(A_1-A_2)}{\sum\frac{\lvert A_1-A_2\rvert}{n}}$ at 58.2m	$\Delta= \frac{(A_3-A_4)}{\sum\frac{\lvert A_3-A_4\rvert}{n}}$ at 50m	$\Delta= \frac{(A_5-A_6)}{\sum\frac{\lvert A_5-A_6\rvert}{n}}$ at 40m
Max	**Max**	**Max**
56.636	44.804	26.318
Standard Dev	**Standard Dev**	**Standard Dev**
3.219308	2.055242	2.314397
Min	**Min**	**Min**
-35.617	-53.729	-57.342
Expected (if no bias)	**Expected (if no bias)**	**Expected (if no bias)**
±1	±1	±1
Normalization Divisors= Mean of Absolute Differences = $\sum\frac{\lvert A_i-A_{i+1}\rvert}{n}$		
0.2274	0.2219	0.1976
No. of Outliers (> 2 standard deviations of normalized differences)		
509 out of 52,181	635 out of 52,181	609 out of 52,181

Figure 25: Summary Statistics for Evaluation of Redundancy of Data

Analysis shows that at height 58.2m most significant variation occurs at isolated periods within the first half of the year. The variation in the second half is more consistent, and is generally within a positive standard deviation from the mean variation. As noted in the figure above, there are 509 outliers but all of these fall within just 14, mostly consecutive days. This implies some data disrupting event occurred in the period spanned by the deviant days, but was subsequently resolved.

For heights 50m and 40m respective, there were 635 and 609 outliers, virtually dispersed across the entire year. The most significant variation occurred at isolated periods within the first half of the year. The variation in the second half is more consistent, and is on average within a positive standard deviation from the mean variation. This suggests more systematic sources of variation than with the anemometer pair at 58.2m elevation.

General Conclusion: The problematic data sets represent less than 1% of the data. Since subsequent analysis mainly employed averages, we considered it not worthwhile to remove the data pairs with outlying differences. Aggregation of measurements, through taking the arithmetic means of each pair of readings, and then, for the most part, condensing the entire stream of data into a few discrete averages effectively mutes abnormal differences. The data therefore can be regarded as true to the wind pattern and therefore useful for further analysis.

5.3.3 Weibull Distribution

In this section, we model the wind speeds at the Enfield wind farm with the Weibull distribution.

The Weibull distribution, named after the Swedish physicist W. Weibull, who applied it when studying material strength in tension and fatigue in the 1930s, provides a close approximation to the probability laws of many natural phenomena. In our analysis, it has been chosen to represent wind speed distributions for wind resource modeling due to its great flexibility and simplicity. Besides, it can give a better fit to wind speed measurement than the Rayleigh distribution, which uses one parameter to determine its shape rather than two. The following figures show the comparison the Weibull distribution and the Rayleigh distribution to the observed wind speed distribution at three different heights. It is seen that the Weibull distribution is closer to the observed distribution at each height using bin increments of 0.5 m/s.

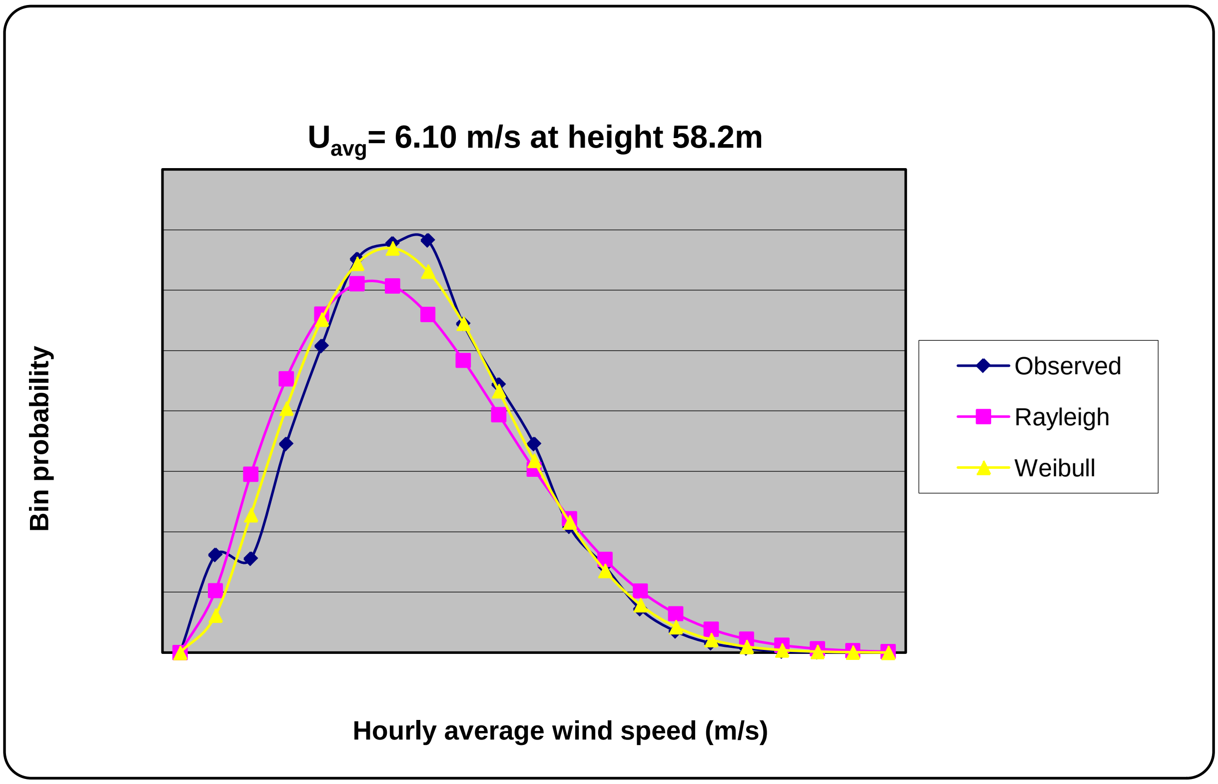


Figure 26: Comparison of the Wind Speed Distribution at 58.2m

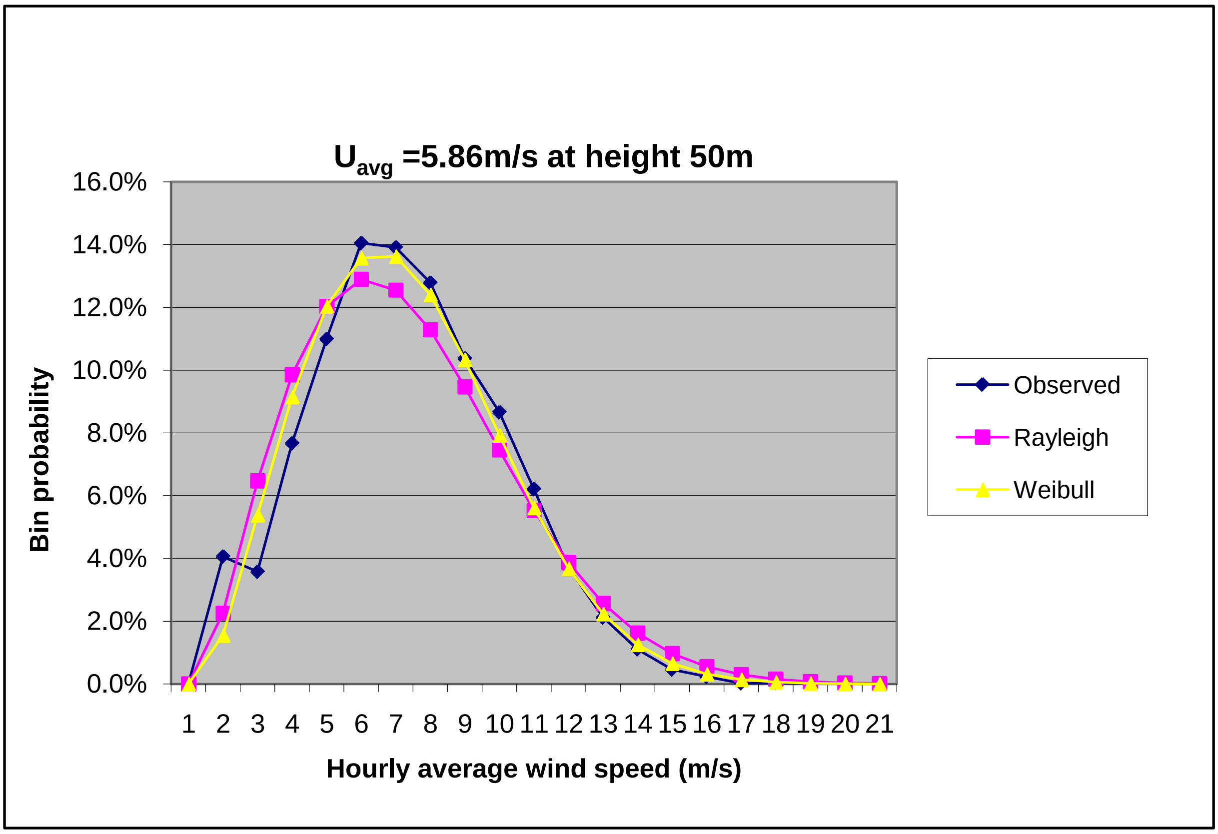


Figure 27: Comparison of the Wind Speed Distribution at 50m

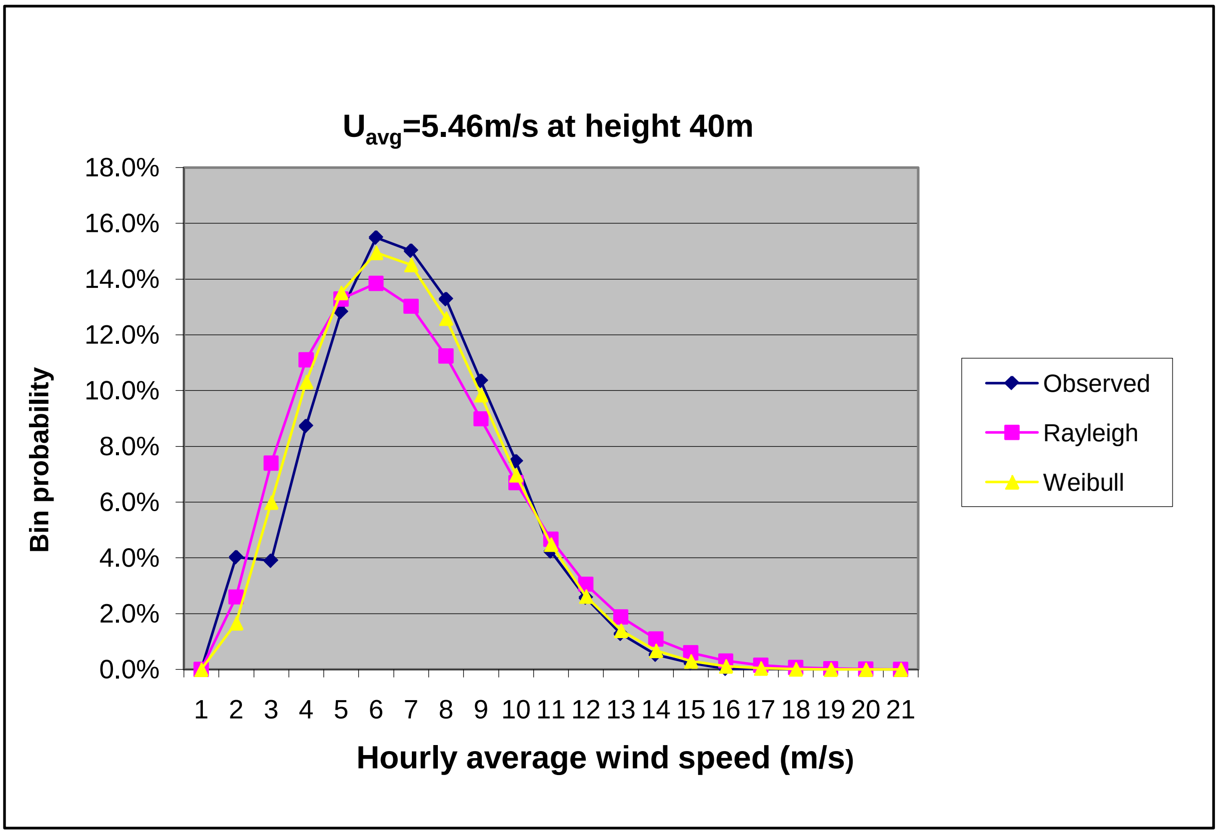


Figure 28: Comparison of the Wind Speed Distribution at 40m

The probability density function for the two parameters Weibull distribution function can be expressed mathematically as

$$f(x) = 0, \text{ for } x < 0$$

$$f(x) = \left(\frac{k}{c}\right) \cdot \left(\frac{c}{x}\right)^{k-1} \cdot \exp\left[-\left(\frac{x}{c}\right)^{k}\right], \text{ for } x \geq 0, k > 0, b > 0 \quad (1)$$

Where;

x ≥ 0 is the hourly average wind speed (m/s)

k > 0 is a shape parameter

c > 0 is a scale parameter (m/s)

The corresponding cumulative distribution function for the two parameter Weibull distribution is

$$F(x) = 0, \text{ for } x < 0$$

$$F(x) = 1 - \exp\left[-\left(\frac{x}{c}\right)^{k}\right], \text{ for } x \geq 0 \quad (2)$$

5.3.3.1 Parameter estimation

In our analysis, we used both analytical and graphical methods to estimate the parameters of the Weibull distribution.

Analytical method

There is a close relation between the average wind speed and the two Weibull parameters k (shape parameter) and c (scale parameter). The relationship can be expressed as the following experimental equations (Jang & Lee, 1997):

$$k = (\sigma / U_{avg})^{-1.068} \quad (3)$$

$$c = U_{avg} / \Gamma(1+1/k) \quad (4)$$

Where;

U_{avg} is the mean of annual average wind speed

σ is the standard deviation of annual average wind speed

Γ is the Gamma function

By applying Eq.(3) and (4), we obtained the two parameters of Weibull distribution at three heights. The mean wind speed and the standard deviation of wind speed are calculated from the wind speed measurements. The result shows in the table below.

Height (m)	*Uavge* (m/s)	σ	Shape parameter k	Scale parameter c
40	5.47	2.57	2.24	6.18
50	5.82	2.75	2.23	6.57
58.2	6.10	2.84	2.26	6.89

Table 13: Estimation of Weibull Parameters with Analytical Method

Please see Appendix A-14 for more details on the Weibull distribution such as a graphical method for the parameter estimation, performance analysis and power output estimation.

5.4 Wind Pattern Characterization

This section presents the seasonal, monthly and daily variations in the wind data.

5.4.1 Annual Pattern

The supplied wind speed data starts with the first observations in November 2006. Plots of a 20-day moving average over the course of the year show that the wind has two distinct speed phases; a higher average in winter and a lower one in the summer. There is a difference of about 2 m/s between the seasonal averages. Plots at each height are depicted in Figure 29, Figure 30 and Figure 31. They all show the same underlying pattern.

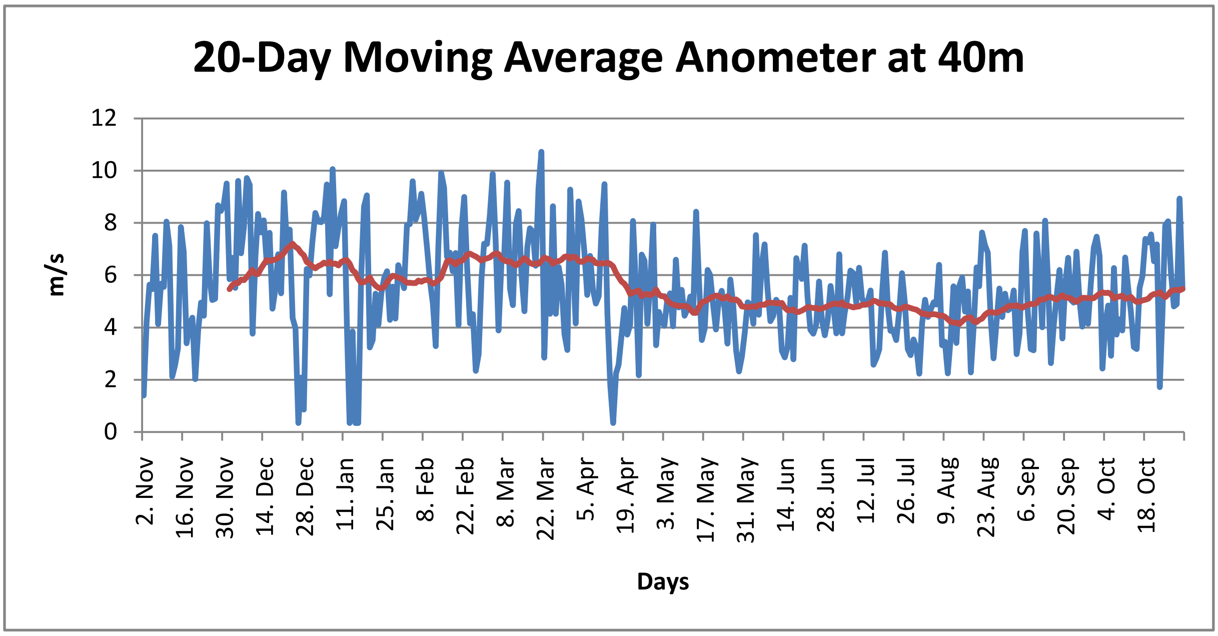


Figure 29: Daily Average Wind Speeds at 40m

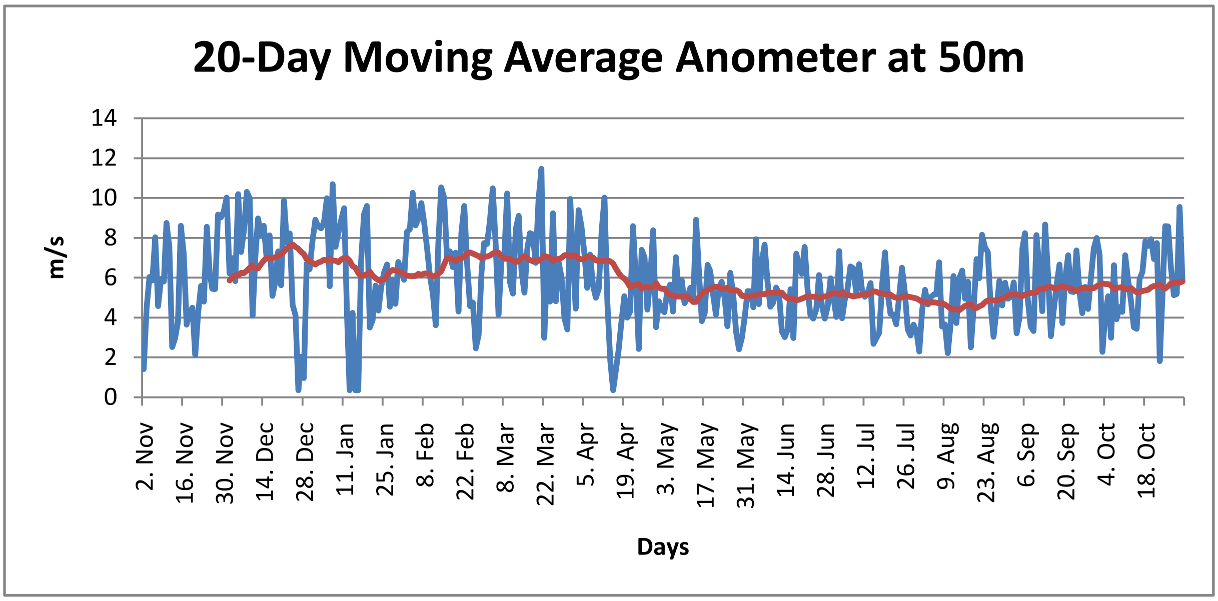


Figure 30: Daily Average Wind Speeds at 50m

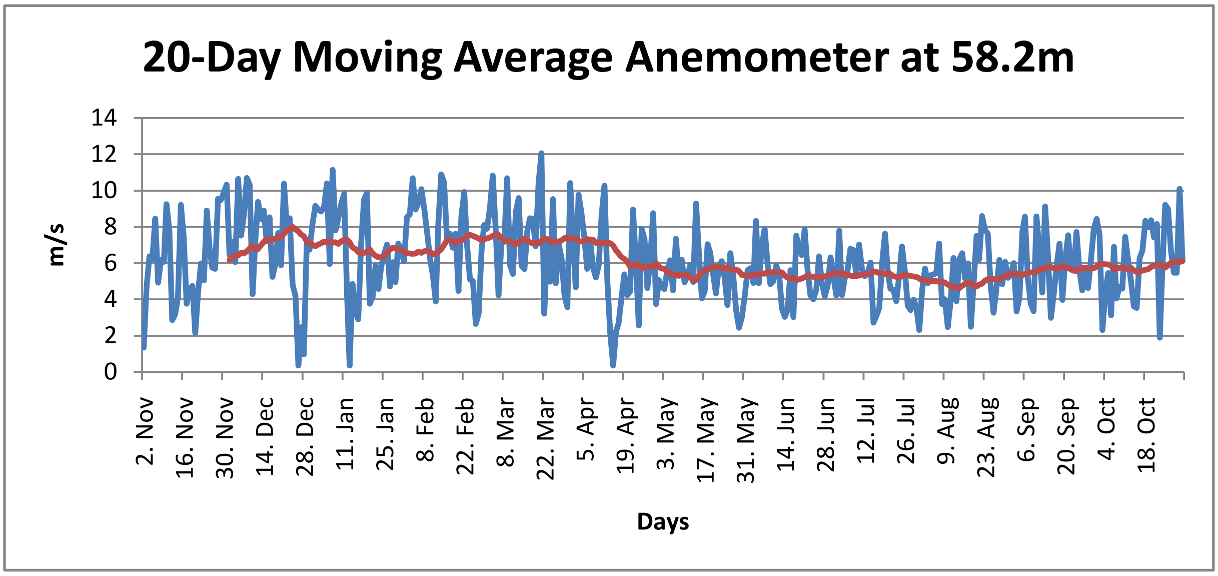


Figure 31: Daily Average Wind Speeds at 58.2m

5.4.2 Diurnal Wind Speed Variation

Another analysis was conducted for the wind-speed variation at the various heights across the day. Figure 32 below presents the variation at 58.2m for different yearly quarters, and is representative of the wind variation across the three heights. The quarters chosen were nominal; January-March, April-June, July-September and October-December.

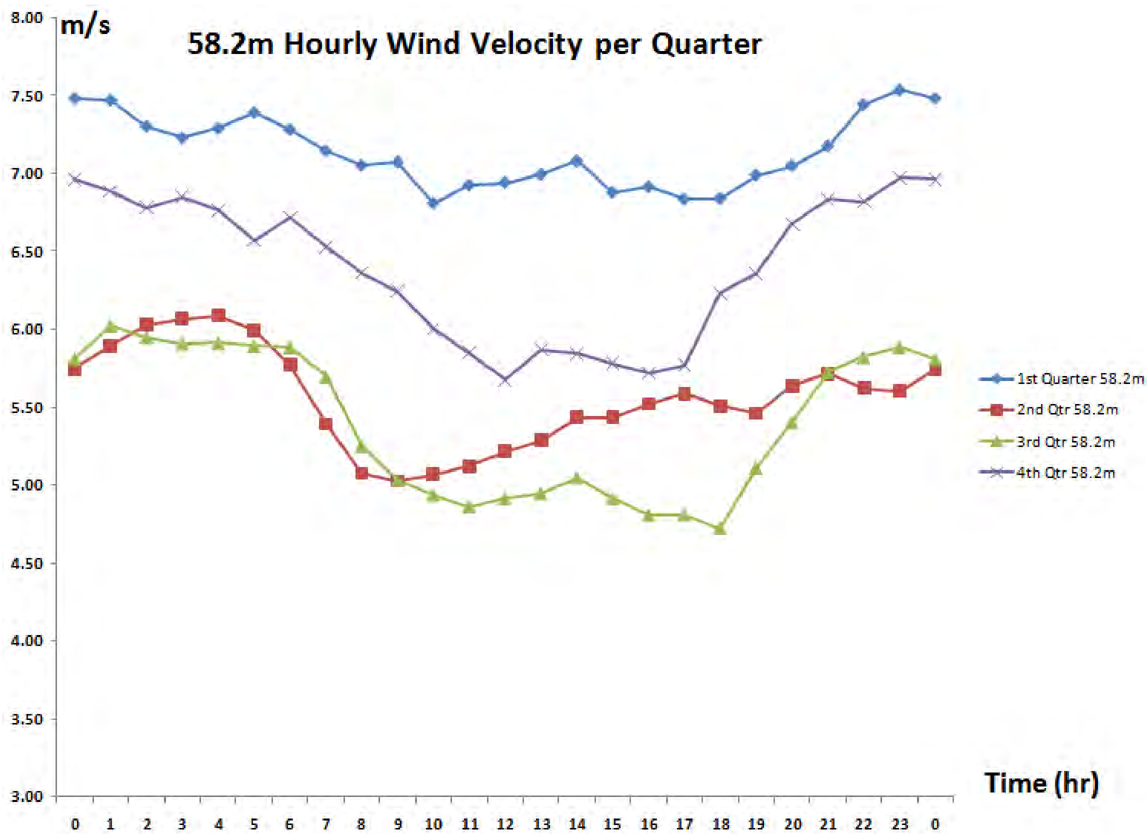


Figure 32: Hourly Wind Speed Variation, for Different Annual Quarters.

Figure 32 above shows that the highest speeds are experienced in the 1st and 4th quarters, corresponding to winter months. The dip is in the 2nd and 3rd quarters, roughly summer. This corroborates the moving average across the year in the preceding section. Of note in this plot is that the wind speeds are consistently lower during the day and pick up at night. This distribution depends on a particular site, and for Black Oak Wind Farm this implies wind-supply will be out of phase with electricity demand cycles. Further exploration of this occurs in the economic analysis sections

Figure 33 below is another portrait of the diurnal speed variation, showing measured hourly averages for wind speed across the year for the different heights. The speeds increase with height, as has been established from theory.

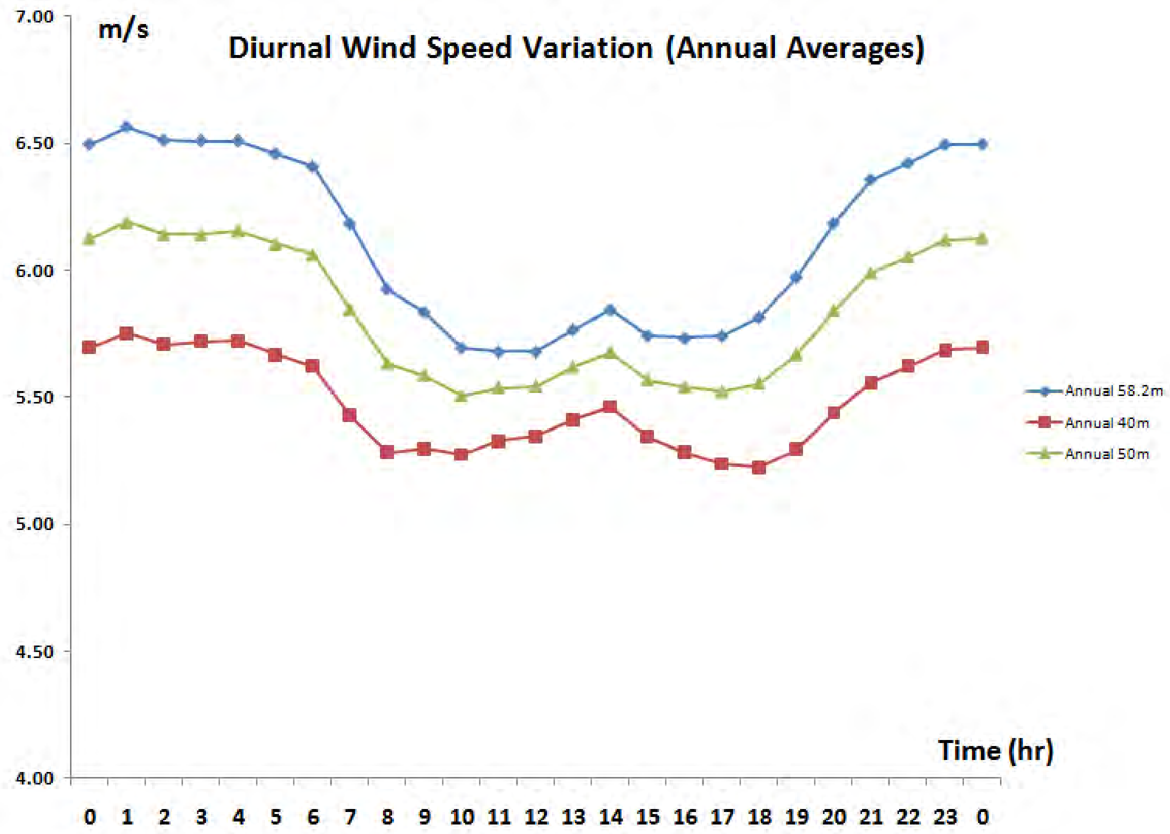


Figure 33: Hourly Measured Wind Speed Averages at the Three Different Heights Across the Year.

5.4.3 Wind Speed Variation by Height

As mentioned above, Enfield Wind measured wind speeds on a meteorological tower with two anemometers at each of the heights 40m, 50m and 58.2m. Please see Appendix A-15 for the different wind-speed bins. The following table condenses the average wind speeds at the corresponding heights.

Anemometer	Height (m)	Annual Avg. Wind Speed (m/s)
1 & 2	40	5.48
3 & 4	50	5.82
5 & 6	58.2	6.11

Table 14: Average Annual Wind Speeds at Different Heights

Enfield Wind's choice of the height sequence for data collection was an economical one. The height planned for the turbine installation, also known as the hub height, is 80m instead of 40m, 50m or 58.2m. The wind speed was not measured at 80m and was therefore estimated from the log-law relation depicted in Equation 2.

$$U(z) = U(z_r) * \left(\frac{z}{z_r} \right)^{\alpha}$$

Equation 2: Log Law relation for wind speed. U(z) = projected wind speed at height z, U(zr)= windspeed at reference height zr, U(zr) = reference wind speed and the site parameter α = wind shear factor.

The log-law has proved to be statistically robust. The wind shear factor, α, for open flat-lands with no intervening structures has been determined to be 0.2 (Vanek & Albright, Energy Systems Engineering: Evaluation and Implementation, 2008, p. 344). Even though Black Oak Farm is not completely flat, we have assumed an α-value of 0.2 as an approximation for the calculation of the average speed from measured values at 58.2m to 80m. The table below presents a more complete summary.

Anemometer	Height (m)	Annual Avg. Wind Speed (m/s)	Avg. Wind Speed (mph)
1 & 2	40	5.48	12.25
3 & 4	50	5.82	13.02
5 & 6	58.2	6.11	13.66
α = 0.2	80 (Hub Height)	6.51	14.56

Table 15: Wind Speed Extrapolation

5.5 Power Calculation

5.5.1 Power Curve

For the purpose of our calculations, we chose the N90HS Nordex wind turbine which has a typical power curve and a rated power output of 2.5 MW (see Table 16). This nominal output corresponds to what Enfield is going to install. This output will be generated at a nominal wind speed of 13m/s which is 29.1 mph. Most commercial wind-farms to date have featured wind turbines at 1.5MW rated output. However, the 2.5 MW turbines feature new and advanced technologies which include increased durability, offer higher energy capture due to the increased rotor size, and have advanced control features to help mitigate the increased loads of the larger rotor. More recently wind farms have opted for the 2.5 MW turbines. GE already has successfully tested a 2.5-MW prototype wind turbine, which was installed in May 2004 at Wieringermeer, the Netherlands, about 50 kilometers north of Amsterdam (GE Energy, 2005). In the US, Klondike, a wind farm in Oregon, will include a total of 338 - 2.5MW turbines in 2011 and 2012 (General Electric, GE, 2009).

Wind turbine data N90HS	
Nominal power	2500 kW
Rotor diameter	90 m
Rotor blade type	LM 43.8P, NR45
Nominal wind speed	approx. 13 m/s
Cut out wind speed	25 m/s

Table 16: Wind Turbine Data

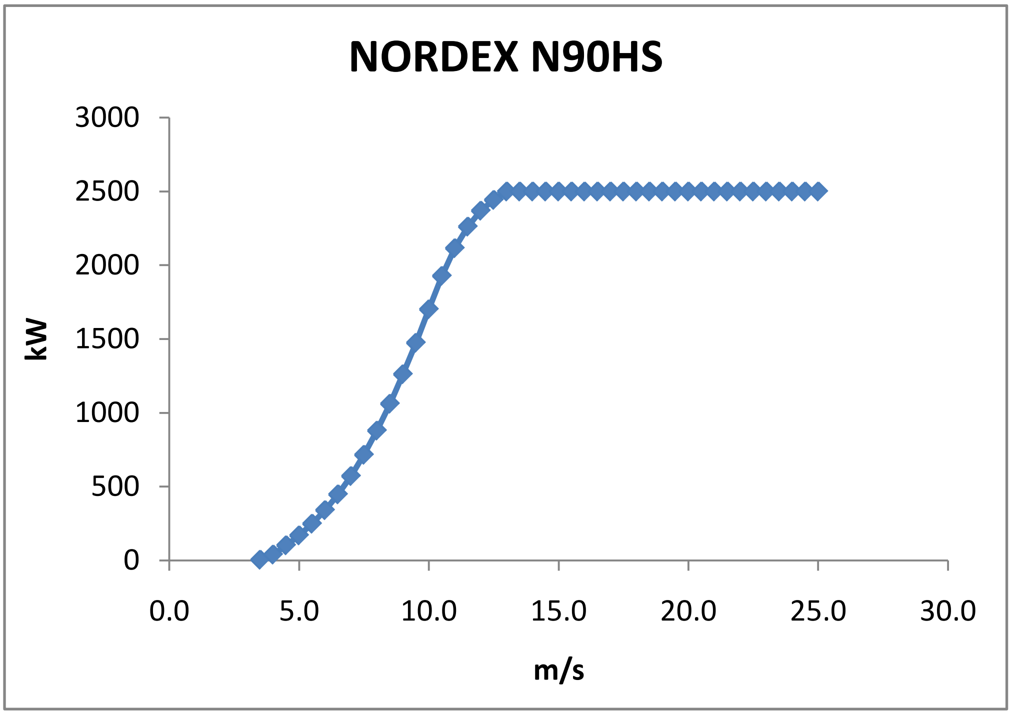


Figure 34: Power Curve

5.5.2 Power Output Calculation

First, we calculated the power output for all 20 turbines based on the velocities at the different heights by multiplying the different occurrences of each wind speed bin by the power curve. The corresponding data is shown in Appendix A-16. This gross power output was then averaged as and extrapolated it to the target height of 80m. At these heights the relationship between height and power is almost linear as shown in Figure 35.

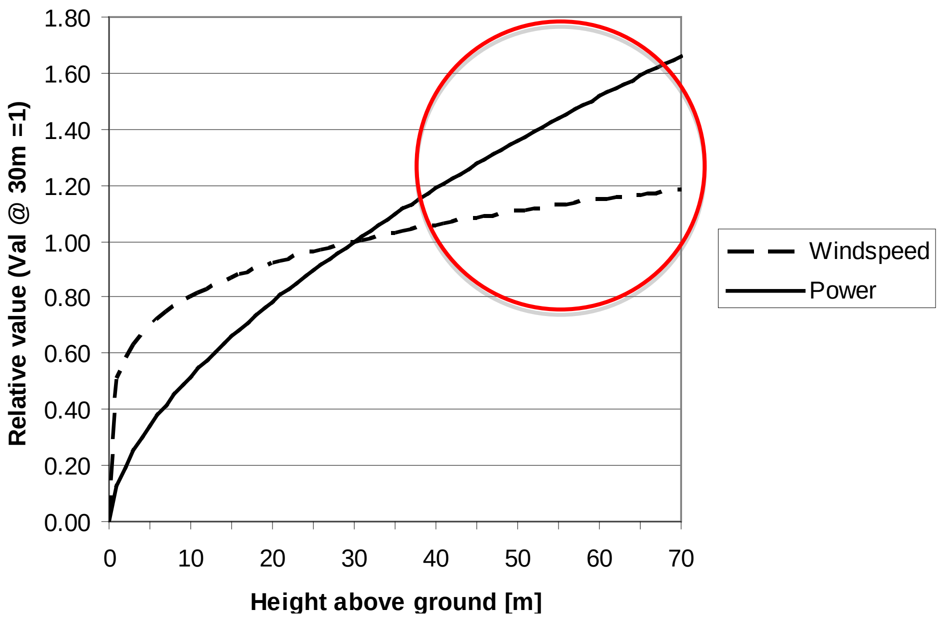


Figure 35: Power Output and Wind Speed over Height

Source: (Vanek & Albright, Energy Systems Engineering: Evaluation and Implementation, 2008, p. 345)

Figure 36 shows the estimated output based on a linear extrapolation.

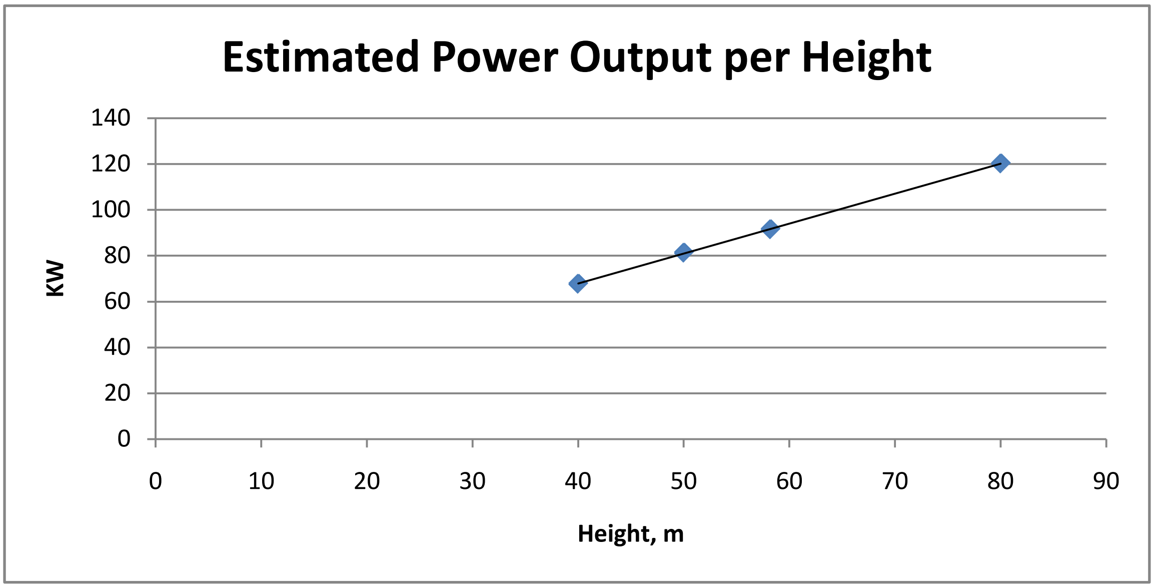


Figure 36: Calculated Power Output

The estimated Net Power Output for 20 turbines (after losses) is 120.2 GWh/year. Table 17 shows the exact values for each of the anemometer heights and the target turbine height.

Height (m)	Estimated Net Power Output (GWh)
40	67.69
50	81.26
58.2	91.47
80	120.17

Table 17: Estimated Power Output for Each Height

The estimated capacity factor equals 27.4% based on the calculated power output versus the rated one. This is similar to the Sheldon wind farm which is expected to produce 260 million kWh from 112.5 MW.

The gross power output over the occurring wind speed can be depicted as shown in Figure 37. The corresponding graphs for the gross power output at 40m and 50m are shown in Appendix A-17.

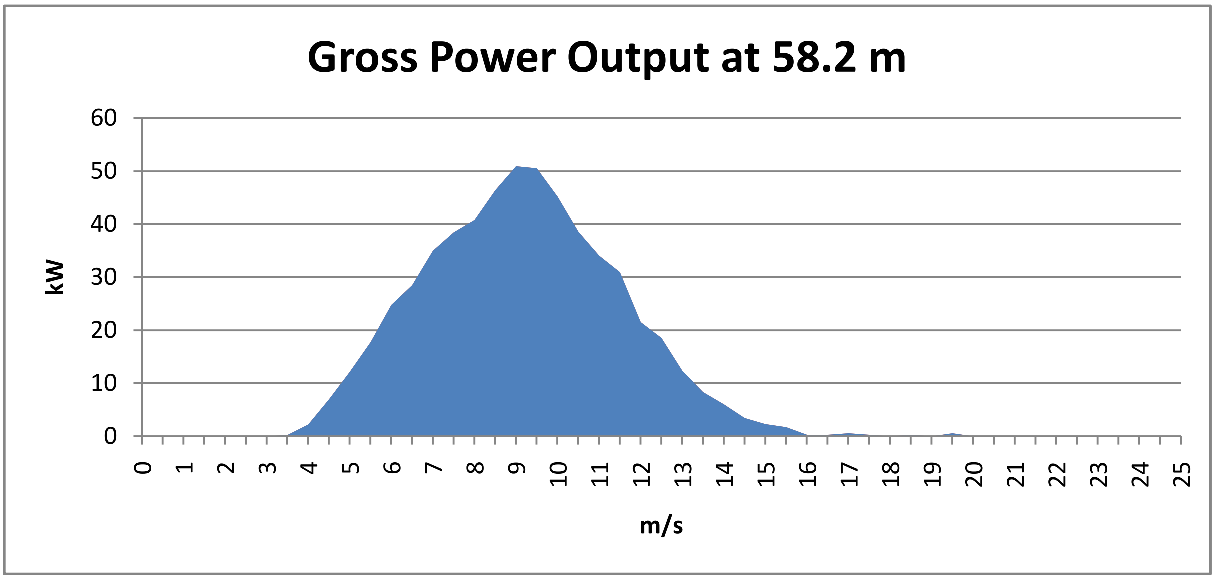


Figure 37: Gross Power at 58.2m

5.6 Enfield Supply versus Demand

The original proposal of the wind farm in Enfield had set out to supply the electricity needs of Tompkins County. This was therefore included in the analysis so as to verify the possibility of this idea. New York Independent System Operator (NY ISO) administers and monitors the wholesale electricity markets for New York and manages the efficient flow of power. By building a custom report program from the NY ISO database, data was generated for the electricity demand in the Central Zone in New York and consisted of the average load in each hour in the year 2009. This data was analyzed to compute monthly load averages. The annual average load for each hour in a day was also determined so as to view the profile of the 24-hour demand.

The central zone includes the counties of Cayuga, Oswego, Onondaga, Cortland, Herkimer, Madison, Oneida and Tompkins. The electricity demand for Tompkins County was therefore obtained by scaling down the electricity demand from that of the Central Zone using population. This assumes uniform personal electricity usage in the County. Table 18 below shows the summary of the population data used to estimate the percentage of the Central Zone demand that can be allotted to Tompkins County.

County	Population	%
Cayuga County	79,823	6.84%
Oswego County	121,395	10.40%
Onondaga County	452,633	38.79%
Cortland County	48,302	4.14%
Tompkins County	***101,136***	***8.67%***
Herkimer County	62,200	5.33%
Madison County	69,766	5.98%
Oneida Country	231,590	19.85%
TOTAL	**1,166,845**	**100%**

Table 18: Populations of the Counties in the Central New York Zone

The population of Tompkins County is therefore 8.67% of the population of the Central New York Zone. This percentage was therefore assumed to be the electricity demand. The corresponding demand for Tompkins County was compared to the expected Enfield supply and the demand was found to be an order of magnitude higher than the supply.

Tompkins County population for 2000	36,420 Households
Household Growth Rate (1990-2000)	9.20%
Estimated Tompkins Population for 2010	39,770.64 households
Energy Consumption per Household in NY State for 2001	5,974.00 kWh/ year
Tompkins County Total Residential Consumption	237,589.80 MWh/ year

Table 19: Statistics used to determine Tompkins County Residential Demand
Source: (US Census Bureau)

The Tompkins County residential demand was estimated using the number of households in the county and the average energy consumption per household in NY State as shown in Table 19. The Enfield Community was assumed to be all residential and the average energy consumption per household for NY State was applied to determine the Enfield Community Demand. This data is highlighted in Table 20 below:

Power Consumed per Household (NY State Average)	5,974.00 kWh/ year
Enfield Population	3369 (from US Census 2000)
Number of people per Household	~2.5
Number of households	1347.6
Total Residential Power Consumed for Enfield Town	8,051 MWh/ year

Table 20: Statistics used to determine Enfield Community Demand

Source: (Energy Information Administration, 2006)

Figure 38 below therefore shows a comparison of the monthly power averages of the Enfield Supply, Enfield Community Demand and the Tompkins County Demand.

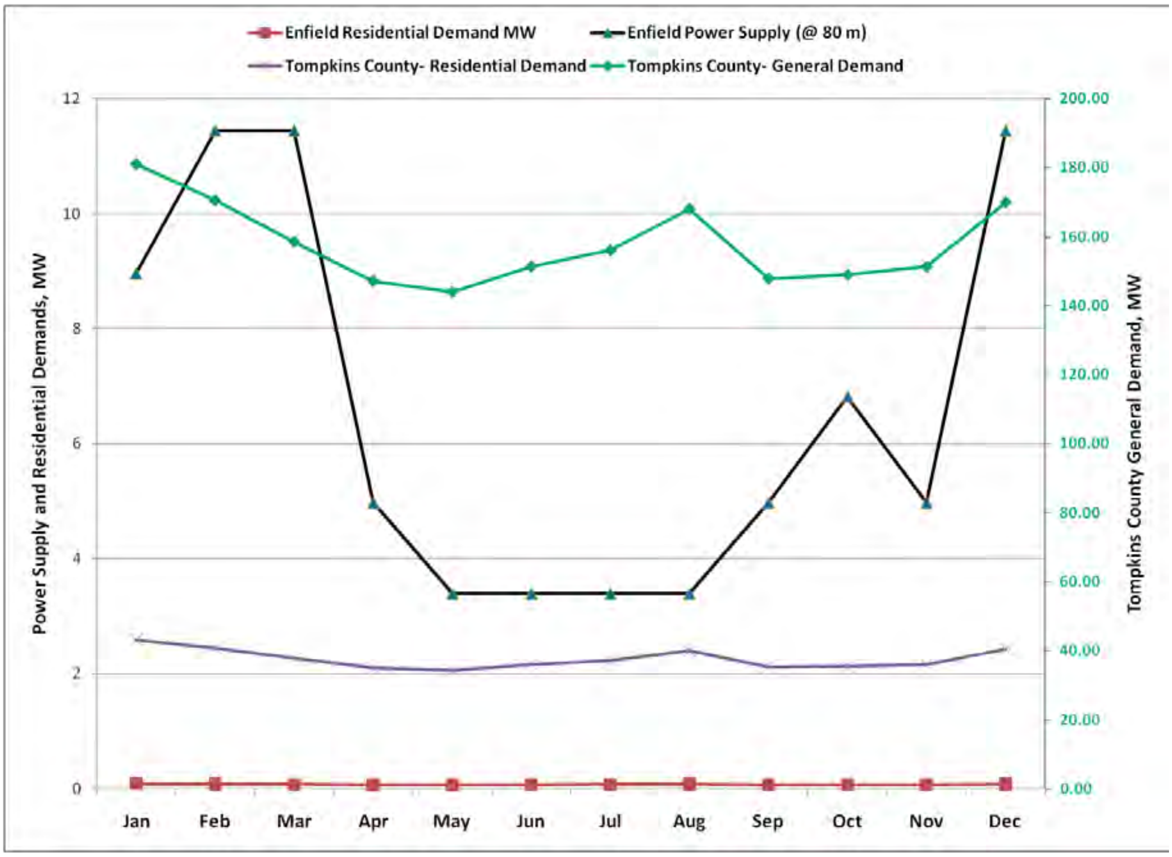


Figure 38: Monthly Power Supply and Demand (Enfield average load: 0.92 MW)

It also shows that the Enfield Supply is maximized in the colder months (November to April) and can supply more than the needs of the Enfield Community during those months. However, during the summer months when the supply is reduced due to the expected reduction in the wind speeds, the supply is inadequate for the demand of the Enfield Community. Overall, the extra supply in the winter months exceeds the shortfall in the summer months which leaves positive net annual supply.

Figure 39 below shows the annual average power cycle over the 24 hour period of the Enfield Supply, Enfield Community Demand and the Tompkins County Demand:

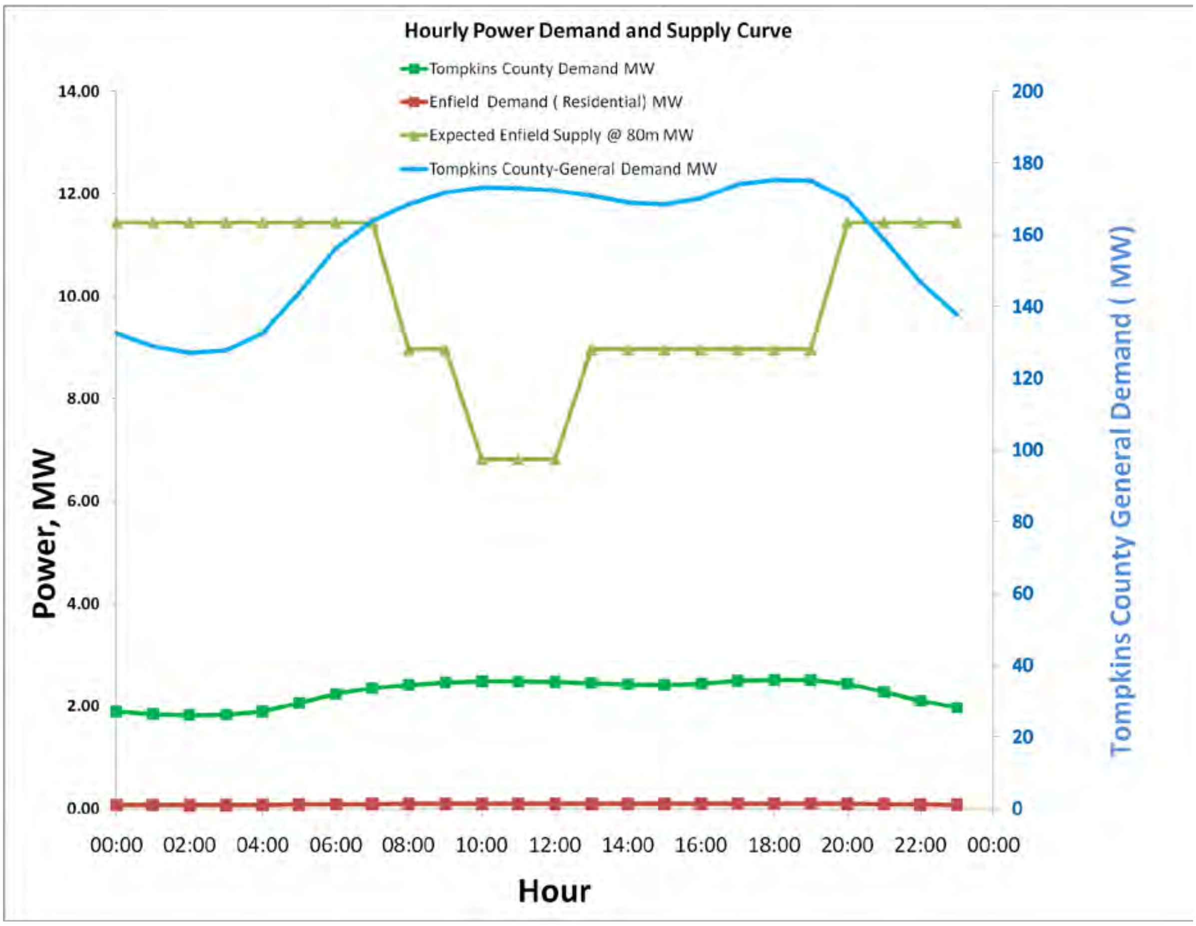


Figure 39: Power Supply and Demand over 24-hour period (Enfield average load: 0.92 MW)

Figure 39 above shows that the average annual Enfield supply is adequate to meet the needs of the Enfield community. It shows how the peak supply and peak demand are out of phase with each other and therefore Enfield has the lowest available supply during the hours of peak demand load (~ 9 a.m. to 6 p.m.). The idea however, is that once the energy is supplied to the grid it can be complemented with other sources, resulting in a net supply of power that meets the instantaneous demand.

5.7 Financial Analysis

In order to evaluate the financial benefit of the Enfield wind farm, a Net Present Value (NPV) analysis was conducted. The NPV equals the present value of the investment's future net cash flows minus the initial investment. Therefore, it is the difference between an investment's market value and its cost and it presents a measure of how much value is created or added today by undertaking an investment (Ross, Westerfield, & Jordan, 2009).

To calculate the NPV, the Discounted Cash Flow (DCF) Method was used. As a first step, future cash flows were estimated which were then discounted to year zero. The NPV equals the difference between the present value of the future cash flows and the cost of the investment (Ross, Westerfield, & Jordan, 2009).

For the calculation, an equity debt ration of 40% equity and 60% debt was assumed. Finally, the Levelized Cost per kWh and Levelized Worth per kWh could be determined based on NPV calculation.

The following general assumptions were made for the investment analysis.

5.7.1 General Assumptions

- The system life time is assumed to be 20 years
- The output is calculated based on a total of 20 turbines
- The electricity output includes 10% losses
- Electricity price is expected to be $0.08 with an annual escalation of 3%
- Annual escalation of revenue: 3%
- Discount Rate: 10%
- Income tax: 35%
- Tax Credit: $0.021 per kWh for 10 years with annual escalation of 2%
- Carbon Credit $3 per MWh

5.7.2 Installation Cost and Annual Expenses

Installation and annual operation cost had to be identified to successfully conduct a NPV analysis.

Table 21 shows the installation cost per turbine and for all the 20 turbines of the wind farm. All values are based on industry standards (GE Wind).

Installation Cost	Cost Per Turbine ($)	Total ($)
Turbine Cost	3,307,000	66,140,000
Roads and pads	132,732	2,654,640
Foundations	279,465	5,589,300
Turbine Erection	186,310	3,726,200
BOP Electric w/Transformer	419,197	8,383,940
Engineering & Maintenance	232,887	4,657,740
Spare parts	50,000	1,000,000
Early stage development costs	93,155	1,863,100
Legal and Accounting	5,000	100,000
Miscellaneous Professional fees	1,000	20,000
Insurance	1,500	30,000
Licenses and Permits	1,500	30,000
Working Capital Reserve	275,000	5,500,000
Sub Total		**99,694,920**
Education center		2,500,000
Development Fees		8,000,000
	TOTAL	**110,194,920**

Table 21: Installation Cost

In addition to the material and production cost, also expenditures for insurance, accounting and licenses were included.

On April 16, 2010, the team visited High Sheldon Wind Farm in Strykersville, NY, southeast of Buffalo, a working windfarm that has been in operation since March 2009. The operator confirms that estimated costs for the Enfield project are consistent with Sheldon costs, although Sheldon is not allowed to reveal exact financial information for their project due to commercial sensitivity. Sheldon projects typical annual output of 260 million kWh, and for the period 3/11/2009 - 12/31/2009 produced 172.9 million kWh.

Table 22 shows the annual expenses of the wind farm operations.

EXPENSES	Year 1	Year 2 - Year 5	Year 6 – Until
Operations & Maintenance	$900,000	$900,000	$900,000
Operations & Maintenance Contingency Fund	$500,000	$100,000	$100,000
Project Management Fee	Salaries are in the O & M section		
Insurance	$420,000	$420,000	$420,000
Property Tax	$200,000	$200,000	$200,000
Lease Payments to Landowners	$240,000	$240,000	$240,000
Admin/Financial/Legal Management	This can be taken from contingency as necessary		
Production Tax Expense ($/kWh)	Not relevant		
Warranty Expense	$400,000	$400,000	For 5 years only
Distribution			
Annual Expenses	**$2,660,000**	**$2,260,000**	**$1,860,000**

Table 22: Annual Expenses

The following assumptions were made with regard to the annual expenses:

- Project Management Fees are included in the operation and maintenance cost
- 20% of Contingency Fund is used and replaced annually
- Warranty Expenses only anticipated for 5 years
- Production Tax is not included as an expense

For the purpose of calculation, we assumed annual cost of 15% of the total installation cost. This results in $2,107,770.97 and equals approximately the above given assumptions.

5.7.3 Levelized Cost

The following figure shows the calculation of the levelized cost. Levelized cost is defined as the annualized cost divided by the output in kWh. The present value of the total cost was based on the After Tax Cash Flows (ATCFs). From that the annual cost was calculated by using the following formula:

$$Annuity\ Present\ Value = Annuity * \frac{\left[1-\frac{1}{(1+i)^n}\right]}{i}$$

LEVELIZED COST	7.0% Interest Rate	9.5% Interest Rate
Present Value of Cost	-$87,231,752.43	-$74,708,260.74
Annualized Cost	-$8,234,060.33	-$8,477,646.54
Levelized	-$0.068	-$0.071

Table 23: Levelized Cost

Table 23 shows that the levelized cost varies between $0.068 and $0.071 depending on whether a 7.0% or 9.5% interest rate is used. Both cases are based on 40% equity 60% debt financing structure. This assumes that the owner only expects a return on the 40% equity after the windfarm is paid off. Compared to recent electricity prices close to $0.039 (05/02/2010 at 20:00 ET) (NY ISO) per kWh, the investment would still be negative. On the other hand, with regard to historic electricity prices, wholesale prices are meant to increase. Table 24 below shows a weighted average of the peak wholesale electricity price from 2005 to 2010.

YEAR	$/kWh
2005	8.79
2006	6.95
2007	7.76
2008	9.02
2009	4.63
2010 (As of May 7th)	5.11

Table 24: Peak Wholesale Electricity Prices for New England 2005 – 2010
Source: (Energy Information Administration, 2010)

This shows the significant reduction in the price from 2008 to 2009 with a slight improvement in 2010. This is most likely due to the global economic crisis and the prices are therefore expected to increase to the previous values and so a price assumption of $0.08 per kWh seems to be representative for the net present value calculation.

Alternatively, the levelized cost can be calculated as the electricity price for which the NPV will be zero by using the solver function (assuming 40% equity 60% debt financing structure). This procedure is more accurate than the one described before because it does not factor any assumption of the selling price, a figure which is highly volatile. The electricity costs calculated above are slightly higher due to the higher tax expenses. For an interest rate of 7.0%, the corresponding electricity cost is $0.0611/ kWh and for an interest rate of 9.5%, the selling price would be $0.0644/ kWh.

Lastly, the most conservative interpretation of the levelized cost would not assume any government incentivization or debt financing but 100% equity investment. Table 25 shows the total installation and operation cost under these assumptions, annualized over the life time of the system.

Installation Cost	$110,000,000	$110,000,000
Discount Rate	7.00%	9.50%
Annualized Installation Cost	$10,383,222	$12,482,436
Annual Expenses	$2,107,771	$2,107,771
Total Annual Expenses	**$12,490,993**	**$14,590,207**
Output (kWh)	**120,248,65**	**120,248,658**
Levelized Cost ($/kWh)	**$0.104**	**$0.121**

Table 25: Levelized cost under consideration of total cost

5.7.4 Net Present Value Analysis

Table 26 shows the anticipated After Tax Cash Flows (ATCF), their value if they were discounted back to year zero, and the NPV. For the purpose of demonstration, two different interest rate (7.0% and 9.5%) were assumed. The calculation of each of the cash flows is shown in Appendix A-18.

Year	ATCF	Present Value of Cash Flow 7.0%	NPV	Present Value of Cash Flow 9.5%	NPV
0	($30,800,000.00)	($30,800,000.00)	($30,800,000.00)	($30,800,000.00)	($30,800,000.00)
1	$9,333,091.48	$8,722,515.41	($22,077,484.59)	$8,523,371.22	($22,276,628.78)
2	$14,425,043.77	$12,599,391.89	($9,478,092.70)	$12,030,644.71	($10,245,984.07)
3	$8,872,471.53	$7,242,579.67	($2,235,513.03)	$6,757,752.11	($3,488,231.96)
4	$5,510,548.93	$4,203,971.39	$1,968,458.36	$3,832,996.18	$344,764.22
5	$5,436,962.07	$3,876,478.82	$5,844,937.18	$3,453,708.72	$3,798,472.94
6	$2,885,344.47	$1,922,626.85	$7,767,564.03	$1,673,836.19	$5,472,309.14
7	$326,071.99	$203,061.25	$7,970,625.28	$172,748.65	$5,645,057.79
8	$229,457.43	$133,546.31	$8,104,171.59	$111,016.92	$5,756,074.71
9	$123,664.48	$67,265.29	$8,171,436.88	$54,640.91	$5,810,715.61
10	$7,821.21	$3,975.91	$8,175,412.78	$3,155.97	$5,813,871.58
11	($119,027.18)	($56,548.95)	$8,118,863.83	($43,862.24)	$5,770,009.34
12	($257,926.16)	($114,522.30)	$8,004,341.53	($86,801.25)	$5,683,208.10
13	($410,020.55)	($170,143.95)	$7,834,197.58	($126,014.95)	$5,557,193.15
14	($576,563.90)	($223,601.42)	$7,610,596.16	($161,826.55)	$5,395,366.59
15	($758,928.87)	($275,070.75)	$7,335,525.41	($194,531.21)	$5,200,835.39
16	$4,943,140.19	$1,674,412.61	$9,009,938.02	$1,157,116.33	$6,357,951.71
17	$4,943,140.19	$1,564,871.59	$10,574,809.61	$1,056,727.24	$7,414,678.95
18	$4,943,140.19	$1,462,496.82	$12,037,306.43	$965,047.71	$8,379,726.65
19	$4,943,140.19	$1,366,819.45	$13,404,125.88	$881,322.11	$9,261,048.76
20	$4,943,140.19	$1,277,401.36	$14,681,527.24	$804,860.37	$10,065,909.13

Table 26: NPV Calculation

It can be seen that in both cases the NPV gets positive in year 4. The estimated future NPV's of the whole investment vary between $14,681,527.24 and $10,065,909.13 depending on the interest rate of 7.0% or 9.5%.

5.7.5 Levelized Worth

The Levelized Worth differs from Levelized cost in that it takes into factor both revenue and expenses. In essence, levelized worth is the profit that will be generated per kWh.

Table 27 shows how many $/kWh of the generated revenue will result in profit.

Based on the NPV the annual worth could be calculated by using the following formula:

$$Annuity\ Present\ Value = Annuity * \frac{\left[1-\frac{1}{(1+i)^n}\right]}{i}$$

We assumed an electricity price of $0.08 per kWh**.** Enfield Wind will make a profit of $0.012 for a 7.0% interest rate and a profit of $0.009 for a 9.5% interest rate.

LEVELIZED WORTH	7.0% Discount Rate	9.5% Discount Rate
NPV	$14.681.527	$10.065.909
Annualized Worth	$1.385.832	$1.142.246
Levelized Worth	$0.012	$0.009

Table 27: Levelized Worth

5.8 Conclusion

Enfield Wind's Black Oak Farm, even with moderate wind speeds of 6.51 m/s (14.56 mph) at a hub height of 80m is a profitable venture. Profitability however, is still largely a function of incentivization such as the accelerated depreciation schedule for the first five years as well as the 30% grant from the Federal government to off-set intial costs. Because of the high investment costs, significant debt and equity have to be expended. Maintainance costs, however, are a fraction of the costs and the payback period is relatively short in a good market. Wind is an intermittent resource, therefore demand does not always match supply. The ability to sell electricity to the grid at all times is pivotal to success. We assumed residential use, and therefore wholesale prices of the lectricity; greater profitability could be obtained by selling to the industrial sector where both prices and revenue from Carbon Credits would be significantly high. Black Oak suggests that wind energy can be profitably exploited in New York State, and that both technological and sociological barriers can be effectively met.

6 Recommendations

Offshore wind has great promise and should be studied further and in greater depth. While we made a first pass investigation of offshore wind it would be useful to form an MEng team that includes both engineering management students and structural analysis students to work together. The dynamic of doing a business / feasibility study and an engineering analysis at the same time would be beneficial to both groups of students. The potential for New York State is upwards of 10,000 MW of capacity, a huge fraction of the electrical power demanded and the turbines will be operating at a substantial capacity factor.

Additionally, future teams should re-evaluate the renewable energy plans especially wind and check if the estimates for meeting RPS target change from what we estimated. Also, based on information from the Cape Wind project, the first offshore wind project in the US, a new analysis of the cost for the Great Lakes project could be done to see how it compares with our current analysis. An more in depth study on if New York State will meet the 15% efficiency target of the RPS clean energy goal can also be explored by future teams.

The Enfield project is a worthwhile investment. However, to attract more investors and to highlight its value, the Enfield business plan should modified to include a Net Present Value analysis and levelized cost. The 40% equity 60% debt financing structure shown above gives favorable results and should be evaluated for other options for the financing structure that may improve these results. Enfield Wind should market their project idea to commercial and industrial facilities in and out of state, to encourage them to purchase power from the Enfield site. This would result in a more even load demand, higher revenues and higher carbon credits compensation. Finally, Enfield Wind should evaluate different wind turbine options and should select one with a relatively low nominal speed to match the average wind speed at Enfield.

say we had a good team experience.

7 Wind Energy in Selected Regions of the World

7.1 Germany

7.1.1 Overview

Until 2007, Germany was the world's largest user of wind power, now it is in the second position behind the USA. The installed capacity is currently approximately 25 GW.

In 2007, the German industry contributed to nearly 28 per cent of the total worldwide turnover of 22.1 billion euros. Close to 100,000 people are employed in this sector.

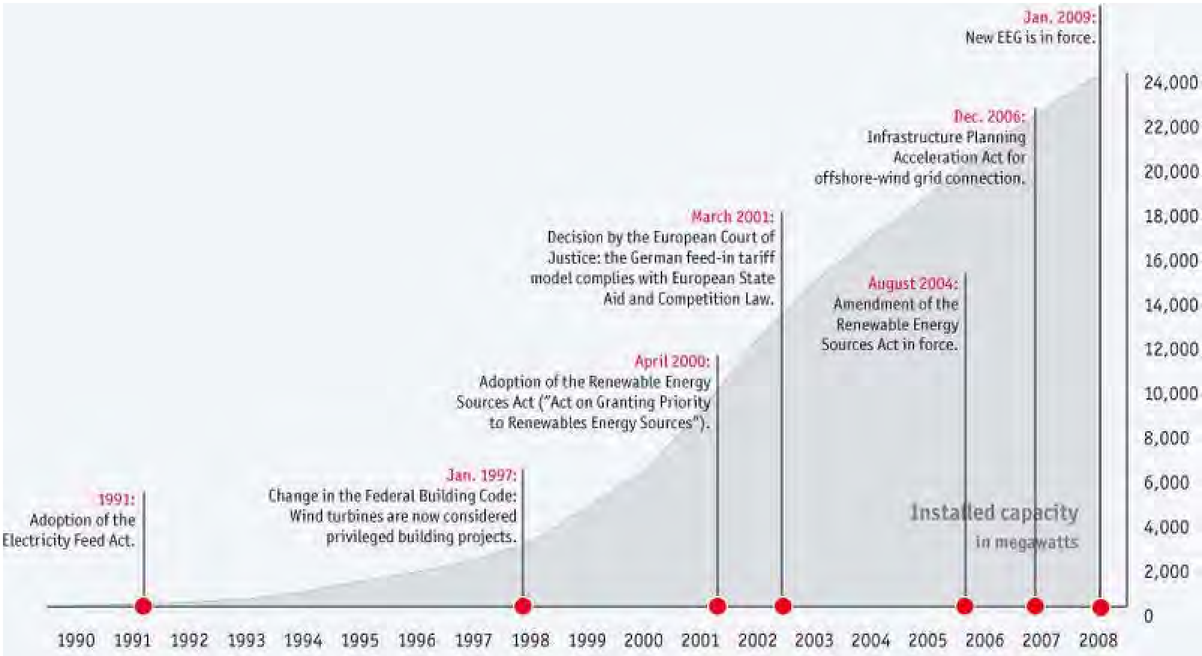
7.1.2 Installed Wind Capacity

The following table shows the installed wind capacity (MW) in Germany by year and the percentage of the electricity supply. Wind power accounts for proximately six percent of Germany's total electricity supply.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Installed wind capacity (MW)	6,104	8,754	11,994	14,609	16,629	18,415	20,622	22,247	23,903	25,000
Wind power share in the electricity supply (%)						5.1	5.4	6.6		

7.1.3 The EEG Regulations

The first feed-in law for wind electricity has existed in Germany since 1991. The Renewable Energy Sources Act (EEG = „Erneuerbare-Energien-Gesetz") was initiated in 2000 and is since then the basis of success for wind energy in Germany. Electricity produced under EEG regulations is given priority for grid connection and grid access. Grid operators are therefore obliged to feed in electricity produced from renewable energy and buy it at a minimum price within their supply area. Furthermore, grid operators are required to optimize and enhance the existing grid by EEG regulations and therefore a repowering bonus is offered for replacing turbines which are ten or more years old with turbines with at least double the rated capacity.

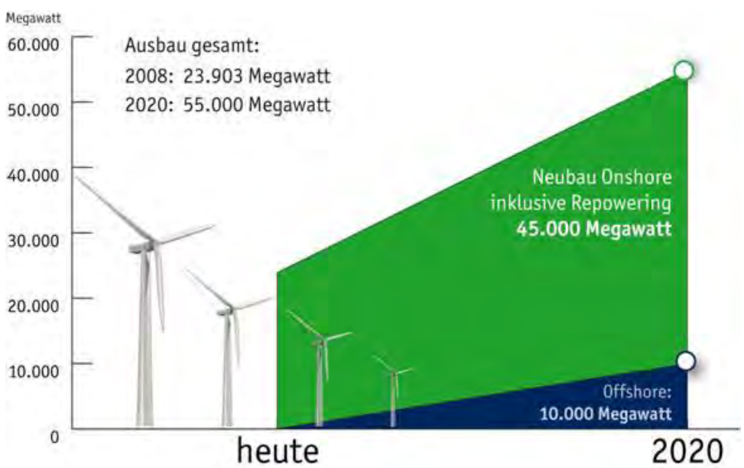


7.1.4 Offshore Wind Power

Offshore wind energy offers great potential in Germany. Wind speed at sea is between 70 and 100 percent higher than onshore and more constant. The first offshore German windturbine completed construction in July 2009. This turbine is one of the 12 wind turbines for the Alpha Ventus Offshore Wind Farm in the North Sea.

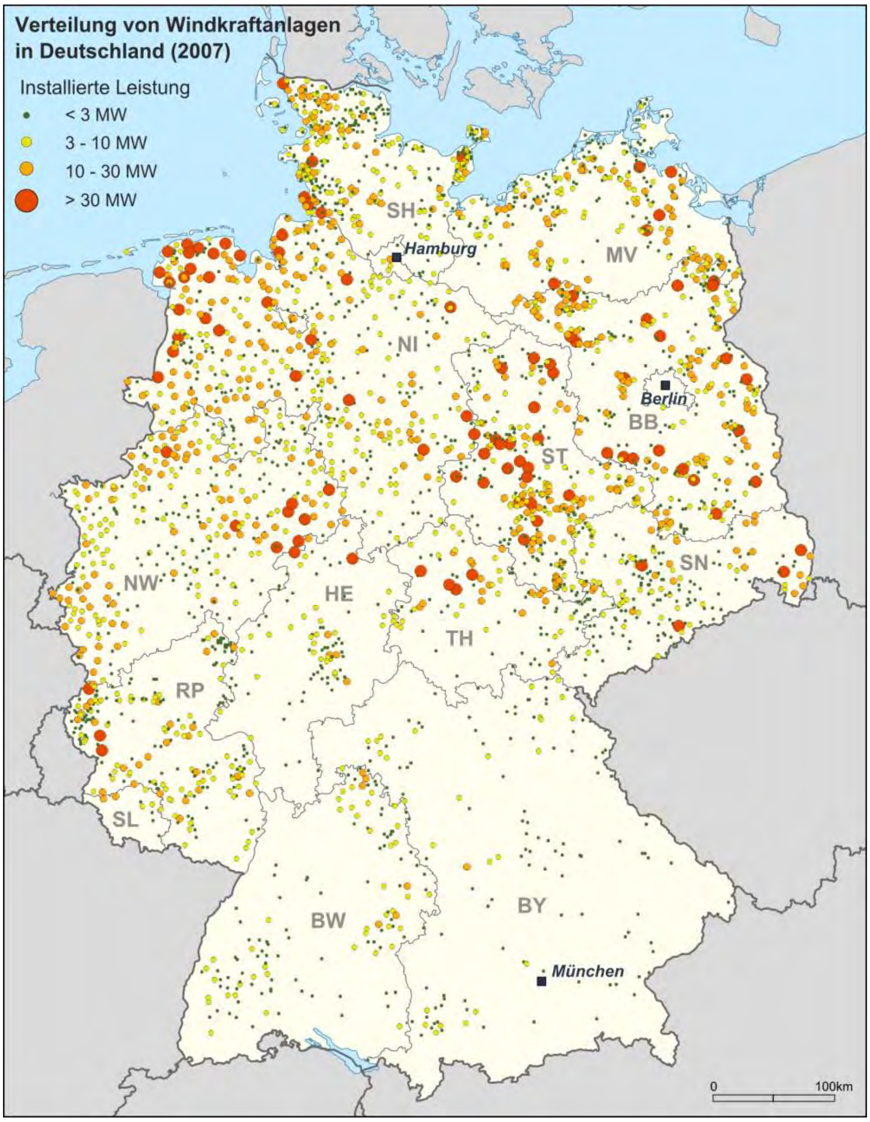
7.1.5 Future prospects

According to calculations from BWE (the German WindEnergy Association), the total German onshore capacity could reach 45,000 MW by 2020. In addition, 10,000 MW could be generated by offshore wind farms. The electricity supply from wind would equal 25% by this time (considering a generation of about 150 TWh/year).



7.1.6 Distribution of Wind Power Plants in Germany

The following figure shows the distribution of wind power plants in Germany with their installed capacity (indicated by the size and the color of the circle).



Abbreviations of the 16 German states:

- BW – Baden-Württemberg
- BY – Bayern
- BE – Berlin
- BB – Brandenburg
- HB – Bremen
- HH – Hamburg
- HE – Hessen
- MV – Mecklenburg-Vorpommern
- NI – Niedersachsen
- NW – Nordrhein-Westfalen
- RP – Rheinland-Pfalz
- SL – Saarland
- SN – Sachsen
- ST – Sachsen-Anhalt
- SH – Schleswig-Holstein
- TH – Thüringen

7.2 Jamaica

7.2.1 Overview

Wind Energy only contributes approximately 2% to the overall power generation in Jamaica. In 2006 the government projected that 10% of the country's electricity demand would be from renewable sources by 2010, 15% by 2020 (Jamaica Information Service, 2006). This projection then included the expansion of the sole existing wind farm from 20 MW to ~ 60MW. However, the projected expansion has not been completed and instead an expansion from 20 MW to 38 MW is expected by third quarter 2010 (Jamaica Information Service, 2009), (Wigton Windfarm Ltd, 2010).

7.2.2 Installed Capacity

Wigton Wind Farm is located in Manchester, Jamaica and is the only commercial wind producing facility in the English speaking Caribbean. It has twenty-three (23) 900kW wind turbines which began operations in 2004. The farm has a capacity of 20.7 MW and an average supply of 8.9 MW (Wind Energy Project - Grid Connected Wind Farm, 2009). The average wind speed for Wigton Windfarm is 8.3m/s at a hub height of 49m, rotor diameter of 52.2m and site elevation of 750m. A new overhead transmission line of 11.3 km was built to add its power into the grid at the nearest power substation (Jackson, Gary; General Manager-Wigton Wind Farm Ltd., 2009).

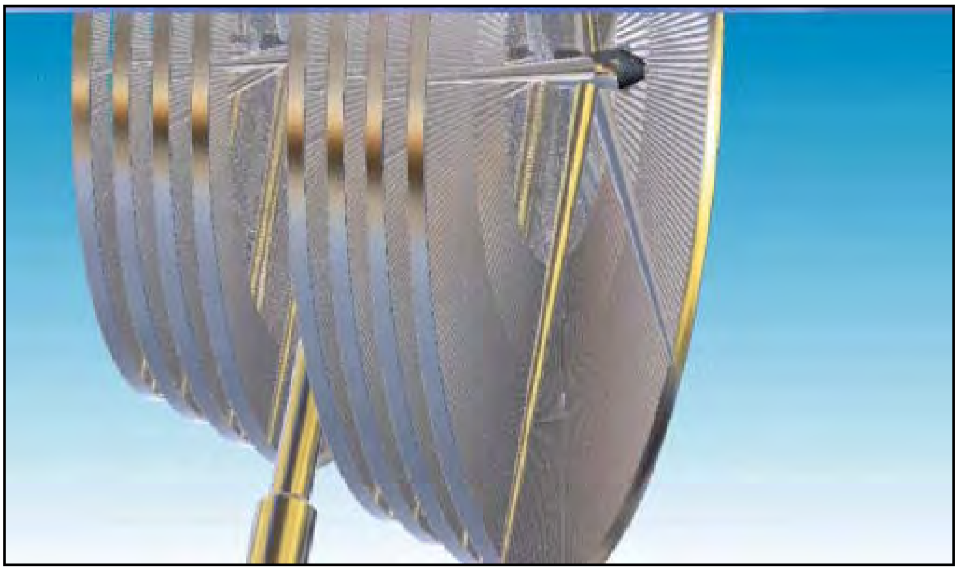
Picture of Wigton Wind Farm, Manchester, Jamaica,
Source: (Potopsingh, Ruth; Managing Director- Petroleum Corporation of Jamaica, 2009)

7.2.3 Challenges

- One of the main limiting factors of the growth of wind energy in Jamaica is that a comprehensive wind mapping exercise for the island is incomplete and so the full potential of wind energy and the corresponding sites for the island are not known.
- No Renewable Energy Legislation in Jamaica
- Jamaica is located in a hurricane and earthquake zone so construction standards have to be appropriate and special disaster and response plans needed for site
- Transportation of the material for construction of the wind turbines is difficult and expensive due to the mountainous terrain, narrow roads and poor road surface conditions. The widening of the road and repairs to the road surface is an additional cost to the project

7.2.4 Future

- The completion of the wind mapping exercise has restarted with 20 sites that have been identified for data collection and analysis (Jamaica Information Service, 2009).
- The current expansion in capacity by 18 MW will be from 9 2MW vestas V80 turbines to be added to the Wigton Windfarm (Wigton Windfarm Ltd, 2010).
- New technologies are being reviewed for implementation (Potopsingh, Ruth; Managing Director- Petroleum Corporation of Jamaica, 2009). This includes the 'Windjet Prototype' design shown below and compared to the traditional turbine:

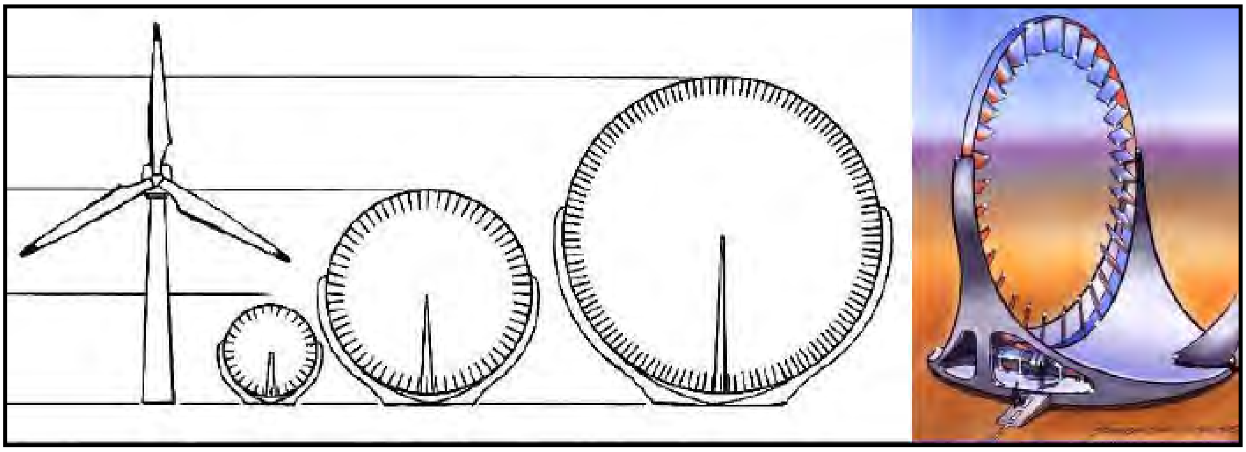


Windjet Prototype Design – Figure 1
Source: (Potopsingh, Ruth; Managing Director- Petroleum Corporation of Jamaica, 2009)

Specifications	Traditional turbine	Windjet turbine

Capacity (MW)	1.6	14
Height (m)	122.2	38.1
Diameter (m)	82.6	30.5

Source: (Potopsingh, Ruth; Managing Director- Petroleum Corporation of Jamaica, 2009)



Windjet Prototype Design – Figure 2

Source: (Potopsingh, Ruth; Managing Director- Petroleum Corporation of Jamaica, 2009)

7.3 Zimbabwe

7.3.1 Overview of Electricity Production [1]

Zimbabwe is a landlocked, sub-Saharan African country with a population of roughly 14 million. The bulk of the nation's electricity is produced at Hwange Thermal Power Station, 920 MW, in western Zimbabwe, seconded by Kariba Hydro Electric Power Station, 666MW, and then by three smaller power stations in the nation's capital Harare, 135 MW, in Bulawayo, 120 MW and in Munyati, 120 MW. Almost 70% of consumed electricity is imported from DRC, South Africa and Mozambique, with frequent outages and rationings in the recent past because of a significant dips in the economy which in turn impacted the solvency of the nation.

To complement the national grid, there are localized electricity generation schemes dispersed throughout the nation. The following table illustrates nascent sources of power-generation from an UNEP1 funded investigation published in 2002.

Technology	Installed (MW)	Potential (MW)
Solar Photo Voltaics	0.8	>300
Solar Water Heater	10, 000 units	1 Million units
Mini Hydro	1.7	20
Micro Hydro	1	15
Biogas	250 units	5000 units
Wind	---	----
Bagasse-based cogeneration	45	150
Power Generation from Sawmill Waste	0	250

[1] Implementation of Renewable Energy Technologies – Opportunities and Barriers, Zimbabwe Country Study (2002) (United Nations Energy Program Collaborating Centre on Energy and Environment, ISBN- 87-550-3012-2)

7.3.2 Wind

As can be noticed above, wind data is missing. This is because of a very modest attempt at harnessing wind for power generation owing to low annual mean speeds of around 3.8 m/s at 10m above the ground. This is typical of landlocked locations. There have not yet been exhaustive measurements at higher heights because of the pessimism stemming from this initial assessment. There are, however, some modest realizations in place which are illustrative of how small scale harnessing of wind can beneficial for some remote, rural communities. The most notable is the Temaruru Project.

7.3.3 Temaruru [2]

Temaruru Community Power Trust, Eastern Highlands of Zimbabwe was started in 1998 under the direction of ZERO, to provide the previously un-electrified Temaruru community with basic power. The mode of the electricity was wind, chosen ahead of conventional photovoltaics because of the inferior cost-benefit attributes of the latter. One of the objectives was, in fact, to harness power from the wind at a similar scale as photovoltaics in the same cost range. (Zimbabwe is very sunny and lends itself naturally to photovoltaic deployment, were the costs not so prohibitive). Temaruru Wind Power was designed to provide 230 AC mains and (car) battery charging capability. There were multiple stages in the perennial project, culminating in the development of a 4kW turbine to power Temaruru Secondary School. The project was executed with a good deal of success. The model of wind generator deployed, and pictured below, was manufactured by African Windpower (AWP) in Harare, Zimbabwe. "It was specifically designed for lower wind speed regimes which are typical of the inland areas of southern Africa3" with a rotor diameter of 12 feet and a rated output of 1 KW. 100% local production greatly diminishes the cost of the generators. A prominent "Made in Zimbabwe" can be seen on the tail of the turbine.

[2] http://www.zeroregional.com/programs/special_projects/wind_power.htm

[3] *Home Power #76 • April / May 2000,* http://homepages.enterprise.net/hugh0piggott/african36

Figure 40: AWP36 Wind Turbine

7.3.4 Other Implementations

Zimbabwe Energy Research Organization (ZERO) has also undertaken several other wind-power assessment projects in collaboration with public and private sectors (ZERO is a non-profit NGO). The following list is from their website[4], and is condensed here with minimal other alterations.

- Market surveys to gauge market response, three monitoring systems were erected in Chimanimani, Chivhu and lower Gweru.
- Setting up battery charging systems.
- Socio-economic study to assess economic viability of wind-powered water pumping system.
- Production of 1kW and 4kW wind turbines and installation of four turbines with a combined capacity of 4kW at Temaruru Business center, Rusape and two 1kW turbines at Chikukwa Permaculture Center, Chimanimani and Masampa Fishing camp on the shores of Lake Kariba respectively.

7.3.5 Overall Assessment

The referenced UNEP Collaborating Center on Energy and Environment study (2002) concludes that there is minimal potential for large scale wind energy deployment in Zimbabwe. However, there is significant market at household and community center level because of inadequacy in the reach of national grid to locations far from major urban centers. In particular, small wind turbines have been shown to be a formidable competition for high cost household -level photo-voltaic arrays when the turbines are optimally designed for low wind speeds and when they are locally produced. There is significant local manufacturing activity through African Wind Power for these micro-scale turbines and as adoption grows, so

[4] http://www.zeroregional.com/programs/special_projects/wind_power.htm

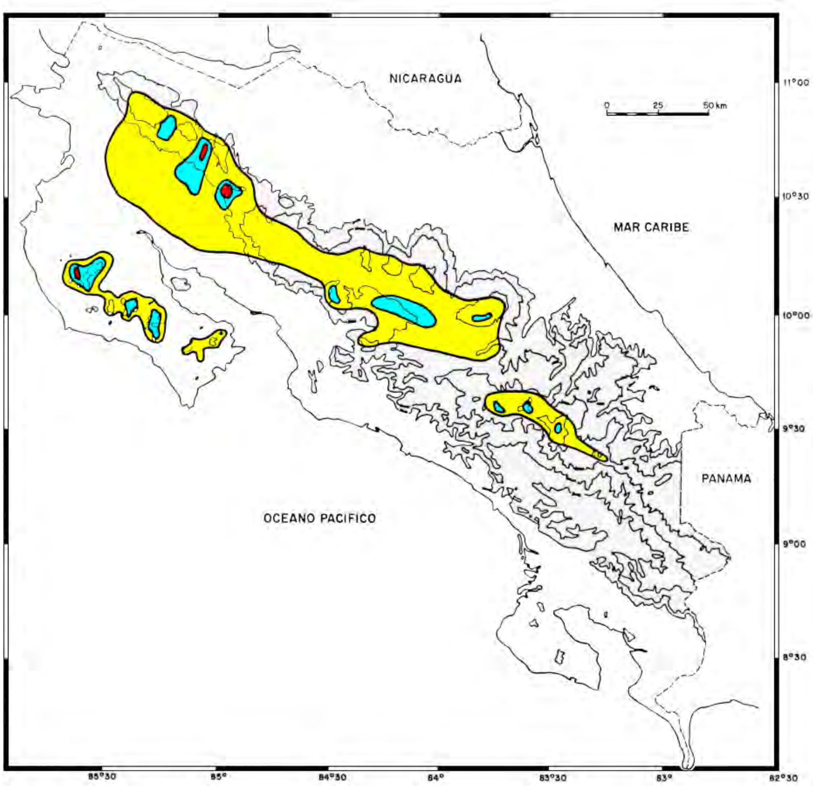
will the participators. Low height deployment, while not capturing the fastest winds which tend to be in the upper regions of the atmosphere, greatly lowers the associated infrastructural costs. Further meteorological study of wind at the higher levels is pending, as are investigations into the wind economics at those levels.   Regardless, the sunshine resource in Zimbabwe is significantly comparatively larger than the wind –resource and as photo-voltaics improve in cost-performance, they are apt to be the renewable energy sources of choice at both micro- and mini- scales. It should be noted that the driver for electricity generation alternatives in Zimbabwe is not yet “green” consciousness but need arising from shortfalls in both HEP and coal-thermal local production as well as in import quotas.

7.4 Costa Rica

7.4.1 Overview

Costa Rica's energy supply is 99.2% renewable and sustainable. While the country receives less than 0.5% (70MW) of its energy from wind energy, that amount is quickly increasing. Costa Rica generates its electricity with 49.4% hydro-energy, 35.7% geothermal, 7.9% cane products, 3.2% sustainable residential timber, 2.2% sustainable biomass, 0.5% wind and solar, 0.3% sustainable vegetal carb, and 0.1% sustainable industrial timber. The remaining portion of the nation's electricity comes from non-sustainable biomass (0.6%) and oil (0.2%).[5]

7.4.2 Distribution of Wind in Costa Rica



MAPA DE LA ENERGIA EOLICA EN COSTA RICA

ZONA	DENSIDAD DE ENERGIA (Wm⁻²)	VELOCIDAD DEL VIENTO (m sec⁻¹)
1	≥ 470	≥7
2	171 - 470	5 - 7
3	37 - 171	3 - 5
4	0 - 37	0 - 3

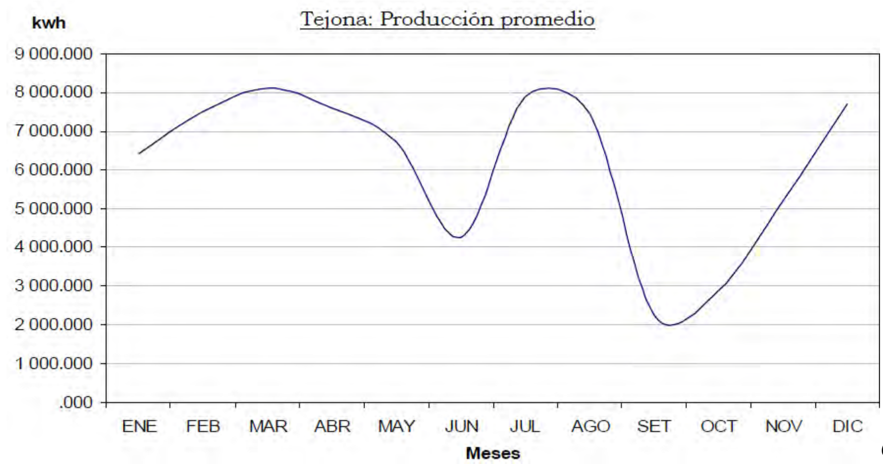
Wind power has a strong potential for growth in Costa Rica because of the high winds along the country's major ridgelines and in the northern province of Guanacaste. Among many of the windiest areas of the Guanacaste province, average annual wind speeds range between 15 and 20 miles per hour at 80 m. Wind energy has become a very attractive alternative to hydro-energy in Costa Rica since the supply of hydroelectric power drops significantly during dry season, which is the windiest season of the year.

7.4.3 Installed Wind Capacity

5 www.grupoice.com/

Project	Capacity (MW)	% Supply
PESA	19.8	27%
AEROENERGIA	9.75	13%
MOVASA	24	33%
TEJONA	19.8	27%
Total	73.35	100%

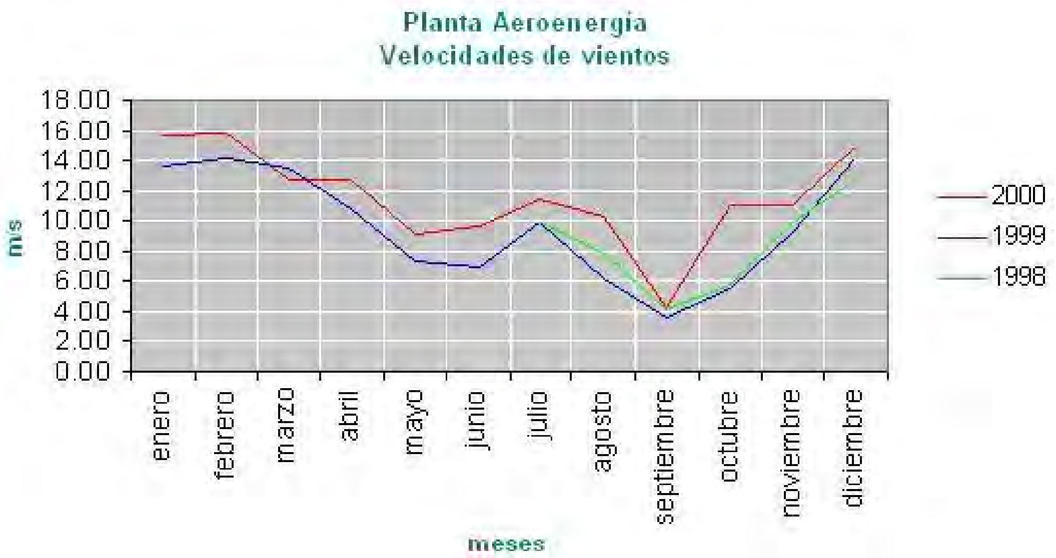
There are four operating wind farms in Costa Rica which are all located in the northwestern province of Guanacaste. The first wind farm was installed in 1992 in Tejona. Since then, a few others have materialized. One of the largest in Latin America, the Tierras Morenas Wind Farm (MOVASA) built in 1999, is located near the Nicaraguan border. The winds at this farm typically average around 20 mph at 80 m hub height. The wind farm sells its electricity to the national electric company, Instituto Costarricense de Electricidad, under a 15 year energy purchase agreement. The farm's 32 Micon brand wind turbine generators produce 70,000 MWh of electricity a year. The monthly energy production for the Tejona wind farm in 2006 can be found in the graph below.



[6]

As you can see wind energy production in Costa Rica drops significantly during the rainy season, in particular September and October, the rainiest months of the year. However, this has little impact on the nation's grid as hydroelectric energy production is greatest during these months. The wind speeds at the AEROENERGIA project located near Lake Arenal, in Tilaran Costa Rica depict the same seasonal effects. The graph below shows the significant range in wind speeds from 16 m/s in January to 4 m/s in September.

[66] www.eep-ca.org/docs/presentaciones/gustavo_jimenez.pdf



Wind power in Costa Rica also faces a unique challenge. Tilaran and most of the other wind farm locations are highly seismically active. In fact, the AEROENERGIA project is located only 20 miles from Arenal, the most active volcano in Costa Rica. Therefore, significant investments have made towards building sophisticated turbine foundations to withstand both wind and seismic shearing forces.

7.4.4 The Future of Wind Energy in Cost Rica

The future of wind energy looks bright in Costa Rica. The strong winds in many areas of Costa Rica make it an appropriate place to install more wind farms, while declining costs make these farms more possible each year. Furthermore, the Costa Rican government is developing plans to begin offsetting all of the country's carbon dioxide emissions by the year 2021. The nation's energy provider, ICE, has also pledged to increase wind energy capacity by 80MW near the Tejona project, and the World Bank has funded two wind projects as part of its Prototype Carbon Fund in Chorotega and Vera Blanca, Costa Rica. The private wind sector is also growing. Mesoamerica Energy and Grupo Saret currently have several large wind projects under development in Costa Rica and throughout Central America.

7.5 New Jersey

7.5.1 Overview

New Jersey currently ranks as the 29th state in wind energy potential. Unfortunately, it ranks as only 33rd in existing wind energy capacity. This is largely due to New Jersey's lack of high wind areas over its landmass. The only areas in New Jersey that have a good wind resource potential are either off the coast or on the coast.

1. **Installed Wind Capacity**

Currently, there is only wind farm in New Jersey. It is located Atlantic County, NJ and is visible from Atlantic City and the Atlantic City Expressway. Jersey-Atlantic Wind Farm consists of five 1.5 MW GE wind turbines. They are located on ACUA Wastewater Treatment Plant, and stand 397 ft. tall.

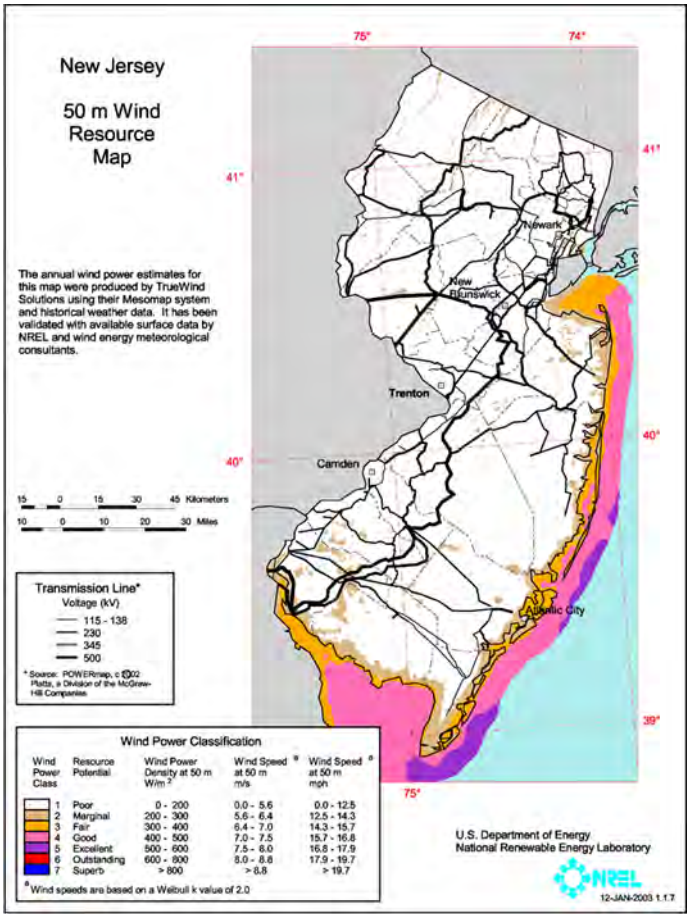
Name	Location	Power Capacity (MW)	Units	Turbine Mfr.	Developer	Owner	Power Purchaser	Year Online
Jersey Atlantic Wind Farm	Atlantic City	7.5	5	GE Energy	Jersey American Wind, LLC	Babcock & Brown owns majority	Atlantic County Utilities Authority	2005

7.5.2 Current Energy Sources

Energy production in New Jersey is dominated by nuclear power. Over one-half of all the power generated in the state of New Jersey is nuclear. Other than nuclear power, New Jersey also uses a large amount of natural gas. Below is a map of New Jersey indicating what its power sources are and where they are located:

7.5.3 Future Wind Enegy

Bluewater Wind won a state sponsored wind energy competition that will allow them to build a 350 MW offshore wind farm. In 2008, New Jersey's government paid for an offshore meteorological tower to be put up by Bluewater Wind at the future site of the offshore wind farm. This facility will consist of 96 wind turbines that will be in a rectangular grid about 20 miles off the coast of Atlantic and Cape May counties. Below is a map of wind resource potential in New Jersey: (Atlantic City is labeled to give an idea of where this will be located.)



New Jersey is leading the way for development of offshore wind in the US and is serving as a model for other states to follow. Governor Jon Corzine has called for the development of 1,000 MW in offshore wind by 2012 and an additional 2,000 MW by 2020. This will help New Jersey to meet its goal of 30% of the state's electricity coming from renewable resources by 2020.

7.6 China

7.6.1 Overview

In 2008, over 6GW new capacity was installed in China and the total capacity reached more than 12GW. In the past 4 years, China has a stunning growth in the wind energy, doubling the installed capacity every year. In 2009, new installed capacity is expected to double again, contributing to one-third of new installations globally. By 2010, China will have the world's second largest wind power capacity, meeting its 2020 target of 30GW, a decade ahead of schedule. The aggressive government policies will continue supporting the rapid growth of the domestic wind energy industry to diverse its electricity supply.

7.6.2 The Wind Resource

The national average wind power density is 100W/m^2. The potential for on-shore wind energy capacity is 2.53 billion kW on-shore and 7.5 billion kW off-shore separately. The best wind resources are located in the Northwest regions, Northeast regions and southern sea shores.

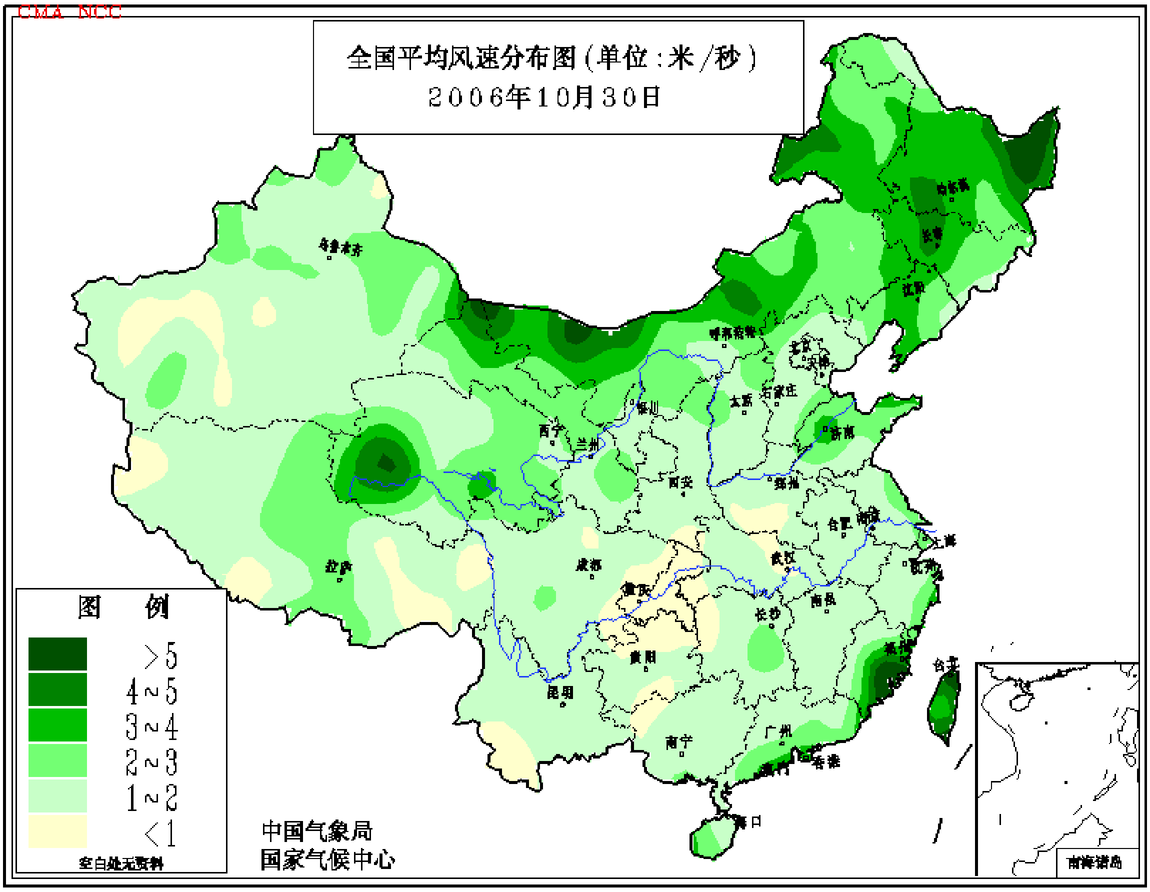


Figure 1 – National on-shore average wind speed (m/s) map, 2006

Note: the black spots on the map indicate the capital of each province in China

Source: Center for Wind and Solar Energy Resources Assessment, China Meteorological Administration

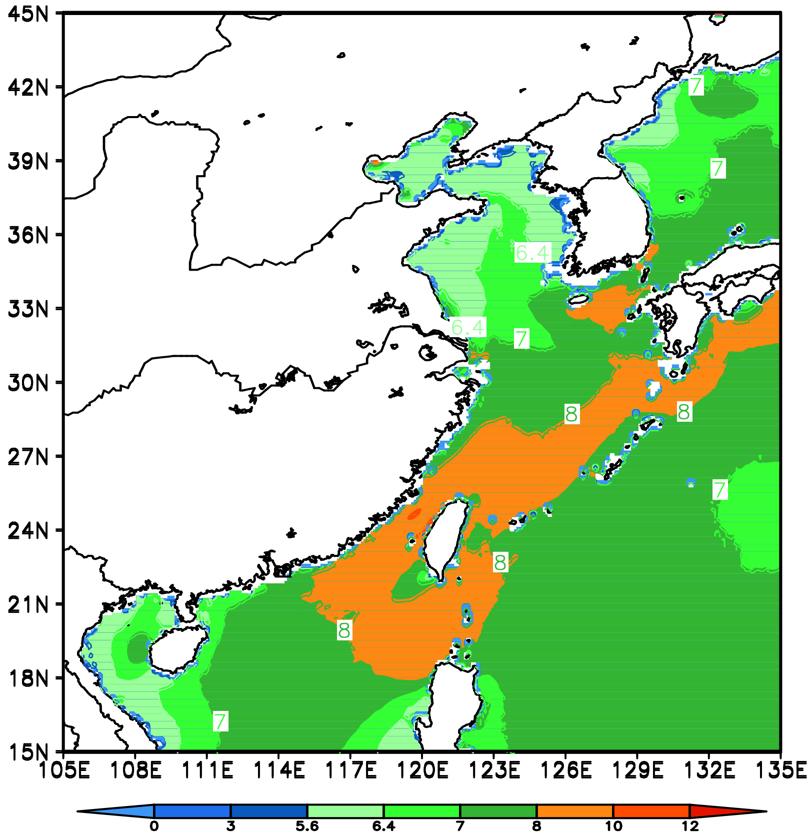


Figure 2 – National off-shore average wind speed (m/s) map, 2000-200

Source: Center for Wind and Solar Energy Resources Assessment, China Meteorological Administration

7.6.3 The Current Status

7.6.3.1 Capacity of wind energy

TOTAL INSTALLED CAPACITY

year	2000	2001	2002	2003	2004	2005	2006	2007	2008
MW	346	402	469	567	764	1,260	2,599	5,910	12,210

Table1 – Total Installed Capacity in China (2000-2008)

Source: Global Wind 2008 Report, Global Wind Energy Council

7.6.3.2 The policies

The Chinese government has identified the development of wind energy as one of the key economic growth areas. The Renewable Energy Law was published in 2006, there was a 0.001 RMB (0.0001 Euro) Renewable Energy Premium added for each kWh of electricity produced as a fund collected by the government. In 2007, the fund reached 3 billion RMB (300 million Euro) totally and has been used to the reimbursement to renewable energy operators, including wind energy producers. In 2008, this premium was raised to 0.002 RMB (0.0002 Euro).

In August 2008, the Ministry of Finance issued a regulation to rewards the operated domestic brands turbines which use domestic manufactured components and be certified by China General Certification (CGC).

7.6.3.3 Wind farms in China

By 2008, there are more than 200 wind farms in China.

Figure 3 – Location map of wind farms

Note: red spot presents existing wind farm, blue spot presents projected wind farm and black cycles indicate the capital city of each province in China

Source: 2009 China Wind Power Report, Beijing Unbank information center

7.6.3.4 Manufacturing

More than 20 new turbine manufacturers entered the Chinese market in 2008, bringing the total number of manufacturers in China to 70. The top three domestic manufacturers are Goldwind, Sinovel and DEC (Dongfeng Electric), have an annual manufacturing capacity of 4 GW, and the major international brands manufacturing in China are Vestas, Suzlon, GE, Gamesa, Nordex and Repower.

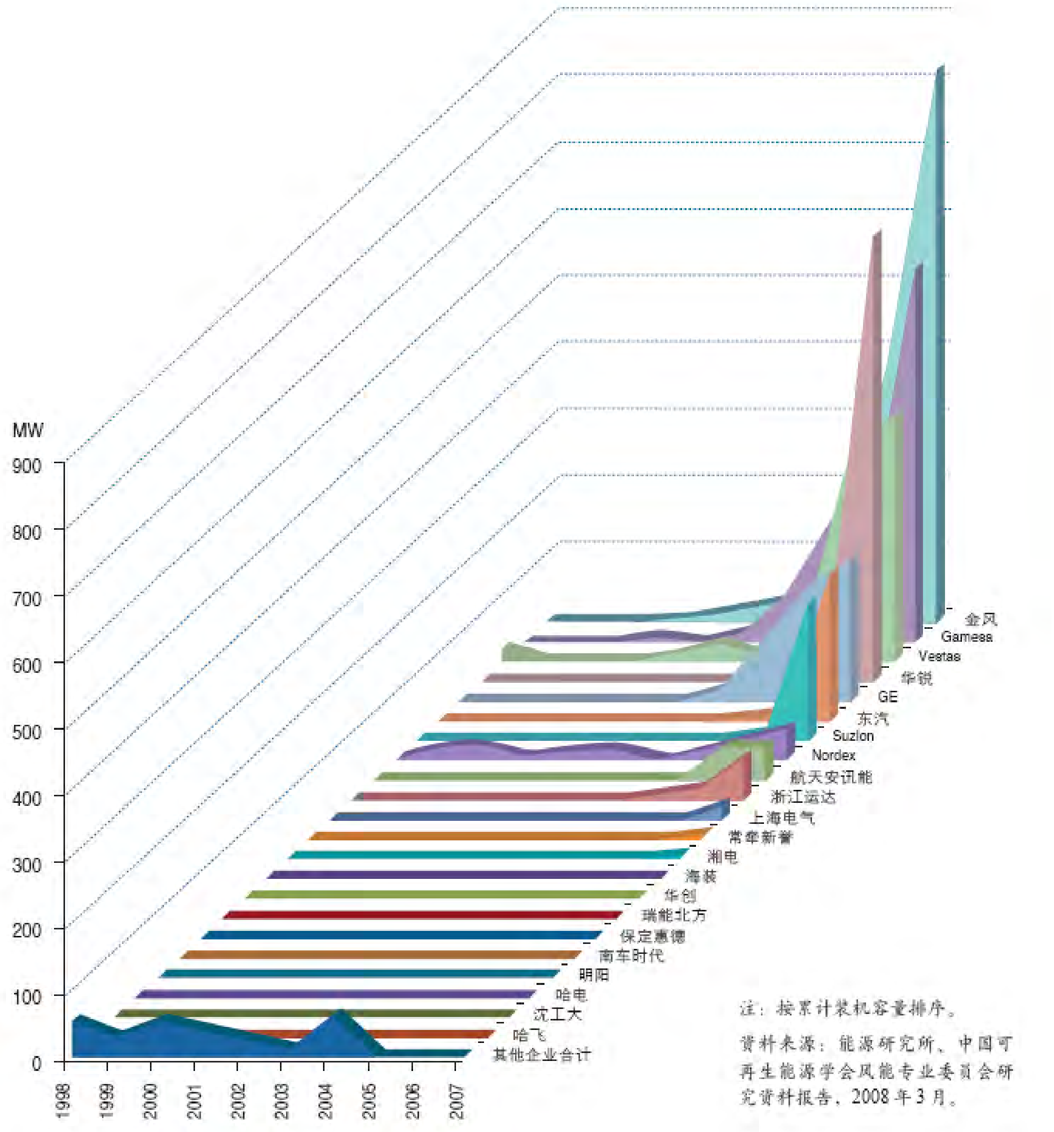


Figure 4 – Wind turbines market in China (1998-2007)

Note: the accumulated installed capacity (1998-2007) from manufactures

Source: 2008 China Wind Power Development Report, Chinese Renewable Energy Industry Association

7.6.3.5 Challenges

There a huge challenge on wind produced electricity transmission across regions and on grid system. Most of the new wind farms are located in north-west China, where the existing grid structure is weak and not much motivation to expand service to match the fast growth of wind energy.

7.6.4 Future Development

7.6.4.1 Wind base projects

In 2008, the National Energy Administration selected 6 sites located in the 5 provinces which has the best wind resources and planed the Wind Base Projects to develop more than 10GW capacity by 2020 in each site. By 2009, all wind base projects are under development: 20 GW at Mengxi (Western Inner Mongolia); 30 GW at Mengdong (Eastern Inner Mongolia); 10 GW in Hebei Province; 20 GW at Hami (Xinjiang); and 10 GW in Jiangsu Province, 7 GW of which will be offshore. The program will ensure more than 100GW of installed capacity producing 200 TWh per year by 2020.

7.6.4.2 Manufacturing

The manufacturing industry will become more mature in the whole supply chain and will not only satisfy domestic demand, but also meet international needs, especially for components.

7.6.4.3 Industry forecast

The following table summarizes the forecast on the wind power development.

表 4-1 我国风电发展预测目标

年份	发展目标（低）			发展目标（中）			发展目标（高）			GWEC 预测
	装机	年均新增	年均增长速度	装机	年均新增	年均增长速度	装机	年均新增	年均增长速度	全球平均增长速度
	万 kW	万 kW	%	万 kW	万 kW	%	万 kW	万 kW	%	
2005	126		72%							40%
2006	260	133	105%	260			260			
2007	604	344	132%	604			604			
2010	800	100	15%	1 000	133	18.5%	2 500	633	60.9%	18.0%
2015	2 000	240	20.1%	3 000	400	24.6%	7 000	1 000	22.8%	18.0%
2020	4 000	640	14.9%	7 000	800	18.5%	12 000	1 500	11.4%	14.0%
2030	12 000	800	11.6%	18 000	1 100	9.9%	27 000	1 500	8.4%	7.0%
2040	25 000	1 300	7.6%	30 000	1 200	5.2%	42 000	1 300	4.5%	2.0%
2050	40 000	1 500	4.8%	45 000	1 500	4.1%	50 000	1 500	1.7%	0.5%

Table 2 - Wind Power Development Forecast

Notes: in first row, the three cells are “low development goal”, “middle development goal” and “high development goal”; for each development goal, the three columns under it are “installed capacity”, “annual new added capacity” and “annual increase rate” separately.

Source: 2008 China Wind Power Development Report, Chinese Renewable Energy Industry Association

7.7 Florida

7.7.1 Overview

Florida has one of the highest per capita residential electricity demands in the country, due to heave use of air conditioning and heat, however, the overall energy demand is not high because industrial energy use is low. The state has minor oil and gas reserves. Also, Florida currently only utilizes a few of its renewable energy resources. Its population of 18.5 million people uses approximately 253 billion BTUs of energy.[7]

7.7.2 Renewable and Alternate Energy Initiatives

In July 2007, Governor Charlie Crist signed three executive orders to initiate energy policies in Florida. These orders show a commitment to reducing greenhouse gases and increasing energy efficiency.[8] Additionally, legislation was signed into law, which authorized the Florida Public Service Commission to develop a new Renewable Portfolio Standard (RPS) by early 2009. The state still does not have an RPS, but there are laws in place that require major facility projects to be built with energy efficiency standards.[1] Concerning renewable energy resources, the terrain and climate in Florida make it an ideal candidate for solar energy initiatives and biofuel crop production.[3]

7.7.3 Wind Potential and Barriers

Since Florida has relatively light winds, large-scale commercial wind farms are not a viable option. Small installations are best for homes and businesses in windy areas.[9] According to a new wind resource map published by the National Renewable Energy Laboratory, at the 80 m hub height, Florida has a potential installed capacity of 0.4 MW that correlates to an annual generation of 1 GWh. This is because 99.2 percent of windy land in Florida was excluded in the study since most of these areas were protected environmental areas or had heavy urban development. These areas had a gross capacity of 30 percent or more at the 80 m level.[10]

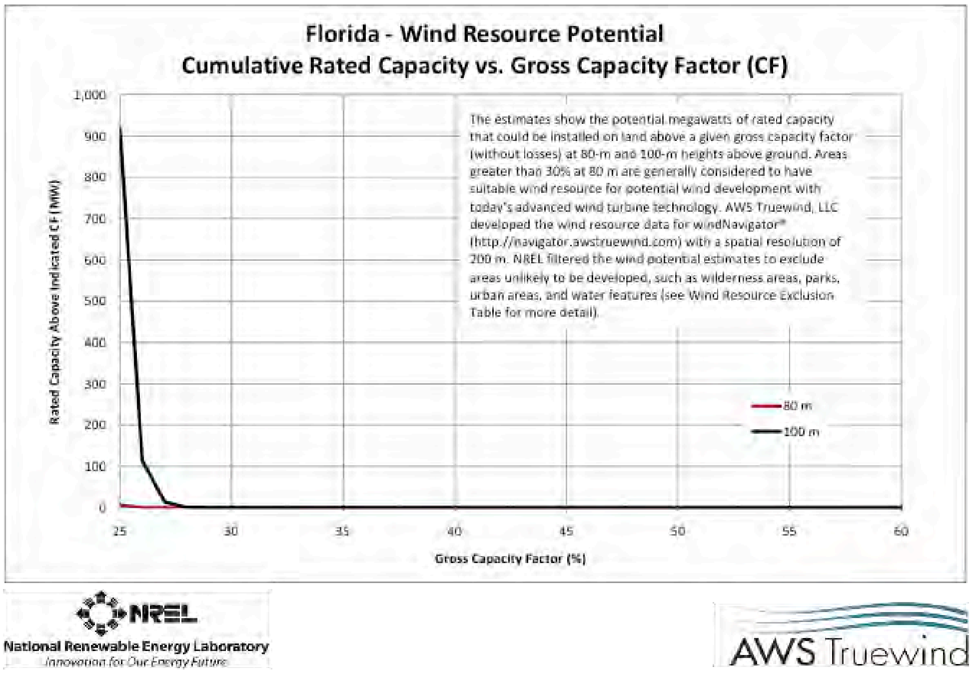
---

[7] http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=FL

[8] http://www.dep.state.fl.us/climatechange/eo.htm

[9] http://www.nrdc.org/energy/renewables/florida.asp

[10] http://www.windpoweringamerica.gov/wind_resource_maps.asp?stateab=fl



Small wind turbines would work for homes and small businesses in the windiest of areas. However, zoning restrictions of neighborhood and community associations have been a major hurdle or on site renewables. Despite Florida and other states enacting laws against these restrictions, they largely go ignored or unpublicized.[11] Additionally, Congressional and Presidential moratoria prohibiting energy development in most of the Outer Continental Shelf, on Florida's west coast, were lifted in 2008. However, a separate Act banning energy development within 100-125 miles of Florida remains in effect until 2022.

7.7.4 Future Wind

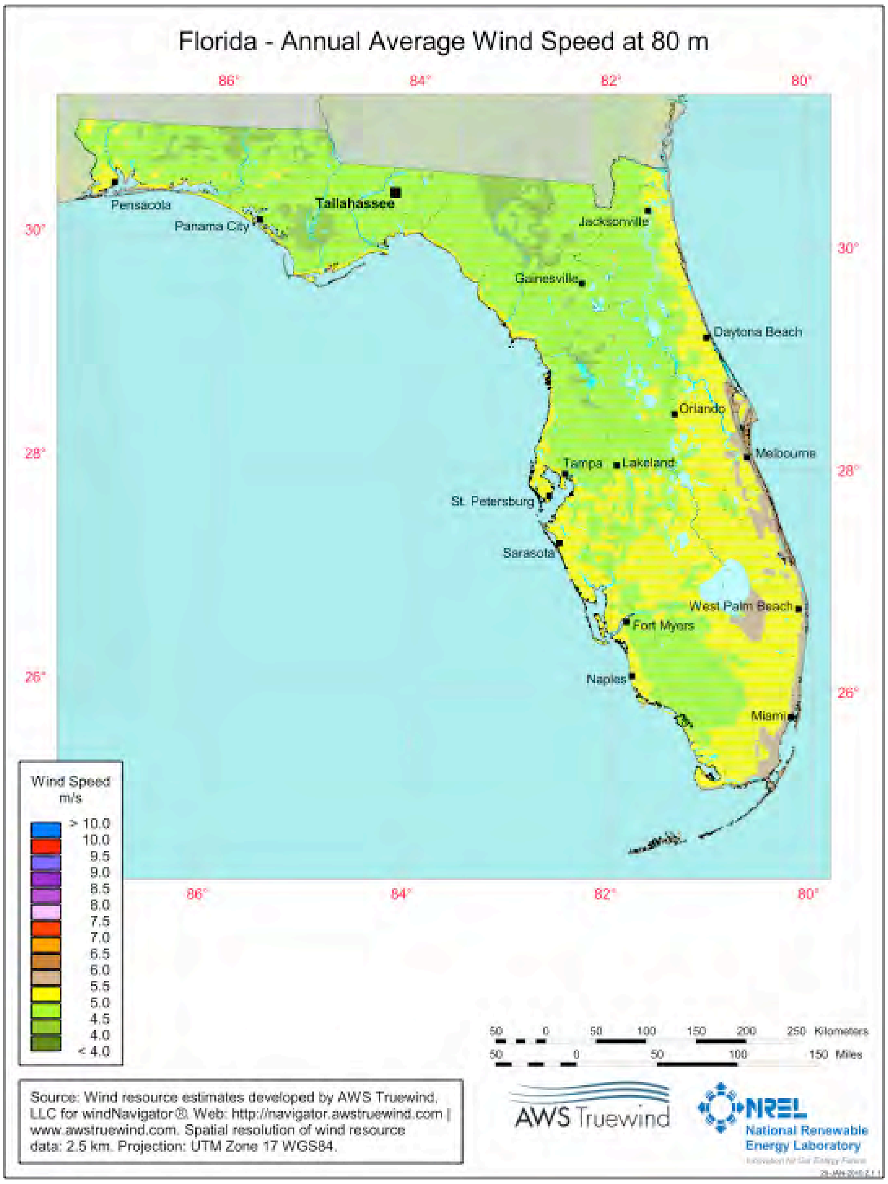
In early 2008, the Florida Department of Environmental Protection awarded a grant of $2.5 million to Florida Power and Light to establish "St. Lucie Wind". This would mark the construction of the first wind energy facility in Florida.[12] Offshore wind would also be a great resource to heavily populated coastal states like Florida. Due to the state's costal winds, approximately 154,500 GWh of electricity could be produced from offshore wind. This is

---

[11] http://www.awea.org/smallwind/pdf/2008_AWEA_Small_Wind_Turbine_Global_Market_Study.pdf

[12] http://www.dep.state.fl.us/secretary/news/2008/02/0226_02.htm

more of a possibility for the future since hurdles to costal wind development have recently been knocked down.[13]



[13] http://www.tampabay.com/news/politics/national/article984902.ece

7.8 The Gulf Coast Region

7.8.1 Overview

The Gulf Coast of the United States is composed of the 5 states which border the Gulf of Mexico: Texas, Louisiana, Mississippi Alabama and Florida. While Texas is the only state which has great potential for installed inland wind capacity, the 350 miles of coastline of Texas and Louisiana are considered prime locations for the first major offshore turbines. This region is attractive for off-shore wind production because of the relatively shallow coastline and existing oil and gas infrastructure.

7.8.2 Current Capabilities

Texas is the only state in this region where wind power contributes a measurable amount to its total current energy production. In 2006 Texas surpassed California to become the country's largest wind energy producer. Currently there are over 2,000 wind turbines in West Texas alone, and the numbers continue to increase due to decreasing development costs and the improvement of wind turbine technology. At 736 MW, the Horse Hollow Wind Energy Center in central Texas is the largest wind power facility in the world. Even with the current generation capacity, wind and other renewable energy sources currently contribute minimally to the Texas power grid in comparison to fossil fuel based plants.

7.8.3 In-land Wind Potential

The major wind resource areas in this region are the Texas Panhandle and the mountain passes and ridge tops of the Trans-Pecos mountains. A map of the average wind speeds can be seen in *Figure 1* In-land wind capacity is growing substantially with Texas becoming the first State to reach to install one gig watt of wind capacity in a single year in 2007. One of the driving factors of the new production may be the heavy demand for electricity. Texas is currently the number one producer and consumer of electricity in the US and has the highest average residential electricity bill besides Hawaii. This heavy demand likely has affected the growth of the wind industry.

Unlike Texas, the other states in the Gulf Coast region simply do not have the in-land wind resources to make development economical. In Louisiana the average annual wind speed is less than 4.5 m/s for 97% of its land area. The remaining 3% of Louisiana has an average annual wind speed of less than 5 m/s, and this area is confined to a small area along the Mississippi River below Port Sulphur and along exposed shore lines of the Gulf of Mexico. However, average wind speeds of 6.5m/s to 7.0m/s have been measured in the area 50km of the coast and over 7.0m/s 50-100km offshore.

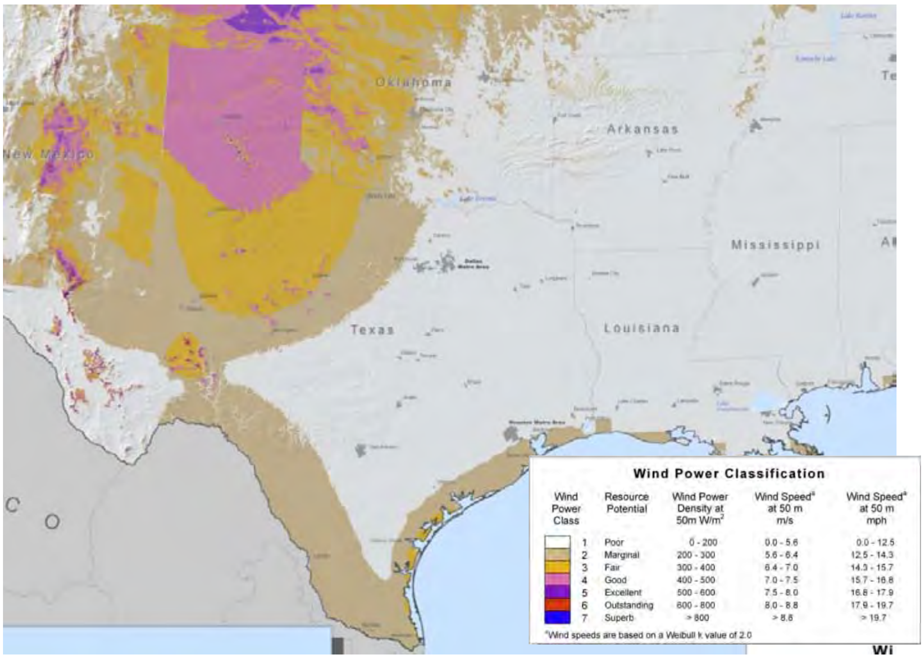


Figure 1. Wind Speed Map of Louisiana and Texas

http://www.eere.energy.gov/windandhydrop/windpoweringamerica/wind_maps.asp

7.8.4 Off-Shore Wind Potential

While the in-land regions of the Gulf Coast, aside from Northern Texas, may not be suitable for wind energy development the areas directly off-shore may provide a number of viable opportunities. Of particular interest to wind power developers is the area along the Texas Gulf Coast south of Galveston. Figure 2 shows the mean average wind speed at 90m.

Offshore wind development requires special construction considerations not present in in-land installation. One of the appeals of the Gulf Coast is that the coastline has a far-reaching continental shelf, in some areas extending 80 miles while having water depths less than 150 feet. There are nearly 3,500 active drilling platforms in Gulf of Mexico in water depths up to 200m. These structures have been designed to withstand the harshest conditions and their construction is a well documented, proven process. Current proposals for wind development involve incorporating turbines using the existing rig infrastructure or at the very least similar design concepts. This marriage of technologies results in an economic method of providing electrical power to the mainland with an already environmentally-proven system.

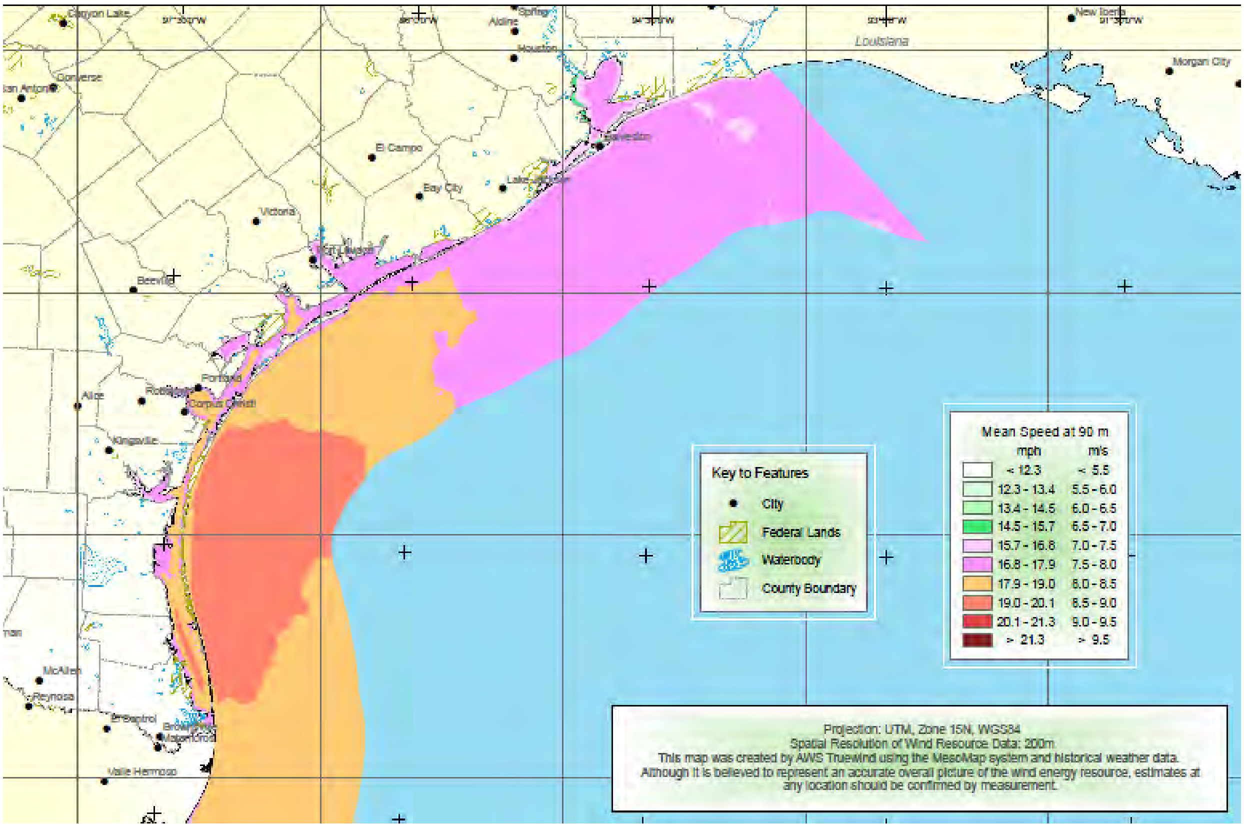


Figure 2. Wind Map of Offshore Texas: Mean Annual Wind Speed at 90m

AWSTrueWind

7.9 Bahrain

7.9.1 Overview

The kingdom of Bahrain is an archipelago of 33 small islands in the Arabian Gulf. In 1932, petroleum was first discovered in the Middle East in Bahrain. Ever since Bahrain has been a exporter of Oil and natural gas. The main industries in Bahrain are Petroleum processing and refining and Aluminum Smelting.

7.9.2 Current Energy Production

All of Bahrain's energy production is generated currently from petroleum powered thermal plants. The electricity production, transmission and distribution in Bahrain are the responsibility of Ministry of Electricity and water, which operates five stations with total installed capacity of 2.9 GW. The load in Bahrain can be categorized into four main sectors, industrial, domestic, commercial and desalination. The current demand is around 2.0 GW[14]

7.9.3 Carbon Free Energy Initiative

As the reserves of petroleum are depleting rapidly, the government of Bahrain has started studying the feasibility of renewable sources of energy such as wind energy. As a result, public and private sectors have started to look for potential sites. An innovative early project has been the construction of the first large-scale wind integrated office building in the world, the Bahrain World Trade Center.

Figure 41: Bahrain World Trade Center

The wind turbines are expected to provide 11% to 15% of the towers' total power consumption, or approximately 1.1 to 1.3 GWh a year.[15]

[14] http://www.mew.gov.bh/default.asp?action=category&id=64

[15] http://www.bahrainwtc.com/news35.htm

7.9.4 Wind Resource Assessment

Studies by the Bahrain Meteorological Directorate (BMD) indicate a wind speed of 4.8 m/s at a 10m height. From the study of wind patterns, BMD was able to identify a couple of locations that were favorable to install wind farms as shown in the wind distribution diagram below.

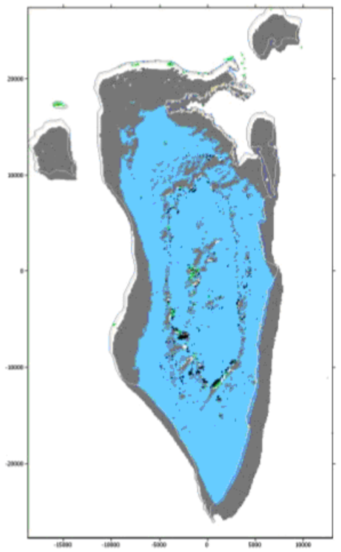


Figure 42: Geographical distribution of wind at a height of 10m[16]

However the comparison of wind power and energy demand shown below, indicate the maximum wind speeds occurs during the low power demand during the day.

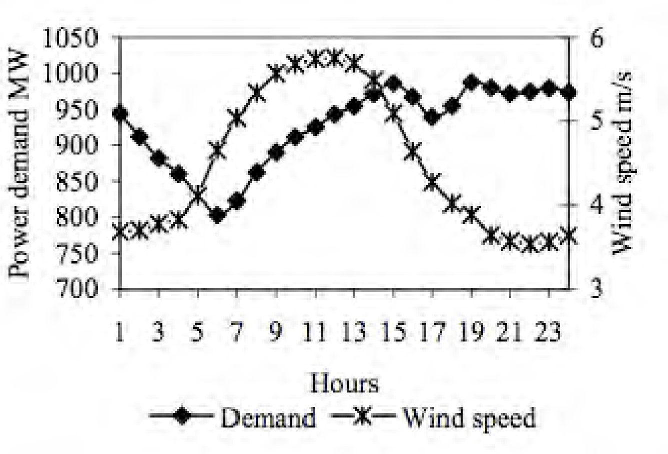


Figure 43: Diurnal patterns for power demand and wind speed[16]

Similarly the mismatch between wind power and energy demand was observed during the monthly means, especially during summer from July to September when temperatures soar above 100 F.

---

[16] http://www.ewec2007proceedings.info/allfiles2/361_Ewec2007fullpaper.pdf

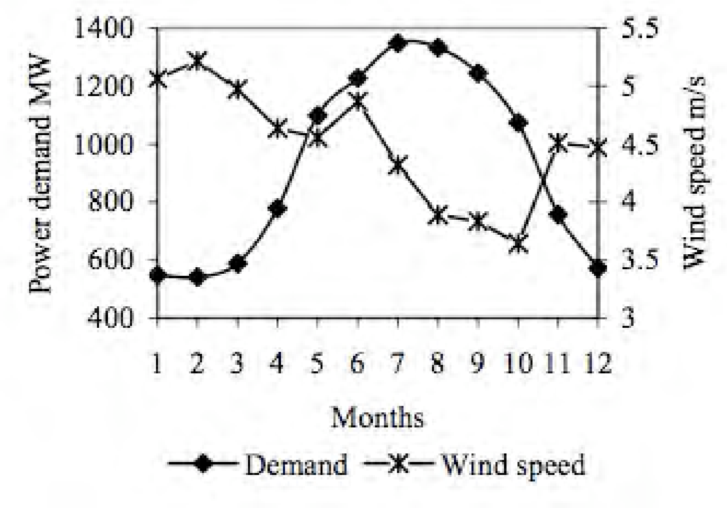


Figure 44: Monthly mean power demand and wind speed[17]

7.9.5 Conclusion

Thus the wind study concluded that Wind energy might not be optimal for Bahrain's energy solution. Solar power looks more promising and studies are being done to access its feasibility.

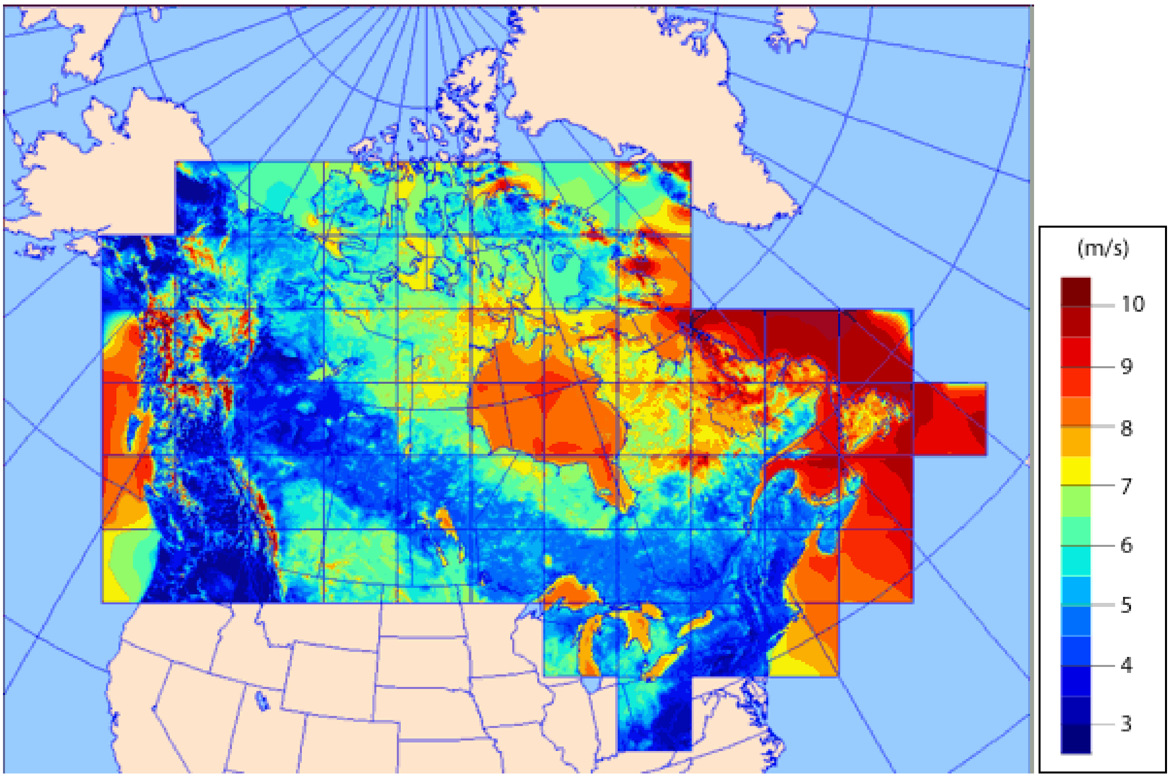
[17] http://www.ewec2007proceedings.info/allfiles2/361_Ewec2007fullpaper.pdf

7.10 Canada

7.10.1 Overview

Canada generates 1.1% of its electricity by wind energy, but wind is the fastest growing segment of its energy portfolio as the country moves to renewable sources. Canada has outlined a strategy to meet 20% of the countries needs with wind by 2025 with a planned capacity of 55GW. Currently there are nearly 100 commercial wind farms with a total of 3.2GW installed capacity and another 4.4GW in planning or under construction. The country is the world's second largest producer of hydroelectric power behind China generating 59% of its electricity with hydro-energy. Nuclear power provides 15% and the remaining portion of the nation's electricity comes from non-renewable oil, coal, and natural gas fired plants. Canadians are resoundingly (84%) in favor of wind power and against nuclear power (75%)[18].

7.10.2 Distribution of Wind in Canada



[18] Recall that Canada was the second nation in the world to develop a nuclear reactor, starting research in 1942 with British aid and has had an extensive nuclear industry since.

Wind power has a strong potential for growth if only because of its large area of potential sites and limited population. Ultimately wind power may be limited by the fact that most of the population is clustered in areas of limited wind speed and very sparsely populated elsewhere. Newfoundland, the Rockies, and the remote northern areas appear to have immense wind reserves but limited population and demand. Toronto, Montreal, and Vancouver are the three major population centers but each are far from on-shore ideal sites. Off-shore wind farms in the great lakes are currently under study since they provide attractive wind speeds and are close to population centers.

7.10.3 Installed Wind Capacity

Province/Territory	Current Installed Capacity (MW)[7]	Planned or Under Construction (MW)[8]	Expected 2015 Capacity (MW)	Installed Capacity per Capita (W)
Alberta	590	409	999	162
British Columbia	102	170.7	272.7	27
Manitoba	104	138	242	86
New Brunswick	195	114	309	261
Newfoundland and Labrador	54.4	0	54.4	107
Nova Scotia	59.3	244	303.3	63
Ontario	1161.5	647.2	1808.7	88
Prince Edward Island	151.6	0	151.6	1080
Québec	659	2671.5	3330.5	85
Saskatchewan	171.2	24.75	195.95	165
Yukon	0.81	0	0.81	24
Total	**3248.81**	**4419.15**	**7667.96**	**96**

There are 99 operating wind farms in Canada with much of the capacity in the populous Ontario and Quebec provinces.

7.10.4 The Future of Wind Energy in Canada

The future of wind energy looks bright in Canada because of strong local support and the forward looking goals set by the nation. Local manufacture of components for wind farms has begun. There are still many isolated communities in Canada that are not connected to a power grid. These communities have been experimenting with local small scale wind power; some using wind to generate hydrogen (via electrolysis) which is stored to generate power when the wind speeds are insufficient.

8 Works Cited

American Wind Energy Association (AWEA). (1996-2010). *AWEA Legislative Affairs*. Retrieved April 2010, from American Wind Energy Association: http://www.awea.org/legistlative/

American Wind Energy Association (AWEA). (1996-2010). *Production Tax Credit*. Retrieved April 2010, from American Wind Energy Association: http://awea.org/policy/ptc.html

AWS Truewind, L. (2010). *New York's Offshore Wind Energy Development Potential in the Great Lakes: Feasibility Study.* Albany: NYSERDA.

AWS. (2007). *Wind resource estimates developed by AWS Truewind, LLC for wind Navigator*. Retrieved from http//:navigator.awstruewind.com

Collaborative, T. L.–N. (2009). *THE LONG ISLAND – NEW YORK CITY OFFSHORE WIND COLLABORATIVE.* Albany: NYSERDA.

DOE Energy Information Administration. (n.d.). Retrieved May 5, 2010, from http://tonto.eia.doe.gov

DOE Energy Information Administration. (2003-2007). *Annual Electric Generator Report.* EIA, DOE.

Dorner, W. W. (1999). *Using Microsoft Excel for Weibull Analysis.* Retrieved 2010, from Quality Digest: http://www.qualitydigest.com/jan99/html/body_weibull.html

Energy Information Administration (EIA). (2007). *Renewable energy sources by state*. Retrieved from http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/table1_15.pdf

Energy Information Administration. (2006, January 30). *New York Household Electricity End Uses Report.* Retrieved May 2010, from US Department of Energy: http://www.eia.doe.gov/emeu/reps/enduse/er01_ny.html

Energy Information Administration. (2010, May 7). *Wholesale Day Ahead Prices at selected hubs.* Retrieved April 2010, from US Department of Energy: http://www.eia.doe.gov/cneaf/electricity/wholesale/wholesale.html

Enfield Wind Farm Waits for Green Light to Proceed. (n.d.). Retrieved from http://www.windaction.org/news/17659

GE Energy. (2005, September 23). *GE Energy Expands Its 1.5-MW Series of Wind Turbines; 2.5 and 3-MW Units*. Retrieved May 2010, from Transmission & Distribution World: http://tdworld.com/news/GE-wind-turbines/

GE Wind. (n.d.). *Wind Energy - The Facts - Volume 2 - Costs & Prices.* Retrieved 2010

General Electric, GE. (2009, December 10). *GE Wins First 2.5mw 1.4 Billion Oregon Wind Farm*. Retrieved May 2010, from Wind4me: http://seekingalpha.com/instablog/258208-wind4me/39320-ge-wins-first-2-5mw-1-4-billion-oregon-wind-farm

Ghosh, A. (1999). A FORTRAN program for fitting Weibull distribution and generating samples. *Computers & Geosciences 25* , 729 - 738.

Henbest, D. (2008, August 27). *Enfield Wind Farm Waits for Green Light to Proceed.* Retrieved April 2010, from Ithaca Times: http://www.windaction.org/news/17659

Hydro-Queubec Annual Report. (2009). *Shaping the Future.* Montreal.

Jackson, Gary; General Manager-Wigton Wind Farm Ltd. (2009, April). *2009 ARPEL Conference on Sustainable Development - Jamaica's Wind Energy and Development.* Retrieved from http://arpel.clk.com.uy/ppt/VIERNES%2024/Mesa%20redonda%205/Jackson.pdf

Jamaica Information Service. (2009, December 5). *E10 Roll Out is Positive, Says PCJ Boss*. Retrieved February 2009, from Jamaica Information Service - Ministry of Energy and Mining: http://jis.gov.jm/minenergymining/html/20091205t060000-0500_22143_jis_e10_roll_out_is_positive__says_pcj_boss.asp

Jamaica Information Service. (2006, June 22). *Renewable Energy to Contribute 10 Per Cent of Electricity Demand by 2010*. Retrieved from Jamaica Information Service: http://www.jis.gov.jm/commerce_science/html/20060621t110000-0500_9166_jis_renewable_energy_to_contribute_10_per_cent_of_electricity_demand_by_2010.asp

Jang, J.-J., & Lee, J.-R. (1997). Analysis of Design Wind Speed Distribution of Taiwan area. *Marine Science and Technology, Vol. 5, No.1* , 55-63.

New York City Department of City Planning. (n.d.). Retrieved February 2010, from http://www.nyc.gov/html/dcp/html/census/popcur.shtml

New York State Energy Planning Board. (2009). *Renewable Energy Assessment New York State Energy Plan 2009.*

New York State Energy Research and Development. (2010). *New York's Offshore Wind Energy Development Potential in the Great Lakes.* AWS True Wind.

NewTechnologyMagazine. (2009, 09 08). Statoil Draws On Offshore Oil Expertise To Develop World's First Floating Wind Turbine. Retrieved from NewTechnology magazine.

NY ISO. (2009). *Load and Capacity Data report.*

NY ISO. (2009). *Market Overview.*

NY ISO. (n.d.). *Markets & Operations.* Retrieved May 2010, from NY ISO - New York Independent System Operator: http://www.nyiso.com/public/markets_operations/market_data/maps/index.jsp

NY ISO. (n.d.). *New York Independant Systems Operator*. Retrieved March 2010, from http://www.nyiso.org

NY ISO. (2010). *Power Trends 2010.*

NY State Energy Planning Board. (2009, December). *Renewable Energy Assessment New York State Energy Plan.* Retrieved February 2010, from http://www.nysenergyplan.com/final/Renewable_Energy_Assessment.pdf

NYSEG. (n.d.). *NYSEG | FAQs*. Retrieved 5 13, 2010, from NYSEG: http://www.nyseg.com/YourHome/newwindenergy/faqs.html

NYSEG. (n.d.). *NYSEG: NewWind Energy: Yes! Sign Me Up for NewWin Energy Today*. Retrieved 5 13, 2010, from NYSEG: https://ebiz1.nyseg.com/cusweb/NewWindEnergy.aspx

NYSEIA. (2010, April 6). *NYS Solar Thermal Industry Ready for Leadership with New Incentives and Roadmap*. Retrieved April 10, 2010, from NYSEIA: http://nyseia.org/posts/nys-solar-thermal-industry-ready-for-leadership-with-new-incentives-and-roadmap-22.php

NYSEIA. (2010, April 30). *NYS Solar Thermal Industry Ready for Leadership with New Incentives and Roadmap*. Retrieved from http://nyseia.org/posts/nys-solar-thermal-industry-ready-for-leadership-with-new-incentives-and-roadmap-22.php

NYSERDA. (2009). *Patterns & Trends Report.*

NYSERDA. (2003). *Statewide Feasibility Study.*

NYSERDA. (n.d.). *The New York Renewable Portfolio Standard.* Retrieved February 2010, from http://www.nyserda.org/rps/index.asp

Pacific Northwest Laboratory. (1991). *An Assessment of the Available Windy Land Area and the Wind Energy Potential in the Contiguous United States.* PNL-7789, Pacific Northwest Laboratory.

Potopsingh, Ruth; Managing Director- Petroleum Corporation of Jamaica. (2009). *World Bank Energy Week 2009 - Wind Energy Development in Jamaica.* Retrieved from http://siteresources.worldbank.org/INTENERGY/Resources/335544-1232567547944/5755469-1239633250635/Ruth_Potopsingh.pdf

Ross, Westerfield, & Jordan. (2009). Fundamentals of Corporate Finance.

Transmission Developers Inc. (2010). *CHPExpress*. Retrieved April 2010, from Champlain Hudson Power Express: Project Portal: http://www.chpexpress.com

Truewind, A. (2010). *Great Lakes Offshore Wind Power Project.* Albany: NYSERDA.

Truewind, A. (2009). *Offshore Wind Technology Overview (For the Long Island - New York City Offshore Wind Collaborative).* Albany: NYSERDA.

US Census Bureau. (n.d.). *Census Statistics.* Retrieved May 2010, from US Census Bureau: http://censtats.census.gov/usa/usa.shtml

US Census Bureau. (n.d.). *US Census Bureau*. Retrieved February 2010, from http://www.census.gov/popest/state/NST-ann-est.html

US Department of Energy. (2008, 11 5). *Green Power Network: News*. Retrieved 5 13, 2010, from Department of Energy: http://apps3.eere.energy.gov/greenpower/news/news_template.shtml?id=612

US Department of Energy. (1995-2010). *New York Incentives/Policies for Newables & Efficiency*. Retrieved February 2010, from DSIRE Database of State Incentives for Renewables & Efficiency: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NY41F&re=1&ee=1

US Department of Energy. (1995-2010). *New York Incentives/Policies for Newables & Efficiency*. Retrieved February 2010, from DSIRE Database of State Incentives for Renewables & Efficiency: http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=NY

Vanek, F. (2010, January). CEE 5910 Wind Energy Project; Background Material. Ithaca, New York. Retrieved 2010

Vanek, F., & Albright, L. (2008). Energy Systems Engineering: Evaluation and Implementation. New York: McGraw-Hill.

Wigton Windfarm Ltd. (2010, March). *News and Other Information*. Retrieved from Wigton Windfarm Ltd: http://www.pcj.com/wigton/news.html

Wind Energy Project - Grid Connected Wind Farm. (2009). Retrieved from Retscreen International - Clean Energy Decision Support Centre: www.retscreen.net/download.php/da/842/3/WIND09-C.pdf

Appendix

A-1 Non-Wind Renewable Energy Projects in the NYISO Interconnection Queue

INTERCONNECTION REQUESTS AND TRANSMISSION PROJECTS / NEW YORK CONTROL AREA

Page 1 of 1

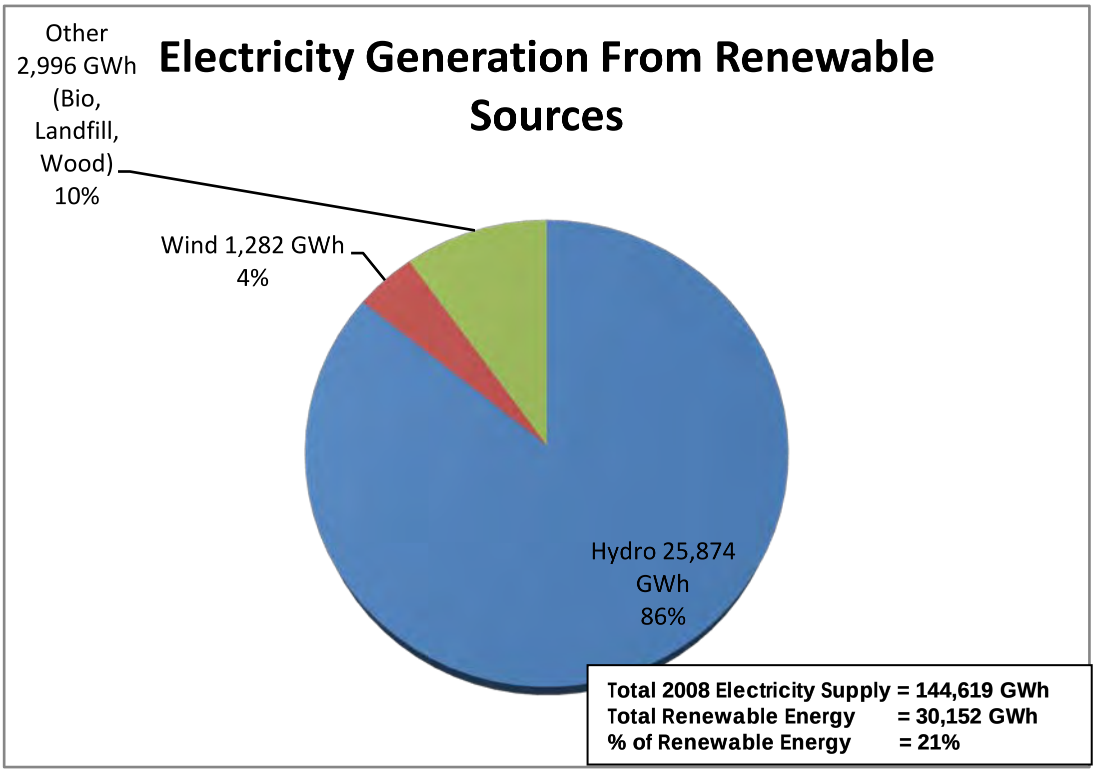
Queue Pos.	Owner/Developer	Project Name	Date of IR	SP (MW)	WP (MW)	Type/ Fuel	Location County/State	Z	Interconnection Point	Utility	S	Last Update	Availability of Studies	Proposed In-Service Original	Proposed In-Service Current
257	RG&E	Brown's Race Uprate	9/12/07	2	2	H	Monroe, NY	B	Beebee Station 34kV	RG&E	7	10/14/08	None	2008/12	2009/09-2010/10
264	RG&E	Seth Green	10/23/07	2.8	2.8	H	Monroe, NY	B	11kV	RG&E	7	10/14/08	None	2008/04	2010/01
338	RG&E	Brown's Race II	8/11/09	8.3	8.3	H	Monroe, NY	B	Station 3 / Station 137 34.5kV	RG&E	3	2/16/10	None	2011/08	2011/08
340	RG&E	Brown's Race III	9/2/09	2	2	H	Monroe, NY	B	Station 6 34.5 kV	RG&E	2	11/30/09	None	2010/12	2010/12
231	Seneca Energy II, LLC	Seneca	11/2/06	6.4	6.4	M	Seneca, NY	C	Goulds Substation 34.5kV	NYSEG	8	3/31/10	SRIS	2009/07	2010/10
239A	Innovative Energy System, Inc.	Modern Innovative Plan	1/31/07	6.4	6.4	M	Niagara, NY	A	Youngstown – Sanborn 34.5kV	NM-NG	8	2/16/10	None	2007/12	2011/07
245	Innovative Energy System, Inc.	Fulton County Landfill	4/17/07	3.2	3.2	M	Montgomary, NY	F	Ephratah – Amsterdam 69kV	NM-NG	9, 11	3/31/10	None	2008/Q3	2010/05
250	Seneca Energy II, LLC	Ontario	7/2/07	6.4	6.4	M	Ontario, NY	B	Haley Rd. - Hall 34.5kV	NYSEG	10	3/31/10	None	2009/10	N/A
284	Broome Energy Resources, LLC	Nanticoke Landfill	3/6/08	1.6	1.6	M	Broome, NY	C	Nanticoke Landfill Plant 34.5kV	NYSEG	10	11/30/09	None	2008/07	2010/05
342	Albany Energy, LLC	Albany Landfill	9/3/09	4.8	4.8	M	Albany, NY	F	34.5kV	NM-NG	4	12/22/09	None	2010/12	2010/12
348	Casella Waste Systems	Hyland Landfill	12/2/09	0.8	0.8	M	Allegany, NY	B	Station 249	RG&E	7	2/16/10	None	2010/Q3	2010/Q3
330	BP Solar	Upton Solar Farms	4/7/09	32	32	S	Suffolk, NY	K	8ER Substation 69kV	LIPA	7	3/31/10	None	2011/05	2010/09-2011/09
341	Covanta Energy	Hempstead Expansion	9/2/09	37	39	ST-SW	Nassau, NY	K	Hempstead 138kV	LIPA	4	11/30/09	None	2013/07	2013/07
349	Taylor Biomass Energy, LLC	Taylor Biomass	12/30/09	22.6	22.6	SW	Montgomery, NY	F	Maybrook - Rock Tavern	CHGE	2	3/31/10	None	2012/04	2012/04
225A	Schenectady International, Inc.	SII Rotterdam Junction	9/8/06	9.3	9.3	Wo	Rotterdam, NY	F	69kV	NM-NG	10	10/28/09	None		N/A
227A	Laidlaw Energy Group Inc.	Laidlaw Energy & Env.	10/30/06	7	7	Wo	Cattaraugus, NY	A	13.2kV	NM-NG	7	10/28/09	None		N/A
315	CRC Renewables, LLC	Onondaga Renewables	10/23/08	47	47	Wo	Onondaga, NY	C	Geres Lock 115kV	NM-NG	5	2/16/10	None	2011/03	2011/03

Other Renewables Planned 200

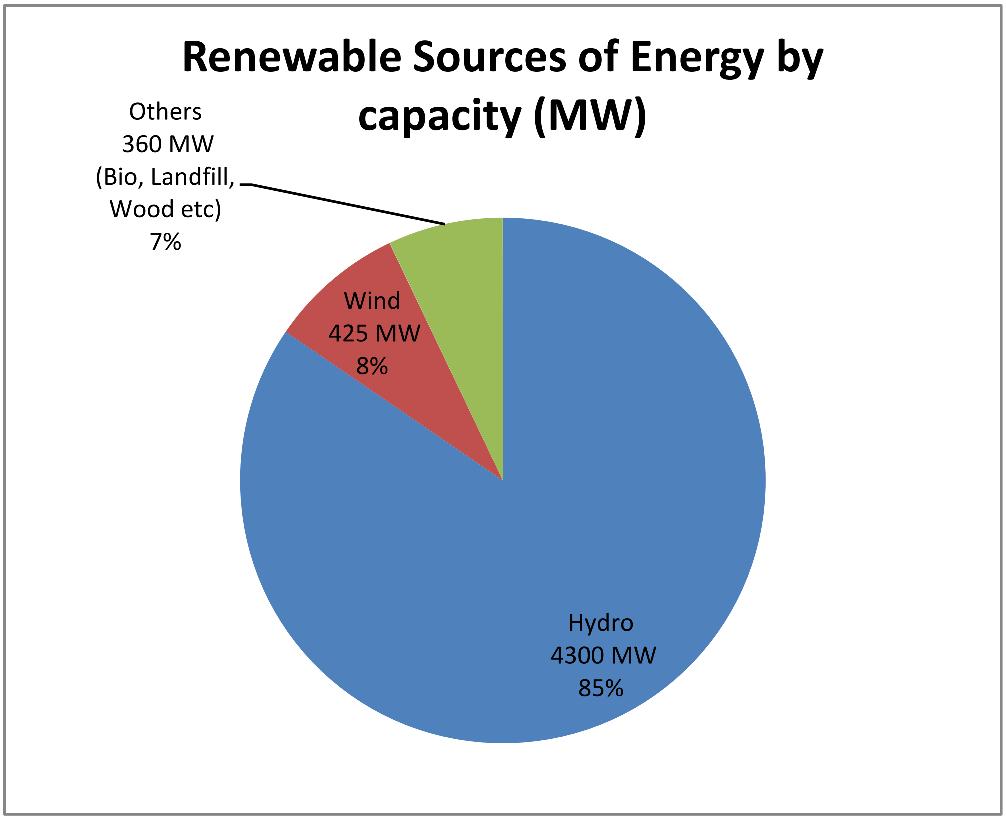
H = Hydro
M = Methane from Waste
SW = Solid Waste
Wo = Wood

Source: (NY ISO)

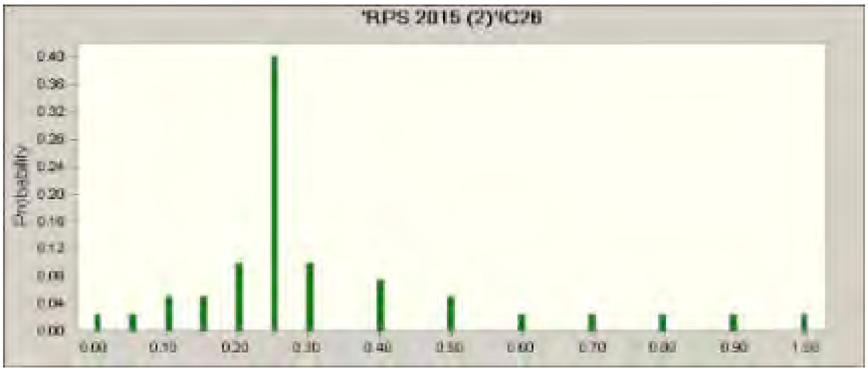
A-2 Current Renewable Energy Portfolio of New York State



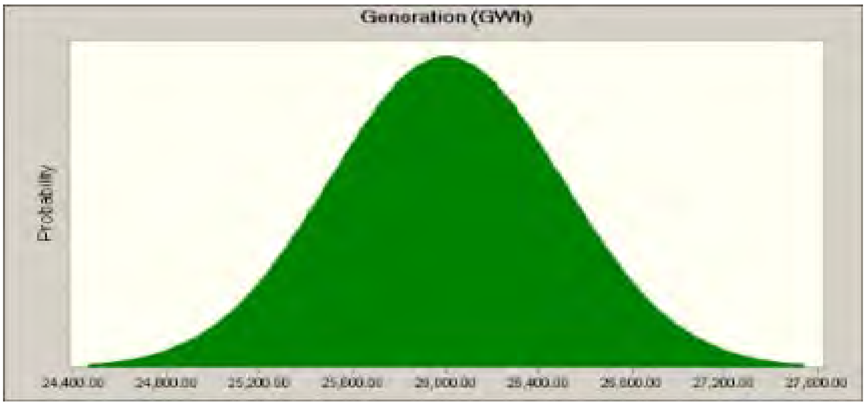
A-3 Renewable Energy Portfolio by capacity



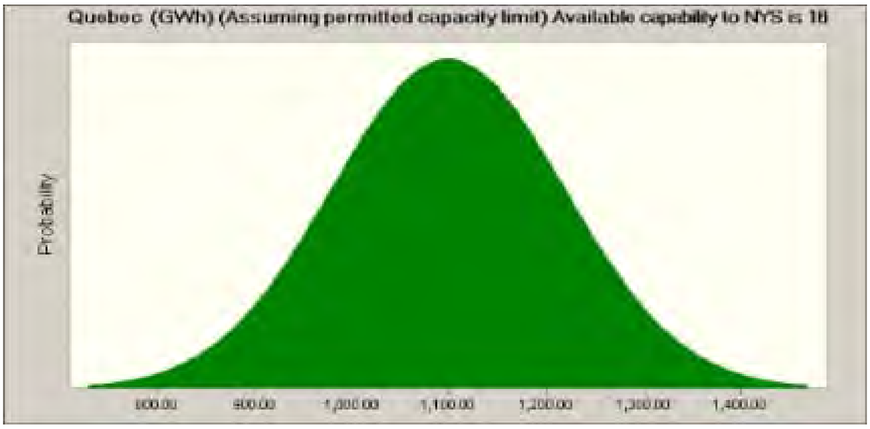
A-4 Probability distribution of percentage of projected 7000MW of Wind Capacity becoming operational by 2015



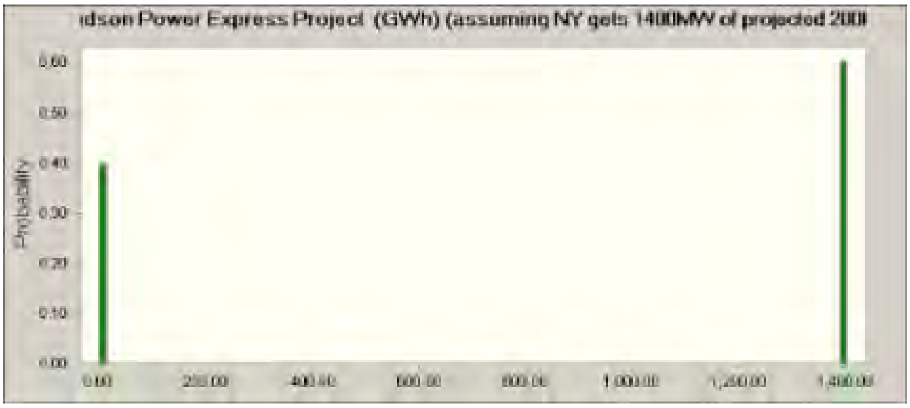
A-5 In-State Hydro-Electricity Forecast Model



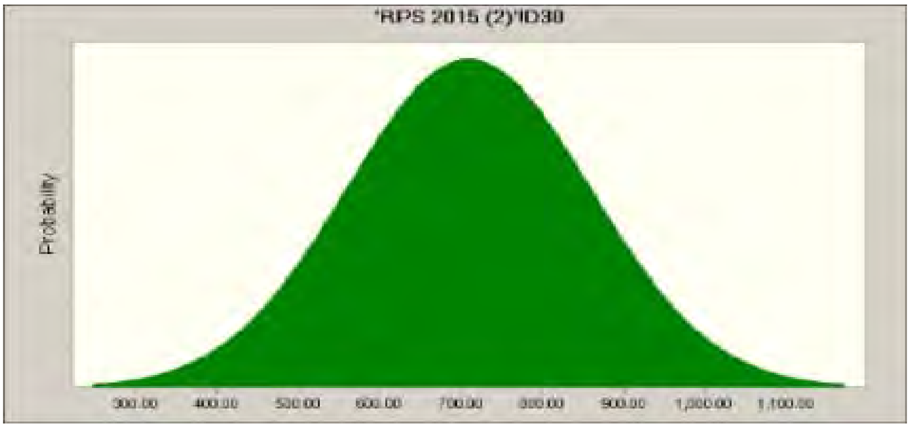
A-6 Hydro-Quebec Forecast model



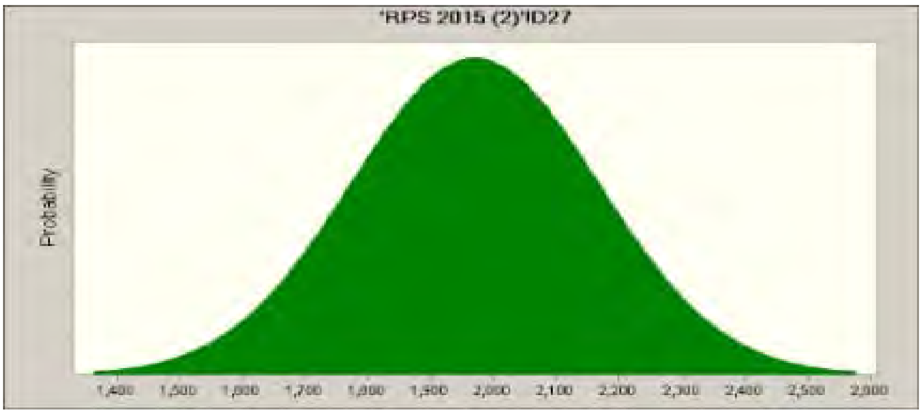
A-7 Champlain Hudson Power Project Forecast Model



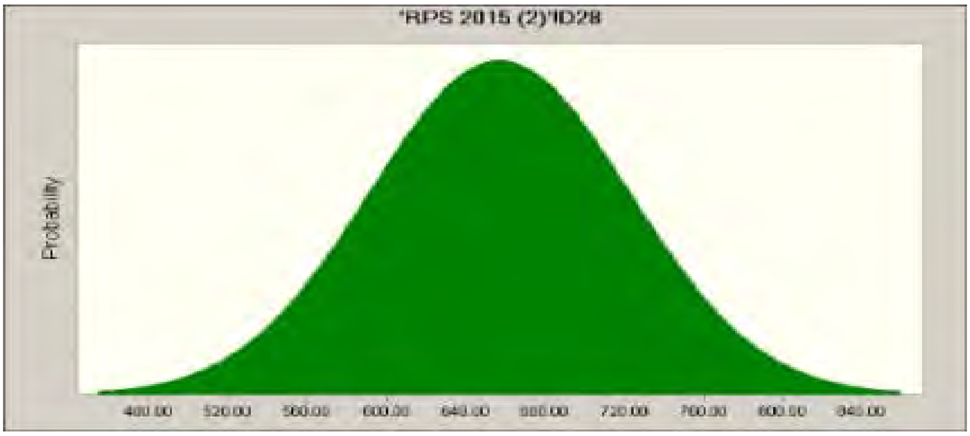
A-8 Solar Energy Forecast Model



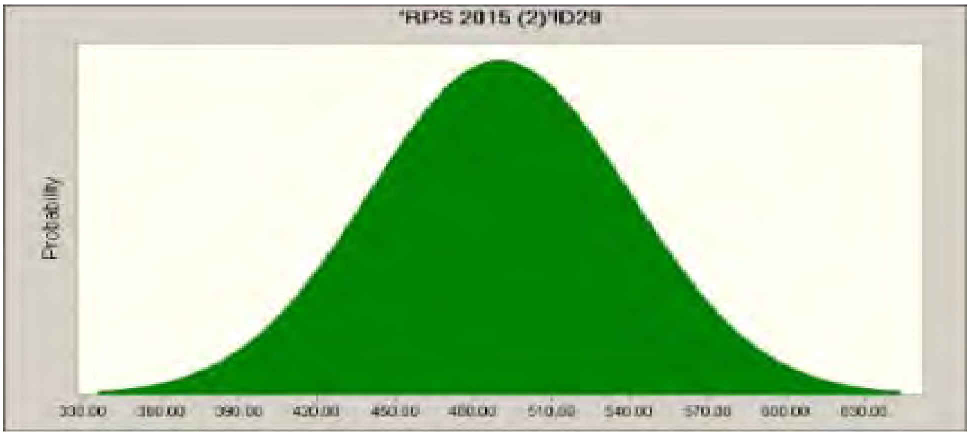
A-9 Landfill Gas Forecast Model



A-10 Biodiesel Forecast Model



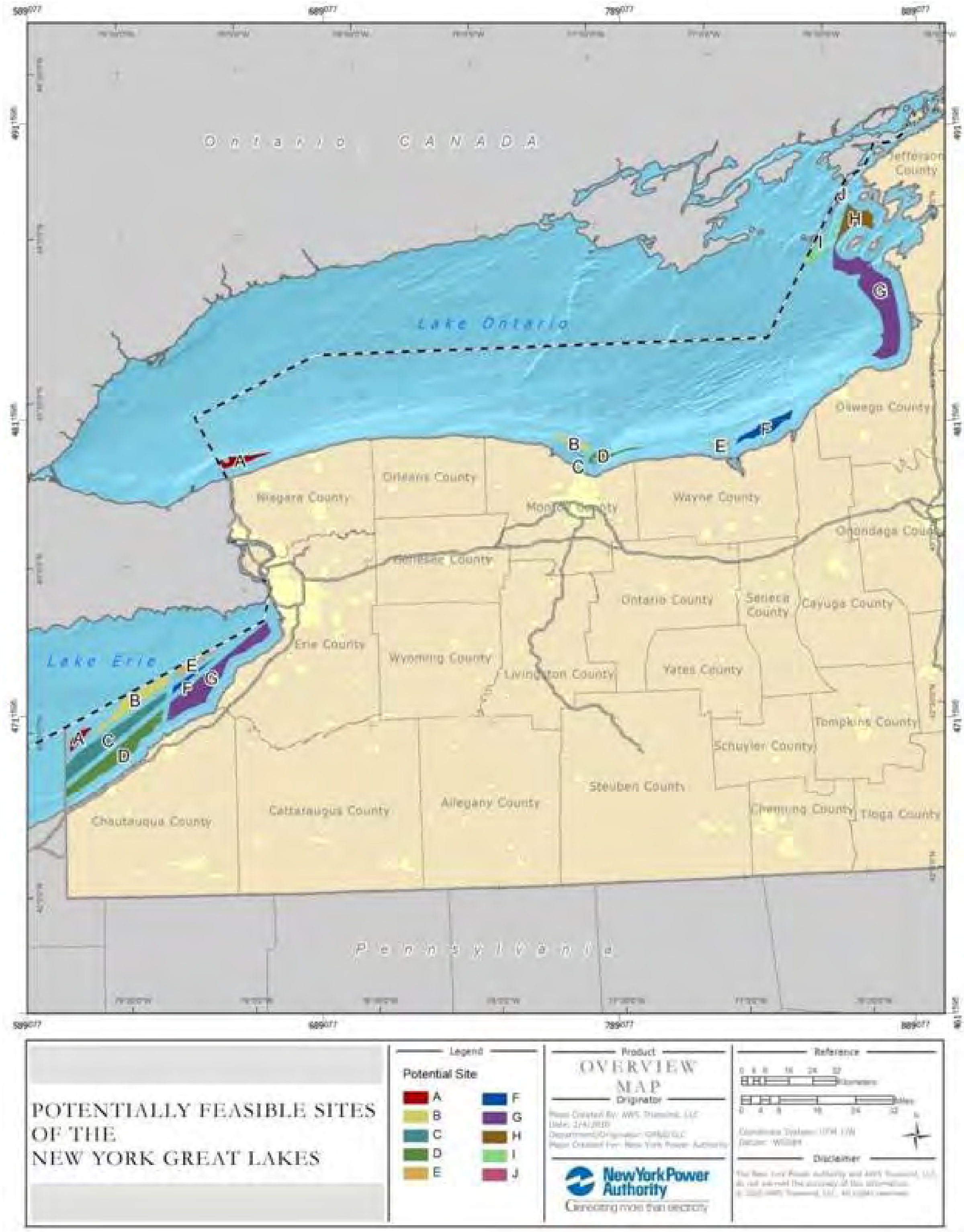
A-11 Wood Forecast Model



A-12 Offshore Project Costs and Statistics

Project Name	Country	Status	Operating Year	Project Cost ($M)	Project Capacity (MW)	Project Cost per MW ($M)	No. Turbines	Turbine Size (MW)	Turbine Model	Water Depth (m)	Distance from Shore (km)
Middelgrunden	Denmark	Commissioned	2001	$ 51	40	$ 1.28	20	2	Bonus 2 MW	5 to 10	2 to 3
Horns Rev	Denmark	Commissioned	2002	$ 295	160	$ 1.84	80	2	Vestas V80	6 to 14	14 to 17
North Hoyle	United Kingdom	Commissioned	2003	$ 138	60	$ 2.30	30	2	Vestas V80	5 to 12	7.5
Nysted	Denmark	Commissioned	2004	$ 316	165.6	$ 1.91	72	2.3	Siemens 2.3	6 to 10	6 to 10
Scroby Sands	United Kingdom	Commissioned	2004	$ 136	60	$ 2.27	30	2	Vestas V80	2 to 10	3
Kentish Flats	United Kingdom	Commissioned	2005	$ 179	90	$ 1.98	30	3	Vestas V90	5	8.5
Barrow	United Kingdom	Commissioned	2006	$ 172	90	$ 1.91	30	3	Vestas V90	15	7
Burbo Bank	United Kingdom	Commissioned	2007	$ 170	90	$ 1.89	25	3.6	Siemens 3.6	10	5.2
Egmond aan Zee	Netherlands	Commissioned	2007	$ 300	108	$ 2.77	36	3	Vestas V90	17 to 23	8 to 12
Inner Dowsing	United Kingdom	Commissioned	2008	$ 289	97.2	$ 2.97	27	3.6	Siemens 3.6	10	5.2
Lillgrund	Sweden	Commissioned	2008	$ 254	110.4	$ 2.30	48	2.3	Siemens 2.3	2.5 to 9	10
Princess Amalia	Netherlands	Commissioned	2008	$ 582	120	$ 4.85	60	2	Vestas V80	19 to 24	> 23
Alpha Ventus	Germany	Commissioned	2009	$ 350	60	$ 5.83	12	5	Multibrid & REpower	30	45
Gunfleet Sands I	United Kingdom	Commissioned	2009	$ 406	108	$ 3.76	30	3.6	Siemens 3.6	2 to 15	7
Horns Rev Expansion	Denmark	Commissioned	2009	$ 854	209.3	$ 4.08	91	2.3	Siemens 2.3	9 to 17	30
Rhyl Flats	United Kingdom	Commissioned	2009	$ 358	90	$ 3.98	25	3.6	Siemens 3.6	8	8
Robin Rigg	United Kingdom	Commissioned	2009	$ 651	180	$ 3.62	60	3	Vestas V90	>5	9.5
Sea Bridge	China	Under construction	2010	$ 345	102	$ 3.38	34	3	Sinovel 3 MW	8 to 10	8 to 14
Gunfleet Sands II	United Kingdom	Financing secured	2010	$ 275	64.8	$ 4.24	18	3.6	Siemens 3.6	2 to 15	7
Nordergrunde	Germany	Financing secured	2010	$ 440	90	$ 4.89	18	5	REpower 5M	4 to 20	30
Walney	United Kingdom	Financing secured	2010	$ 746	151.2	$ 4.93	42	3.6	Siemens 3.6	20	7
Belwind	Belgium	Financing secured	2011	$ 897	165	$ 5.44	55	3	Vestas V90	20 to 35	46
Thanet	United Kingdom	Financing secured	2011	$ 1,200	300	$ 4.00	100	3	Vestas V90	20 to 25	7 to 8.5
London Array	United Kingdom	Financing secured	2012	$ 3,095	630	$ 4.91	175	3.6	Siemens 3.6	23	>20
Sheringham Shoal	United Kingdom	Financing secured	2012	$ 1,500	316.8	$ 4.73	88	3.6	Siemens 3.6	16 to 22	17 to 23

A-13 Potential Sites for Offshore Wind Development in the Great Lakes Region



A-14 Weibull Distribution

Graphical method

This method is to plot the relation between the shape parameter and scale parameter of Weibull distribution (Ghosh, 1999), (Dorner, 1999). Before the plotting, we take the double natural logarithmic transformation on the Eq. (2) with a reasonable assumption: the wind speed is larger or equal to zero (m/s).

We have:

$$1 - F(x) = \exp\left[-\left(\frac{x}{c}\right)^k\right] \quad (5)$$

$$\ln\left(1 - F(x)\right) = -\left(\frac{x}{c}\right)^k \quad (6)$$

$$\ln\left(\frac{1}{1 - F(x)}\right) = \left(\frac{x}{c}\right)^k \quad (7)$$

$$\ln\left[\ln\left(\frac{1}{1 - F(x)}\right)\right] = k \ln\left(\frac{x}{c}\right) \quad (8)$$

$$\ln\left[\ln\left(\frac{1}{1 - F(x)}\right)\right] = k \ln x - k \ln c \quad (9)$$

After the transform, the Weibull C.D.F. have a straight line form as

Y= mX + b (10)

Where,

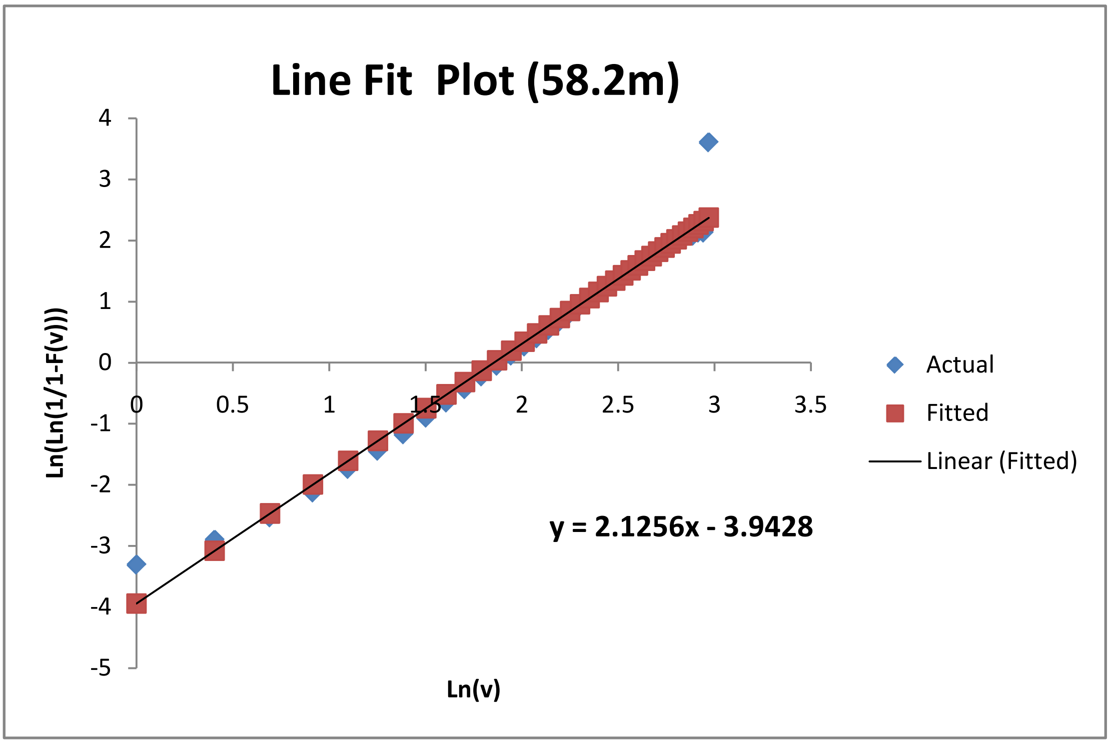
The left side of Eq. (9) corresponds to Y in Eq. (10)

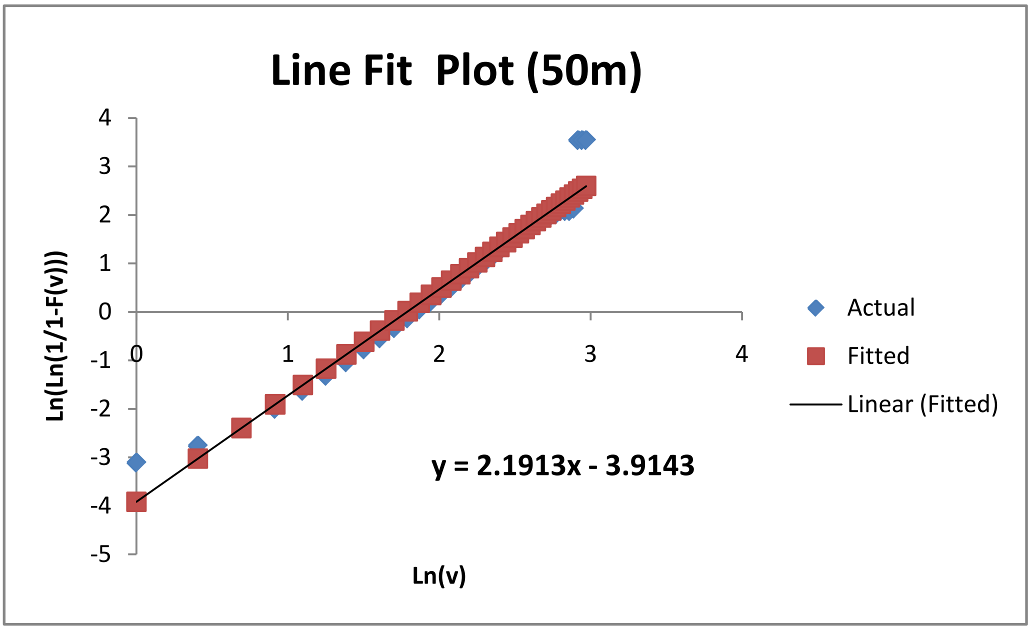
The lnx in Eq.(9) corresponds to X in Eq. (10)

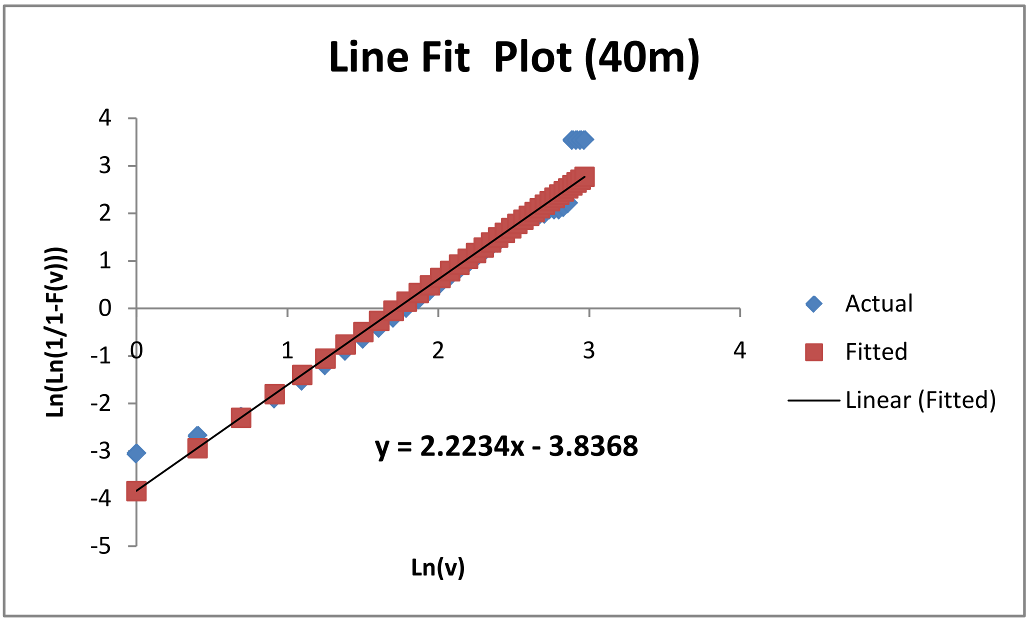
With the observed wind speed distribution at three heights, we perform the linear regression to generate the best fit straight line. The characters of the line are used to estimate the two Weibull parameters k and c. The Weibull shape parameter k is the slope of the line in form of Eq. (10). With the parameter k and the intercept of the line b, the Weibull scale parameter c can be calculated as

$$c = e^{-\left(\frac{b}{k}\right)} \quad (11)$$

The regression lines are shown as the following figures:







The results are summarized in the table below:

Height (m)	Slope	Intercept	Adjusted R square	Shape parameter k	Scale parameter c
40	2.2234	-3.8368	0.9582	2.2234	5.6163
50	2.1913	-3.9143	0.9576	2.1913	5.9674
58.2	2.1256	-3.9428	0.9764	2.1256	6.3910

Estimation of Weibull parameters with graphical method

Performance analysis

In the previous section, we applied both approach and graphical methods to estimate the Weibull shape parameter and scale parameter. The generated Weibull distributions are an approximation of the actual probability distribution of observed wind speeds. In order to statistically evaluate the performance of two estimation methods, the root mean square error (RMSE) was used to provide information on the generated Weibull distributions. RMSE can be expressed as

$$RMSE = \sqrt{\sum_{i=1}^{n} (y_i - x_i)^2 / n} \qquad (12)$$

In our application, the xi is the observed frequency and yi is the Weibull frequency, where n is the size of the frequency set.

By applying Eq. (12), we calculated the RMSE of the Weibull frequency to the observed frequency at three heights. The comparison of two methods of parameter estimation is given in the table below as following:

Height (m)	RMSE with graphical estimation	RMSE with analytical estimation
40	0.00856	0.01051
50	0.00841	0.00517
58.2	0.00721	0.00450

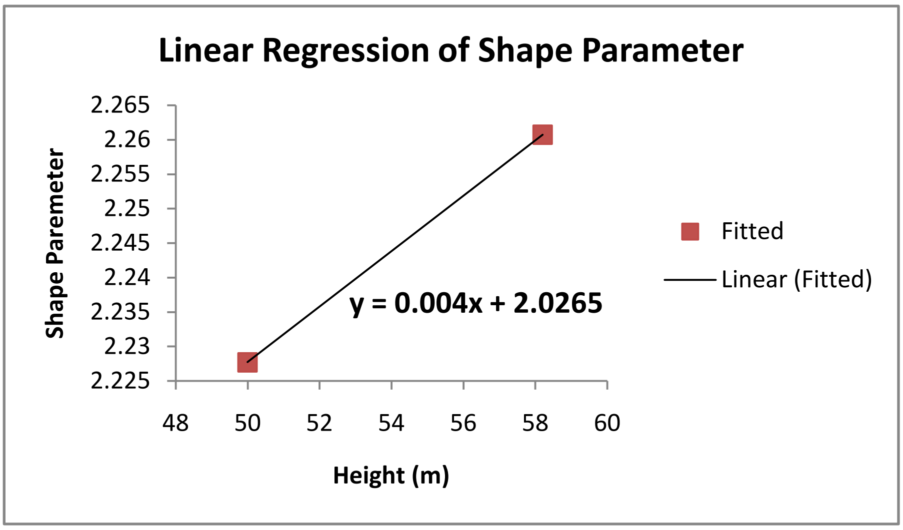
Comparison the performance of the Weibull distributions

The comparison shows that the Weibull distribution which parameters are estimated by using graphical method gives a better fit to the wind speed records. At height 50m and 58.2m, the Weibull distributions which parameters are estimated by using analysis method give better approximations with the actual wind speed distribution.

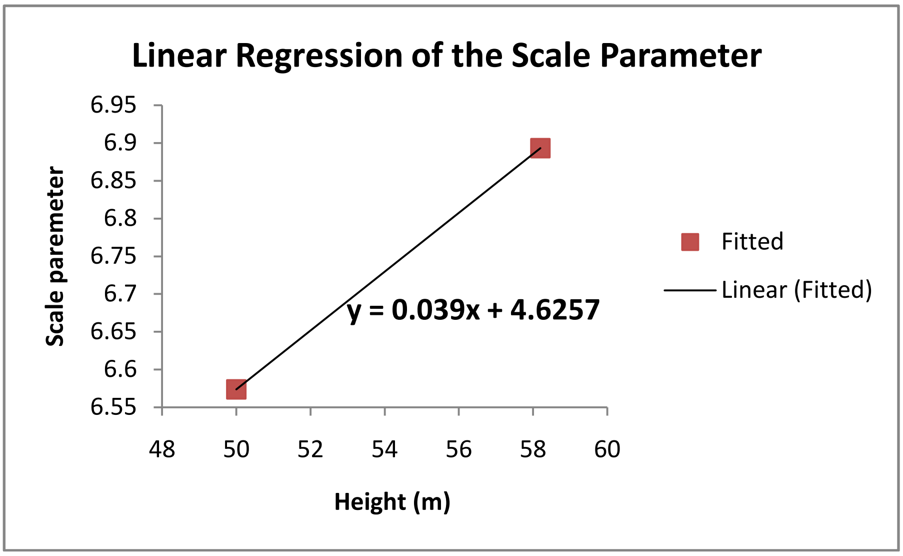
Power output estimation

The Enfield wind farm project selected the 2.5MW turbine. In order to study the available energy in the wind, we need to consider the wind resource at 80m height above the ground. However, there are no actual wind speed measurements at 80m. To cope with this issue, one reasonable solution is to apply the Weibull distribution to approximate the actual wind speed distribution at 80m height. And we will estimate the annual available wind energy at 80m by using the Weibull distribution.

First, we consider the relation between the height above the ground and the shape parameter and the scale parameter of the Weibull distribution. For each height, we chose the parameters pair which form the Weibull distribution fitting the observed distribution better. The linear regression is performed to estimate the possible Weibull parameter at 80m.



The figure above gives the result of linear regression for shape parameter. At 80m, the estimated shape parameter k = 0.004*80 + 2.0265 = 2.3465

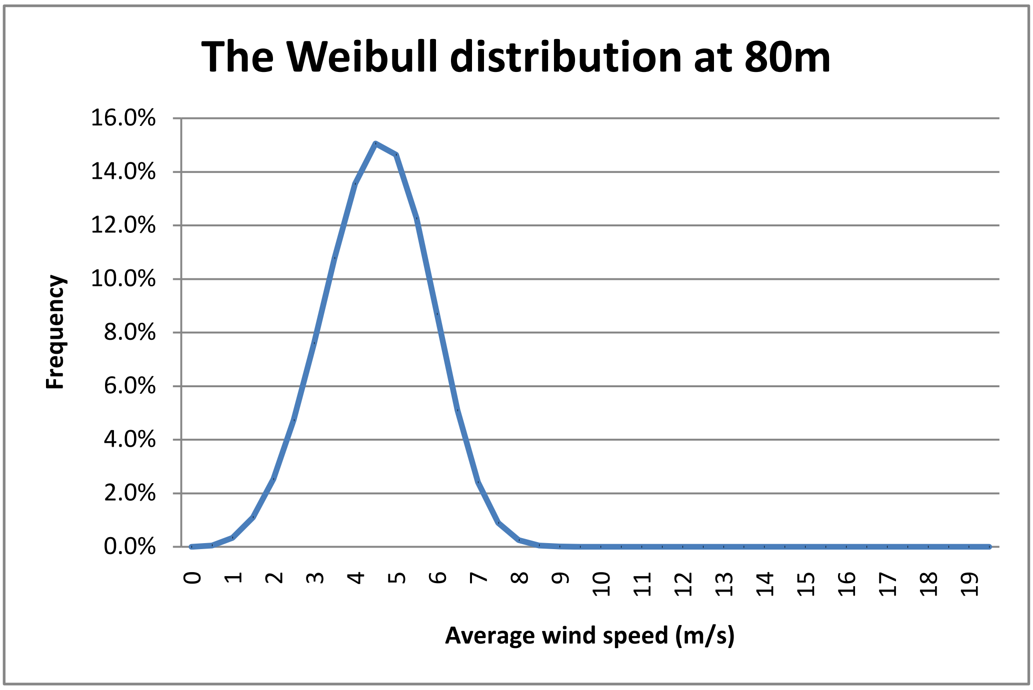


This figure gives the result of linear regression for shape parameter. At 80m, the estimated shape parameter c = 0.039*80 + 4.6257 = 7.7457

For Enfield wind farm, the corresponding cumulative distribution function of the Weibull distribution at height 80m has the following form:

$$F(x) = 0, \text{ for } x < 0$$

$$F(x) = 1 - \exp\left[-\left(\frac{x}{7.7457}\right)^{2.3465}\right], \text{ for } x \geq 0 \quad (13)$$



For a given wind speed, the average wind power available is calculated as follows (Vanek & Albright, Energy Systems Engineering: Evaluation and Implementation, 2008):

$$P = 0.5\rho U^3 \quad (14)$$

Where,

P is the available power in the wind per square meter of cross-sectional area.

ρ is the air density.

U is the wind speed

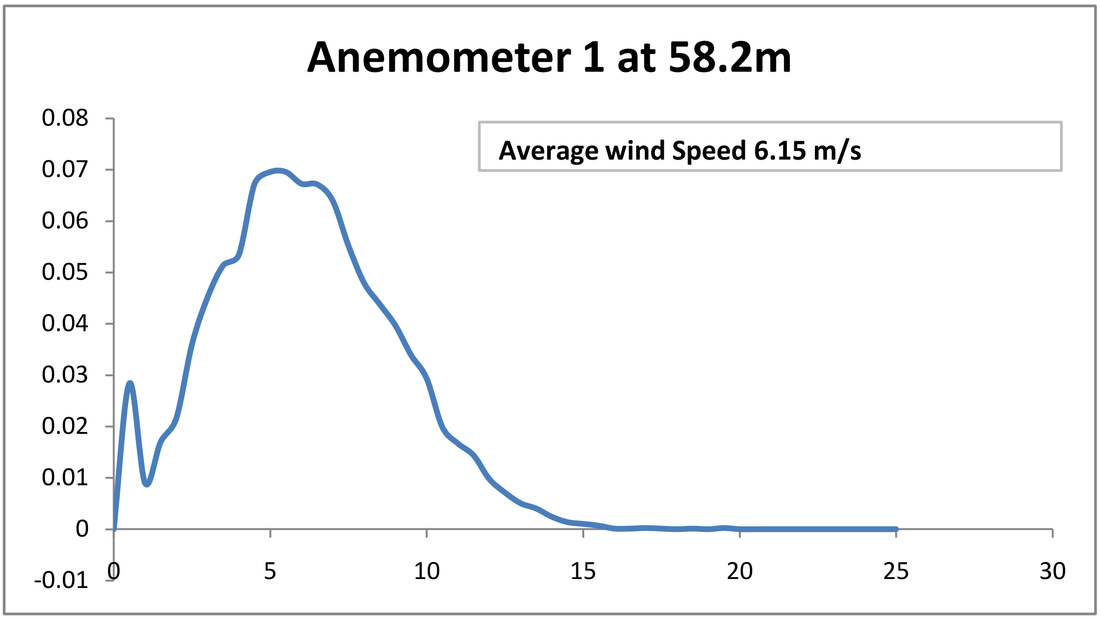
Assume the air density ρ = 1.15 kg/m3. By apply Eq. (13) and (14), the available wind power in each bin can be calculated. The results are given in the following table:

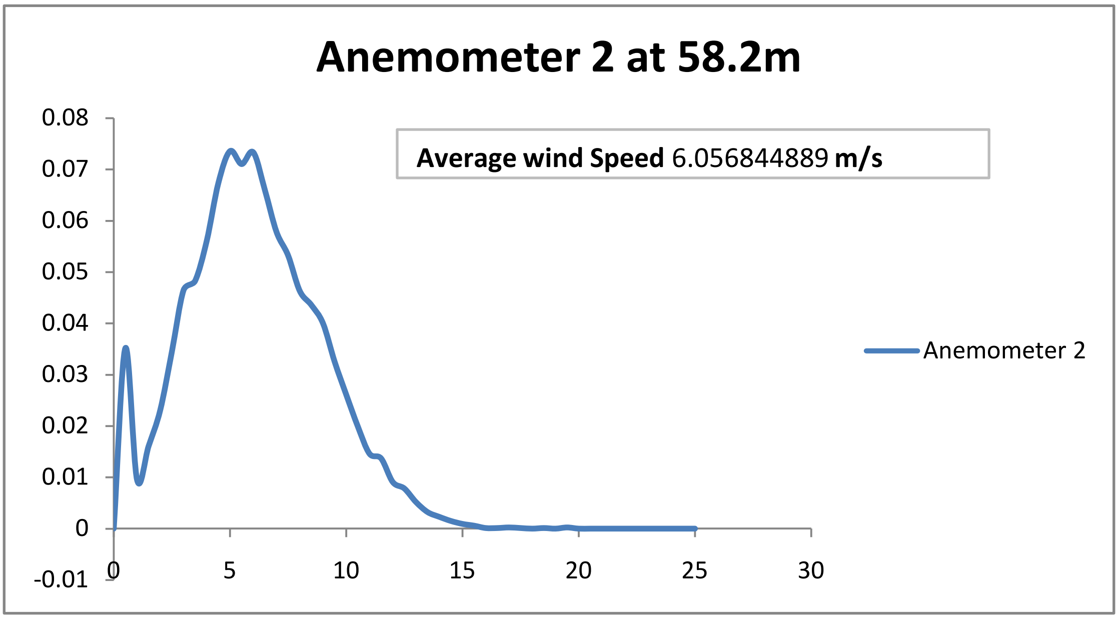
Bin	Average speed (m/s)	Hours/year	Average power (W/m2)	Estimated output (Wh/m2)
1	0	0	0.0	0.0
2	0.5	4	0.1	0.3
3	1	30	0.6	17.0
4	1.5	96	1.9	185.6
5	2	220	4.6	1011.5
6	2.5	411	9.0	3693.3
7	3	661	15.5	10266.6
8	3.5	937	24.7	23103.7
9	4	1178	36.8	43345.7
10	4.5	1309	52.4	68569.0
11	5	1272	71.9	91450.5
12	5.5	1066	95.7	102014.6
13	6	756	124.2	93875.6
14	6.5	443	157.9	69957.8
15	7	209	197.2	41286.9
16	7.5	78	242.6	18807.2
17	8	22	294.4	6425.4
18	8.5	5	353.1	1595.3
19	9	1	419.2	278.2

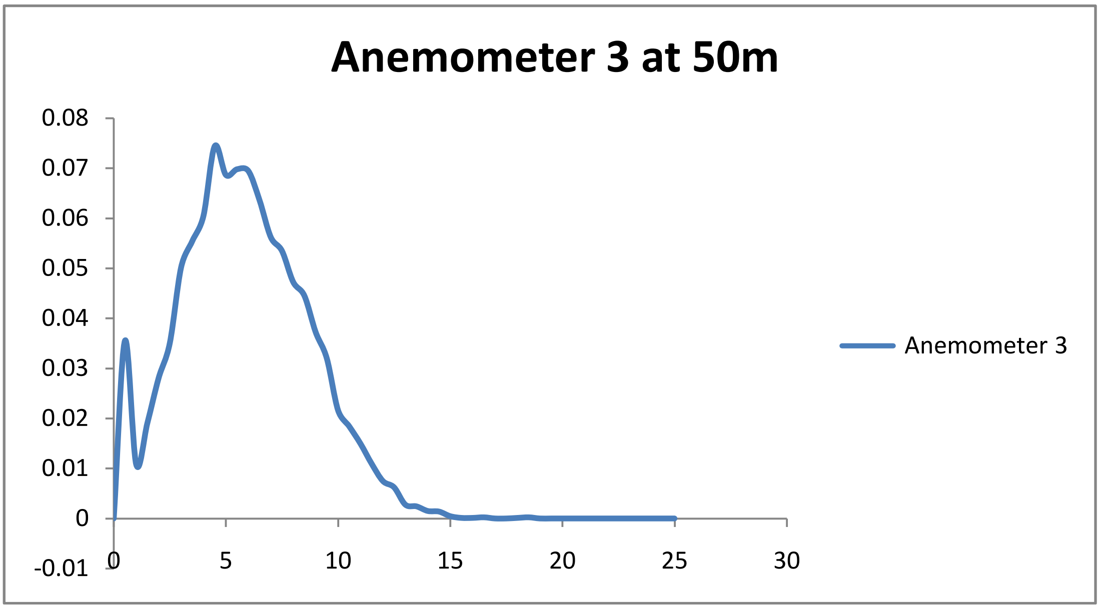
20	9.5	0	493.0	32.8
21	10	0	575.0	2.5
22	10.5	0	665.6	0.1
23	11	0	765.3	0.0
24	11.5	0	874.5	0.0
25	12	0	993.6	0.0
26	12.5	0	1123.0	0.0
27	13	0	1263.3	0.0
28	13.5	0	1414.7	0.0
29	14	0	1577.8	0.0
30	14.5	0	1753.0	0.0
31	15	0	1940.6	0.0
32	15.5	0	2141.2	0.0
33	16	0	2355.2	0.0
34	16.5	0	2583.0	0.0
35	17	0	2825.0	0.0
36	17.5	0	3081.6	0.0
37	18	0	3353.4	0.0
38	18.5	0	3640.7	0.0
39	19	0	3943.9	0.0
40	19.5	0	4263.6	0.0

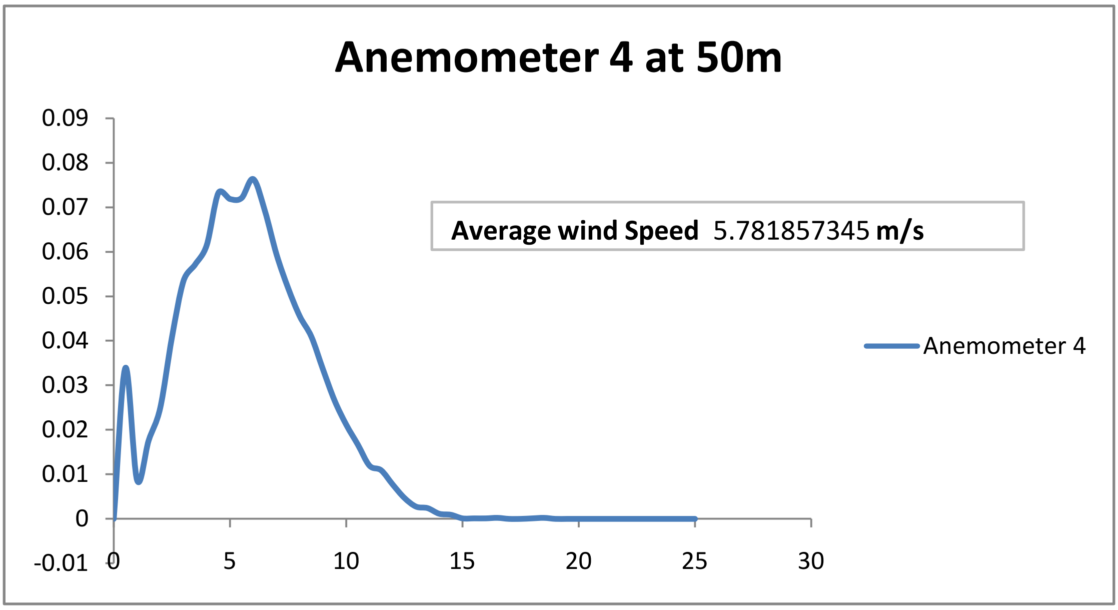
The estimated total annual output is 575.9kWh/m2.

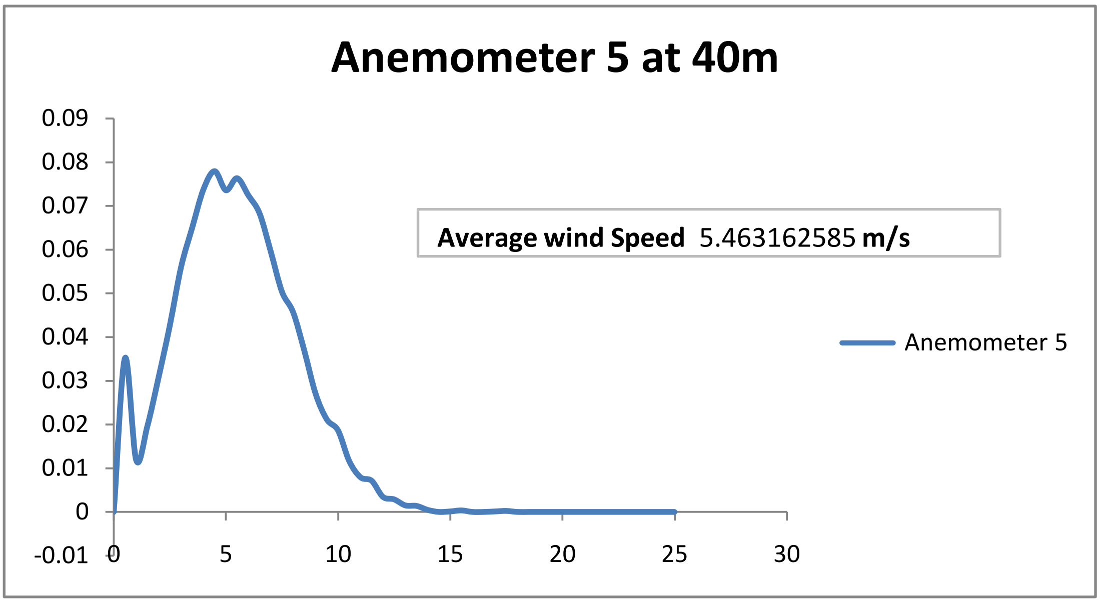
A-15 Wind Speeds at Different Anemometers

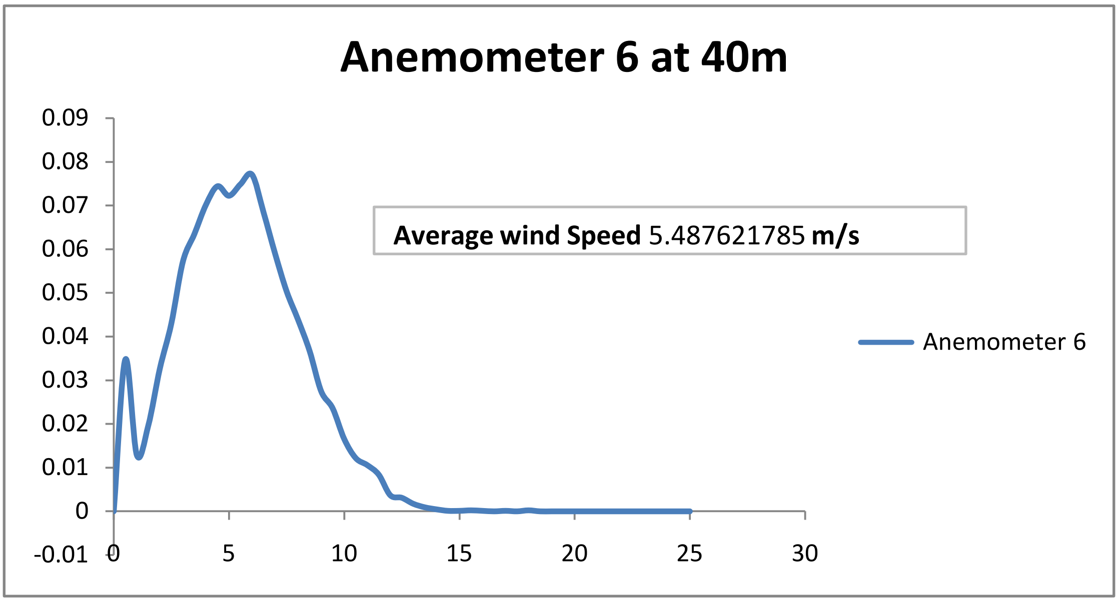





Anemometer 3 at 50m
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0
5
10
15
20
25
30
Anemometer 3


Anemometer 4 at 50m
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0
5
10
15
20
25
30
Average wind Speed 5.781857345 m/s
Anemometer 4

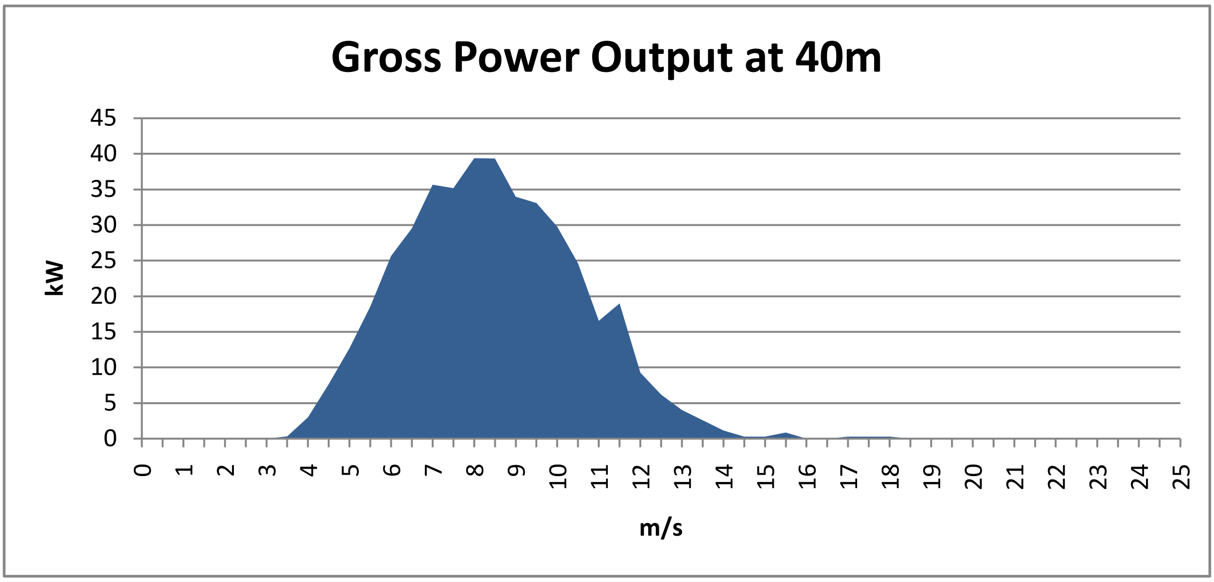

Anemometer 5 at 40m
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0
5
10
15
20
25
30
Average wind Speed 5.463162585 m/s
Anemometer 5

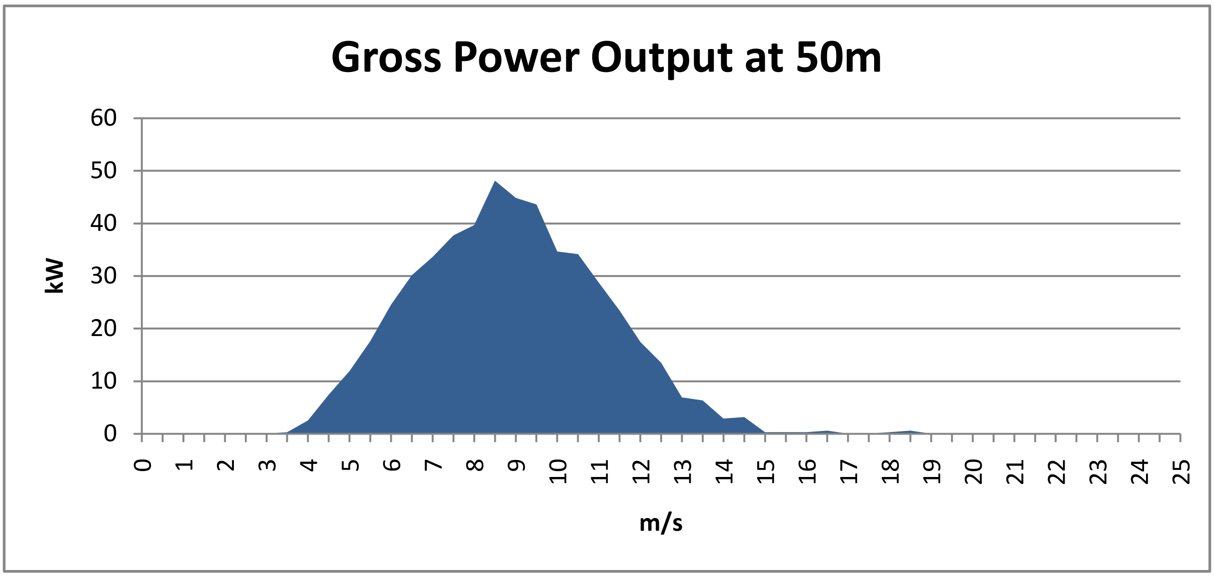

Anemometer 6 at 40m
Average wind Speed 5.487621785 m/s
Anemometer 6
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0
5
10
15
20
25
30

A-16 Power Output at Each Anemometer

	Power Output [kW]		
Bin	Anomometer 1&2	Anomometer 3&4	Anomometer 5&6
0	0	0	0
0.5	0	0	0
1	0	0	0
1.5	0	0	0
2	0	0	0
2.5	0	0	0
3	0	0	0
3.5	0.247786593	0.282856157	0.321950098
4	2.226054961	2.525008624	3.003334483
4.5	6.975623778	7.425664022	7.662527308
5	12.15821548	11.90410486	12.70553064
5.5	17.7509486	17.60779579	18.55260435
6	24.78003909	24.54478556	25.64263539
6.5	28.48614465	30.13452915	29.51638496
7	34.98953662	33.6083707	35.64723468
7.5	38.44682074	37.70587559	35.15373117
8	40.77727952	39.66425204	39.36069909
8.5	46.40220766	48.11176268	39.31976544
9	50.93273543	44.83822008	33.95515695
9.5	50.54041624	43.58686904	33.07174888
10	45.20662297	34.63884098	29.74634932
10.5	38.57330114	34.13958836	24.6071059
11	34.06232034	28.70967	16.54455559
11.5	30.95067265	23.40807175	18.98654709
12	21.52811314	17.44049672	9.265263884
12.5	18.53949638	13.48327009	6.179832126
13	12.36058411	6.898930666	4.024376222
13.5	8.336207888	6.324019777	2.587099
14	6.036564333	2.874554444	1.149821778
14.5	3.449465333	3.162009888	0.287455444
15	2.299643555	0.287455444	0.287455444
15.5	1.724732666	0.287455444	0.862366333
16	0.287455444	0.287455444	0
16.5	0.287455444	0.574910889	0
17	0.574910889	0	0.287455444
17.5	0.287455444	0	0.287455444
18	0	0.287455444	0.287455444
18.5	0.287455444	0.574910889	0
19	0	0	0
19.5	0.574910889	0	0
20	0	0	0
20.5	0	0	0
21	0	0	0
21.5	0	0	0
22	0	0	0
22.5	0	0	0
23	0	0	0
23.5	0	0	0
24	0	0	0
24.5	0	0	0
25	0	0	0
Average	580.0811774	515.3191905	429.3038979

A-17 Gross Power Output





A-18 After Tax Cash Flow Calculation

Year	CapEx (Equity)	Debt Pmt	All Other	Unpaid Debt	Interest	Principal	Depr rate (MACRS)	Deprec.	Revenue	Carbon Credit	Income Before Tax	Tax	After Tax Income	ATCF
0	$ 30,800,000													$ (30,800,000)
1		$ 5,901,759	$ 2,107,771	$ 46,200,000	$ 4,389,000	$ 1,512,759	$ 0	$ 22,000,000	$ 9,619,893	$ 360,746	$ (18,876,878)	$ (7,361,983)	$ 12,953,621	$ 9,333,091
2		$ 5,901,759	$ 2,107,771	$ 44,687,241	$ 4,245,288	$ 1,656,471	$ 0	$ 35,200,000	$ 9,619,893	$ 360,746	$ (31,933,166)	$ (12,453,935)	$ 18,189,286	$ 14,425,044
3		$ 5,901,759	$ 2,107,771	$ 43,030,771	$ 4,087,923	$ 1,813,836	$ 0	$ 21,120,000	$ 9,619,893	$ 360,746	$ (17,695,802)	$ (6,901,363)	$ 12,794,078	$ 8,872,472
4		$ 5,901,759	$ 2,107,771	$ 41,216,935	$ 3,915,609	$ 1,986,150	$ 0	$ 12,672,000	$ 9,619,893	$ 360,746	$ (9,075,487)	$ (3,539,440)	$ 9,604,470	$ 5,510,549
5		$ 5,901,759	$ 2,107,771	$ 39,230,785	$ 3,726,925	$ 2,174,834	$ 0	$ 12,672,000	$ 9,619,893	$ 360,746	$ (8,886,803)	$ (3,465,853)	$ 9,719,567	$ 5,436,962
6		$ 5,901,759	$ 2,107,771	$ 37,055,951	$ 3,520,315	$ 2,381,443	$ 0	$ 6,336,000	$ 9,619,893	$ 360,746	$ (2,344,194)	$ (914,236)	$ 7,374,559	$ 2,885,344
7		$ 5,901,759	$ 2,107,771	$ 34,674,508	$ 3,294,078	$ 2,607,680	$ -	$ -	$ 9,619,893	$ 360,746	$ 4,218,043	$ 1,645,037	$ 5,041,523	$ 326,072
8		$ 5,901,759	$ 2,107,771	$ 32,066,827	$ 3,046,349	$ 2,855,410	$ -	$ -	$ 9,619,893	$ 360,746	$ 4,465,773	$ 1,741,652	$ 5,192,639	$ 229,457
9		$ 5,901,759	$ 2,107,771	$ 29,211,417	$ 2,775,085	$ 3,126,674	$ -	$ -	$ 9,619,893	$ 360,746	$ 4,737,037	$ 1,847,444	$ 5,358,110	$ 123,664
10		$ 5,901,759	$ 2,107,771	$ 26,084,743	$ 2,478,051	$ 3,423,708	$ -	$ -	$ 9,619,893	$ 360,746	$ 5,034,071	$ 1,963,288	$ 5,539,300	$ 7,821
11		$ 5,901,759	$ 2,107,771	$ 22,661,035	$ 2,152,798	$ 3,748,960	$ -	$ -	$ 9,619,893	$ 360,746	$ 5,359,323	$ 2,090,136	$ 5,737,704	$ (119,027)
12		$ 5,901,759	$ 2,107,771	$ 18,912,074	$ 1,796,647	$ 4,105,112	$ -	$ -	$ 9,619,893	$ 360,746	$ 5,715,475	$ 2,229,035	$ 5,954,956	$ (257,926)
13		$ 5,901,759	$ 2,107,771	$ 14,806,963	$ 1,406,661	$ 4,495,097	$ -	$ -	$ 9,619,893	$ 360,746	$ 6,105,460	$ 2,381,129	$ 6,192,848	$ (410,021)
14		$ 5,901,759	$ 2,107,771	$ 10,311,865	$ 979,627	$ 4,922,131	$ -	$ -	$ 9,619,893	$ 360,746	$ 6,532,494	$ 2,547,673	$ 6,453,339	$ (576,564)
15		$ 5,901,759	$ 2,107,771	$ 5,389,734	$ 512,025	$ 5,389,734	$ -	$ -	$ 9,619,893	$ 360,746	$ 7,000,097	$ 2,730,038	$ 6,738,576	$ (758,929)
16		$ -	$ 2,107,771	$ -	$ -	$ -	$ -	$ -	$ 9,619,893	$ 360,746	$ 7,512,122	$ 2,929,727	$ 7,050,911	$ 4,943,140
17		$ -	$ 2,107,771	$ -	$ -	$ -	$ -	$ -	$ 9,619,893	$ 360,746	$ 7,512,122	$ 2,929,727	$ 7,050,911	$ 4,943,140
18		$ -	$ 2,107,771	$ -	$ -	$ -	$ -	$ -	$ 9,619,893	$ 360,746	$ 7,512,122	$ 2,929,727	$ 7,050,911	$ 4,943,140
19		$ -	$ 2,107,771	$ -	$ -	$ -	$ -	$ -	$ 9,619,893	$ 360,746	$ 7,512,122	$ 2,929,727	$ 7,050,911	$ 4,943,140
20		$ -	$ 2,107,771	$ -	$ -	$ -	$ -	$ -	$ 9,619,893	$ 360,746	$ 7,512,122	$ 2,929,727	$ 7,050,911	$ 4,943,140