Transition to Sustainable Energy in the US

Wind Energy Option

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EXECUTIVE SUMMARY

Due to political, environmental, and economic forces, power generation from wind energy has been brought to the forefront of many efforts to realize a solution to multiple problems faced by the world today. Energy demand continues to increase as world populations grow and citizens of 2nd and 3rd world countries desire a standard of living comparable to that of major industrialized nations. However, as this increased generation capacity is sought from traditional energy sources, environmental concerns inherent to the use of such fossil fuels are becoming more and more pronounced. With concerns abound about our world's current energy use and associated emission of green house gases, it has become evident that the effect of this new required capacity may further exacerbate the issues surrounding climate change. Thus there is a present need to offset current and future global energy demands traditionally provided by fossil fuels with energy sources that are considered less damaging to the environment.

Since the previous century, human ingenuity has provided several possible solutions to these developing needs. Now leading the way in 'renewable' energy technologies, wind power brings with it promises of both reduced environmental impact and reduced cost, as wind power technology has finally progressed to being economically competitive with traditional fossil fuel sources. Technological limitations have traditionally proven to be the most significant barriers to wind power penetration into existing transmission and distribution systems. Now that these technical problems of the turbines have been significantly resolved, political issues have arisen that threaten the further expansion of wind power and its role in reducing the harmful effects of fossil fuel-based energy production. Also, there are challenges with grid upgrading and energy storage.

In this comprehensive report, major policy and development concerns behind further penetration of wind power generation are explored. Considering both worldwide as well as domestic United States trends, the existing need for generation is examined and compared that to all possible sources of electrical power. Most of the world's leading nations have already developed policies or goals to obtain at least some level of power generation from wind sources, and an examination of the significant geographic regions involved with these initiatives is included. Additional treatment is given to the wind power industry promulgation in the United States with regards to the incentives and barriers that exist or will need to be created to construct a system that is reliable, efficient, and cost effective.

With the recent focus given to wind power generation in today's society, there has been a significant rise in the demand for wind turbine systems. The current wind turbine industry is significantly overloaded, resulting in long lead times and the existence market inefficiencies that provide unnecessary costs to those involved in the industry. As part of the analysis, world manufacturing leaders were studied and their contributions to the industry were researched to determine what barriers exist that are currently preventing worldwide growth to meet the targets set forth by the many national governments involved.

Finally, three site studies were conducted to demonstrate the feasibility of wind power installation in different application scenarios. An industrial-sized turbine for generation to be consumed primarily by the turbine's owner was analyzed for use at the Greek Peak Ski Resort in Cortland County, NY. This scenario is applicable to any business that consumes large amounts of electricity on-site as needed for manufacturing and operating activities. In contrast, a large, commercial-scale power generation facility was analyzed in Northern Oregon, at the Klondike III site. These types of facilities are generally owned by investors, installed on non-owner property, with the electricity sold to areas located long distances from the actual generation site. Finally, an offshore generation site was analyzed to explore the potential for wind generation in relatively shallow waters off the coast of the Eastern United States. This site is located in the Nantucket Sound, off the coast of Massachusetts, and has many aspects similar to offshore sites already installed and operating in northern Europe. Similar to the Klondike III site, the power generated in this case would be sold to customers who are not involved in the ownership, generation, or financing of the project.

PART I: INTRODUCTION

I.1. Motivations for the project

The growth of the wind industry represents a global trend towards the broad investment in renewable energy infrastructure during a time when gross energy consumption and cost of generation are both steadily increasing. Wind energy is, in fact, the fastest growing renewable source in the world and the industry finds itself in the spotlight as it matures and develops into an integral member of the solution to meet future energy demands.

As the traditional electricity generation mostly involves burning of fossil fuels, in addition to deforestation caused by human activities, the concentration of carbon dioxide (CO_2) in the atmosphere has been increasing since the industrial revolution. Global atmospheric concentrations of CO_2 were 36% higher than they were before the Industrial Revolution, from approximately 280 parts per million (ppm) in pre-industrial times to 382 ppm in 2006 according to the National Oceanic and Atmospheric Administration's (NOAA) Earth Systems Research Laboratory. Because of its strong ability in retaining solar heat, CO_2 has become the major cause of global warming and long-term climate change. Oxides and nitrogen, sulfur dioxide, particulate matters, etc. are also emitted during the use of fossil fuels, which creates air pollution problems such as ozone effects and acid rain. Wind power stands as a source of clean energy to generate electricity.

With the effects of global climate change and the intent to reduce emissions, it is a necessary endeavor to examine the present state of the industry, further defining its efficiencies and obstacles, technologies, externalities, and future development scenarios. This project is intended to provide a robust informational overview of the macro- and micro-level aspects of the industry while detailing industry economics and environmental effects with respect to global climate.

I.1.1. Planet climate change

I.1.1.1. Evidences of climate change

The climate of the planet is changing without any doubt. Global worming is confirmed by the increase of the average air and ocean temperatures, decreasing of the snow and ice covers and increasing of the average sea level (Fig. I.1.1).

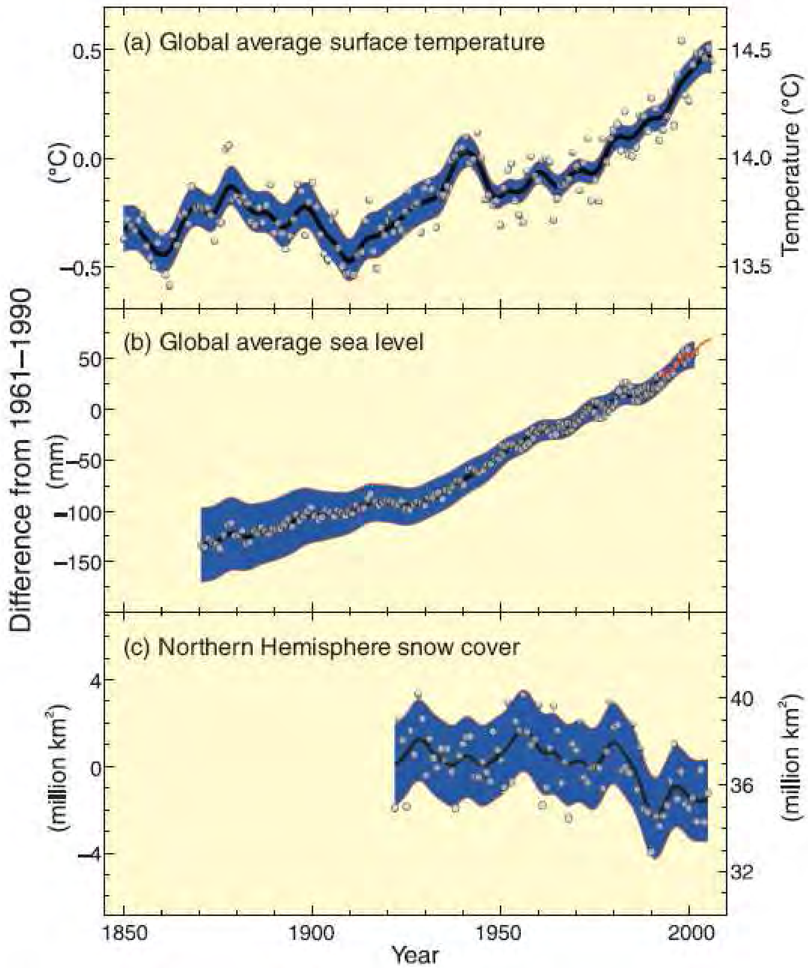


Figure I.1.1: Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averaged for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals [1].

The temperature is rising over the entire planet and the rate of change is increasing. The northern hemisphere is warming faster. Consistent with the temperature increase is the decrease of the amount of ice and snow, the Arctic sea ice coverage has been shrinking with 2.7 % [1] per decade. Natural consequence from ice melting is the increase of the sea level which has been confirmed from satellite observations and on-site measurements. The planet warming is a scientifically confirmed fact.

I.1.1.2. Reasons for planet climate change

There is very high confidence that the reason for accelerating climate change is the human industrial activities in the last 250 years. The rise of the industrial societies and resulting welfare has been powered by combustion of fossil fuels. Releasing the energy in the chemical bonds of these carbon-hydrogen fuels is accompanied with emission of various products. Some of these products are greenhouses gases (carbon dioxide, methane and nitrous oxide). The main anthropogenic greenhouse gas is carbon dioxide. Measurements of the air trapped in cylinders of ice (ice cores) showed that pre-industrial CO2 level was 278 ppm and the variation of that value between 1000 and 1800 AD is within 7 ppm. In 1958, the carbon dioxide level was 315 ppm, in 2004 is already 378 ppm, 36 % increase from the pre-industrial level (see Fig. I.1.2 and Fig. I.1.3) [2].

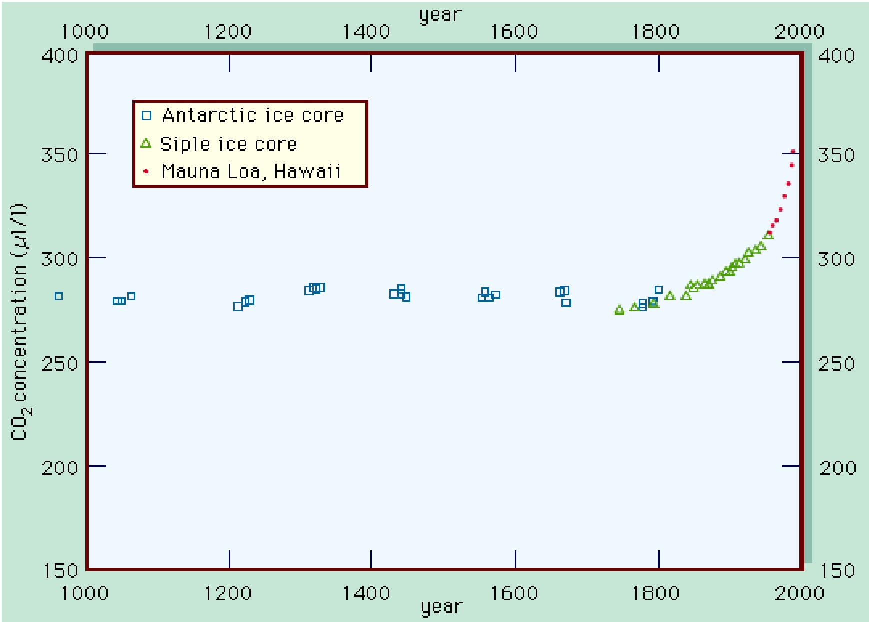


Figure I.1.2: CO2 concentrations in the atmosphere over the last thousand years. Values before 1958 are derived from measurements of air trapped in polar ice [2]

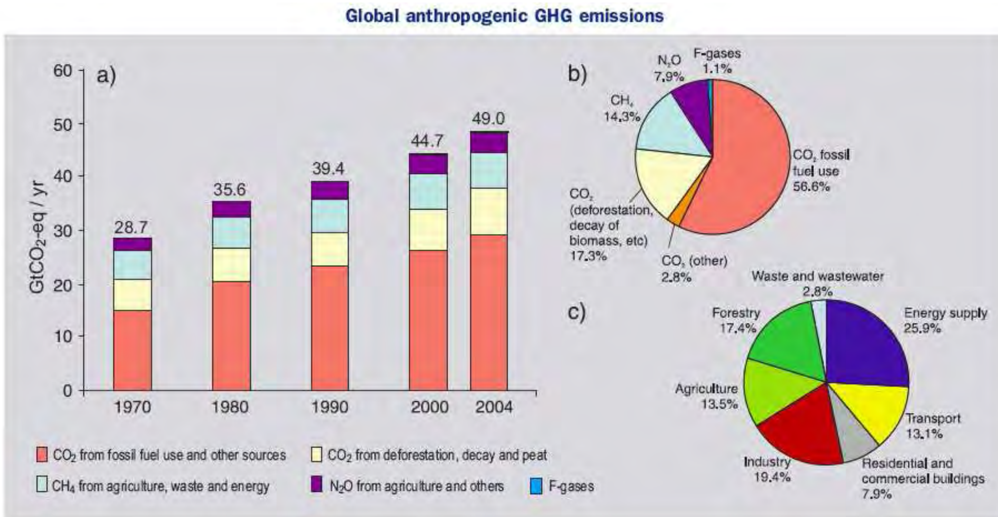


Figure I.1.3: (a) Global annual emission of anthropogenic GHGs from 1970 to 2004. (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of carbon dioxide equivalent. (c) Share of different sectors in total anthropogenic GHG emission in 2004 in terms of Co2-eq. [1].

It is very unlikely that the global worming will only make the Ithaca winters more pleasant. The climate change will affect the water availability in many areas around the globe, increase the risk for extinction of many species, decrease food productivity, and flood the coastal areas. These effects will be more severe the higher the temperature will be. It is evident that with the current policies, the GHG emissions will continue to increase in the next decades [1]. Figure 4 shows what the equilibrium temperature increaser from pre-industrial value would be for different CO2-concentration stabilization levels.

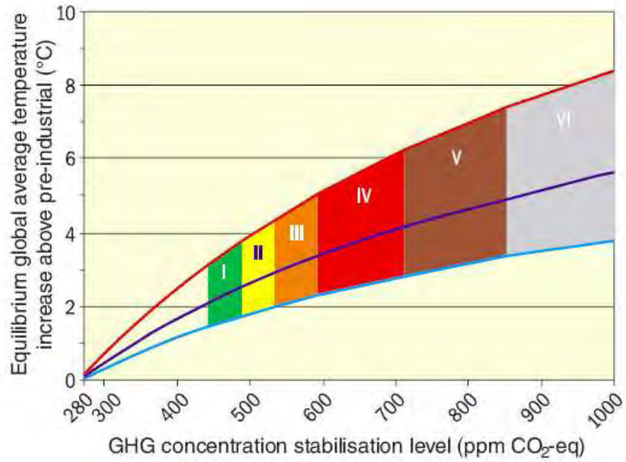


Figure I.1.4: Ranges of the global temperature change above pre-industrial using different climate temperature sensitivity [1].

As can be seen form Fig. I.1.3c, the main industrial activity that is responsible for anthropogenic GHG emissions is the energy production. Fixing the planet climate is an energy problem. The best case IPCC scenario, the CO2 stabilizes at 450 ppm. This would require the global CO2 emissions to peak around 2015 and then to start to decrease rapidly by 2050 to 70 % below 2000 levels. Current policies and industries trends will not result in energy-originated CO2 emissions to peak before 2020. This could happen if very aggressive policies are devised and implemented to switch to renewable and nuclear power generation, to improve the efficiency of the existing fossil-fuel based energy technologies, improve the efficiency of the way energy is used and transported, and capture and store the emitted CO2. The cost of all these approaches is going to be considerable [1].

I.1.2. Present world energy needs and future projections

I.1.2.1. Drivers of energy needs growth

The world population reached 6 billions at the dawn of the new millennium. The 20th century saw world population almost quadrupled, result of increased fertility, wide spreading of healthcare and increase of life expectancy. Although the population growth rate has declined from its peak (2.04%, late 1960s), the world population will continue to increase substantially during this century with a tendency to reach 9 billion around 2050 (Fig. I.1.5).

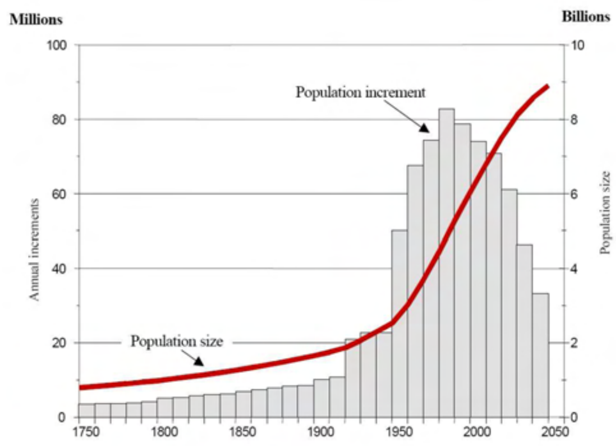


Figure I.1.5: World population growth 1750 – 2050 [3]

Industrial revolution started in Britain in the mid 18th century and for almost 200 years only a handful number of European and North American nations enjoyed the fruits of industrial society. The last 50 years, an increasing number of nations all over the world have taken the road of rapid economical development. This trend is well illustrated with the increase of the Gross World Product (see Fig. I.1.6).

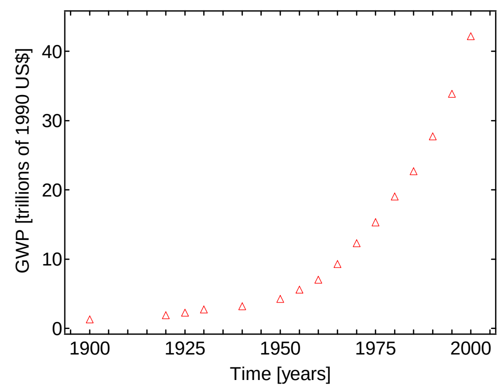
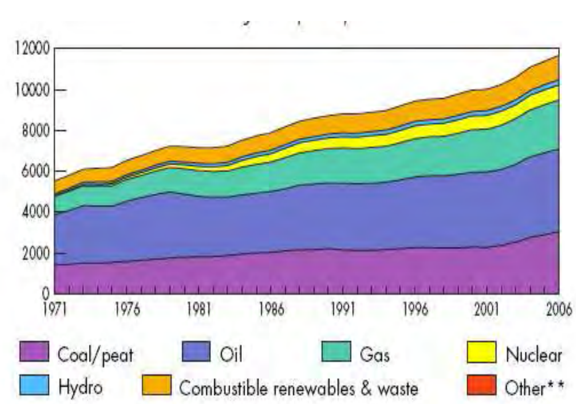


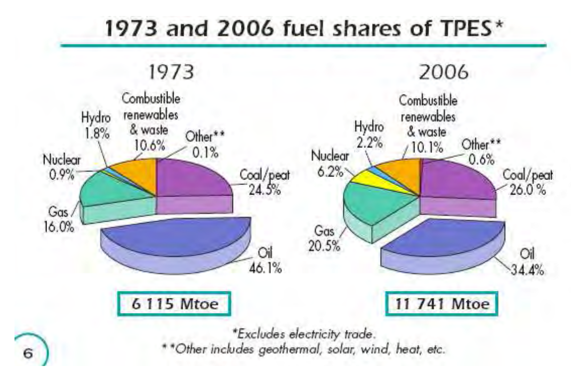
Figure I.1.6: World Product in 1990 US$ for a period of 100 years. [4]

I.1.2.2. Historical dynamics of primary energy needs and future projections

Rapid population growth and accelerate economical development all over the world are the main drivers of energy needs increase. In 2005, the world consumed 11.4 billion of tons of oil equivalent of energy. If noting in today's policies changes, the 2030 consumption would be 17.7 billion tons of oil equivalent, growth of 55 %, an average annual increase of 1.8 %. In Fig 7a, we see the trend in the total world energy consumption for the period of 35 years. Over that period the energy supply almost doubled. Although the share of the fossil fuels went down to 81 % (2006) from 87 % (1973), they still heavily dominate the energy production [6].



(a)



(b)

Figure I.1.7: (a) World total primary energy supply by fuel type. The y-axis units are Mega Tons of Oil Equivelent (Mtoe, see appendix on for conversion into more familiar units). (b) Fuel shares into total energy supply for years 1973 and 2006 [6].

Projections for USA are that the energy consumption will increase with 0.5 % annually from 2007 till 2030 (Fig. I.8.8a). The renewable energy source will see largest growth and the traditional fossil fuels will grow moderately. It is estimated that around 2030, depending on how the policies will change, the fossil fuels will give 82% (nothing change) or 76.3% (favorable policies adopted) from total energy supply (Fig. I.1.8d) [5].

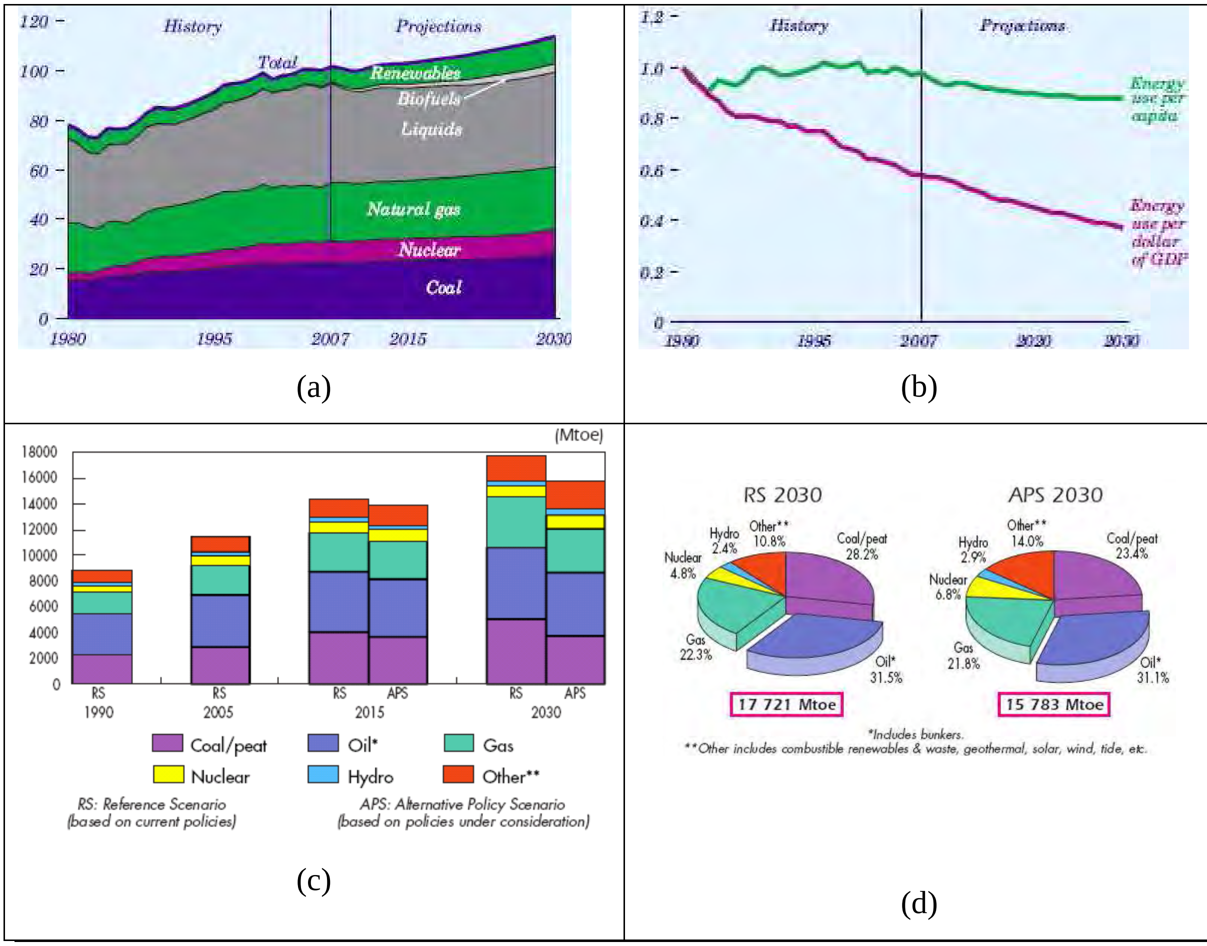
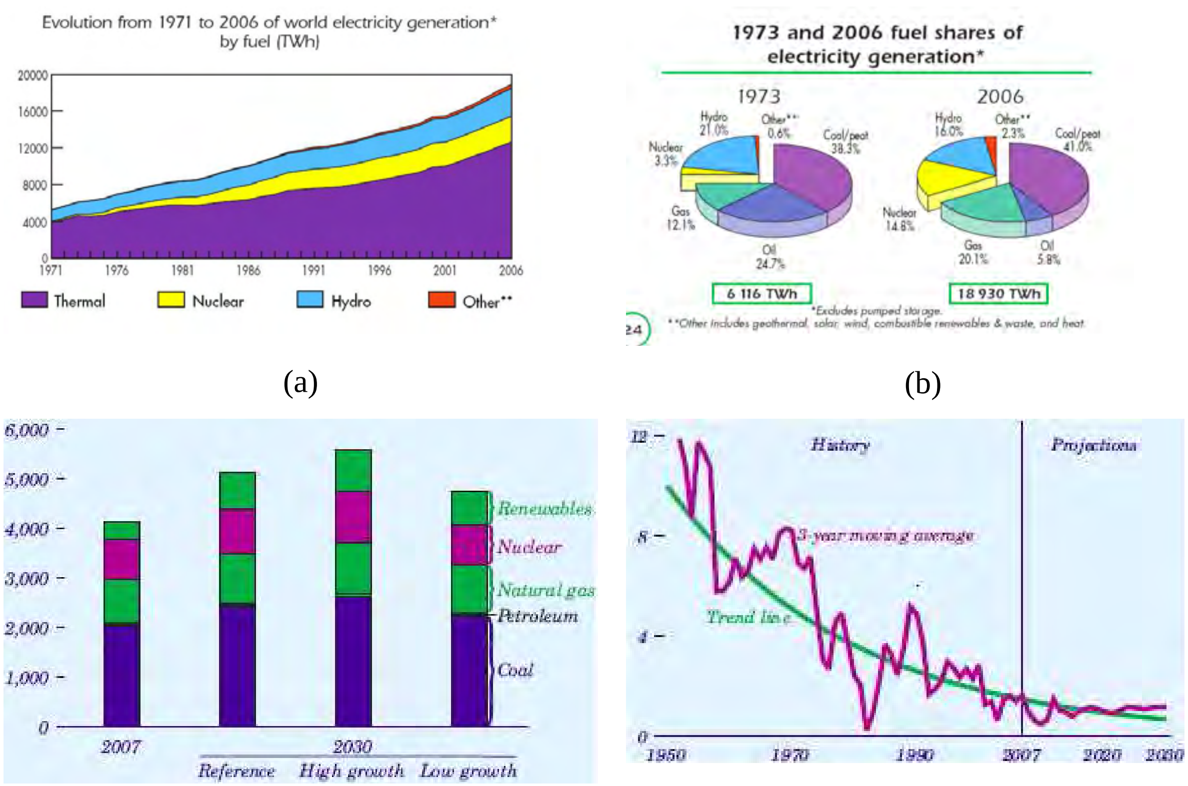


Figure I.1.8: (a) Primary energy use by fuel for the period 1980 – 2030 in US. The y-axis is in BTU. (b) Energy used per capita and per $ of GDP (baser year is 1980). [eia] (c) Total primary world energy supply by fuel type for four years. (d) Fuel shares of world total energy supply for two alternative policies scenarios [6].

In near term, the energy/climate problem will be alleviated most by increasing the efficiency of energy use. The new renewable technologies are great long term solution but they required time to mature and to be deployed. As can be seen in Fig I.1.8(b), the usage per capita in US is flat but it is projected to decline whereas the energy used to produce $1 of GDP has been declining steadily since 1980 [5].

I.1.3. Electricity generation

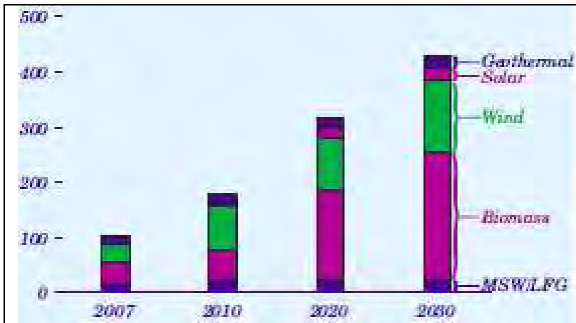
Electricity is produced in a number of ways but most of it comes from burning fossil fuels (Fig. I.1.9a). Coal has the larges share in electricity production, nearly 41 % in 2006 (Fig. I.1.9b) [6]. Among the fossil fuels, coal has the largest CO2 emission (227 lbs per 10^8 BTU, for anthracite coal), almost twice as much as natural gas (117 lbs per 10^6 BTU). Electricity generation is the major driver for CO2 emission growth. It is expected that the electricity use will double by 2030, the electricity share in final energy consumption goes from 17% (2005) to 22 % (2030). In line with this projection, the coal consumption increases by more than 70 %, its share in total energy supply grows with 3 % (25 to 28 %) [7]



(a) (b) (c) (d)

Figure I.1.9: (a) World electrical energy supply for the period of 1971 till 2006. (b) fuel shares of electricity generation for the years of 2007 and 2006 [6]. (c) USA electricity production for 2007 and projections for 2030 for three different scenarios. Reference one is if economy keeps current trends. The y-axis is in billions of kWh. (d) Electricity demand growth in the USA since 1950 and projection till 2030 (see the text for more explanaitions) [5].

In the USA the electricity production is expected to grow between 20 % to 35 % (Fig. I.1.9c), depending which economic scenario would happen. The coal share would decline but the in absolute terms will increase. Since 1950, the electricity demand growth in the USA has been decreasing (Fig. I.1.9d) [5]. The electricity needs are still increasing but the rate of increase has been decreasing.



(a)

(b)

Figure I.1.10: Figure 10: (a) Projection for US renewable source (excluding hydro) electricity generation. MSW/LFG stands for municipal solid waste/landfill gas. The x-axis is in billion kWh. (b) Generation from renewable sources connected to the grid, historical data and projections [5].

The growth potential of renewables electricity sources depends on variety of factors as states and federal renewable energy support policies, technological development, access to the transmission grids and the cost of fossil fuels. If nothing changes in the current trends/policies, the electricity generation from wind power is expected to grow from 0.8% (2007) to 2.5 % (2030). Biomass has comparable to the wind share of 0.9 % but it is expected to grow to 4.5 % in 2030. Geothermal sources will grow without increasing its share. Solar grid connected facilities are still too costly to achieve wider applications. Most of the current facilities are in California. The growth there is due to strong states support policies. As a whole, the renewables (excluding hydro) grow from 100 billion of kWh to almost 400 billion of kWh (Fig I.1.10b). Biomass and wind are the major sources of electricity from all renewable sources.

I.2. Overview of the parts of the project: industry-wide and site-specific, recommendations at end, etc.

The four core areas of study entail the current and future demand for wind energy, the industry's manufacturing leaders, the relationship of wind energy with plug-in hybrid electric vehicles, and specific site studies in three locations. Research for the current and future demand for wind energy will encompass two broad areas of wind energy; in the US and in other influential countries. Research in the domestic US wind energy development will focus on policies and incentives of both the federal and state governments. This will include an analysis of the Department of Energy plan to have 20% of our energy production from wind resources by 2030 and the 'We Campaign' founded by former Vice President Al Gore. International wind energy policies will be examined to find successful patterns of implementation in developed and developing nations.

The exploration of the manufacturing leaders in wind energy will focus on major components of large and small wind turbine systems, including their related design, installation, transportation, energy use, and transmitted pollutants. A review of the major parties in the wind industry will be completed and their business models will be discussed in the context of industries current and future economic climates. The supply chains involved in production of wind turbines will be analyzed to determine sources of raw materials and locations of processing facilities in the US as well as internationally.

The relations of wind energy to plug-in electric hybrid vehicles will be studied with respect to the obstacles, successes, and efficiencies of integrating wind technology with the transportation sector.

In addition to researching the industry wide objectives, the group will focus on three site-specific studies including a utility-scale wind farm, an offshore development, and small-scale implementation at the Greek Peak ski area new Cortland, New York. The study of the Greek Peak site will focus on the economic viability and technical requirements for a wind turbine at the resort. The large scale (>20MW) site will serve as a current assessment of the wind energy industry as large-scale wind farms are becoming more popular both nationally and internationally for their generation capacities. The investigation of the site will make use of the research regarding industry manufacturers and will further delineate federal and state incentives and regulations for such projects within the United States The offshore investigation will be geared towards future developments in wind industry expansion. The site study will examine the feasibility of offshore sites with respect to constructability, current policy, and production potential.

The technical resource base for the industry is developing alongside the global installed capacity and the final deliverable for this project will provide summary of the pertinent available resources and documents. Background information and necessary resources to support this project will be gathered from manufacturer specifications, industry studies, professional organizations, and government agencies. A comprehensive bibliography will be supplied with final deliverable.

Two final deliverables will be generated as a result of this project. The first will be the informational report regarding the findings for core objectives and site-specific studies. A separate feasibility study will be developed for submittal to the members of the Greek Peak ski area management team. The feasibility study will detail the economics of installing a wind turbine at the ski area while using available wind data to make technical recommendations for the site. A group presentation will be made at the end of the semester, summarizing the group's research and allowing for questions to be submitted by the attending public.

I.3. Introduction to the team and team structure

Subgroups of two to four people will cover the noted topics of the project (see hierarchy charts in Appendix D). For the industry-wide objects Dimitre, Jesse and Alejandro will focus on the Current and Future Demands of the Wind Industry. Christine, Reginald, Stephen, and Yash will focus on the Manufacturing Leaders, and Nancy and Nael will be researching the relationship of the wind industry with Electric Vehicles.

For the site case studies, Reginald, Yash, and Nael will continue the Greek Peak Study. Alejandro, Christine and Jesse will focus on a large-scale site. Stephen, Nancy and Dimitre will look into offshore wind sites as well.

Additionally, Alex Hernandez and Christine Acker will act as organizational managers to track progress, facilitate project-wide communication, and enforce completion dates (See Appendix A for group member's educational background and working experience).

Part I: Introduction References

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PART II: INDUSTRY-WIDE RESEARCH

II.1. Current and Future Demands

II.1.1. Introduction to Part II

Extensive recent observations and studies have led to a better scientific understanding of the link between human-produced greenhouse gases and climate change. Stabilization of global CO_2 levels requires extensive efforts in many areas: efficiency improvement, transition to smart electrical grids, and development of renewable energy resources. Presently, alternative energy strategies have already begun to be employed around the world. One of the most influential and pivotal areas that will be crucial to further growth of renewable energies is wind energy. This report summarizes the status of the wind energy business in the context of other renewable sources, and is primarily based on the findings of the "RENEWABLES 2007 GLOBAL STATUS REPORT," published by the Renewable Energy Policy Network for the 21st Century.

A renewable energy resource is one that can be replenished in short period of time. Usually these sources are natural fluxes – water, air, or photons. With exception of geothermal energy, all other renewable sources can be reduced to solar energy. Energy sources are usually compared in two perspectives – their share in total energy supply and their share in final consumption. For example, since natural gas can be used to power cars, its use in this case is considered solely for final consumption. At the same time, natural gas can also be used to generate electricity, so it must also be considered as part of the total energy supply.

II.1.2. Renewable Electricity-generating Sources

II.1.2.1. Review of new renewable resources

II.1.2.1.1. Biomass Power

Biomass is the general term that refers to biological material derived from dead plants or animals used for energy production. Biomass could be specially-grown agriculture for fuel, unused part of general crop, or simply the biogenic part of solid waste. Biomass differs from fossil fuels by the amount of time that has passed from death of the organisms its originates from to the present.

Fossil fuels are simply what biomass turns into millions of years later. Biomass produces energy through a combustion process that is accompanied with CO_2 and other GHG emissions. However, biomass does not emit all the CO_2 incorporated in the plant since part of it is stored in plants' roots that are left in the soil. Besides, GHGs released during biomass combustion have not been out of the planetary carbon cycle for a very long time as is the case with fossil fuels.

Wood is considered traditional biomass and it has been used for centuries as fuel mainly for heating and rarely for electricity production. Modern biomass is still used for heating but its use for power generation has expanded. In 2006, the modern biomass electricity generation capacity was estimated to be 45 GW [1], mostly in some developed countries in Europe and North America. Biomass is also used in co-firing with coal in traditional power plants. In 2003, there were 80 operating biomass power plants in the US with total capacity of 1.6 GW. The DOE expects that in 2030, the biomass electrical capacity in US would be more than 250 billion kW [2] comprising more than 50 % of all new renewable energy resources capacity.

II.1.2.1.2. Geothermal Power

Geothermal electricity generation is based on thermal energy stored in Earth's crust. There is a vast resource of geothermal energy stored in water and steam at drillable range of 3 to 6 miles (Fig. II.1.11). This power originates from the radioactive decay of minerals, absorption from the sun, and from earth's heated core. The resource in USA stored at this depth range is estimated to be 14 million quads (1 quad = 1 quadrillion BTU). To put this in perspective, the USA annual energy demand is about 100 quads. Therefore, tapping even a small percent of the geothermal recourse would make a significant difference in deferring the use of traditional, non-renewable energy sources. However, an essential characteristic of the geothermal resource is that it is not as easy accessible as solar and wind resources. At the same time, as will be discussed later, the problems with solar and wind lie in their conversion efficiencies.

The nature of geothermal energy dictates that it will not suffer from conversion challenges, but rather the difficulty in accessing it in an economically viable way. However, the future of the energy source is promising, with 5.6 GW of capacity expected to be installed in the western US states in the near future. The projected capacity is 13 GW by 2030. The world capacity is about 10 GW and the growth rate is 3-4% in the last five years [1]. Twenty four countries around the world generate geothermal electricity. In Iceland, the geothermal power satisfies 24 % of electricity consummation.

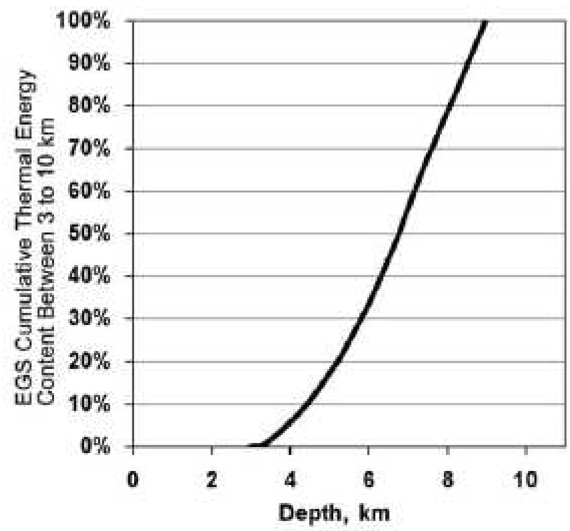


Figure II.1.1: Geothermal energy distribution with depth [3]. (EGS stands for Enhanced Geothermal System)

II.1.2.1.3. Solar photovoltaic

In relative terms, solar PV is the fastest-growing renewable electricity source whereas wind power grows fastest in absolute terms. Solar PV consists of semiconductor devices that absorb light and convert it into direct current. When the PV system is connected to the grid, the DC must be converted into alternating current. The installed capacity is not too large, comparatively, at 7.8 GW (grid connected solar PV) expected by the end of 2007. At the end of 2008, there was 800 MW grid-connected solar PV in the US [16]. The key for the success of solar PV technology is improved efficiency of the semiconductor cells. The first solar cell (Bell Labs, 1950s) had only 4 % efficiency while today's crystalline silicon cell is 15-20 % efficient. A module consisting of a string of cells has lower efficiency, 10-15 %. The cost of the electricity produces from solar PV is high and although it is heading down (Fig. II.1.12b), the solar PV industry still needs a lot of incentives to become economically viable.

Solar PV facilities can be installed all over the US but the best resource is in the southwest. The total solar power that hits the USA is $5x10^{13}$ kWh/day and the daily electricity used in 2004 was 10^{10} kWh/day. The total solar energy that reaches the Earth's surface for one year is $3.8x10^{24}$ Joules and the world consumed only $500x10^{18}$ Joules in 2005. The intermittency of the solar resource requires development of storage capacities. Currently, the leading countries are Germany, USA, and Japan. In Europe, Spain has witnessed the fastest increase in capacity, with an almost fourfold growth over one year, 2007. There are around 800 plants with more than 200 kW capacity each and 8 with capacity larger than 10 MW. Off-grid installations with capacity of less kW are also growing with double-digit rates of expansion and are expected to have total capacity of 2.5 GW by the end of 2007 [1, 4].

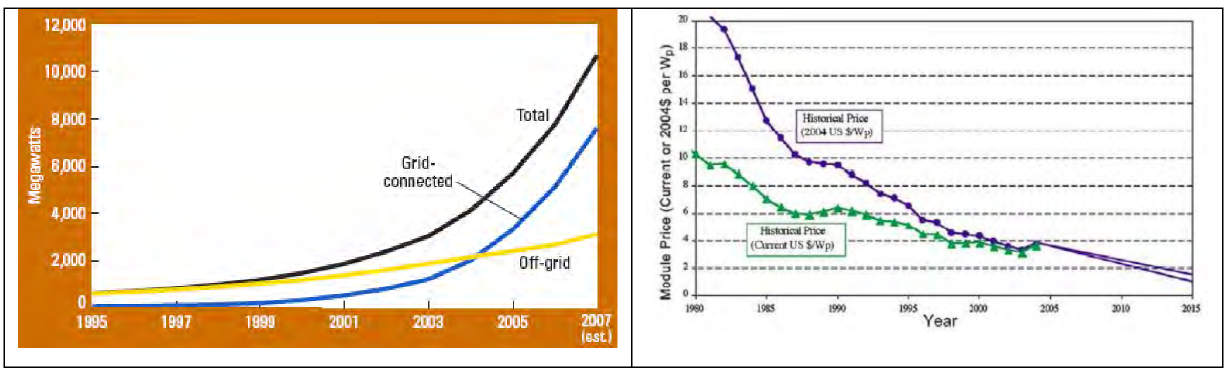


Figure II.1.2: (a) Solar PV (grid and off-grid) Capacity (1995-2007) [1]
(b) Historical and targeted PV module prices [4]

II.1.2.1.4. Concentrated Solar Power

Concentrated solar power (CSP) technology uses mirrors and lenses mounted on tracing systems to effectively concentrate the sun's light onto collectors that transform light energy into thermal, which is later used to drive traditional heat turbines to produce electricity. The most developed CSP technologies are the parabolic dish, the solar trough, and the solar power tower. CSP locations require direct solar irradiation of at least 6.75 kWh/m^2, at least 10 km^2, and fairly flat land (slope smaller than 1 %). Taking into account these requirements, the total resource in the southwest of the USA is nearly 7,000 GW. It is estimated that under the current conditions and policies, up to 30 GW capacity plants could be practically deployed in the Southwest. If more aggressive policies are implemented (such as the introduction of a carbon tax), then it is economically feasible to deploy 80 GW by the year of 2030. The interest in this technology was renewed in 2004 and since then a number of plants have been open in USA, Spain, Portugal and Israel. There are projects under development in Algeria, China, India and South Africa. The world goal is to install CSP capacity of 100 GW in the next 25 years [1, 2, 4]

II.1.2.1.5. Wind Power

Wind power has the largest installed capacity of all renewable resources excluding large hydro: 120.8 GW by the end of 2008. The rise of wind power has been promising, from 6 GW in 1996 to almost 20 times that value in 2008. Wind power energy production capacity increased almost 26 % percent in 2006 which is far less then solar PV but in absolute terms is the largest increase, 21 GW. There are wind plants in more than 70 countries around the world but 2/3 of all capacity is in six countries: USA, Germany, Spain, India, Italy, and China. The total wind resource that can be developed commercially is estimated to be 72 TW while the world's energy consumption in 2005 was estimated to be 15 TW [4, 5].

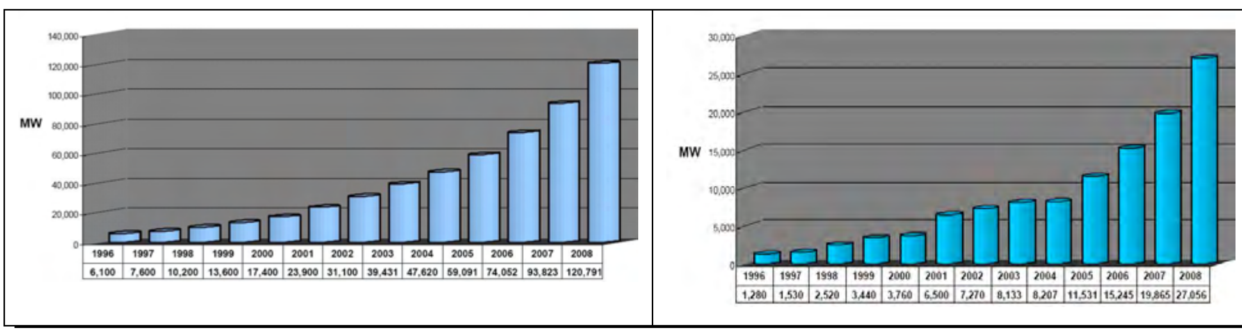
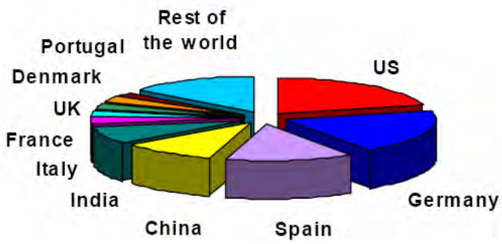
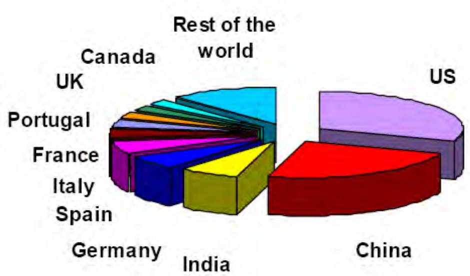


Figure II.1.3: (a) Wind power capacity, (b) Wind power added capacity [5]



	MW	%
US	25,170	20.8
Germany	23,903	19.8
Spain	16,754	13.9
China	12,210	10.1
India	9,645	8.0
Italy	3,736	3.1
France	3,404	2.8
UK	3,241	2.7
Denmark	3,180	2.6
Portugal	2,862	2.4
Rest of the world	16,686	13.8
Total top 10	**104,104**	**86.2**
World total	**120,791**	**100.0**

Figure II.1.4 - Countries with the Largest Installed Wind Power Capacity as of 2008 [5]

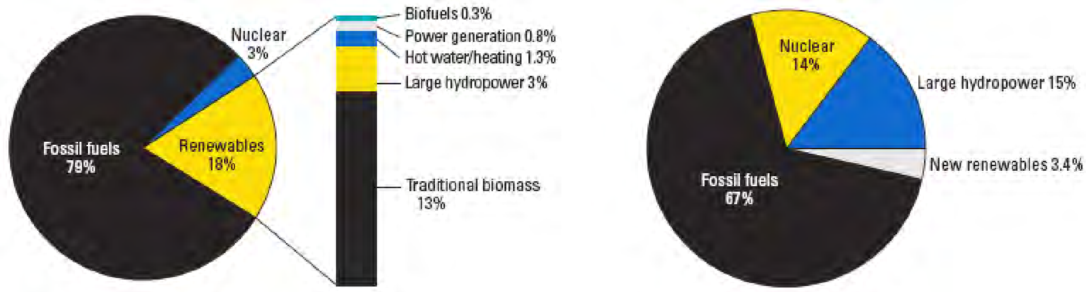


	MW	%
US	8,358	31
China	6,300	23
India	1,800	7
Germany	1,665	6
Spain	1,609	6
Italy	1,010	4
France	950	4
UK	836	3
Portugal	712	3
Canada	523	2
Rest of the world	3,293	12
Total top 10	**23,763**	**88**
World total	**27,056**	**100**

Figure II.1.5: Countries that added the most wind power capacity in 2008 [5]

II.1.2.2. Comparative Study of Renewable Electricity Generating Sources

In 2006, about 18 % of final energy consumption came from renewable resource. Most of it was due to large hydro and traditional biomass, while new renewables contributed only 2.4 %. When compared only in the context of electricity generation, the new renewables are accountable for 3.4 % of production and about 5 % of capacity. The conclusion is that new renewable energy resources have started to make a dent in the fossil-fuel share in energy production but it is a long way before they become the dominant resources [1].

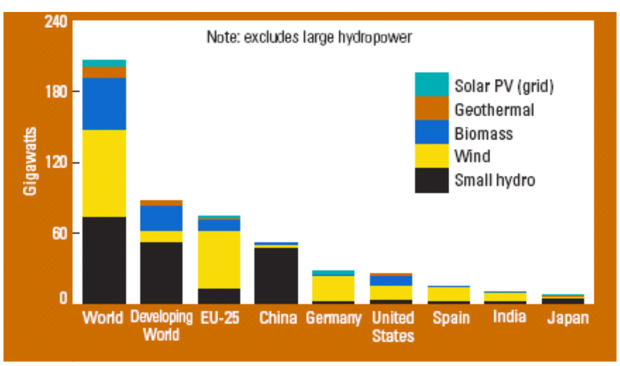


(a) (b)

Figure II1.6: (a) Share of renewable energy resource in world final energy consumption (2006) (b) Share of renewable resources in world electricity generation (2006) [1]

Renewable resources directly replace the fossil fuels in electricity production, heat generation, transportation, and off-grid resources. Since wind power is used exclusively for electricity generation, we consider only renewable resources for electricity generation (grid connected and off-grid as well) in our discussion.

For all renewables used for electricity generation capacity, a total of 207 GW was produced in 2006, an increase of 14 % from 2005. All power capacity installed in 2006 was about 4300 GW, so renewables were about 5 % of that. Developing countries accounted for 43 % of world renewable energy capacity, which is around 88 GW.



(a)

Country	2006 added capacity, GW
China	52
Germany	27
USA	25
Spain	14
India	10
Japan	7

(b)

Figure II.1.7: (a) Capacities of renewable energy resources.

(b) Top six countries in terms of capacity [1].

In absolute terms, the renewable resources capacity is very small but the growth rate is spectacular (Fig. II.1.18). Grid-connected photo-voltaic (PV) is the fastest growing renewable resource, 60 % annual growth for the period of 2002 to 2006.

Indicator	2005	2006	2007
Investment in capacity, $ billion	40	55	71
Capacity (excl. large hydro), GW	182	207	240
Total renewables capacity, GW	930	970	1010
Wind, GW	59	74	95
Grid-connected PV, GW	3.5	5.1	7.8
Solar PV production, GW	1.8	2.5	3.8
Countries with national programs	52		66

Table II.1.1: Comparison of renewable electricity-generating resource [1]

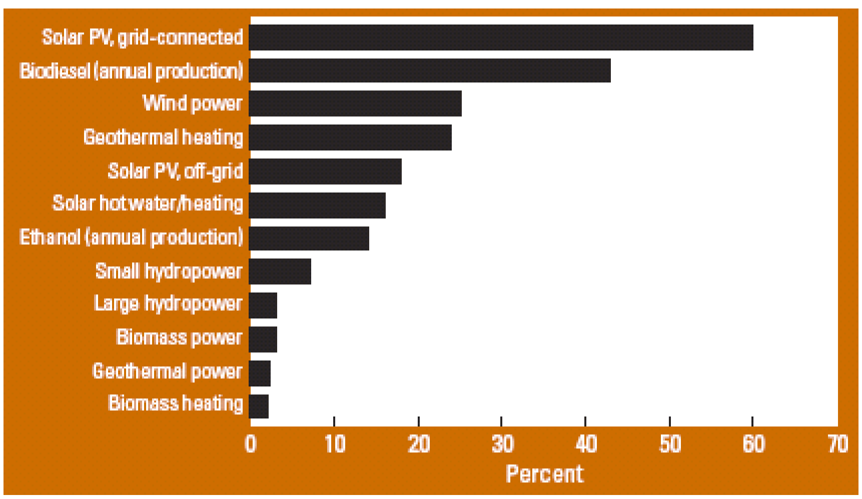


Figure II.1.8: Renewable energy resources capacity annual growth rate (2002-2006) [1]

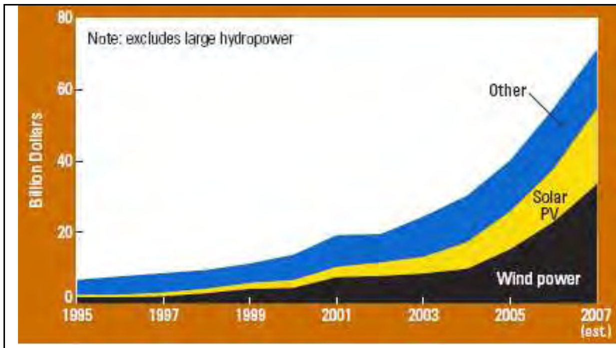
Technology	Typical Scales	Energy costs (US cents/kWh)
Large hydro	Plant Size: 10- 18 000 MW	3 – 4
Small hydro	Plant Size: 1-10 MW	4 – 7
On-shore wind	Turbine: 1-3 MW Blade dia: 60-100 m	5 – 8
Off-shore wind	Turbine: 1.5 – 5 MW Blade dia: 70 – 125 m	8 – 12
Biomass	Plant size: 1 – 20 MW	5 – 12
Geothermal	Plant size: 1 – 100 MW	4 – 7
Solar PV	Single crystal: ~ 17% efficiency Polycrystaline: ~ 15% amorphous silicon: 10% thin film: 9-12%	
Rooftop solar PV	Peak capacity: 2 – 5 kW	20 – 80
Concentrating solar thermal	Plant size: 50 -500 MW	12 – 18

Table II.1.2: Typical scales and energy cost of renewable electricity generation technologies [1]

Some typical characteristics of renewable electricity generation technologies are listed in Table 2. Typical cost of a kWh of energy generated from traditional fuel is between 4 and 8 cents. Most of the renewable resources produce electricity at higher cost and they still need policy support. Technology improvements and maturing of the market result in declining of the cost of the renewable electricity. One advantage that renewable offer is much less variability of prices.

II.1.2.3. Financials and Investment Flows

The worldwide money flow into renewable energy businesses has been increasing rapidly recently. The total investment in 2005 was $40 billion, $55 billion in 2006 and the estimate for 2007 is about $71 billion. In 1995, only $5 billion were invested, signifying growth of almost 15 times the 1995 levels over a period of 12 years. As it can be seen from Fig. 19, the lion's share in 2007 went into wind power (47 %) and solar (30 %).



Country	Investment in new renewable capacity in 2007, $ billions
Germany	14
China	12
USA	10

Figure II.1.9: (a) Investments in new renewable energy capacity (1995 – 2007)
(b) Top 3 countries investing in renewable technologies [1]

Investment in solar PV manufacturing plants and equipment was $10 billion in 2007, an increase of 25% over the previous year. Significant financial resources are used to support the R&D activities in the renewable energy sector, estimated to be $16 billion from public and private resources in 2006. Taking into account capacity, manufacturing capabilities, and R&D, the renewable energy sector was funded with more than $100 billion. This money came from the private sector (banks and venture capital firms, about $3 billion mostly for solar PV and biofuels) and from established government programs that aim to support and promote renewable energy technology development and deployment. Projects in developing countries are funded by multiple public resources, with the largest among them being KfW Entwicklungsbank (Germany, committed $300 million to renewable energy projects in the developing world), World Bank ($220 million) and Global Environment Facility. Recipient countries also participate in financing [1].

The increased attention to the renewable energy sector was also reflected in higher stock valuation and increased trading in the number of public companies in this sector. In 2006, there were 85 companies in the renewable energy sector, while a year and a half later there were 140 renewable energy companies with total market capitalizations of 100 billion. All clean-energy companies raised about $10 billion through the stock market in 2006 which is twice as much the amount in 2005. The estimation for 2007 is $17 billion. Most of these companies are traded in Europe [1].

II.1.3. International Goals and Growth

It is very difficult to make forecasts and predictions about wind energy during the present global financial crisis, as The Global Wind Energy Council made public in their last report (GWEC, 2008). Already during the first half of 2008, as the price of crude oil climbed steadily towards $US 150/barrel, there was growing concern over the instability of the American financial sector. As the financial crisis started to spill over into the "real" economy, credit started to tighten. By the time banks started failing, it became very difficult for anyone to get financing for any new projects, including those for wind power. It is predicted that 2009 is going to be a tough year as well, while we continue to wait for the bottom of the economic downturn and as governments seek to restructure the fundamentals of the banking sector. The medium and long-term outlooks, however, remain positive. All of the fundamental drivers that have made wind power the technology of choice for those seeking to build a secure, clean energy future are all still in place. Wind power is clean, indigenous, fast to deploy, job-creating, uses virtually no water, and is economically competitive. Neither the threat of climate change nor the macroeconomic insecurity due to reliance on imported fossil fuel is going to go away because of a recession. The governments of China, the US, and the EU all seem to agree with this assessment, as their recent stimulus packages all emphasize the development of renewable energy in general, and wind power in particular. The Chinese wind industry, at least, continues to power ahead, largely unaffected by the financial crisis. In Europe, the legally binding target of 20% of final energy consumption from renewable energy by 2020 will maintain the focus on wind energy. The big question is the reaction of the US, as President Obama seeks to mend the banking sector and stimulate the stumbling economy while tackling energy security and climate change.

II.1.3.1. International Treaties, from Kyoto to Copenhagen

During the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in June 1992, participant nations agreed to achieve a "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UN, 2005). The Kyoto Protocol establishes legally binding commitments for the reduction of four greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride), and two groups of gases (hydrofluorocarbons and perfluorocarbons) produced by "Annex I" (industrialized) nations, as well as general commitments for all member countries. As of 2008, 183 parties have ratified the protocol (Figure II.1.10), which was initially adopted for use on 11 December 1997 in Kyoto, Japan and which entered into force on February 16, 2005. Under Kyoto, industrialized countries agreed to reduce their collective GHG emissions by 5.2% compared to the year 1990. National limitations range from 8% reductions for the European Union and some others to 7% for the United States, 6% for Japan, and 0% for Russia. The treaty permitted GHG emission increases of 8% for Australia and 10% for Iceland.

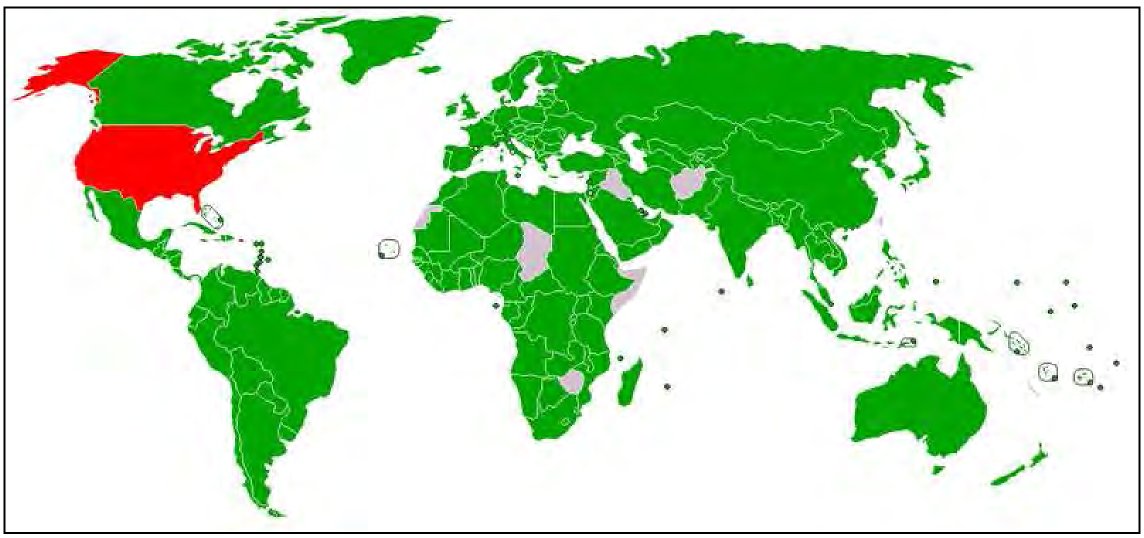


Figure II.1.10: Participation in the Kyoto Protocol: Signed and ratified Signed, ratification pending Signed, but not ratified Non-signatory (source: Wikipedia)

Kyoto includes defined "flexible mechanisms" such as Emissions Trading, the Clean Development Mechanism (CDM), and Joint Implementation to allow Annex I economies to meet their greenhouse gas (GHG) emission limitations by purchasing GHG emission reductions credits from elsewhere. These other sources would be through financial exchanges, projects that reduce emissions in non-Annex I economies, from other Annex I countries, or from Annex I countries with excess allowances. In practice this means that Non-Annex I economies have no GHG emission restrictions, but have financial incentives to develop GHG emission reduction projects to receive "carbon credits" that can then be sold to Annex I buyers, encouraging overall sustainable development. In addition, these flexible mechanisms allow Annex I nations with efficient, low GHG-emitting industries, and high prevailing environmental standards to purchase carbon credits on the world market instead of reducing greenhouse gas emissions domestically. Annex I entities typically will want to acquire carbon credits as cheaply as possible, while Non-Annex I entities want to maximize the value of carbon credits generated from their domestic Greenhouse Gas Projects.

II.1.3.1.1. Opposition of Social Movements

There has being a growing opposition to market-based mechanisms, defined as the privatization of the atmospheric commons by social movements and NGO's. In her book "Soil, not Oil", Vandana Shiva summarizes some of the arguments of the opposition: "The allocation of marketable pollution permits constitute a form of limited privatization as the government conveys to private parties limited entitlements to use the public atmosphere." "Rights to the earth's carbon cycling capacity are gravitating into the hands of those who have the most power to appropriate them and the most financial interest to do so". With the CDM, by developing green energies abroad, corporations get credits that allow them to pollute at home. However, this issue is insignificant, since only 2% of the CDMs of the Kyoto Protocol cover renewable energy projects. Seventy-two percent of the projects are based on carbon capture and 21 percent on biomass, effectively translating the problem of air pollution into a land grab. CDM based in preserving or reforesting new areas translates in the occupation of land and/or enclosure of the commons in countries in the south, sometimes causing a limitation in the access of local communities to the resources and limiting the capacity of expansion and development. Preservation of forests and reforestation should be done in a global scale, but should not compete with as a "clean" compensation for dirty development in the north. The final argument is that ecological options disappear from the carbon market, as the trade is done between polluters – those who continue to pollute, and those who have partially reduced pollution. Non-polluters are excluded. Economic entities that never polluted were never allocated credits and therefore are never able to sell them, so there is no incentive to encourage further sustainable behavior from these groups nor are there rewards for their previous efforts to reduce GHG emissions.

II.1.3.1.2. Global GHG emissions

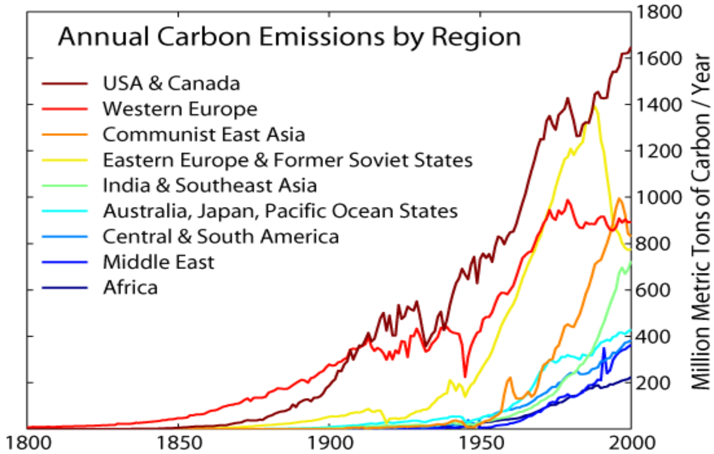


Figure II.1.11: Annual Carbon Emissions by Region: [Source: Robert A. Rohde, Global Warming Act Project]

As of August 27, 2008 China surpassed the United States as the world's biggest emitter of CO_2 from power generation, according to new data from the Centre for Global Development (CGD). Although, on a per capita basis, U.S. power-sector emissions are still nearly four times those of China, the world's top-ten power sector emitters in absolute terms are China, the United States, India, Russia, Germany, Japan, the United Kingdom, Australia, South Africa, and South Korea. If the 27 member states of the European Union are counted as a single country, the E.U. would rank as the third biggest CO2 polluter, after China and the United States. In per capita terms, emissions from the U.S. power sector are the second highest in the world. Americans' electricity usage produces about 9.5 tons of CO_2 per person per year, compared to 2.4 tons per person per year in China, 0.6 in India, and 0.1 in Brazil. Average per capita emissions from electricity and heat production in the EU is 3.3 tons per year. Only Australia, at greater than 10 tons per year, emits more power-related emissions per person than the U.S.

II.1.3.1.3. Copenhagen: Effects on Wind Energy

The first commitment period of the Kyoto Protocol is coming to an end in 2012. In Bali in 2007, governments agreed to negotiate a follow-up climate deal by the time the UNFCCC (United Nations Framework Convention on Climate Change) conference takes place in Copenhagen in December 2009. The one clear message from the IPCC's 4th Assessment Report is that if we are to have any chance of avoiding the worst and irreversible damages of climate change, global greenhouse gas emissions must peak and begin to decline before 2020. The UNFCCC is the only international forum that discusses the future of energy and the role that renewable energy can and must play in the future. In the climate negotiation, the basic points that directly affect wind energy are outlines as follows:

II.1.3.1.3.1. Targets

The emission reduction targets for industrialized countries under consideration (minus 25-40% in 2020 compared with 1990 levels) are much greater than those under the Kyoto Protocol's first commitment period. If targets in this range are agreed and enforced, this will have an immediate impact on the framework conditions of the wind sector. Although negotiators in Bali agreed to negotiate in the 25-40% reduction range, only the EU to date has agreed to a 20% cut by 2020 (to be increased to 30% as part of a new international agreement), and to sourcing 20% of its final energy demand from renewable resources by the same date.

II.1.3.1.3.2. The flexible mechanisms

The Kyoto Protocol's Clean Development Mechanism has already had a substantial impact on wind energy development in China and India. The CDM also impacts to a lesser extent other developing countries, and income from Certified Emission Reductions (CERs) can make a substantial contribution to a project's profitability. There are more than 25,000 MW of wind power projects currently in the CDM pipeline (Table II.1.3).

COUNTRY	PROJECTS	MW
India	270	5,072
China	314	16,977
Mexico	12	1,272
Brazil	11	687
South Korea	11	317
Cyprus	4	207
Dominican Republic	3	173
Egypt	3	285
Philippines	2	73
Morocco	2	70
Costa Rica	2	69
Nicaragua	2	60
Panama	1	81
Mongolia	1	50
Jamaica	1	21
Colombia	1	20
Israel	1	12
Argentina	1	11
Chile	3	73
Vietnam	1	30
Ecuador	1	2
Total	647	25,560

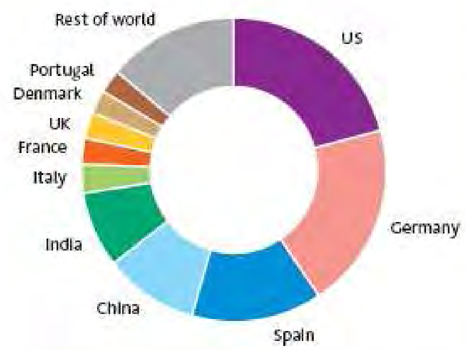
Table II.1.3: Wind CDM projects (2009) [Source: UNDP Risoe Center CDM pipeline]

II.1.3.2. The Status of Global Wind Power in 2008

In another record year for new installations, global wind energy capacity surged by 28.8% in 2008. The US passed Germany to become the number one market in wind power, and China's total capacity doubled for the fourth year in a row. The world's total installed capacity reached 120.8 GW at the end of 2008, over 27 GW of which came online in 2008 alone, representing a 36% growth rate in the annual market. These figures show that there is huge and growing global demand for emissions-free wind power, which can be installed quickly almost anywhere in the world. Wind energy has become an important player in the world's energy markets, with the 2008 market for turbine installations worth about $50 (€ 36.5) billion.

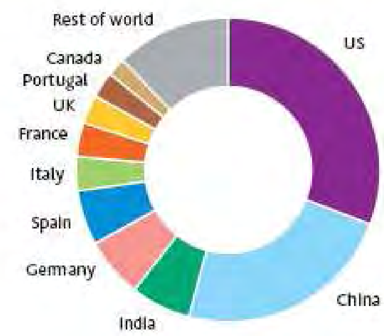
Three regions are continuing to drive global wind development: North America, Europe, and Asia, with the majority of 2008's new installations evenly distributed among them.

TOP 10 TOTAL INSTALLED CAPACITY 2008



	MW	%
USA	25,170	20.8
Germany	23,903	19.8
Spain	16,754	13.9
China	12,210	10.1
India	9,645	8.0
Italy	3,736	3.1
France	3,404	2.8
UK	3,241	2.7
Denmark	3,180	2.6
Portugal	2,862	2.4
Rest of world	16,693	13.8
Total top 10	**104,104**	**86.2**
World total	**120,798**	**100.0**

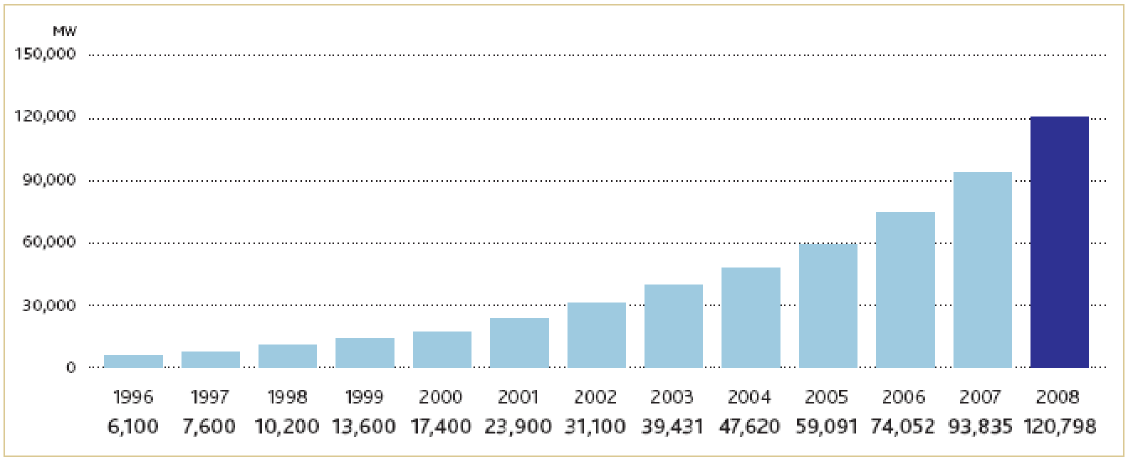
TOP 10 NEW CAPACITY 2008



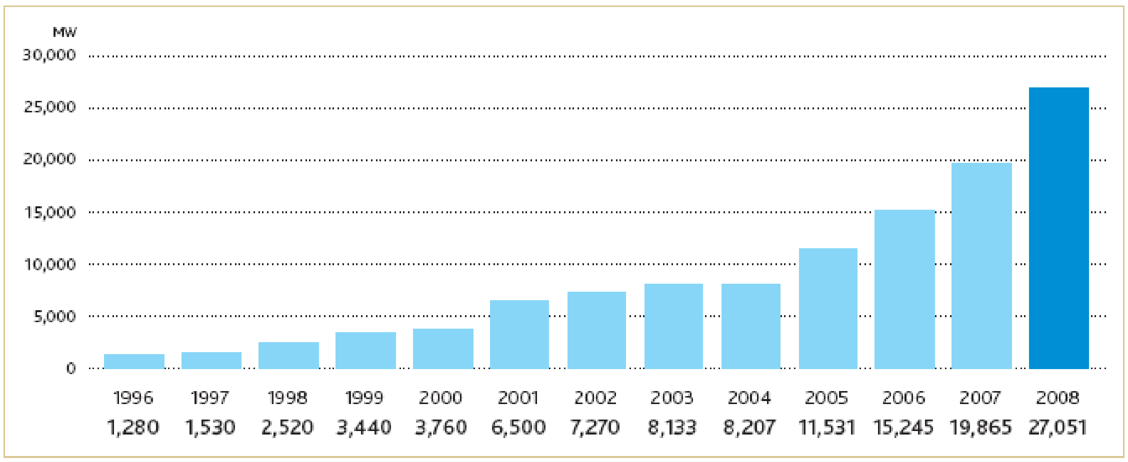
	MW	%
USA	8,358	30.9
China	6,300	23.3
India	1,800	6.7
Germany	1,665	6.2
Spain	1,609	5.9
Italy	1,010	3.7
France	950	3.5
UK	836	3.1
Portugal	712	2.6
Canada	526	1.9
Rest of world	3,285	12.2
Total top 10	**23,766**	**87.8**
World total	**27,051**	**100.0**

Figure II.1.12: Installed Capacity [Source: GWEC, Global Wind 2008 Report]

GLOBAL CUMULATIVE INSTALLED CAPACITY 1996-2008



GLOBAL ANNUAL INSTALLED CAPACITY 1996-2008



ANNUAL INSTALLED CAPACITY BY REGION 2003-2008

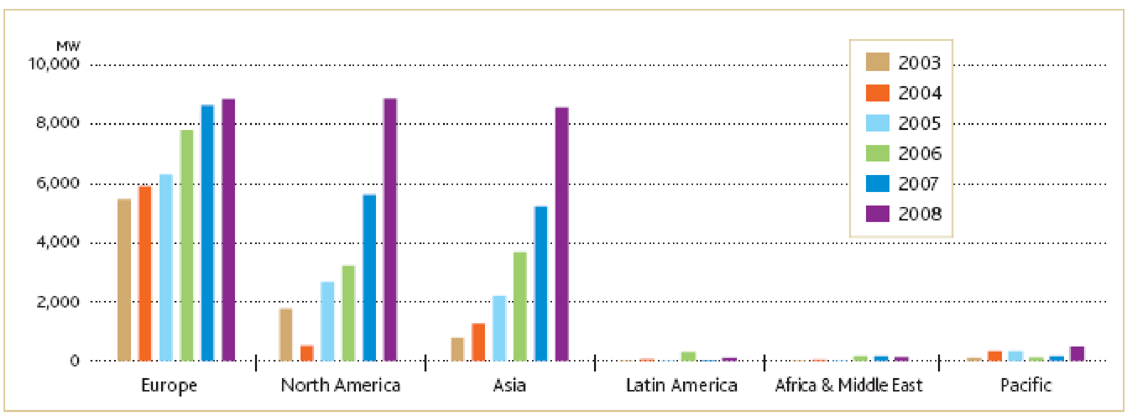


Figure II.1.13: Global Installed Capacity [Source: GWEC, Global Wind 2008 Report]

GLOBAL INSTALLED WIND POWER CAPACITY (MW) – REGIONAL DISTRIBUTION

		End 2007	New 2008	Total end 2008
AFRICA & MIDDLE EAST	Egypt	310	55	365
	Morocco	124	10	134
	Iran	67	17	85
	Tunisia	20	34	54
	Other[1]	17	14	31
	Total	**539**	**130**	**669**
ASIA	China	5,910	6,300	12,210
	India	7,845	1,800	9,645
	Japan	1,538	346	1,880
	Taiwan	281	81	358
	South Korea	193	43	236
	Philippines	25	8	33
	Other[2]	5	1	6
	Total	**15,795**	**8,579**	**24,368**
EUROPE	Germany	22,247	1,665	23,903
	Spain	15,145	1,609	16,754
	Italy	2,726	1,010	3,736
	France	2,454	950	3,404
	UK	2,406	836	3,241
	Denmark	3,125	77	3,180
	Portugal	2,150	712	2,862
	Netherlands	1,747	500	2,225
	Sweden	788	236	1,021
	Ireland	795	208	1,002
	Austria	982	14	995
	Greece	871	114	985
	Poland	276	196	472
	Norway	326	102	428
	Turkey	147	286	433
	Rest of Europe[3]	955	362	1,305
	Total Europe	**57,139**	**8,877**	**65,946**
	of which EU-27[4]	*56,531*	*8,484*	*64,948*
LATIN AMERICA & CARIBBEAN	Brazil	247	94	341
	Mexico	87	0	87
	Costa Rica	70	0	70
	Caribbean	55	0	55
	Argentina	29	2	31
	Other[5]	45	0	45
	Total	**533**	**95**	**629**
NORTH AMERICA	USA	16,824	8,358	25,170
	Canada	1,846	526	2,372
	Total	**18,670**	**8,884**	**27,542**
PACIFIC REGION	Australia	824	482	1,306
	New Zealand	322	4	326
	Pacific Islands	12	0	12
	Total	**1,158**	**486**	**1,644**
	World total	**93,835**	**27,051**	**120,798**

1 South Africa, Cape Verde, Israel, Lebanon, Nigeria, Jordan;
2 Thailand, Bangladesh, Indonesia, Sri Lanka;
3 Belgium,Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Faroe Islands, Finland, Hungary, Latvia, Lithuania, Luxembourg, Romania, Russia, Slovakia, Switzerland, Ukraine;
4 Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK;
5 Colombia, Chile, Cuba;

Please note: project decommissioning of 89 MW and rounding affect the final sums

Table II.1.4: Installed Capacity: Regional Distribution [Source: GWEC, Global Wind 2008 Report]

II.1.3.3. Global Market Forecast for 2009-2013

GWEC predicts that in 2013, global wind generating capacity will stand at 332 GW, up from 120 GW at the end of 2008. During 2013, 56.3 GW of new capacity will be added to the global total, more than double the annual market in 2008. The annual growth rates during this period will average 22.4% in terms of total installed capacity, and 15.8% for the annual market. These predictions are based in the continued expansion of Chinese markets being relatively unaffected by the global credit crisis.

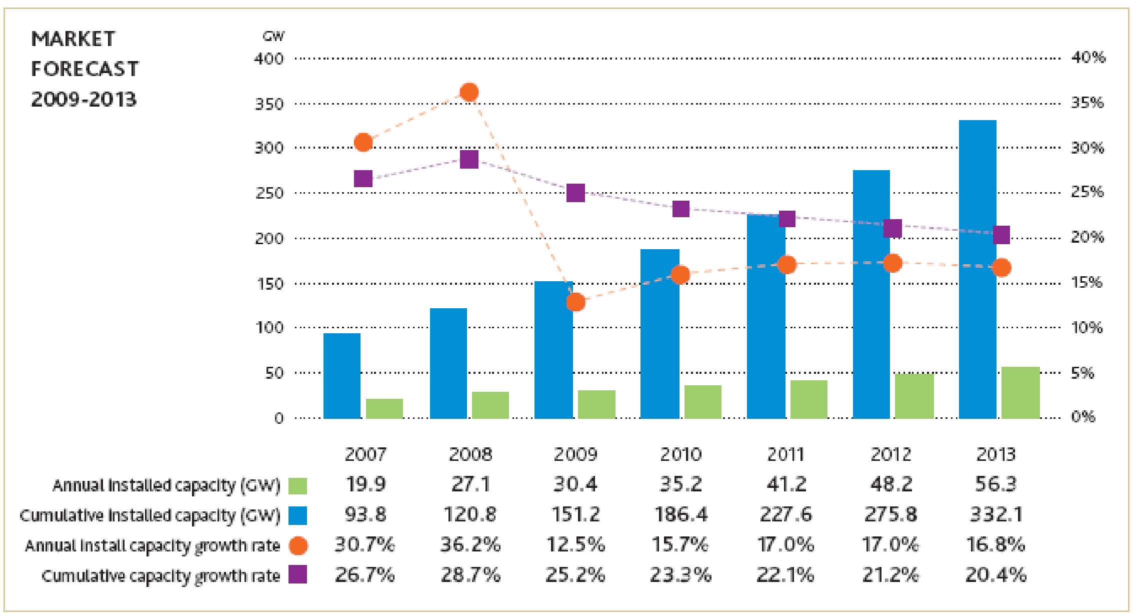
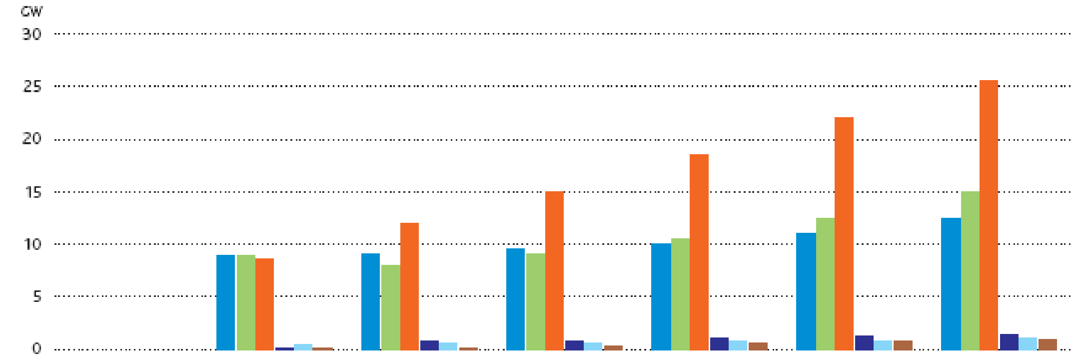


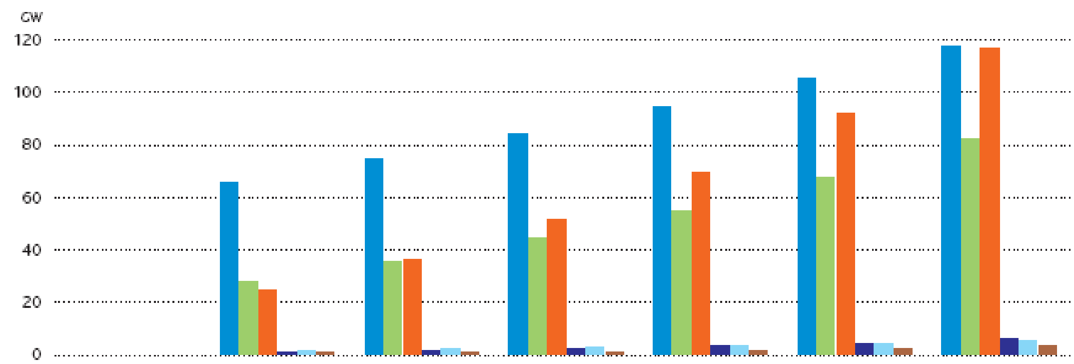
Figure II.1.14: Market Forecast (2009 – 2013) [Source: GWEC]

ANNUAL MARKET FORECAST BY REGION 2008-2013 (GW)



	2008	2009	2010	2011	2012	2013
Europe	8.9	9.0	9.5	10.0	11.0	12.5
North America	8.9	8.0	9.0	10.5	12.5	15.0
Asia	8.6	12.0	15.0	18.5	22.0	25.5
Latin America	0.1	0.7	0.8	1.0	1.2	1.4
Pacific	0.5	0.6	0.6	0.7	0.8	1.0
Middle East & Africa	0.1	0.1	0.3	0.5	0.7	0.9

CUMULATIVE MARKET FORECAST BY REGION 2008-2013 (GW)



	2008	2009	2010	2011	2012	2013
Europe	66.0	75.0	84.5	94.5	105.5	118.0
North America	27.5	35.5	44.5	55.0	67.5	82.5
Asia	24.4	36.4	51.4	69.9	91.9	117.4
Latin America	0.6	1.3	2.1	3.1	4.3	5.7
Pacific	1.6	2.2	2.8	3.5	4.3	5.3
Middle East & Africa	0.7	0.8	1.1	1.6	2.3	3.2

Figure II.1.15: Regional Market Forecast [Source: GWEC]

II.1.3.4. Focus Regions

II.1.3.4.1. European Union

While Germany and Spain are still battling over the top spot for number of new installations, the 2008 market was much more balanced than in previous years. A group of 'second wave' countries emerged (Italy, UK, France), and are providing real momentum to the surge of wind energy. Ten EU Member States now each have more than 1,000 MW of installed wind capacity. A distinct 'third wave' became visible for the first time in 2008 as the new EU Member States had their strongest year ever. The financial crisis, however, is specially affecting Eastern Europe, and it is still uncertain what will happen in countries like Hungary and Bulgaria.

II.1.3.4.1.1. The current EU legislative framework for wind energy, past trends

The EU's Renewables Directive (77/2001/EC) has been in place since 2001. The EU aimed to increase the share of electricity produced from renewable energy sources (RES) in the EU to 21% by 2010 (up from 15.2% in 2001), thus helping the EU reach the RES target of overall energy consumption of 12% by 2010. The Directive, which set out differentiated national indicative targets, has been a historical step in the delivery of renewable electricity and constitutes the main driving force behind recent policies being implemented. In the pursuit of the overall target of 21% from renewable electricity by 2010, the Renewable Electricity Directive 2001 gives EU Member States freedom of choice regarding support mechanisms. Thus, various schemes are operating in Europe, mainly feed-in tariffs, fixed premiums, green certificate systems and tendering procedures. These schemes are generally complemented by tax incentives, environmental taxes, contribution programmes or voluntary agreements. However, despite the efforts of Member States and despite some improvements to the regulatory frameworks, major barriers to growth and integration of renewable electricity remain. The main causes of the slow development in some Member States are not policy related, but delays in authorization, unfair grid access conditions and slow reinforcement of the electric power grid.

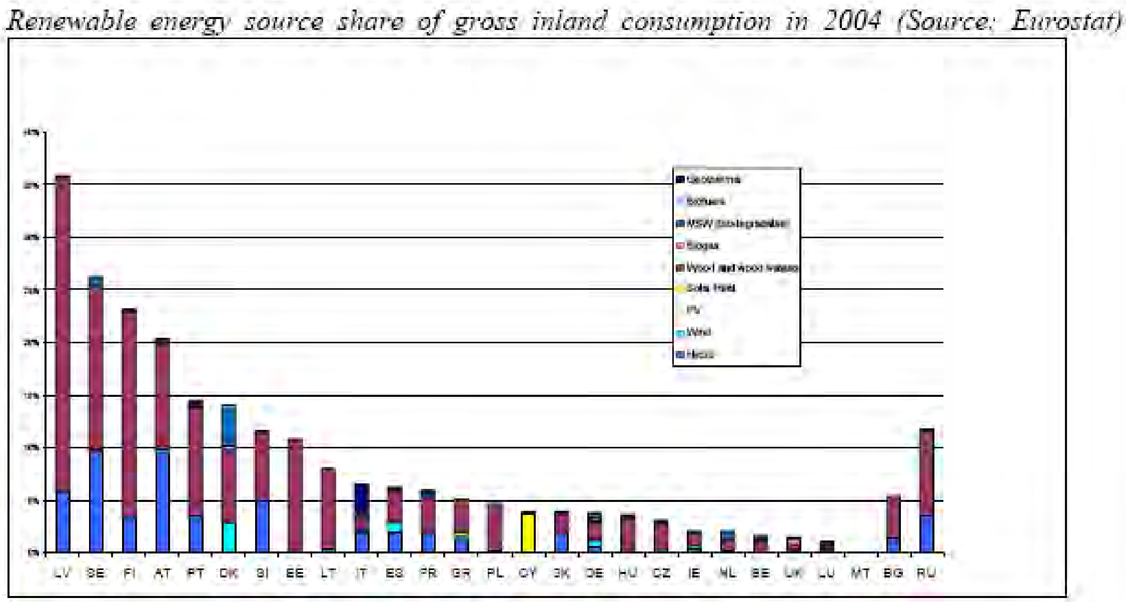


Figure II.1.16: Gross Inland Consumption – [Source: Renewable Energy Road Map, EU Commission]

II.1.3.4.1.2. The future EU legislative framework for wind energy

In December 2008, the European Union agreed to a new Renewable Energy Directive to implement the pledge made in March 2007 by the EU Heads of State for a binding 20% renewable energy target by 2020. The EU's overall 20% renewable energy target for 2020 has been divided into legally binding targets for the 27 Member States (Table II.1.5), averaging out at 20%. In terms of electricity consumption, renewables should provide about 35% of the EU's power by 2020. By 2020, wind energy is set to contribute more than a third of all the power coming from renewables.

The directive legally obliges each EU Member State to outline the steps it will take to meet its target in a National Renewable Energy Action Plan (NAP) to be submitted by 30 June 2010 to the European Commission. NAPs will set out how each EU country is to meet its overall national target, including elements such as sectoral targets for shares of renewable energy used for transport, electricity and heating/ cooling and tackling solving the administrative and grid connection barriers.

The Directive requires EU countries to take “the appropriate steps to develop transmission and distribution grid infrastructure, intelligent networks, storage facilities and the electricity system” to help develop renewable electricity. They must also speed up authorization procedures for grid infrastructure. EU countries must ensure that transmission system operators and distribution system operators guarantee the transmission and distribution of renewable electricity and provide for either priority or guaranteed access to the grid system or access.

II.1.3.4.1.3. Industry concerns about future policy

The biggest concerns expressed by the industry about the new legislation are about the following three questions:

Should the EU have a single EU-wide harmonized support scheme?

EWEA believes that a hasty move towards a harmonized EU-wide payment mechanism f or renewable electricity would put European leadership in wind power technology and other renewables at risk. Changes in frameworks always create uncertainty and have to be based on sound knowledge and well-proven tools. Experience shows that even small adjustments to a framework can have a profoundly negative effect on the markets for wind power and other renewables, particularly changes to the basic framework of a successful system. More fundamental changes will have an even greater effect on the markets. A dramatic shift in all Member States’ frameworks would jeopardize national renewable targets and undermine investor confidence.

Should cross border trade in guarantees of origin for electricity produced from RES be possible in order to allow underperforming Member States to meet the national target?

In EWEA’s view, possibly a percentage of the national target could be traded, provided that the country who acts as seller is over-performing in terms of electricity produced by renewables. Cross border trade in renewable energy certificates of origin should only occur once national targets are achieved, and strictly controlled by the Commission on an annual basis.

The question of national targets: how they should be distributed (‘burden sharing’/’opportunity sharing’)?

EWEA would favour a sharing of the 20% target using a model based on available potential in each Member State. However, such an approach would most likely entail a very long negotiation process with an undecided end, resulting in uncertainty for the industry over the coming years. EWEA therefore proposes an alternative, simpler approach, which would consist of adopting a basic 1% increase of renewable energy per country per year until 2020. Given that the EU currently produces 7% of its energy consumption with renewable energy, a 1% annual increase each year until 2020 would achieve the 20% target.

Member State	Share of renewables in 2005	Share required by 2020
Austria	23.3%	34%
Belgium	2.2%	13%
Bulgaria	9.4%	16%
Cyprus	2.9%	13%
Czech Republic	6.1%	13%
Denmark	17%	30%
Estonia	18%	25%
Finland	28.5%	38%
France	10.3%	23%
Germany	5.8%	18%
Greece	6.9%	18%
Hungary	4.3%	13%
Ireland	3.1%	16%
Italy	5.2%	17%
Latvia	32.6%	40%
Lithuania	15%	23%
Luxembourg	0.9%	11%
Malta	0%	10%
The Netherlands	2.4%	14%
Poland	7.2%	15%
Portugal	20.5%	31%
Romania	17.8%	24%
Slovak Republic	6.7%	14%
Slovenia	16%	25%
Spain	8.7%	20%
Sweden	39.8%	49%
United Kingdom	1.3%	15%

Table II.1.5 : National Renewable Energy Share [Source: EU Renewable Energy Policy (http://www.euractiv.com/en/energy/eu-renewable-energy-policy/article-117536)]

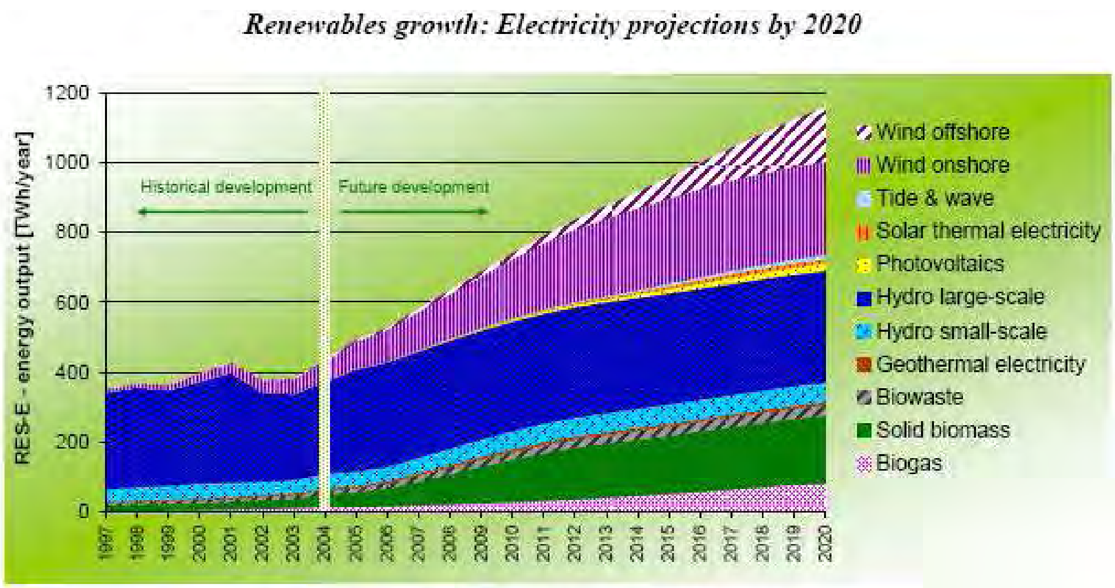


Figure II.1.17: Growth of Renewable [Source: Renewable Energy Road Map, EU Commission]

II.1.3.4.1.4. Energy Efficiency Scenarios and Wind Energy

Wind energy penetration is affected by new efficiency regulations. Wind energy is actually competing with new construction of fossil fuel power plants, but rarely do wind projects cause the closure of an existing plant. A way to reduce GHG emissions would be to increase energy efficiency, reducing overall energy consumption. Even in that scenario, wind energy would help reducing even more GHG emissions and energy dependency, but in this case the situation would be of substituting existing plants (coal-fire) with wind turbines.

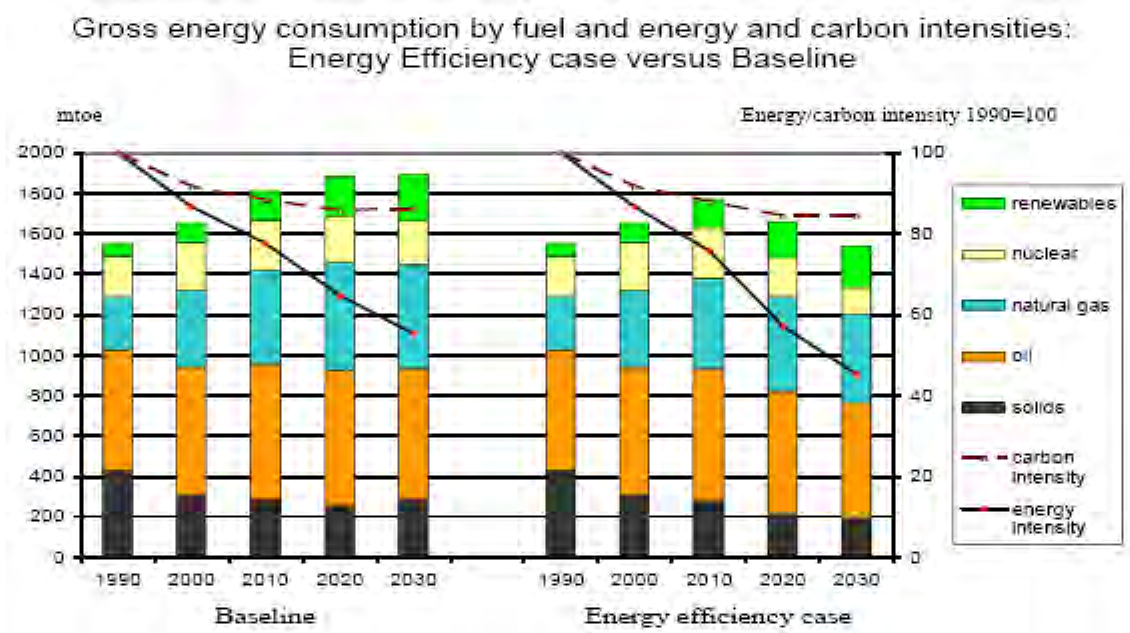


Figure II.1.18: Energy Consumption 1 [Source: Scenarios on Energy Efficiency and Renewables, EU Commission]

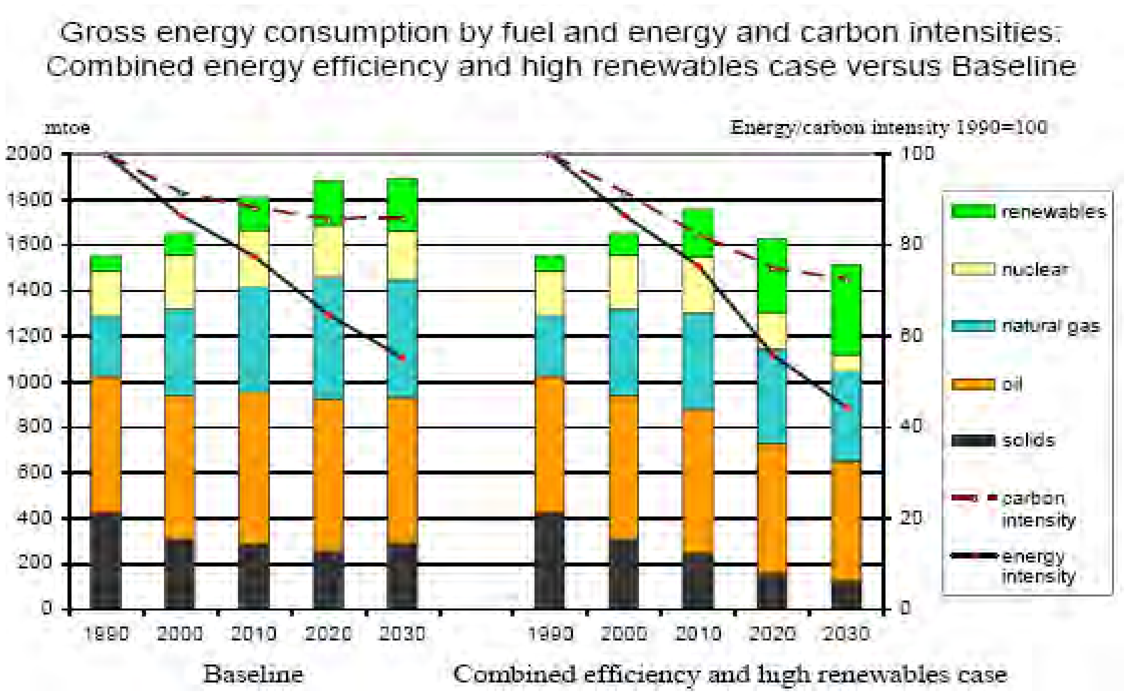


Figure II.1.19: Energy Consumption 2 [Source: Scenarios on Energy Efficiency and Renewables, EU Commission]

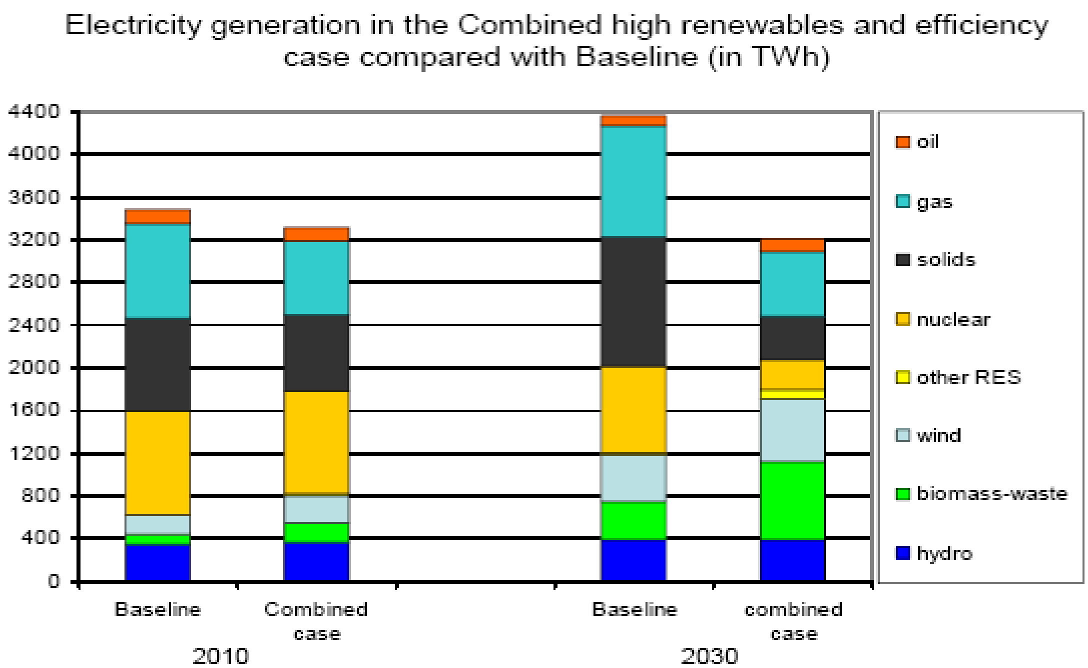


Figure II.1.20: Energy Generation Comparisons [Source: Scenarios on Energy Efficiency and Renewables, EU Commission]

II.1.3.4.2. People's Republic of China

II.1.3.4.2.1. New Role in International Negotiations as Major Polluter

Some important changes have occurred since the Kyoto Protocol was signed in the 1990's. Countries like China or India were not included in the list of countries committed to reduce their GHG emissions, and this actually was the argument of the US Congress to reject the treaty. Since then, China's GHG emissions have increased by 120%, while U.S. emissions have barely changed over the same period. China now exceeds the United States as the single largest GHG emitter, and accounts for more than a fifth of global GHG emissions. China relies more heavily on coal-fired power plants, the most GHG-intensive energy source, than do most OECD countries. Between now and 2012, the increase alone in Chinese coal-based emissions will exceed the entire level of coal-based emissions in the United States. Copenhagen will set a new game terrain playing field in where which US, China and the EU will have to lead the world in a drastic reduction of GHG emissions.

Powerplant Type	Electric Generating Capacity Amount	Share	Electricity Generated Amount	Share
Coal-Fired Power	252.1 GW	66.5%	1,281 TWh	74.4%
Gas or Oil-Fired	12.1 GW	3.2%	61 TWh	3.6%
Large Hydropower	84.6 GW	22.3%	271 TWh	15.7%
Other Renewable	26.0 GW	6.9%	83 TWh	4.8%
Nuclear Power	3.7 GW	1.0%	25 TWh	1.5%
Total	378.5 GW	100.0%	1,721 TWh	100.0%

Figure II.1.21: Fuel Shares of Generating Capacity and Output in China in 2002. [Source: Asia Pacific Energy Research Center]

Powerplant Type	Electric Generating Capacity Amount	Share	Electricity Generated Amount	Share
Coal-Fired Power	1,078 GW	30.8%	5,989 TWh	38.9%
Gas-Fired Power	729 GW	20.8%	2,676 TWh	17.4%
Oil-Fired Power	501 GW	14.3%	1,241 TWh	8.1%
Hydropower	776 GW	22.2%	2,650 TWh	17.2%
Other Renewable	61 GW	1.7%	249 TWh	1.6%
Nuclear Power	354 GW	10.1%	2,586 TWh	16.8%
Total	3,498 GW	100.0%	15,391 TWh	100.0%

Figure II.1.22: Fuel Shares of Generating Capacity and Output in the World in 2000 [Source: Asia Pacific Energy Research Centre]

In June 2007, China unveiled a 62-page climate change plan and promised to put climate change at the heart of its energy policies and insisted that developed countries had an “unshirkable responsibility” to take the lead on cutting greenhouse gas emissions and that the "common but differentiated responsibility" principle, as agreed upon in the UNFCCC should be applied.

II.1.3.4.2.2. The 10 GW-size Wind Base Program

In 2008, the newly established National Energy Administration (NEA) highlighted wind energy as a priority for diversifying China’s energy mix. The bureau selected six locations from the provinces with the best wind resources: Xinjiang, Inner Mongolia, Gansu, Hebei and Jiangsu. Each site will have more than 10 GW of installed capacity by 2020. The Wind Base projects will ensure more than 100 GW of installed capacity producing 200 TWh per year by 2020. This is crucial to reach the Chinese government’s National Mid and Long-Term Development Plan of 3% non-hydro renewable electricity production by 2020. Whereas wind projects in Europe are often decentralized and the electricity is consumed locally, the Chinese wind resources are rich in the northwest, where the population is sparse and the electricity demand is low. China must build large scale, centralized projects, with high voltage and long distance transmission, and the Wind Base projects are posing huge challenges for transmission and grid construction. In 2008, the State Power Grid Corporation started work on a 750 kV high voltage transmission project in Gansu. The project will transmit the electricity to the east of the country where the electricity demand is high.

II.1.3.4.2.3. Motor of Global Growth in the Financial Crisis

The financial crisis is beginning to have an impact on the global wind market. Not only does the global financial crisis not pose a substantial threat to the Chinese wind industry, it actually brings new opportunities. Firstly, it will accelerate the consolidation of Chinese wind industry manufacturing through intensive competition. Secondly, the state owned wind power developers, such as HUANENG and Datang HUADIAN, will receive priority access to low interest loans for wind farm construction. Power generation companies in China had a difficult year in 2008. In the first half of the year the price of coal increased dramatically, while the electricity price was not allowed to rise accordingly, causing 90% of power generation companies to report huge losses by the end of the year. These losses have encouraged power generation companies to begin to invest further in wind power development.

II.1.4. Federal Incentives

II.1.4.1. Introduction

Federal incentives have played an important role in the growth of the US wind industry. Growth trends have been visibly dependent on the development and renewal of incentives, as evidenced by Figure II.1.23, which shows yearly capacity installation through 2006.

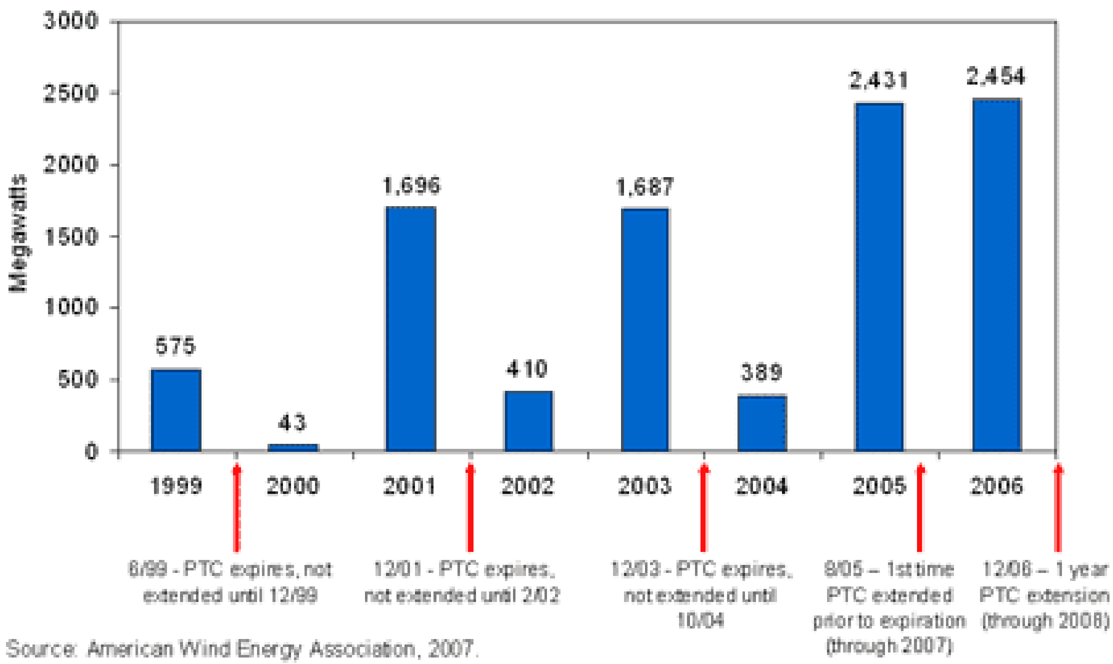


Figure II.1.23: Annual Additions to US Wind Capacity (1999-2006) [9]

The federal government has offered a broad range of incentives covering entities from multi-billion dollar corporations in the energy industry to individual homeowners wishing to supplement their electricity use from the grid with small-scale renewable sources. Along with the support of the 20-by-30 Plan and the current administration, led by President Obama, wind energy incentives are growing and enabling the industry to diversify through competition, more comprehensive utility coordination and agreement, and further defined land use agreements. The American Recovery and Reinvestment Act of 2009, issued on February 17, introduced additional provisions to the existing incentive structure, namely by providing a three year extension of the production tax credit (through 2012), creating a tax credit for advanced energy manufacturers, and offering a grant program from the treasury department as an alternative to accepting the investment tax credit [9].

Effectively all U.S. states and several U.S. localities offer financial incentives in either the government or private sector regarding the development and commercial sale of electricity generated by alternative energy sources, including wind energy. The Database of State Incentives for Renewables & Efficiency (DSIRE) maintains a web-based resource outlining these financial incentives (http://www.dsireusa.org/) and it generally differentiates the wind-based incentives into one of the ten following categories [6]:

- Personal Tax Incentives
- Corporate Tax Incentives
- Sales Tax Incentives
- Property Tax Incentives
- Rebates
- Grants
- Loans
- Industry Support
- Bonds
- Production Incentives

Federal incentives have a long history within the energy industry and as energy infrastructure grew nationwide between the 1950’s and 1970’s, (according to the DOE, incentives totaled over 500 billion dollars) and as the time approaches for another stage of major infrastructure growth and maturation, federal incentives will continue to play an integral role in the wind energy industries success. Growth of the market has been heavily dependent on the federal production tax credit (PTC), and its renewal cycle has often had wind energy developers in a wait-and-see mode before moving forward with major projects for fear that the PTC will be suspended; eliminating the most fruitful wind incentive. However as incentives develop and stabilize, wind energy’s share of the total federal incentive market will grow. For an industry that is being used to compose a base for a new national energy strategy, it is important to foster genuine economic success to aid in robust social acceptance of the technology.

Research conducted in 2003 by the National Commission on Energy Policy indicated that federal energy subsidies approached 64 billion dollars for the year, with the wind market receiving approximately one percent of that total. It is noted that while the wind energy industry works to develop a stable incentive program, the fossil fuel-based energy industry maintains an expansive portfolio of incentives, some of which date back to the 1920’s. This section of the study will focus on Federal wind energy incentives as they currently exist and the following is a review of the incentives for 2009, that draws largely on information presented on the DSIRE web database. How the rest of the federal energy subsidies (99 %) are distributed will not be discussed at this time.

II.1.4.2. Corporate Tax Credits

Business Energy Investment Tax Credit - The DSIRE indicates that the credit covers up to 30% of expenditures attributed to the installation of a small-scale wind turbine, and has no maximum credit limit for turbines commissioned after December 31, 2008. Qualified turbines include those up to 100 kW in capacity. Generally, the credit has been capped at $4,000 for eligible turbines commissioned between 3 October 2008, and before 1 January 2009. However, the American Recovery and Reinvestment Act (ARRA) of 2009 rescinded this maximum credit limit. The American Recovery and Reinvestment Act of 2009 entitles entities eligible for the federal renewable electricity production tax credit (PTC) to receive the federal business energy investment tax credit (ITC) or a grant from the U.S. Treasury Department as an alternative to taking the PTC for new installations [6].

Renewable Energy Production Tax Credit - The federal renewable electricity production tax credit (PTC), as defined by the DSIRE, is a per-kilowatt-hour tax credit for electricity generated by qualifying energy resources such as wind power and subsequently sold by the taxpayer to an unrelated person during the taxable year. The PTC was first introduced in 1992 and is an incentive that has been renewed and modified multiple times since its inception, most recently in February of 2009. The October 2008 legislation extended the in-service deadlines for wind energy and all other qualifying renewable technologies. The February 2009 revision to the PTC extended the in-service deadline for eligible wind technology (as well as most other renewable sources) by three years and allowed qualifying facilities to opt to take the federal business energy investment credit (ITC) or an equivalent cash grant from the U.S. Department of Treasury. The current PTC amount is 2.1¢/kWh (currently, after increases from 1.5¢ and 1.9¢/kWh) for some technologies, and near half of that amount for others (see Table II.1.6) [6].

Resource	In-Service Deadline	Credit Amount
Wind	31 December 2012	2.1¢/kWh
Closed-Loop Biomass	31 December 2013	2.1¢/kWh
Open-Loop Biomass	31 December 2013	1.0¢/kWh
Geothermal Energy	31 December 2013	2.1¢/kWh
Landfill Gas	31 December 2013	1.0¢/kWh
Municipal Solid Waste	31 December 2013	1.0¢/kWh
Qualified Hydroelectric	31 December 2013	1.0¢/kWh

Table II.1.6: Federal Production Tax Credits per Renewable Energy Source [6]
(Closed-loop biomass systems use biomass specifically planted for energy production. Open-loop systems incorporate biomass from non-discretionary sources).

Wind energy commands the highest credit amount at 2.1¢/kWh and has also enjoyed the highest rate growth in recent history. This credit is generally active for 10 years from the commission date of the facility, with the exception of some biomass and geothermal facilities. Additionally, the credit is reduced for projects receiving other federal tax credits, grants, tax-exempt financing, or subsidized energy financing [6].

II.1.4.3. Corporate Depreciation

Modified Accelerated Cost-Recovery System and Bonus Depreciation – Since 1986, a 5-year Modified Accelerated Cost-Recovery System (MACRS) depreciation schedule has been in place for most types of renewable properties including solar, geothermal, and wind. In 2005, the federal Energy Policy Act defined fuel cells, microturbines, and solar hybrid lighting equipment as five-year assets. In October 2008, The Energy Improvement and Extension Act allowed for geothermal heat pumps, combined heat and power, and small wind to be depreciated on a 5-year MACRS schedule, allowing for greater revenues to be shown early in the property’s operation. The federal Economic Stimulus Act of 2008 was introduced to include a 50-percent bonus depreciation provision for eligible technology operating in 2008 [9]. The American Recovery and Reinvestment Act of 2009 extended this depreciation schedule through the 2009 tax year.

According to DSIRE USA, wind energy projects must satisfy the following criteria, to become eligible for the bonus depreciation:

- The turbine(s) must have an investment recovery period of 20 years or less under normal federal tax depreciation rules

- The original use of the turbine must commence with the taxpayer claiming the deduction

- The property generally must have been acquired during 2008 or 2009 and the property must have been placed in service during 2008 or 2009 (or, in certain limited cases, in 2010).

If these requirements are achieved, the owner is entitled to deduct 50-percent of an adjusted property value in 2008 and 2009. The remaining 50-percent of the adjusted property value is depreciated over the ordinary depreciation schedule, and thus greater income may be realized in the initial years of the turbine's operation. When calculating the adjusted property value, it must be noted that the bonus depreciation rules do not override the depreciation limit related to turbines that qualify for the federal business energy tax credit. Prior to the depreciation calculation for a qualifying wind project, including any bonus depreciation, the adjusted value of the project must be reduced by one-half of the amount of the energy credit for which the project qualifies [6].

The option to depreciate wind energy property on a MACRS schedule is currently of particular interest with the strong federal initiative to make wind power a substantial source of generation for the nation's energy demands. It promises to promote new construction, allowing for the emergence of new wind farms and wind farm developers through higher net income realization early in each qualifying project's lifetime. Companies retain higher levels of capital due to the effects of depreciation on the tax payer's corporate income statement, subsequently allowing them to continue to invest in new projects, grow as a company, and continue to pay employees and suppliers.

II.1.4.4. Industry Recruitment and Support

Qualified Advanced Energy Project Investment Tax Credit- The 2009 ARRA established a new ITC in an effort to encourage development in the US manufacturing sector of the renewable energy market. In any taxable year, the ITC is equivalent to 30-percent of the qualified investment required for an advanced energy project, including wind energy, which establishes, re-equips or expands a manufacturing facility that produces any of the following technologies:

- Equipment and/or technologies used to produced energy from the sun, wind, geothermal or "other" renewable resources

- Fuel cells, microturbines or energy-storage systems for use with electric or hybrid-electric motor vehicles

- Equipment used to refine or blend renewable fuels

- Equipment and/or technologies to produce energy-conservation technologies (including energy-conserving lighting technologies and smart grid technologies)

For manufacturers of components related to wind energy, investments include personal tangible property that may be depreciated and is necessary in the production process. Other tangible property may be considered a qualified investment only if it is an essential part of the facility, excluding buildings and structural components. The U.S. Treasury Department states that it will issue certifications for qualified investments eligible for credits, not to exceed $2.3 billion, under the life of the program. Upon certification, the taxpayer must provide additional evidence that the requirements of the certification have been met within one year and the wind project must be commissioned within three years [6].

II.1.4.5. Federal Grant Program

DOE Renewable Energy Grant for Small Wind Turbines - This grant is equal to 30% of the base property value for small wind turbines up to 100 kW in capacity. Qualifying facilities other than wind energy facilities, include closed and open-loop biomass facilities, geothermal energy facilities, landfill gas facilities, qualified hydropower facilities, and hydrokinetic renewable energy facilities [6].

USDA Rural Energy for America Program (REAP) Grants/Loan Guarantees - These incentives are available to agricultural producers and rural small businesses to purchase renewable energy systems (including systems that may be used to produce and sell electricity), to make energy efficiency improvements, and to conduct relevant feasibility studies. Eligible renewable energy projects include wind, solar, biomass and geothermal; and hydrogen derived from biomass or water using wind, solar or geothermal energy sources. These grants are limited to 25% of a proposed project's cost, and a loan guarantee may not exceed $25 million. The combined amount of a grant and loan guarantee may not exceed 75% of the project's cost. In general, a minimum of 20% of the funds available for these incentives will be dedicated to grants of $20,000 or less [6].

Tribal Energy Production Grant - The U.S. Department of Energy's (DOE) Tribal Energy Program promotes tribal energy self-sufficiency, economic growth and employment on tribal lands through the development of renewable energy and energy efficiency technologies. The program provides financial and technical assistance, along with education and training to tribes for renewable energy resource development. The DOE's Tribal Energy Program assists with program management, program implementation, and project management using DOE's own support staff [6].

II.1.4.6. Federal Loan Program

Department of Energy Loan Guarantee Program – This program offers loan guarantees for the advancement of wind technology or manufacturing facilities related to wind technology development. This is a valuable source of funding as studies have shown that greater public acceptance of a technology is realized when the technology is primarily manufactured within the country. Not only is it of value to the economy to supplement the production from traditional industries such as the auto manufacturing industry, but also for the reason that it reduces lead times and transportation costs (not to mention a savings in emissions and energy use) when critical components may be obtained within the country [6].

Clean Renewable Energy Bonds (CREB) – CREBs are bonds issued by the federal government, in which the issuing body (electric co-ops, local municipalities) does not pay interest to bondholder and instead, the federal government gives the bondholder a tax credit. The Treasury Department has set the rate of the credit on a daily basis and when the bondholder purchases the bond, it is locked in for the term of the bond. The credit accrues quarterly and is treated as gross income for the bondholder (as if it were an interest payment on the bond). The bondholder takes the tax credit as a credit against their regular income and alternative minimum tax. So it is noted that CREBs differ from the conventional tax-exempt bond in the sense that tax credits issued through CREBs count towards taxable income for the bondholder. The bond is repaid on a level annual basis and the value to the bondholder in any year of the term is equal to the credit less the tax on the credit. In relation to the PTC, the CREB works as a financing tool through project development, whereas the PTC specifically generates benefits only once the facility has been financed, constructed, and commissioned [10].

The Energy Improvement and Extension Act of 2008 allocated $800 million for new Clean Renewable Energy Bonds and the February 2009 ARRA allocated an additional $1.6 billion for CREBs [9]. The volume of bonds that the federal government has allocated towards the program has constricted participation in the CREB program.

Qualified Energy Conservation Bond – This is new bond system enacted by the Treasury department this quite similar to the CREBs system, but allows bond to be issued with a zero percent interest rate. The borrower only repays the principal on the bond and the bondholder receives federal tax credits in the place of interest from the bond. The qualifications for energy conservation projects are relatively broad under this program and allows fund to be allocated towards projects such as:

- Energy efficiency upgrades in public buildings
- Renewable energy production
- Research and development applications

- Mass commuting facilities reducing energy consumption
- Public energy efficiency education campaigns

It is noted that currently, renewable energy facilities eligible for CREBs are also eligible for energy conservation bonds [10].

II.1.4.7. Personal Tax Credit

Residential Renewable Energy Tax Credit – This tax credit is for small wind-energy property such as residences, for which the home served, does not need to be the taxpayer's principal residence. The maximum credit is $500 per half kilowatt, and is capped at $4,000 per year total for systems placed in service in 2008; there is no cap for systems placed in service afterwards. Qualifying property must be operable from January 1, 2008, through December 31, 2016 [6].

II.1.4.8. Production Incentive

Renewable Energy Production Incentive (REPI) – REPI was enacted in 1992 to supplement the PTC, which is only applicable to those companies that pay a federal corporate tax. Thus REPI serves tribal governments, native organizations, and the District of Columbia in a manner similar to the above outlined PTC [6].

II.1.5. Wind Energy Policy and Planning

II.1.5.1. Overview

As the sources and effects of global warming become increasingly evident, the restriction of greenhouse gas emissions are a paramount objective with which the international community has begun to address using varying avenues of technology, policy, education, and management practices. However, with respect to the global energy market, a Catch-22 of sorts has presented itself. While the relatively unrestricted emission of greenhouse gases warms the atmosphere, global energy demand increases with population growth and the pursuit of higher standards of living across the board, a movement summarized by Figure II.1.24.

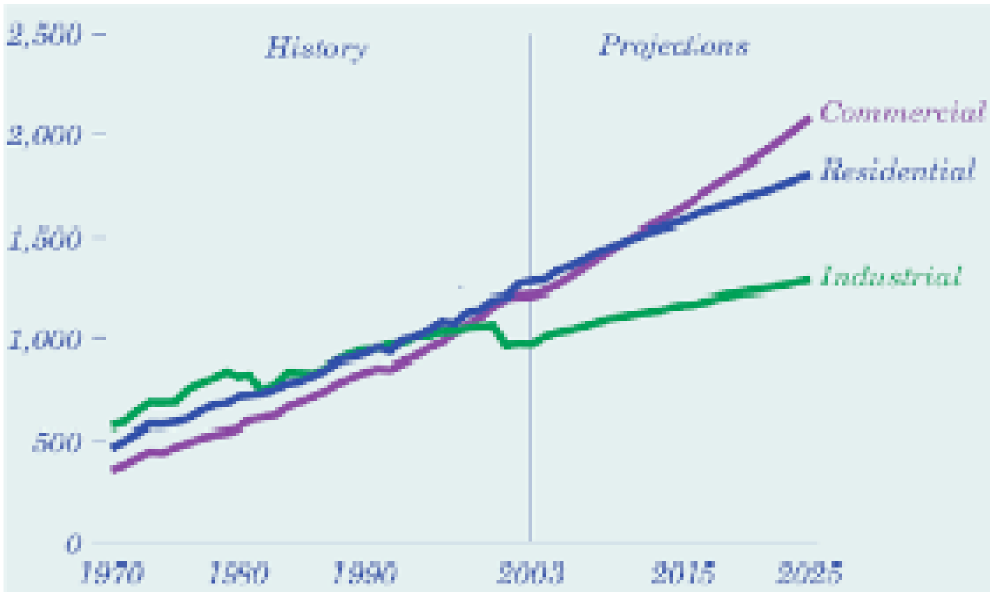


Figure II.1.24: DOE Prediction of US Annual Electricity Sales in billion kWh (February 2005) [7]

Over the past century, the primary infrastructure for the global energy market has been built upon fossil-fuel dependent technology. So with the goal of reducing greenhouse gas emission in mind, it is not only necessary to meet future energy needs with renewable sources, but also the existing infrastructure must be replaced with renewable sources in kind. Beyond the logistical and technological challenges of such a task, is the fact that energy policy has matured under the influence of the fossil fuel industry, which does not translate to an efficient base for renewable energy policy and planning.

As goals for renewable energy portfolios and wind energy capacity are pursued across Europe, Asia, and North America, growing pains are experienced with respect to aspects such as manufacturing capacity, energy transmission, financing, and governmental regulations. Here in the US, the regulatory structure on both the federal, state, and local levels is enduring a period of adjustment to meet the needs of the wind industry while effectively regulating existing emissions sources and it is proving to be a difficult process to both effectively assess and rectify. With multiple entities involved, no robust framework exists with which to efficiently move forward with the aggressive planning, development, and operational activities that have been proposed for the wind industry. Thus there is interest in evaluating the existing framework to assess key deficiencies. There is strong, established competition in the market and the wind energy industry will have to gain broad public acceptance while overcoming some of the competitive disadvantages that exist between themselves and other energy sources such as nuclear and coal.

This section of the study focuses on the policy and planning structure for the wind energy market within the US, which is a broad and expansive topic. Under the umbrella of policy and planning, the industry may be studied at a level concerned with culture, economy, and politics, or it may be addressed through involved discussion of design standards, utility agreements, and tax structure. The following sections will address the federal components of policy and planning through discussion of the economy and environment, as well as the role that the Federal Energy Regulatory Committee (FERC) and Department of Energy (DOE) have occupied in shaping the industry.

II.1.5.2. Federal Aspects

The US government is the largest single consumer of electricity in the world, having consumed an estimated 55,000 GWh in 2005 [7]. Furthermore, it oversees a populace whom consumes more energy per capita than any other population on the planet. So it is not only a process of refocusing a nation, but also one of changing culture from within.

II.1.5.2.1. Economic Policy

Bulk energy has been the driver of economic development since the industrial revolution and the major source of energy has been fossil fuel. On an international scale, policy for developed countries has typically been constructed around supply, relying on outside sources, and subsequently influencing policies covering a broad range of life including national security, transportation, and food supply. Historically, there has been questionable matching between sourcing activities and subsequent energy usage. Long periods of abundant sources and cheap market prices have allowed the inequality between sources and uses, and only during periods of supply shortages has conventional practice been questioned or deviated from. It can be observed that the activities to advance energy efficiency have followed similar trends and development of renewable energy sources has been slow because of fossil-fuel supply and the policies enacted to develop and maintain the industry. As a result, electricity supply has been planned around capacity and the ever-growing national demand, ignoring the impacts of sourcing and creating a competitive disadvantage for technologies such as wind energy.

II.1.5.2.2. Environmental Policy

Seek to address energy issues and social costs originating at the sourcing level and carrying through consumption. The true costs of fossil-fuel based energy generation has shown to be significantly higher than market prices, which is a powerful statement when compared the economic costs of energy in the everyday life of a populations around the World. While wind energy is not free and clear of environmental impacts, they are significantly reduced from those of many other technologies and are also easier to define, quantify, and track. The environmental benefits of wind power are clear in that the technology does not incur repeated extraction costs, has minimal impact on transportation and logistics over its lifetime (taking into account the realization that the initial construction can represent transportation difficulties), and does not emit greenhouse gases or other emissions at the generation site.

II.1.5.2.3. The Federal Energy Regulatory Commission (FERC)

The Federal Energy Regulatory Commission’s role in the development of the wind energy industry is one of some controversy. They are an entity tying all facets of the energy industry together, overseeing some measure of the economic, environmental, and safety interests of the American public, yet their structure and regulatory development is not conducive to multiple aspects of the wind industry. Per their website, FERC states their role within the industry to include [8]:

- Regulating transmission and sale of natural gas for resale in interstate commerce
- Regulating transmission of oil by pipeline in interstate commerce
- Regulating transmission and wholesale sales of electricity in interstate commerce (wind energy included)

- Licensing and inspecting private, municipal, and state hydroelectric projects
- Approval of interstate natural gas pipelines and storage facilities
- Ensuring the reliability of high voltage interstate transmission systems
- Monitoring and investigating energy markets
- Employing civil penalties (in addition to other means) against energy organizations in violation of FERC rules in the energy markets
- Environmental oversight related to major electricity policy initiatives
- Administration of energy accounting and financial reporting regulations

Among these duties, there are two key issues that this study will focus on in relation to the wind industry. The first concern originates within the Open Access Transmission Tariff (Order No. 888), which is aimed at addressing energy imbalance [8]. Energy has traditionally been consumed in a variable and typically uncontrollable fashion over time intervals through the day, month, and year. The behavior forces system operators to schedule generators in an effort to meet the load demands. The delivery of energy in at specified time is generally controllable within reasonable precision for energy sources such as coal, nuclear, or natural gas. However, it also occurs that the energy generated sometime exceeds or falls short of the scheduled energy demand. The disparity between the energy scheduled and actually amount generated per hour amounts to the imbalanced energy quantity that system operators must meet. Order No. 888 promotes enhanced system reliability by incentivizing accurate scheduling and discouraging inefficient of sloppy operating practices, such as intentional deviation from a schedule. While the order addresses both energy imbalance for load and generation, the latter is of primary concern for the wind industry.

Following Order No. 888, FERC issued Order 8901 in 2007, which utilizes a tiered approach to energy imbalance. Under the order, hourly energy imbalances of 1.5 percent (plus or minus) of the scheduled energy (or 2 MW, whichever is larger) are recorded over a monthly period and resolved under the actual incremental or decremental cost [8[. Imbalances outside this range are assessed a charge of 110 percent of system incremental cost for the amount actual energy delivered during the hour that is less than scheduled demand, and are conversely paid 90 percent of the system decremental cost for the actual energy delivered during the hour exceeding scheduled demand. The equivalent is a 10 percent penalty for energy imbalance beyond the 1.5 percent deviation limits [8]. While these deviation measures offer operating flexibility, with penalties to discourage unfavorable generator operating practices, they are counter to the variable nature of wind energy generation.

Considerable developments have been made in the forecasting of wind energy generation, yet there is an inevitable difference between the predicted and actually generated hourly wind energy. With peak demands for energy generally occurring at low points in wind energy production, wind generation facilities face the possibility of selling the bulk of their product at a discounted price, which is counterproductive to the growth of a renewable energy market. With large generation areas, this is easily solved, but in smaller areas, wind normally blows harder at night when demand is lower. Seasonal variations also occur and could happened that places with high demand for air cooling in summer have more wind in winter. These imbalances are better solved when larger areas are used to compensate generation or demand peaks. Studies conducted by the National Renewable Energy Laboratory indicate that the average plant sees a two percent shortfall in revenue as a result of the energy imbalance regulations. While two percent may not seem monumental, it is a sizable sum of revenue of the life of a wind farm and does not change the aspect that the regulation creates a disadvantage for a technology that is heavily promoted as a premier source of tomorrow’s energy. It is a question of perceived net value when comparing the potential losses of revenue for wind farms with the prospective increases in energy grid reliability promoted by the energy imbalance regulations.

A second byproduct of the FERC regulatory structure regards the interaction of developers of generation infrastructure and transmission infrastructure. The transmission structure of the US is a convoluted system to begin with, one that doesn’t necessarily serve the premier site for wind generation at this point in time. The conclusion is that not only does the transmission grid need to be updated, but it also needs to be expanded to allow wind farms to get their product to demand centers. However, operators and owners of the transmission and generation facilities are not one and the same, and FERC regulations do not incentivize developers of transmission infrastructure to place priority on serving the wind industry. For wind energy generators, profits are significantly impacted by the cost to use transmission lines and the potential the there will be no transmission line to service their site. It is noted that publicly owned transmission lines are not subject to FERC regulations. For more information on the subject, please refer to the Transmission Infrastructure section of this study.

II.1.5.2.4. Department of Energy (DOE)

The DOE’s Wind & Hydropower Technologies Program operates under a mission “to improve wind technology and increase the use of wind energy in the U.S [7]. The Wind Program interacts with entities in the wind industry to develop technologies to supplement fossil fuel use. Additionally, the DOE Wind Program collaborates with the electric power industry to integrate wind power into our electricity supply while maintaining the stability and reliability of the electric grid. Finally, the Wind Program works with other federal agencies, states, and communities to reduce barriers to wind power development. These efforts have culminated in some of the industry's leading products today and have contributed to record-breaking growth in the deployment of wind technologies.

II.1.6. General impacts in local communities

The size of new wind-farms, and the capital invested in single locations, is growing at a faster rate than expected. The most current studies refer to projects of less than 100 MW capacity, while new projects accounts for several hundreds of 2.5 MW state-of-the-art wind turbines. New transmission lines will add to this huge rural transformation in what has being called the third industrial revolution. With the pressure to solve the climate change crisis and reduce the dependence on imported fossil fuels, we will experiment in the next years the added urge to revitalize the current economy.

In some locations of Germany, where good wind spots are all taken, the new wave of wind projects are “repowering” the wind farms, updating with bigger more efficient turbines. This will have a minimum effect on local communities, compare to the US were almost all new projects will be developed in ‘virgin’ communities.

From the study done by the National Wind Coordinating Committee [20], comparing the effects of three wind-farms in three different locations, we can estimate some general expected impacts. However, this report was done for projects of less than 100 MW, and it is difficult to calculate the factor of scale applicable for the new projects. It will also be important to consider in the future the creation of clusters in highly developed regions. Again, the rural, isolated condition of most of the wind farms will probably change when high wind penetration occurs in a region.

The three case study areas are Lincoln County, Minnesota, Morrow and Umatilla counties, Oregon, and Culberson County, Texas. In Lincoln County, the project studied was Lake Benton I, placed in operation in 1998 with 107 MW. In Morrow and Umatilla counties, the project was Vansycle Ridge, placed in operation in 1998 with 25 MW. For Culberson County, the project was Delaware Mountain, placed in operation in 1999 with 30 MW.

Summary of Employment and Income Impacts from Construction Phase

Case Study Area	Employment *(# of jobs)*	Personal Income *($1,000s)*
Lincoln County, Minnesota	8	$98.4
Morrow and Umatilla Counties, Oregon	4	$105.4
Culberson County, Texas	26	$391.3

Summary of Annual Employment and Income Impacts from Operation and Maintenance Phase

Case Study Area	Employment *(# of jobs)*	Personal Income *($1,000s)*
Lincoln County, Minnesota	31	$909.2
Morrow and Umatilla Counties, Oregon	6	$103.6
Culberson County, Texas	11	$346.1

Summary of Tax Effects in 2000 and Annual Landowner Revenues

Case Study Area	Tax Effects *($1,000s)*	Personal Income *($1,000s)*
Lincoln County, Minnesota	$611	$501
Morrow and Umatilla Counties, Oregon	$242	$64
Culberson County, Texas	$387	$51

TableII.1.7: Results from the case study (Source: National Wind)

Based upon the analysis of the three case study areas, the study draws the following conclusions about the economic impacts of wind power development in local areas:

• In each of the case study areas, wind power development provided a modest to **moderate source of new economic activity** and new family wage jobs. The impacts are likely to vary greatly from place to place and project to project.

• The **leasing of land** has an important economic effect on local areas, provided the income from leasing goes to local residents and adds to local household incomes. In all cases, the cost of foregone opportunities from farming and livestock grazing was small compared to the revenues obtained from leases for wind power, as expected for large monoculture farms.

• Tax effects, particularly property taxes that support local entities, were important in all cases. If the entities' budgets do not increase as a result of a project, the assessed value of the tax base increases, and there is a redistribution of the local tax burden from residents to outside owners.

• The counties represented in the case studies had comparatively few economic sectors. Consequently, sector multipliers are comparatively low and leakages of direct expenditures are comparatively high. Because the counties included in the study did not manufacture any of the equipment (towers and turbines) which represents the bulk of the construction costs, these were imported and the impacts occurred elsewhere. If more of the inputs were manufactured locally, local economic impacts would have been greater.

• A major difference among the case study areas was the current rate of economic expansion. While wind power development was important to the economies of all case study areas, it was relatively more important to the counties in decline.

• The return on capital could be an important component of local annual income. In the three case studies, little or none of this income was received by local residents. Local ownership, where feasible, would retain more of this income in the local area and increase the size of the impact.

It is clear that small wind farms, with local ownership and with small turbines (local maintenance and operation), have a broader, deeper impact in local communities and a better acceptance and more economical and easy integration with the energy system and energy policies directed to manage energy demand and energy efficiency.

Almost every new development plan counts on some provisions for local sourcing. This, while improving the local acceptance, is also proving to be limiting and slowing the progress of some projects as manufacturing capacity takes longer to develop.

II.1.7. Opposition to Wind Farms

Local resistance to the erection of wind turbines first appeared in Denmark during the 1970s, however opposition was mostly directed against large, utility-owned projects. Noise and landscape disturbance were indentified as principal concerns of local communities, and the harm caused to birds populations became rallying points in especially sensitive locations. At a regional level, activists claim against the ‘industrialization of the countryside’ [20].

More recently, the main point of a majority of organizations against Wind Power is the lack of confidence in the real effectiveness of this technology to reduce Green House Gas emissions. Activists argue that industrial, utility-owned wind farms are not the most effective use of the tax money, for which they propose investments in energy efficiency and savings. Subsides to highly profitable companies, normally related with traditional ‘dirty’ generation (utilities, GE, Siemens, Arevaetc). also target for critics.

Thus, broadly speaking, criticism of anti-wind groups fall under three main headings: technology choice and energy policy, environmental issues and amenity issues. In most of the case, wind energy can provide a solution to these critics if correct political and economical decisions are made in the mid-term, permitting and adaptation of the system from the conventional energy sources to renewables. This, however, continues to be a common ground for antiwind groups integrated by utilities, coal workers, grid operation etc.

Critics also contend that wind farms have adverse impacts on economic activities conducted on the vicinity of wind farms, particular tourism onshore, and fishing offshore. This, however, is just the other face of the same reality named by pro-wind activist: diversification of local economies and creation of fish ‘sanctuaries’. The scale of resources to imported technology has also prompted criticism. This is probably why in any new plan for wind development in the US or China, an especial emphasis is made on local manufacturing of turbines and capacitating of local labor.

The environment concerns expressed by anti-wind groups tend to focus on the protection of the countryside from industrialization by wind farms. When confronting the dilemma of defending the local environment by impeding the development of a ‘solution’ for the global climate change, activists align themselves with the antinuclear groups, questioning the capacity of these technologies to deliver significant emission reductions.

The third main plank of anti-wind protest arises in relation to undisturbed enjoyment of the countryside and especially on living standards of homeowners near the wind farms. The “Not-in-my-backyard” (NIMBY) phenomenon is growing in importance, as rent-seeking landowners reap the benefits while neighbors endure the costs (both of wind farms and transmission infrastructures). Concerns are about noise, safety, distress caused by visual impact and depressed house values.

Sitting regulations, turbines lay-outs and EIA have being developed in reaction to these critics. Energy plans are tending to give a greater importance to energy saving and efficiency, and new international agreements will probably evolve in the direction of reducing and regulating more the energy consumption.

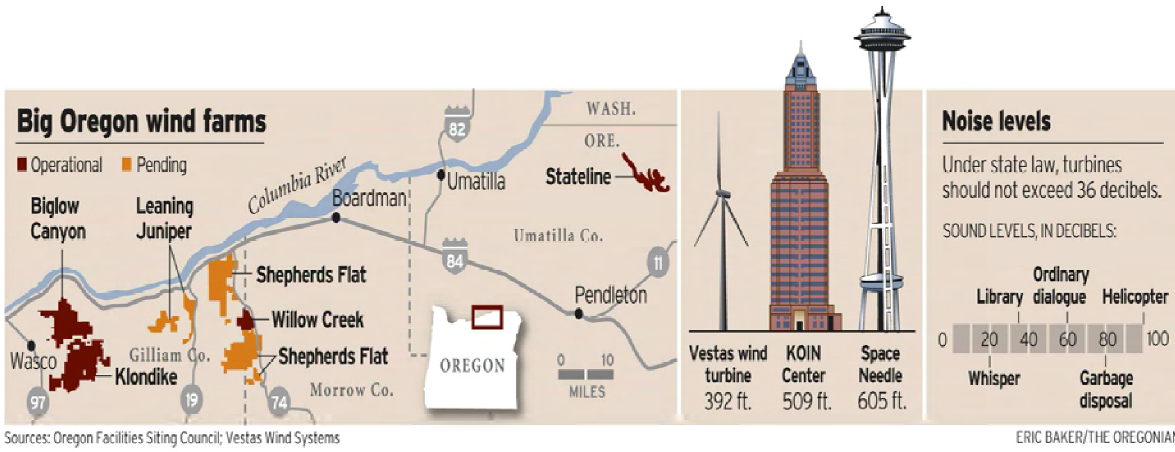


Figure II.1.25: Oregon Wind Farms : Location, Size, and Noise Levels (source : Google Images)

Figure II.1.26: Size of a 1.5 MW Turbine. (source: AWEO)

II.1.8. Transmission Access as an Obstacle for Market Penetration

II.1.8.1. Transmission as the Biggest Impediment for Wind Penetration

It is clear, both with the “20% by 2030” plan and with President Obama’s intentions to double wind power capacity in the next three years and reduce CO2 emissions by 80% by 2050, that the Wind Industry will experience a strong growth in the near future. This will be facilitated by incentives and investments, but probably the biggest issue that will have to big solve is the one related with the transmission system.

Different studies [13] point on this single issue as the reason for the yet small penetration of wind power in the energy mix of the US. By transmission issues, we do not only mean the technical needs and problems when integrating wind power in the system, but the political and regulatory limitations for the necessary adaptation of the system. The U.S. Department of Energy (DOE) has identified transmission limitations as the greatest obstacle to realizing the enormous economic, environmental and energy security benefits of obtaining at least 20 percent of our electricity from the wind.

II.1.8.1.1. Comparison with Europe

As it has being proven by some European countries, wind integration doesn’t represent such a big problem as is being presented in the U.S. As the American Wind Energy Association (AWEA) made it clear in their paper about Wind Energy integration [1], in Germany, Denmark or Spain, they “just did it”. Even if the U.S. has not yet reached similar levels of wind penetration, there have been many more studies and debates about integration issues in than in Europe. This probably has much to do with the different role played by the central government versus private initiatives in the development of the wind energy. In the US, short term economic profits drive most of the new initiatives, while in Europe, where environmental concerns are driving energy policy stronger, and are very active in the development of renewable technologies so that governments have facilitated their penetration in the market.

There is also a fierce opposition to this new source of energy by those groups involved in the national coal, natural gas, nuclear and oil industries. Europe (Germany, Denmark and Spain), because of its higher dependence in imported fossil fuels, has probably seen less of this internal opposition. Where most of the arguments against Wind Power integration focus on economical or technical issues, the advocates of wind energy are clear in declaring that political will is the only big obstacle: While FERC has taken major steps to separate the transmission monopoly power from the interest of utilities as generation competitors, the legacy of a transmission system and related tariffs designed to serve traditional utility power plants remains.

II.1.8.1.2. Additional Reasons for System Update

It is also recognised that some of the very factors that make for smoother integration of wind-such as better use and expansion of physical transmission capacity, well-functioning electricity markets, diversity of resources, and consolidation of balancing areas also make for a more resilient, efficient electricity market for all.

II.1.8.1.3. Integration of Wind

Wind Power has unique characteristics because of the intermittent nature of the wind resource. Yet many transmission policies assume that generators can control and predict their generation levels and penalize them when they do not. A second key characteristic of wind projects is that they must be located at the site of the wind resource. Moreover, good wind sites are often located remotely from electric loads. This means that wind facilities are more dependent upon long-distance transmission and less able to avoid transmission problems than other technologies. A study by the Utility Wind Integration Group (UWIG) [14] highlights some of the findings about the integration of Wind Power as follows:

II.1.8.1.3.1. Costs

The cost of managing possible impacts are found to be incremental (10% or less of the wholesale value of the wind energy at penetrations of up to 20%) and “substantially less” than, for example, imbalance penalties generally imposed by regulators on the market. This means that, at up to wind penetrations of up to 20% of peak demand, a wind farm producing power at 6 cents per kilowatt-hour (kWh) would require at most 0.6 cents (10% or less) in extra resources for balancing the overall system.

II.1.8.1.3.2. Savings

"In many cases, customer payments for electricity can be decreased when wind is added to the system, because the operating-cost increases could be offset by savings from displacing fossil fuel generation"

II.1.8.1.3.3. System stability

"Further, there is evidence that with new equipment designs and proper plant engineering, system stability in response to a major plant or line outage can actually be improved by the addition of wind generation." The new equipment designs include power electronic controls and dynamic voltage support capability.

II.1.8.1.3.4. Back-up and contribution to capacity

"Since wind is primarily an energy and not a capacity source, no additional generation needs to be added to provide back-up capability provided that wind capacity is properly discounted in the determination of generation capacity adequacy." This means that, for planning purposes, wind is largely an energy resource with an "effective load carrying capacity" (ELCC). ELCC calculations for wind can have a wide range, depending not only on capacity factor but also on how closely wind patterns and wind plant output tend to match the system load profile.

II.1.8.1.3.5. Transmission planning and management

"Consolidation of balancing areas or the use of dynamic scheduling can improve system reliability and reduce the cost of integration of additional wind generation into electric system operation," according to the report.

II.1.8.2. Principal Policy-related Problems

Given though that the principle obstacle for Wind Power integration are old practices and legislation, there have being identified five highest transmission policies priorities.

II.1.8.2.1. The Allocation of Embedded Costs of Transmission Facilities

The cost of the capital invested in the construction and operation of existing facilities can be recovered through charges assessed to either users or generators of electricity, or to both. When embedded costs are charged in whole or in part to generation, the charges have a disparate impact on wind projects due to their remote location as well as the intermittent nature of the wind resource. Some utilities have also charged generators based upon their maximum (or "peak") use of the transmission system within a given time period rather than their average use or the number of kilowatt-hours of use over that time period. Due to their intermittent nature, wind facilities are disproportionately affected by such policies because they have a greater disparity between their peak use and their average (or kilowatt-hour-based) use of the system. Worst of all, some utilities have used so-called "megawatt-mile" policies which combine peak use and mileage-based policies described above. These transmission policies hit wind projects doubly hard.

The solution proposed by AWEA is to adopt the policies approved by the FERC for the California Independent System Operator (ISO). This policy allocates the embedded costs of transmission to end-use customers rather than generators. Even where embedded cost charges are allocated to generators (or "transmission customers"—those scheduling the transaction), FERC can avoid unduly penalizing wind facilities by basing charges on the point of delivery, such as is the policy approved by the FERC for the Pennsylvania-Jersey-Maryland (PJM) Interconnection.

This policy makes sense for several additional reasons. First, end-use customers will ultimately pay 100% of the embedded costs of the transmission system, directly or indirectly, under any policy. This is because any portion of embedded costs allocated to generators is passed on to end-use customers indirectly in their electric power charges. Second, this policy also recognizes that, by definition, embedded costs have already been incurred. Thus, the operation of generation has no effect on these costs (generators would pay congestion cost separately from embedded costs). Third, this policy recognizes that generators are already paying for their individual impacts on the transmission system in the form of congestion costs and transmission loss adjustments.

AWEA supports “postage stamp” or “license plate” rates and opposes policies that attempt to assign these costs based on false assumptions that the electric grid is divisible into pieces that are used separately. In fact, the electric power grid is a fully interconnected and interactive system. Customers interconnect to and rely upon all of it. Thus, FERC should enforce the policy it has approved with respect to the California Independent System Operator and others that embedded costs are charged to end-use customers, or at least based upon the point of delivery, without segmentation of the grid. In relation with the second issue, costs should be charged based upon average or kilowatt-hour use of the transmission system and not peak demand.

II.1.8.2.2. Schedule Deviation Policies

Transmission users are often required to schedule in advance some or all of their use of the transmission system. In real-time, electric power demand and generation typically deviate from these schedules. These deliberate changes in generation to accommodate real-time changes in demand are referred as “instructed deviations”. For intermittent technologies such as wind, real time generation is “instructed” by nature and unscheduled deviations are often unavoidable. Historic transmission policies have often imposed severe penalties on uninstructed deviations outside a certain amount. As a solution for this problem, a creation of a real-time balancing market has being proposed. An alternative to this would be to allow generators to schedule as close as possible to real time.

Another interesting possibility has being studied by the NREL: including in the energy mix the possibility of electricity storage, with the capability to shift wind energy from periods of low demand to peak times and to smooth fluctuations in output [14]. This may have a role in bolstering the value of wind power at levels of penetration envisioned by a new Department of Energy report, “20% Wind by 2030”. The ReEDS model was used to evaluate the impact of storage in the development of wind power, considering three different technologies: batteries, pumped-hydroelectric and compressed-air energy storage (combined with natural gas turbine).

Storage can provide benefit to the system in three ways. On super-hourly timescales, storage can provide load-shifting and arbitrage usually by charging overnight and discharging during peak afternoon or evening hours. Because wind tends to blow harder at night in many parts of the country, the benefit can be even greater for wind-heavy systems. On shorter timescales, storage can be used to smooth variations in wind farm output, reducing the need for conventional spinning reserve to be ready to either take up slack or back off to adjust to changes in wind. Quick-acting storage can also add value by providing voltage and frequency regulation and other similar ancillary services. When modelling the influence of storage in the penetration of Wind Power, it seems that overall electricity prices will decrease for the final customer.

Other interesting proposals for dealing with scheduling problems are the development of the Smart Grid, in which the distribution infrastructures would integrate information and communication lines to interconnect individual demand points (i.e. individual houses), providing price signals and generation capacities in real time, so consumers can opt to adapt their individual demand to the low cost time frames (i.e. schedule the washing machine for night operation) and the system operators can manage demand in order to adapt to intermittent generation capacities as wind power.

In this project we will also study the role played by PHEV (Plug-in Hybrid Electric Vehicles) and the V2G (Vehicle To Grid) technologies in flattening the demand curve helping to integrate Wind Power.

II.1.8.2.3. Elimination of Rate Pancaking

When a generator seeks to deliver energy to a distant load, it may have to use the transmission system of multiple owners and operators. The access price for the same transaction using the same pricing policies but assuming a simple owner/operator will be substantially lower. In addition, access rate “pancaking” [1] segments markets, decreasing economic efficiency, reducing competition, increasing market power of local utilities and generators and, ultimately raising prices to consumers. The proposed solution is to eliminate it, either by consolidating of tariffs under an RTO (Regional Transmission Operator) and/or by creating access waiver agreement between multiple owner/operators. Of course, as commented below, the creation of a national-wide transmission infrastructure would eliminate this problem, as big quantities of bulk energy will be transmitted from the windy areas to the load centres.

II.1.8.2.4. The Equitable Allocation of Congested Capacity Among Competing Users

Due to lack of site flexibility and generally remote location from load, wind facilities are less often able to avoid congested transmission facilities. They are also very much affected by policies regarding the upgrade of transmission systems to eliminate congestion. Utilities have historically solved congestion by curtailing more recent market entrants first. Traditional facilities also face less congestion in the first place because transmission facilities were originally built with these facilities in mind.

The first solution proposed was to allocate congested transmission capacity based upon the societal value of the transactions involved or, at a minimum, transmission users should be able to bid for congested capacity on an equal-footing. This bidding system presents two additional problems: the intermittent nature of the resource makes it difficult for wind facilities to bid for constraint capacity, since they don’t know how much capacity they will require for a given hour. The second problem is to consider that all electrons are fungible, as for wind and other facilities seeking to meet consumer demand from “green” power, substituting a non-green resources for wind power to mitigate congestion may violate contracts with “green” power consumers. The solution finally proposed is to eliminate congestion through upgrades and allow wind to bid closer to the operating hour.

It is in this point where infrastructure investments and plans come to play the fundamental role in the integration of Wind Power and, even more importantly, updating the vital existing energy

[1] Rate panckaking refers to the present situation in which it is necesary to cross through different transmission operators to get from the generation point to the load, occurring in a higher fee because of duplicated payments when entering the diferent transmission networks, which wouldn't occur if operated by a single agency.

infrastructure of a country seeking to exit from this Global Crisis with a stronger energy independence and a clear capability to fight climate change.

Economic Losses in the Grid

Several studies have calculated billion-dollar annual losses occasioned by the unreliable existing patchwork infrastructure. Kristina Hamachi estimated [14] $80 Billion annual cost, mostly in the commercial sector and due to the momentary interruptions, because of their frequency. After the 2003 Blackout there were calls for investments to modernize the grid ranging from $50 and 100 billion.

Another study [14] states that a digital society, relying mostly on the information technologies and services is more exposed and sensible to power interruptions and estimates that the U.S economy is losing between $119 and $118 billion annually from power outages and power-quality issues. The risk of not having supply and the risk of not being able to predict the shutdowns is much greater than the risk of increased price. In this context is where a reliable, modern energy infrastructure comes to be a basic pillar for a competitive economy, and it seems that the upgrade investment needs are clearly lower than the current costs of an old-fashioned system and policies.

Solving Congestion: New Transmission Infrastructures

Several high-level studies have being done about the need for “Green Power Superhighways”, moreover after President Obama called for the United States to double the production of renewable energy in three years and to secure 25 percent of its electricity from renewable resources by 2025. Some of the principal advantages of a new, broad improved transmission infrastructure are being identified as:

Coordinating Regional Transmission Operations

Today’s highly constrained patchwork transmission system makes it very difficult to move large amounts of renewable power around the country. A solution is to use the existing grid more efficiently through technology and new operating protocols.

Recognizing the Consumer Benefits of Transmission

A robust transmission grid provides consumers with access to lower-cost electricity. New transmission infrastructure would increase competition in wholesale power markets.

Recovering the Cost of Green Power Superhighways

Studies have consistently found that the costs of transmission investments needed to integrate wind power and other renewable are significantly outweighed by the consumer savings that those investments produce.

Reducing Land Use and Wildlife Impacts

Transmission, like all major infrastructure projects, will affect land use and wildlife, and advance planning is needed to minimize these impacts. High-capacity transmission lines reduce land impacts significantly compared with lower-voltage lines. Moreover, the key to any cost-effective plan is the use of high-voltage transmission lines in place of the low-voltage lines commonly deployed in the U.S. today. Finally, but no less important in a situation of global crisis, from Roosevelt’s New Deal to Eisenhower’s interstate highway system, bold investments in infrastructure have often paved a way out of troubled times by building a foundation for economic growth.

Even though these positive results would be drawn from a new high-voltage network, policy barriers – not technical or economic barriers – are the chief factors impeding the construction of green power superhighways. Few private firms have stepped forward to invest in transmission infrastructure because the benefits of transmission are not adequately accounted for in the incentive structure offered to transmission investors. State regulators, who in many areas have primary jurisdiction over what transmission gets built and who pays for it, are often required to weigh only the benefits that will accrue to residents of that state. Because the benefits of high-voltage transmission infrastructure typically accrue to millions of consumers over broad interstate regions, this process ignores a major portion of these benefits. Under this regulatory structure, it is almost impossible to build an interstate transmission network. On top of this, regulators in a single state can effectively veto a multi-state transmission network by refusing to grant the permits needed for sitting a transmission line if they feel that their state would not receive an adequate share of the benefits of the project. The policy solution proposed include the elaboration of a comprehensive Interconnection-Wide Transmission Planning, transmission cost allocation and certainty for cost recovery by the FERC, based on electricity usage and, finally, the extra-high-voltage facilities defined in the regional plans would be subject to FERC approval and permitting, and separate approval at the state level would not be required, as it already is being done for the interstate natural gas pipelines.

Cost Estimates

Several proposals about this future extra-high-voltage (EHV, might include HVDC, as well as 765kv, 500kv and 345kv technologies) transmission lines have being developed, both at a national level [15] and for the Eastern Interconnection. It is important to note that some of this update plans include not only the transmission lines specifically design to bring the wind power to the load centres, but also the lines needed to update an old, unreliable grid to meet the growing energy requirements. The JCSP (Joint Coordinated System Planning) has being the first inter-regional planning effort to involve most of the major transmission operators in the Eastern Interconnection, and have studied two different scenarios: business-as-usual (with about 5% wind penetration by 2024, mostly produced locally), and the 20% wind energy scenario (with producers located mostly in the mid-west). Both scenarios include specific projects that will contribute to the system’s reliability needs for the ten-year period through the year 2018, and provide economic benefits in the 2024 time frame. The Reference Scenario would add 10,000 miles of new EHV transmission at an assumed cost of approximately $50 billion. Production costs in 2024 (with 5% wind and 54% from base load steam generation) would equal $104 billion and total generation capital investments would equal $604 billion. In contrast, the 20% Wind Energy Scenario, would add 15,000 miles of new EHV transmission at an assumed cost of approximately $80 billion. Under this scenario, energy production costs in 2024 would equal $85 billion and the capital cost of new generation would equal $1,050 billion.

However, these calculations follow a capacity expansion path when dealing with energy demand growths, and storage was not taken in consideration as a way to decrease fast-ramp back-up power. Energy efficiency was assumed to be embedded within the demand forecast of 15% growth by 2024, instead of the usual 30% expected growth. There are high levels of base load steam generation assumed in both scenarios (54% under the Reference Scenario and 42% in the Wind Scenario), with the increased wind generation offsetting primarily base load steam production while requiring more production from fast-response, gas-fired combustion turbines.

The JCSP'08 analysis found that under the Reference Scenario, the generation mix in the Eastern Interconnection produced a total of 35 billion tons of carbon between 2008 and 2024, with 5% wind energy; under the 20% Wind Energy Scenario, comparable carbon emissions reached 32.1 billion tons, an 8% reduction, but it's worth noting that it would not put the United States on the road to reaching an 80 percent reduction by 2050, which President Obama set as his goal in the last campaign. It would not even put the country on the way to a 60 percent reduction, as called for by his Republican opponent, Senator John McCain, or 50 percent, as suggested by former president George W. Bush during his last months in office. A national interstate transmission vision for wind integration bets on a 765KV- 19,000 miles of new lines, with a cost of $60 billion, for the addition of 200-400 GW of bulk transmission capacity (with 20% wind providing approximately 350 GW of the nation electricity demand).

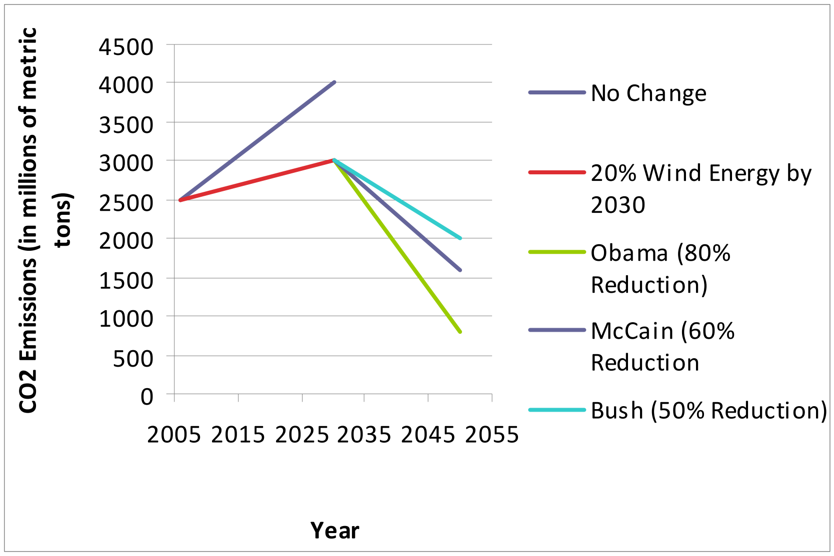


Figure II.1.27: CO2 emission levels predictions under different policies.

II.1.8.2.5. Non-discriminatory Interconnection of Wind Generation Facilities

Interconnection policies often remain controlled by vertically integrated utilities with incentives to discourage market entry by competitors. Because wind facilities are installed in increments rather than large blocks, interconnections can pose special problems. Finally, interconnection costs based on peak output must be recovered across relatively fewer kilowatt hours of sales. For new wind projects, obtaining timely interconnection at reasonable cost continues to be critical. It is necessary for RTO's to establish more standardized interconnection procedures, particularly for small facilities, and in this sense it is perceived as the right solution the FERC's decision to make RTO's the sole authority regarding requests for new interconnections.

Storage can provide a solution both for interconnection and congestion problems. The primary advantage of co-locating storage with wind is the potential to save money by downsizing a long transmission line. There is a trade-off in that the maximum capacity the combined wind-storage system can generate is then limited by the transmission line. Storage at the load does not allow downsized transmission, but the storage will always be able to discharge at full power. Storage at load also assists the movement of wind power to load centres by charging overnight when transmission lines are relatively free, rather than trying to move the power during peak hours when the lines are congested. Storage at the load also allows slightly more wind energy to be stored for the same storage capacity since transmission losses are incurred before the load-sited storage. Similarly, storage at the load site charged from the general grid does not incur transmission losses to and from a remote wind-sited storage facility.

II.1.9. Plug-in Hybrid Electric Vehicles in the Wind Energy Market

Electric Drive Vehicles, (EDV) which include Hybrid Electric Vehicles, Electric Vehicles and Fuel Cells, are projected to penetrate the light fleet vehicle market in the near future. This is going to be accompanied by the projected penetration of wind generation technology in the electric market. Fuel cells are not expected to enter the market until 2030 so the main focus is on hybrid and electric vehicles. The characteristic that hybrid and electric vehicles can store electricity when parked, and with appropriate connections to the grid, supply the grid with electricity, provides an opportunity for the vehicles to stabilized an electric grid that is fed by wind energy. Since light fleet vehicles are parked 96% of the time, and are driven 4% of the time, they are readily available to coupling with the power grid. This technology is called Vehicle-to-Grid Power (V2G), which is summarized in the Figure II.1.28.

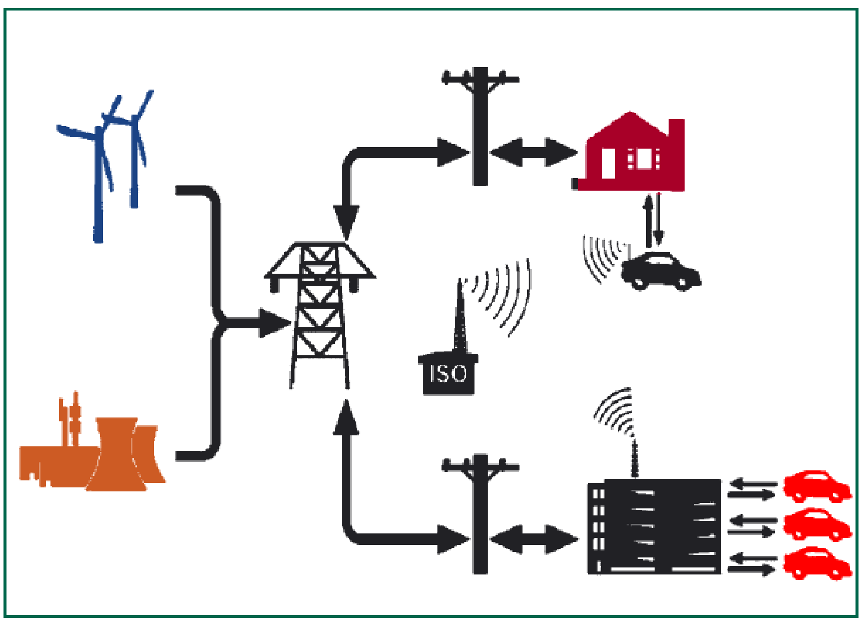


Figure II.1.28: Vehicle- to Grid (V2G) Concept [17]

The vehicles will charge during low electricity demand times, and provide power to the grid when there is high demand. In order for this to work, the vehicles should obviously have a connection to the grid, communication controls and metering controls on-board the vehicle. As illustrated in the figure II.1.28, the grid operator communicates either with individual vehicles, or fleet controllers (parking lots, third party aggregator) to provide power through a wireless signal (radio broadcast, internet connection, cell phone, etc.). Almost all EDVs have a 60Hz AC signal already built-in, thus eliminating the additional cost to place these electronics. Note that hybrid vehicles can also provide electricity as motor-vehicles, however this technology still has dangers and so it is unsure whether it would be ready at the same time as the electric plug-in to the grid. In order to help Plug-in Hybrid Vehicles (PHEV) and Electric Vehicles (EV) penetrate the electric market, they should be coupled to high-value, short duration power markets. The three main markets are peak power, spinning reserves, and regulation.

Peak power refers to when there is a very high demand for electricity, usually in the afternoon in the US. In order to account for the excess demand, additional generators are turned on to account for the surplus. However these generators have high capital costs. PHEVs and EVs may have the ability to take their places, since they have lower capital costs (but higher by kWh provided) and a rapid response. The peak power is expected to last 3-5 hours but the PHEVs and EVs cannot store enough energy to supply the entire duration of the peak. This can be avoided by drawing from fleets of vehicles or coupling solar power with PHEVs and EVs.

The second market is spinning reserves, which holds additional capacity to provide electricity in case of a regular generator going down, or other loss of power. Spinning reserves require fast response, which PHEVs and EVs can supply. Additionally, spinning reserves pay for capacity, and additionally for energy delivered. So, EDV owners will be paid just for being plugged-in and ready. The third market is regulation, which is split into two parts: Regulation-Up and Regulation-Down. When load exceeds electric supply, generation is stepped up and so there is regulation up, and vice versa. The energy dispatched is a fraction of the energy contracted for, given by the following equation:

$$R_{d-c} = \frac{E_{disp}}{P_{contr}\, t_{contr}}$$

Where Rd-c is the dispatch to contract ratio, E_{disp} the energy dispatched, and P_{contr} and tc_{ontr} the power that should be delivered in case and the length of the contract respectively. This ratio is determined for regulation up and down separately. Regulation also pays for capacity, and the energy actually dispatched is paid for as a plus. Note that in regulation, EDVs can make the best profit since EDV owners are paid for storing (regulation down) and delivering (regulation up).

There are two main limits to the power provided by EDVs:

The current-carrying capacity of the circuitry connecting the EDV to the grid (calculated as P_{line} = VA, where P_{line} is power limit in Watts, V the line voltage in Volts, and finally A is the maximum rated current in amperes)

The power available is the stored energy in the vehicle divided by the time dispatched, and can be calculated as:

$$P_{vehicle} = \frac{\left(E_s - \frac{d_d + d_{rb}}{\eta_{veh}}\right)\eta_{inv}}{t_{disp}}$$

Where $P_{vehicle}$ is the maximum power for V2G in kW, E_s is the stored energy in kWh in DC before conversion, d_d is the driven distance in miles when battery was full, d_{rb} is the distance in miles of the buffer range requested by the driver, η_{veh} the vehicle driving efficiency in miles-kWh^{-1}, η_{inv} the electrical conversion efficiency of the DC to AC inverter (dimensionless), and t_{disp} is time the vehicle’s stored energy is dispatched in hours.)

The revenue collected from V2G depends which market is being considered. For the Peak load market, where money is paid only for dispatched energy, revenue is calculated as:

$$r = p_{el}\, E_{disp} = p_{el}\, P_{disp}\, t_{disp}$$

where r is the total revenue in any national currency, p_{el} the market rate of electricity in $/kWh, P_{disp} the power dispatched in kW (for peak power P_{disp} is equal to P, the power available for V2G), and t_{disp} is the total time the power is dispatched in hours. For the spinning reserves and regulation markets, there is first a payment for capacity and another payment for energy delivered. The revenue for the energy delivered is given by the same equation above for Peak Power. The overall equation is:

$$r = p_{cap}\, P\, t_{plug} + p_{el}\, E_{disp}$$

where p_{cap} is the capacity price in (national currency/kW-h), p_{el} is the electricity price in national currency/kWh, P is the contracted capacity available (the lower of $P_{vehicle}$ and P_{line}), t_{plug} is the time in hours the EDV is plugged in and available, and E_{disp} is the energy dispatched in kWh.

The cost equations depend on purchased, wear and capital cost. The cost is summarized by:

$$c = c_{en}\, E_{disp} + c_{ac}$$

where c is the total cost per year, c_{en} is the cost per energy unit produced, E_{disp} is the electric energy dispatched in the year, and c_{ac} is the annualized capital cost.The cost per energy unit produced is given by:

$$c_{\mathrm{en}} = \frac{c_{\mathrm{pe}}}{\eta_{\mathrm{conv}}} + c_{\mathrm{d}}$$

where c_{pe} is the purchased energy cost, and c_d is the cost of equipment degradation (wear) due to the extra use for V2G, in national currency/kWh of delivered electricity and η_{conv} is the efficiency of the vehicle's conversion of fuel to electricity or conversion of electricity through storage back to electricity. The annualized capital cost is:

$$c_{\mathrm{ac}} = c_{\mathrm{c}}\,\mathrm{CRF} = c_{\mathrm{c}} \frac{d}{1-(1+d)^{-n}}$$

Where c_{ac} is the annualized capital cost in national currency/year, c_c the total capital cost in national currency, d the discount rate, and n is the number of years the device will last and CRF is the capital recovery factor.

The markets described above are good for promoting the use of V2G, but the best potential use of EVDs is to stabilize the power grid with renewable energy such as large-scale wind power. For example, when wind is weak, EDVs provide power, but when there is excess supply they store the power. The following table shows the number of vehicles in OECD countries, and the power that could be drawn if all were EDVs, and compared to the total load in the respective country.

Country	Number of passenger vehicles [millions]	V2G @ 15kW from all vehicles (GW)	Average national load (GW)	All vehicles @ 15kW average load (%)
Denmark	1.90	29	4	805
France	29.22	438	50	885
Germany	44.65	670	58	1.149
Ireland	1.47	22	2.6	846
Italy	33.82	507	34	1.473
Netherlands	6.87	103	12	888
Portugal	5.81	87	5	1.740
Spain	18.71	281	26	1.068
Sweden	4.05	61	15	407
UK	28.45	427	40	1.081
USA	191.00	2.865	417	686

Table II.1.8: Vehicle-to- Grid (V2G) Energy Load [18]

Based on the data there is a large potential, especially in countries similar to France or Denmark where the ratio of EDV power to load power is above 800%. However, it should be noted that this is only a power calculation, and so does not take into consideration the discharge timings and the storage energy. Although progress in the wind domain of V2G has been small, a study on 8 Midwest sites in the US shows how viable a complementarily between renewable wind power and EDVs is.

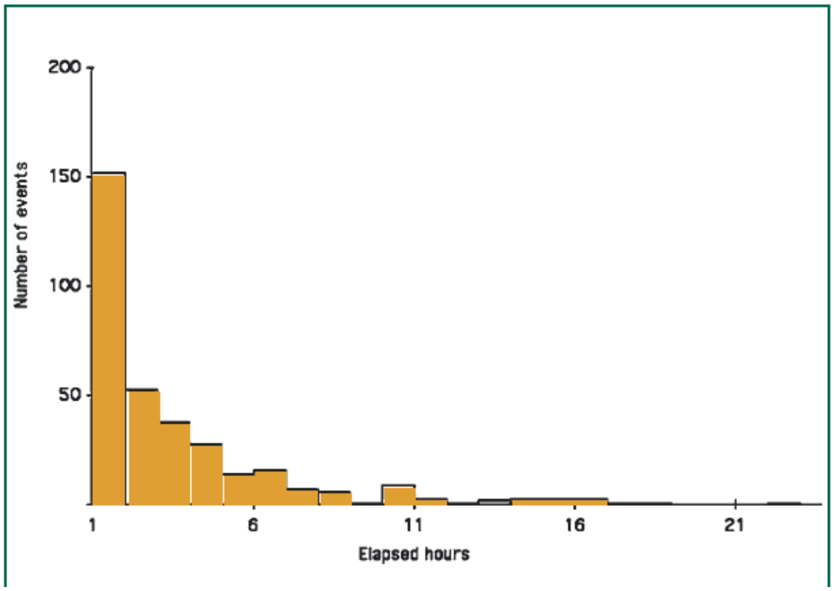


Figure II.1.29: Wind Shortfalls [18]

In the study, storage was assumed to account for a 20% firm capacity, which is approximately two thirds of a 33% wind capacity. Most of the shortfalls below 20% are very short and thus can be accounted for easily by EDVs working on battery. Only two shortfalls are above 16 hours, where the battery may not be sufficient. If safer technology advances fuel from Plug-ins may be used to power the longer shortfalls. Additionally apprehension may arise as to whether the current electric infrastructure can meet the increased demand from PHEVs. The graph below, which considers six US Midwest sites shows that the introduction of PHEVs does not have a large effect on load, even for different percentages of PHEV penetration in the market.

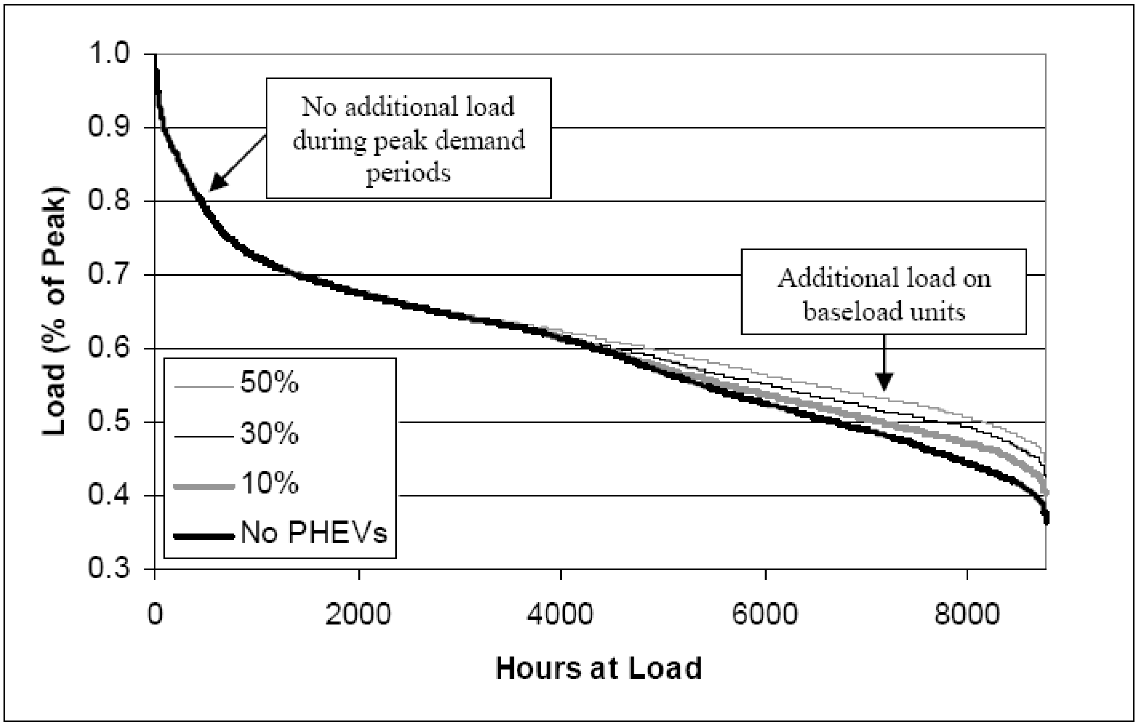


Figure II.1.30: Load Duration Curves with PHEV Charging (Midwestern Region) [19]

In order to transition from the gasoline vehicles to EDVs, there should be first a smooth transition Demonstration fleets should be use for a smooth transition. Since EVs are less expensive than PHEVs, small fleets of EVs should first be implemented in small fleet companies such as taxies. Ideally, as these fleets penetrate the market, many individual people and other fleets would also begin buying EDVs. With time, the markets of spinning reserves and regulation would be saturated and the penetration of PHEVs and EVs will lead to more investments in V2G and renewable energies. EDVs with V2G technology will play the role of complementing wind shortfalls, and stabilizing a grid based on renewable sources.

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II.2. MANUFACTURING LEADERS

II.2.1. Key Players in the Wind Industry

II.2.1.1. GE, Vestas, Suzlon

The wind industry is comprised of several strong players while numerous new companies are constantly entering the market in hopes of gaining market share by generating renewable sources of power. Every company in this industry wants to leave a footprint for making the world a better place to live by reducing the emissions and produce renewable energy from natural sources like wind, hydro, solar, etc. The purpose of the generating power through these sources is to replace the power produced by non renewable and satisfy the world's energy requirements. The major companies that are into the manufacturing of wind turbines are as follows (total capacity of their turbine produced as of 2007):

1) Vestas (Denmark) - 4500MW
2) GE energy (USA) - 3300MW
3) Gamesa (Spain) - 3050MW
4) Enercon (Germany) - 2700MW
5) Suzlong (India) – 2000MW
6) Siemens (Germany) – 1400MW
7) Acciona (Spain) – 870MW
8) Goldwind (China) - 830MW
9) Nordex (Germany) – 670MW
10) Sinovel (China) – 670 MW

The group of the top ten suppliers mentioned above covers about 95% of the total supply in the year 2007. Since then we have seen an interesting development on the supply side of the two prominent Asian manufacturers of wind turbines namely Suzlon (India) and Golwind (China). These two companies are tremendously increasing their market share in the wind energy's global market. The fastest growing market has been from the United States in the last three years and it is expected that United States will have the highest growth in installed capacity over the next few years. It is expected that the annual installation of capacity will grow to around 50,000 MW per annum in 2012. The cumulative capacity by the end of the year 2012 will reach about 287,000 MW.

The key players in the United States wind industry are GE Energy, Vestas, Siemens, Gamesa, Mitsubishi Heavy Industries and Suzlon. However GE has been the most prominent and has taken a lot of initiatives in this industry. United States had about 25GW (25000 MW) of wind energy capacity by the end of 2008. It surpassed Germany and became the world's leading market in wind energy. There was a 50% increase in the capacity of wind turbines within the United States in the year 2008. Prospects are still bright for the current year. In the revised five year forecast till 2012, a significant growth is expected. In the past years, the average growth in annual installation has been 22.3% where as in the forecast until 2012, an annual growth rate of 20.7% is expected.

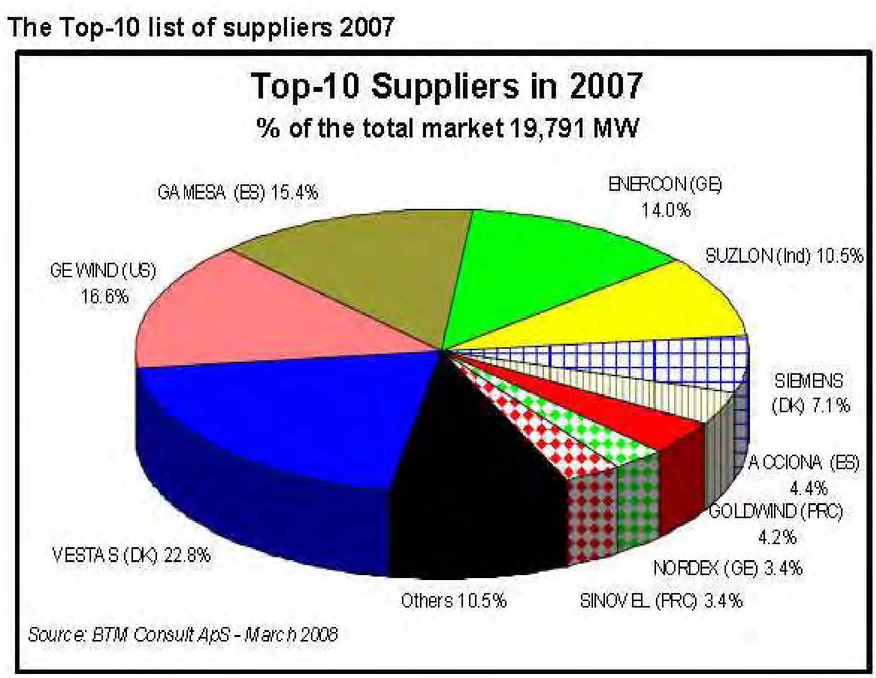

Figure II.2.1: Wind turbine suppliers market share.

One current initiative taking place at GE is the $440 Million investment for 330MW of capacity to be installed in western and northern New York state in Clinton, Franklin and Wyoming counties. Noble Environmental Power, an energy company which is affiliated with J.P. Morgan, is lined up for the $440 million project in financing for the 330MW of wind power projects in the western and the northern parts of the New York state [1]. GE energy financial services had an investment of a little more than $200 Million in this wind portfolio. Also, GE independently took part in a $10 Million investment in Flagstaff, Arizona, based Southwest Windpower, a manufacturer of small wind turbines.

GE is one of the major manufacturers of the wind turbine. They not only do the assembly but they also manufacture the various components that go into the turbines. There are thousands of components and parts and they are all classified under the NAICS codes for reference, with each having a unique code. Most of the components that GE manufactures are located in Tehachapi, California. At this location, GE manufactures the complete wind turbine, power electronic parts as well as the electronic controllers. GE also has a plant in Pensacola, Florida where they manufacture rotor blades for the wind turbines. The gear box components of their wind turbines are built by GE in its own plant in Erie, Pennsylvania.

Copenhagen-based Vestas now finds itself competing with GE for orders as the Obama administration pushes for alternative forms of electricity generation, including wind power, to reduce reliance on coal, natural gas and oil. The administration is expected to increase renewable energy subsidies. Other important companies include Siemens and Mitsubishi which are very active in the wind turbine manufacturing.

In 2008, Vestas opened its first manufacturing facility in Windsor, Colo. The company said it plans to add a second blade factory in Windsor, a nacelle factory in Brighton, Colo., and a tower factor in Pueblo, Colo., this year and the next. Vestas has also opened a new research and development hub in Boston and said it will open a research facility in Houston later this year.

II.2.2. Wind Energy Technology

II.2.2.1. Recent Turbine Technology Advances

Since the turn of the last century, there have been large advances in the technology used in wind-produced electricity. The National Renewable Energy Laboratory (NREL) has coordinated several research programs between the Department of Energy (DOE), other government agencies, and private industries to address issues that face the technological boundaries in turbine design and construction. NREL operates in two areas of wind research, Turbine Research and Development and Technology Applications and Testing. The former has been instrumental in developing the Low Wind Speed Turbine technology. In recent years, energy production cost from 'prime' wind sites has been reduced to a level that is competitive with conventional energy sources, according to NREL. In the future, however, it is going to be important to generate energy at the same competitive levels with sites that are less lucrative, with wind speeds at approximately 5.8 m/s at 10 m height [2].

II.2.2.1.1. Low Wind Speed Turbine

The Low Wind Speed Turbine technology has been developed to raise mechanical, aerodynamic, and electrical efficiencies of the turbines themselves as well as the systems integration of wind turbines into the energy infrastructure. In an effort to reduce proprietary barriers to development, NREL draws on industry leaders to participate in cost shared studies, the results of which are available to the industry. Studies fall into one of three categories: concept and scaling, component development, and low wind speed turbine development [3]. Amongst the areas studied are tower configuration, blade control and aerodynamics, and direct drive systems.

Due to the wind shear effect that reduces wind speed at the hub height of a turbine, there is a significant improvement in power output for a marginal increase in tower height. As power output is proportional to the cube of wind speed, an investment in tower height can provide significant returns. Currently, cold formed steel towers are the industry norm. These towers are manufactured at a central location and shipped to the remote areas where sufficient wind is available. Physical size and weight constraints are imposed on the tower section sizes due to state highway laws and cost constraints for specialized transport equipment that is required. The towers are built in sections to maximize their lengths while conforming to these constraints. Using towers that can be shipped more economically or manufactured on site have been studied by two companies in cooperation with NREL. The Native American Technologies Company of Golden, CO, studied using the LITS-Form™ steel forming process to create fluted steel tower segments on site [4]. This process uses applied thermal stresses in a controlled manner to create a structurally sound, cylindrical tower segment. This process would only require shipping steel plates and the manufacturing rig to the site, which could be significantly more cost effective than shipping a completed tower.

Another approach to tower design is taken by BERGER/ABAM Engineers Inc., of Federal Way, WA. Using a combination of steel and concrete, they studied a hybrid concrete/steel tower and an all-concrete tower (construction similar to an industrial chimney). From several scenarios, they concluded for a 100 meter tower, cast in place concrete construction was the most economical over hybrid, or all steel construction [5]. In either of their proposed designs, they are able to ship basically raw materials to the site, with the hybrid design still requiring a 50 meter steel tower.

The gearbox used to increase the rotational speed of the rotor blades, from approximately 10-20 revolutions per minute (rpm) to that required by a high-speed generator on the order of 1000-2000 rpm, is a known problem in wind turbine design. These gearboxes are heavy, noisy, expensive, and are a high wear system compared to other turbine components. The industry standard design is a three stage planetary gear set. Three alternate configurations were tested with industry members and DOE. Two such systems were a single stage, medium speed generator and a distributed, multiple generator design. The third design was by Northern Power Systems of Waitsfield, VT. They have actually built and are testing a 2.2 MW, direct drive turbine prototype. This prototype is a direct drive, low speed permanent magnet generator that also utilizes other components from the Low Wind Speed Technology studies, namely an advanced power conversion device to turn the low, variable speed output of the generator into the desired line side voltage and frequency parameters [6]. The technology used in the development of this direct drive system is taken from ship propulsion systems designed by General Dynamics, Electric Boat.

II.2.2.1.2. Remote Site Monitoring

System reliability is key to efficient operation of a wind farm. As the number of turbines managed by a firm at any given site increase, the operation and maintenance becomes an increasingly difficult problem. Each of the major wind turbine manufacturers offers real time monitoring solutions for a variety of turbine parameters. Generally speaking, these systems allow monitoring of general operating parameters (wind speed or direction, time operating, energy produced, etc) as well as alarm conditions (high temperature, vibration, lightning strike, etc). With improved communications technology, maintenance personnel can be alerted via internet connection or even cell phone messages to issues that may occur. The company that built the turbine or the owner of the system can also have this data sent to a database for trend analysis.

A major benefit of this type of monitoring system is the reduction in maintenance and inspection cost. Deteriorating conditions can be used to more accurately predict possible failure, which can then be taken into account when planning maintenance and turbine downtime. This is especially relevant in offshore sites where turbine access is more limited due to environmental factors. In addition, with connectivity to a system operator, the output from the turbine can be dispatched similar to a conventional power plant. As shown in figure 2 from ENERCON INDIA LTD's Supervisory Control and Data Acquisition (SCADA) system, if a transmission system event requires a drop in turbine (or wind farm) output, the system operator can adjust output to prevent an overload situation from causing further system protection events. Ethernet and wireless communications devices are in use to allow such monitoring and control.

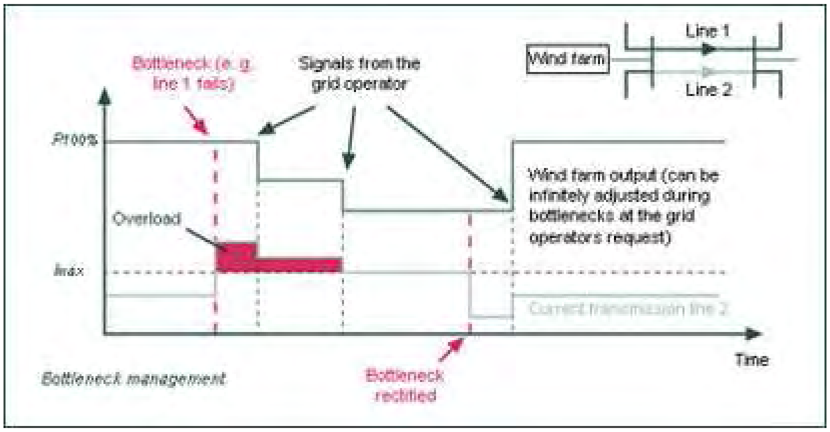

Figure II.2.2: Bottleneck Management as described for Enercon India Limited's SCADA System [7]

II.2.2.1.3. Low Voltage Ride Thru

As the United States increases the penetration of wind generation in the transmission system, wind farm reliability becomes an issue. If the wind generator makes up only a small portion of the generation network for a given sector as was the case primarily in the 1980's, when a fault occurs the wind turbines can be taken offline and later restored when the system fault is corrected. However, with large wind farms reaching 100's of MW's of capacity, simply removing their generating capacity from the grid to protect the wind farm is no longer an option. When hundreds of MW's of generating capacity are removed from the grid and load demand does not change, the additional generation must come from an already online source that is able to respond quickly, or from a generation source that can be started and placed online in a very short period of time. This type of scenario leads to 'brown outs' as the remainder of the system struggles to return frequency and voltage to its specified levels, or black outs if voltage and frequency are unable to be recovered resulting in the further removal of generation capacity from the grid to protect those systems.

When a 'short circuit' fault occurs in the transmission system, abnormally high current flow and corresponding low voltage conditions will exist. The excess current flow can harm system components due to the excess heat created from losses due to resistance in the component itself. This will in effect cause the component to 'burn up' as the heat generated can not be dissipated before causing damage. The traditional protection from this fault type is to install a breaker that will trip free when the fault occurs, precluding the high current flow. However, as described above, allowing a relatively large wind turbine farm to trip off line from the grid causes significant grid management issues that can lead to poor system reliability. Turbines erected at wind farms are now subject to Federal Energy Regulatory Commission standards stipulating the power factor and low voltage ride through capability of the generator [8]. These same standards also dictate the SCADA parameters that must be in place to allow effective control of the generators to promote grid stability.

II.2.3. Turbine Manufacturing within the US

With regards to the U.S.'s ability to manufacture components of wind turbines completely within its borders, it was deduced that this goal is very possible, but economic incentives would be required to jumpstart manufacturing to practical levels [9]. The economic incentives can come in two forms. The first is through Production Tax Credits (PTC), which provide tax credit for each kWh of renewable energy produced, and the second is through a Renewable Portfolio Standard (RPS), which pledges to mandate that a certain percentage of the nation's energy be produced by renewable energy sources by a certain year [9]. The Renewable Energy Policy Project favors the latter, arguing that tax credits will only help those who actually sell wind energy, and profits will only be limited to areas ideal for large-scale wind farms [9]. With the RPS policy implemented instead, even though the majority of future development of wind energy will be in the Great Plains states, the regions most likely to benefit will be those that support manufacturing companies which produce the 20 or so parts critical to building wind turbines [9].

The results of NREL's "Renewable Energy Policy Project Technical Report" indicate that according to NAICS manufactured part identification numbers, over 16,000 firms in the U.S. currently produce at least one component needed for wind turbine construction, and that these companies operate in all 50 states [9]. Of these, 90 companies were identified that have recently or are currently producing a product for a wind project [9]. This is significant, because it shows just how many companies could become involved in the green energy movement if they were made aware of the possibilities and/or were provided economic incentives to do so. The 20 states that are poised to benefit most from an RPS policy contain 75% of the nation's population and are also highly correlated with areas that have lost over 76% of all manufacturing jobs from 2001 – 2004 (see Figure II.2.4) [9]. It is likely that even more jobs have been lost in these areas due to the current economic recession, so an RPS strategy would likely benefit these states even more than the NREL report claims.

Figure II.2.3 presents the results of the study. It is important to note the magnitude of the number of jobs that currently exist that can potentially become involved in the wind industry. In addition to converting jobs from other industries, wind energy also has the potential to create new jobs under the appropriate RPS system. Every 1000MW of nameplate capacity installed creates a potential 3000 manufacturing jobs, 700 installation jobs, and 600 O&M jobs [9]. Figure II.2.4 breaks down the potential for new jobs by state as well as how these states rank in terms of population and manufacturing jobs lost from 2001-2004.

U.S. Summary Table – Manufacturing Firms with Technical Potential to Enter Wind Turbine Market

NAICS code	Code Description	Total Employees	Annual Payroll ($1000s)	Number of Companies
326199	All other Plastics Products	501,009	15,219,355	8,174
331511	Iron Foundries	75,053	3,099,509	747
332312	Fabricated Structural Metal	106,161	3,975,751	3,033
332991	Ball and Roller Bearings	33,416	1,353,832	198
333412	Industrial and Commercial fans and blowers	11,854	411,979	177
333611	Turbines, and Turbine Generators, and Turbine Generator Sets	17,721	1,080,891	110
333612	Speed Changer, Industrial	13,991	539,514	248
333613	Power Transmission Equip.	21,103	779,730	292
334418	Printed circuits and electronics assemblies	105,810	4,005,786	716
334519	Measuring and Controlling Devices	34,499	1,638,072	830
335312	Motors and Generators	62,164	2,005,414	659
335999	Electronic Equipment and Components, NEC	42,546	1,780,246	979
Total		**1,025,327**	**35,890,079**	**16,163**

Figure II.2.3: Companies and personnel involved in wind turbine component manufacturing [46]

Top 20 States Benefiting from Wind Investment, with Population and Job Loss Demographics

State	Potential Number of Jobs	Average Investment ($ Billions)	2001 Population	Rank in U.S.	Manufacturing Jobs Lost, Jan. 2001 - May 2004*	Rank in U.S.
California	12,717	4.24	34,501,130	1	318,000	1
Ohio	11,688	3.90	11,373,541	7	165,500	3
Texas	8,943	2.98	21,325,018	2	169,600	2
Michigan	8,549	2.85	9,990,817	8	129,300	8
Illinois	8,530	2.84	12,482,301	5	131,500	6
Indiana	8,317	2.77	6,114,745	14	63,500	13
Pennsylvania	7,622	2.54	12,287,150	6	155,200	5
Wisconsin	6,956	2.32	5,401,906	18	68,300	10
New York	6,549	2.18	19,011,378	3	130,500	7
South Carolina	4,964	1.65	4,063,011	26	56,800	17
North Carolina	4,661	1.55	8,186,268	11	156,600	4
Tennessee	4,233	1.41	5,740,021	16	59,700	15
Alabama	3,571	1.19	4,464,356	23	45,300	19
Georgia	3,532	1.18	8,383,915	10	65,700	11
Virginia	3,386	1.13	7,187,734	12	57,500	16
Florida	3,371	1.12	16,396,515	4	56,800	18
Missouri	3,234	1.08	5,629,707	17	36,700	23
Massachusetts	3,210	1.07	6,379,304	13	84,900	9
Minnesota	3,064	1.02	4,972,294	21	38,800	21
New Jersey	2,920	0.97	8,484,431	9	65,400	12
20 State Total	120,017	40	212,375,542		2,055,600	
% U.S. Total	80%	80%	75%		76%	

Figure II.2.4: States that will benefit the most from a RPS policy [9]

In terms of the companies that are manufacturing wind turbine components now, it is not common for only one company to be currently providing a specific piece for wind turbine construction, meaning that there is plenty of space in the market for new entrants who wish to profit from green energy incentives. Currently, GE Wind appears to be the only company that manufacturers most wind turbine components in-house [9]. Even still, there are several components that even they do not assemble. Thus, while GE Wind currently holds the most market share in the US wind industry, healthy competition is encouraged in order to make turbine installation procedures competitive and as cost-effective as possible.

There are a few basic raw materials that are required to produce a wind turbine. Steel is the predominant tower material, copper or rare-earth permanent magnets are a significant portion of the generator, and fiberglass is the primary material that is used to produce the turbine blades. Table 1 below shows the percentage of a 1.5 MW turbine that is made up of various raw materials. If the wind industry is going to experience the growth required to achieve 20% of the U. S. energy supply from wind power, it begs the question will the U.S. manufacturing industry be able to support this growth with domestic resources or rely on some level of imports to achieve this goal. Laxson et al concluded sufficient raw material supply does exist, but adjustment must be made in the manufacturing industry to transform this material into the desired end product [10]. For example, the primary raw material used to produce fiberglass for the blades is sand, a resource that is in abundant supply. However, their scenarios estimate 20-35% of domestic fiberglass production at current levels would be needed to satisfy demand to reach the 20% of energy production from wind in 2030 goal. This would likely require additional fiberglass production facilities. The same can be said for permanent magnets in that the U.S. has sufficient natural deposits, but currently little or no manufacturing capacity for them. Steel and copper however, will require neither a substantial shift in manufacturing capacity or raw material supply. Laxson et al estimate 8% and 2% of current capacity respectively will be required to meet the above proposed goal [10].

Main Components and Materials used in 1.5 MW Wind Turbine by %									
1.5 MW	Weight %	Concrete	Steel	Aluminum	Copper	GRP*	Adhesive	Core	Total
Rotor									
Hub	6.0		100.0						100.0
Blades	7.2		2.0			78.0	15.0	5.0	100.0
Nacelle									
Gearbox	10.1		96.0	2.0	2.0				100.0
Generator	3.4		65.0		35.0				100.0
Frame	6.6		85.0	9.0	3.0	3.0			100.0
Tower**	66.7	2.0	98.0						100.0
	100.0								

*GRP-Glass Reinforced Plastic

**Tower includes foundation

Table II.2.1: Main Components and Materials used in 1.5 MW Wind Turbine by % [11]

II.2.4. Manufacturing and Interconnections

II.2.4.1 Interconnections Overview

In terms of understanding manufacturing considerations concerning interconnections equipment and procedures, it is first necessary to trace the path of energy from the turbines to the end distribution system. Rotational energy from spinning turbine blades is first transformed to low-voltage electricity via the gearbox and generator of a wind turbine's nacelle [12]. Electrical lines carry the electricity to transformers usually located at or near the base of the turbine, which increases the voltage to medium levels (25 – 35kV) in order to avoid power losses in transmission lines [12]. Medium voltage lines then connect in an underground network, eventually directing all electricity to the wind farm's main substation. Transformers then increase the voltage of the electricity coming from the entire wind farm to that of the connecting transmission lines while metering equipment at the substation monitors the power flow [12]. High voltage power lines, proper connection equipment, and safety mechanisms are then used to actually connect the high-voltage wind power to the power grid, whose nearest connection point may be up to several miles away [12]. Figure II.2.5 displays the general interconnection equipment layout for a typical wind farm.

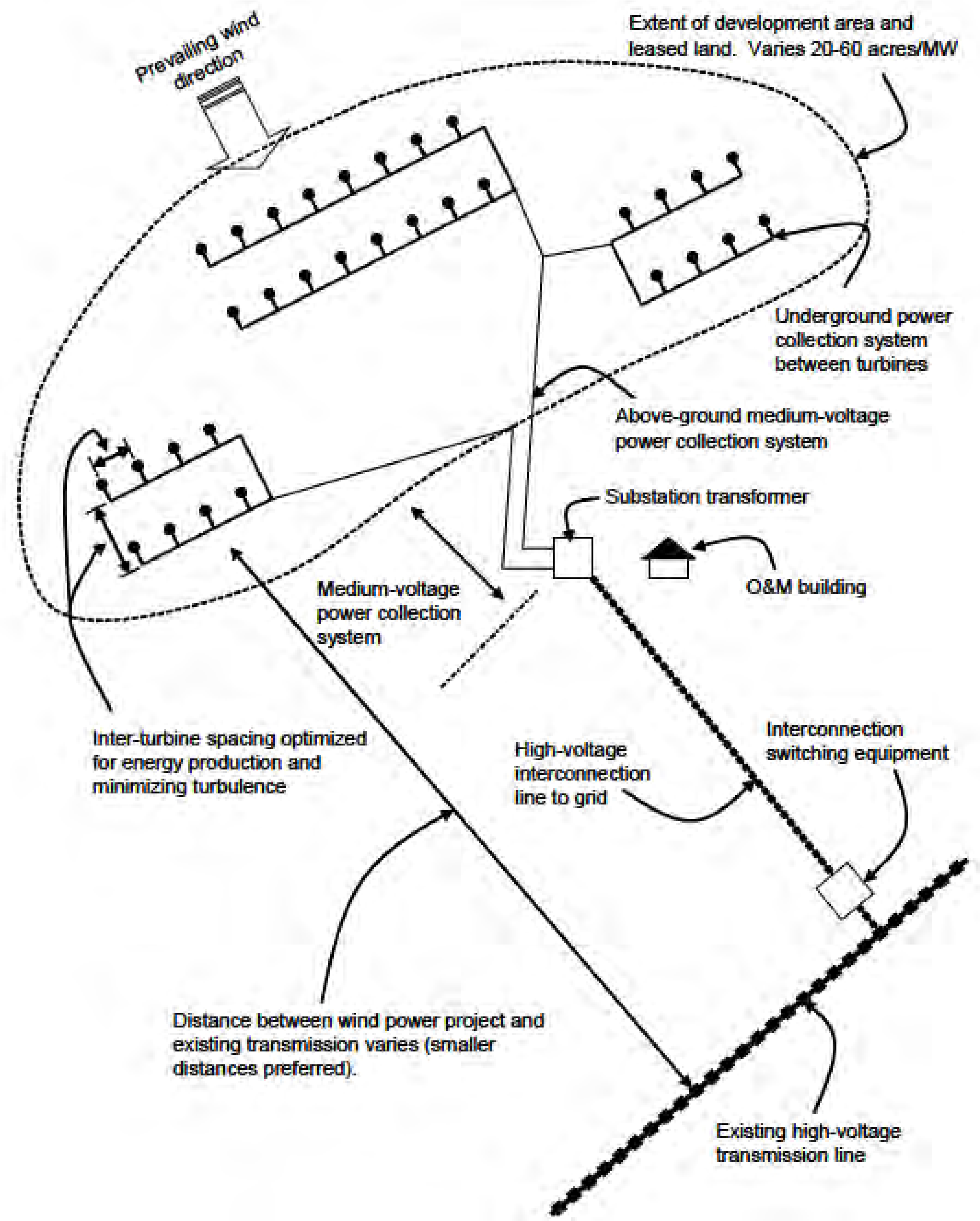

Figure II.2.5: Typical wind energy project components and overall layout [11]

In terms of communication among the turbines and with a central control hub, Supervisory Control and Data Acquisition (SCADA) systems are normally implemented to ensure proper operation and maintenance of wind turbine equipment [12]. Computer terminals are typically houses in O&M facilities near the farm, but can also be located further away [12]. Control wiring for SCADA systems is oftentimes buried alongside power transmission lines underground [12].

II.2.4.2 Interconnections and Intermittency

Due to the intermittent nature of wind energy, wind turbines often make inefficient use of the capacity of the transmission lines that hook them up to the grid. The cables must be able to handle the peak electrical flow produced, but this may be the situation 30% of the time [13]. This capacity may not even be used 50 – 70% of the time [13]. Additionally, if a minimum output is required from a wind farm to power nearby regions, generators must be installed and hooked into the system to make up for the lack of energy when the turbine blades are not spinning [13]. This can greatly increase the costs of a wind energy network, and is one of the main criticisms of wind power.

II.2.4.3 Interconnection Costs

According to the Energy Information Administration, and using 2009 dollars, the "total overnight capital cost including contingency for wind" is about $1,250 per kW while fixed O&M costs can be estimated as $36.65 per kW [14]. In terms of interconnection costs, in general (for any type of overland energy transmission), estimates vary by region from $219 to $594 per kW [14]. EIA also provides estimated costs for adding transmission capacity to serve wind farms, which include data for situations requiring transmission in the 0-5 mile range ($10.93 to $19.05 per kW, depending on region), 5-10 mile range ($32.82 to $57.18 per kW), and 10-20 mile range ($65.65 to $114.35 per kW) [14]. These costs obviously span a broad range of prices and depend heavily on the types of projects involved. A detailed analysis of specific site interconnection costs is presented in each of the individual site studies, later in this report.

II. 2.4.4 Local Connection Issues

According to The National Wind Coordinating Collaborative, the three main issues hampering the smooth implementation of wind energy interconnections to the power grid are related to competition, control, and complexity [15].

Historically, new power generation systems required lead times of five years before connecting to a grid in order to assess the impact of the new connection on the transmission system [15]. This was not an issue because the addition of a large power plant meant that only one study had to be completed when a plant was built, which was relatively not often [15]. Unfortunately, this setup process is not conducive to the easy addition of wind energy to transmission lines. Besides the whole issue of wind energy being highly variable, the fact that so many new wind projects desire connections to the grid within a relatively small time frame is problematic. In other words, it is difficult to assess the effects of a wind energy supply connection on a transmission line when there are so many other projects that need to be evaluated in a similar manner. Instead of studying how one large change could affect an electric system, transmission line operators need must now assess how dozens of new power sources will interact with each other and the system lines, even when the wind energy sources are operating intermittently [15]. The fact that some new wind farms often export electricity as soon as each new turbine is finished further complicates matters. Thus because of the intermittent nature of wind power, energy influxes into the existing electric grid will now be highly dynamic, and operators will not only need more time to model the changes, but they will have a lot less than 5 years to do it in [15].

Control has been an issue because the law states that the only the owners of transmission lines can assess and validate new connections to those lines [15]. Thus some groups waiting to connect have complained of discrimination in choosing priority of new projects, and some have even been asked to provide funds to upgrade the transmissions system for reasons unrelated to the effects of their own energy-generating systems [15].

Another issue has been complexity, as the operation of a transmission system is far more complex that it appears to the outside world. Thus performing proper studies requires the expertise of trained professionals, analytic software, and complete access to transmission line

data and behavior models [15]. On top of this, the results of such studies are often difficult to convey to third parties who are not experts in transmission line operations [15].
Solutions to these problems have been proposed, with the most notable being calls for the standardization of equipment and processes required to interconnect wind energy sources to electric systems [15]. While this will likely not require “one size fits all” wiring and component sizing, it does mean that the procedures for examining the effects of a new power system on a grid should be standardized in hopes of speeding the process. Also, it is recommended that a third party manage the logistics behind applying for interconnection permission given the apparent high volume of discrimination inherent to the current process which gives complete control over such matters to the owners of the transmission line [15].

Limits could also be placed on interconnection studies, or new projects could be grouped so as to decrease the number of separate analyses that need to be performed. Also, given the high volume of applicants, less-strict rules for queuing would be helping [15]. Currently, if a new system owner misses a data report deadline, they will lose their place in line for consideration even if the reason for the delay was out of their control [15]. This current system means that projects experience inconsistent progress when trying to push through new studies, and they could be delayed for long amounts of time if the transmission operators are not 100% pleased with the new system’s cooperation. Finally, increased transparency of transmission line data would mean that studies would be easier to complete given that the transparency can lead to a standardization of the process and the option to have a third party directly analyze the data to help determine the best way to proceed [15].

II.2.5 Life Cycle Analysis (LCA) for a Wind Turbine

II.2.5.1 The Phases of the LCA

The LCA is split into five phases of construction, on-site erection and assembling, transport, operation and dismantling. The construction phase includes the raw material production of concrete, aluminum, steel, glass fiber that is needed to manufacture the tower, nacelle, hub, blades, foundations, and grid connection cables. The on-site erection and assembling phase includes the work of erecting the wind turbine.

The transport phase takes into account the transportation of systems needed to provide the raw materials to produce the different components of the wind turbine, the transport of turbine components to the wind farm site and transport during operation. The operation phase include the maintenance of the turbines, including all oil changes, lubrication and transport for maintenance, usually by truck in an onshore scheme. Finally, the dismantling phase includes taking down the turbine when it is out of service, recycling some components, depositing other into landfill.

The figure below illustrates how each of the five phases relate to each other as well as how they contribute to landfill or incineration, waste, or renewable energy

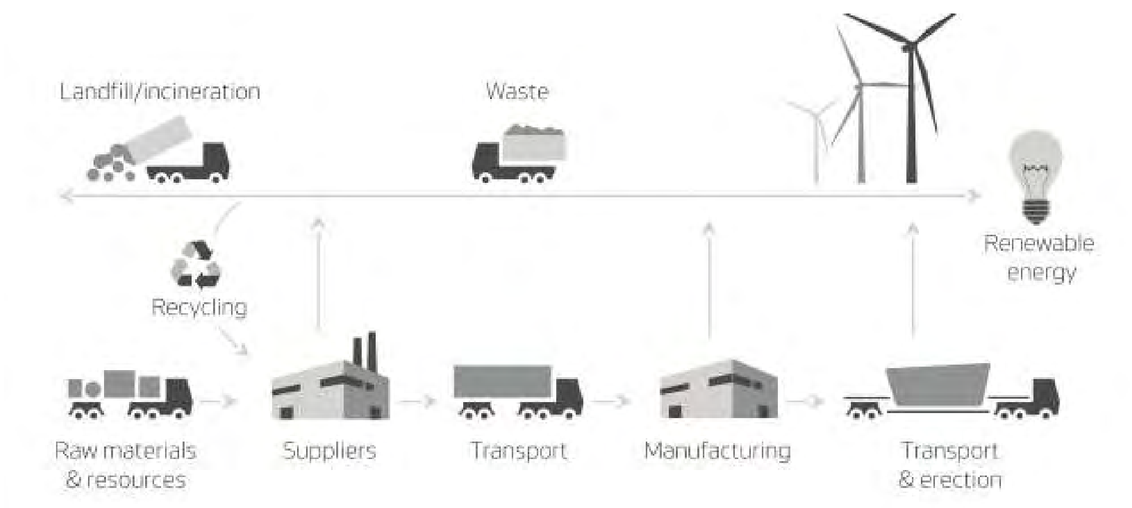

Figure II.2.6: LCA Phases of a Wind Turbine [16]

II.2.5.2 Inputs and Outputs of the phases of the wind turbine.

It is important to break down the phases of the wind turbine and look at the input and outputs at each phase to best determine the environmental effects of the wind turbine.

The construction phase has inputs of steel, cast iron, cooper, plastic, carbon, fibers, glass fibers, epoxy, energy, while the only output is waste in the form of carbon dioxide , sulfur dioxide, NOx. The erection phase requires an input of concrete, gravel, machine work, oil, and energy with the output of waste in the form of Carbon Dioxide, Sulfur Dioxide, NOx. With no outputs other than waste, it is clear why the construction and erection phases are the most energy intensive phase of the wind turbine’s life.

The Operation and Maintenance phase includes an input of oil, energy, turbine components but produces renewable energy and waste only in the form of oil. Lastly, the dismantling and disposal require machine work, oil, and energy and produce waste in the form of Carbon Dioxide, Sulfur Dioxide, NOx. In the disposal phase of the wind turbine, many of the turbine components can be recycled which reduces the overall waste. [16]

The figure below illustrates each of the phases discussed and their necessary inputs and outputs. The main inputs include Materials, chemicals, and energy with the many outputs of renewable energy with bi-products, waste and emissions to air and water

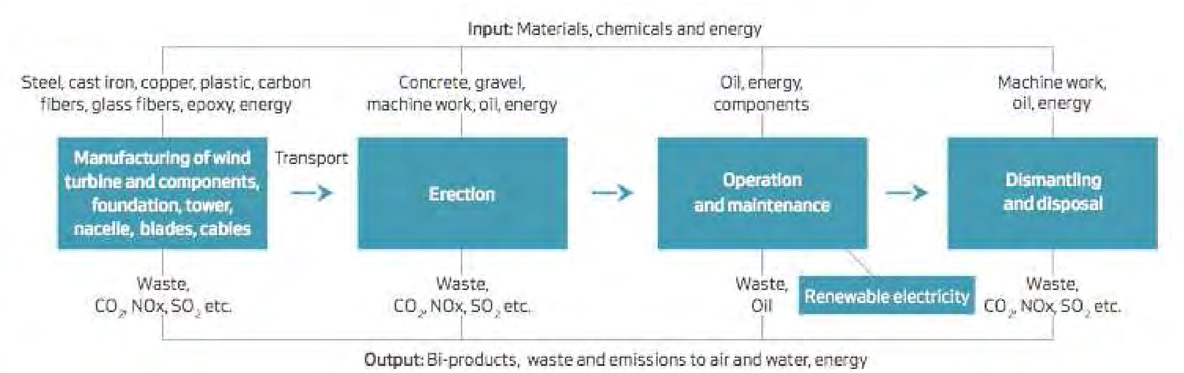

Figure II.2.7: Resources used to produce, erect, and commission a wind turbine [16]

II.2.5.3. The results of the Life Cycle Analysis

All of the emissions from the life cycle of a wind turbine are far below the emissions of conventional technologies, such as natural gas. The figure below graphs the emission with the estimated minimum and maximum amount of emissions.

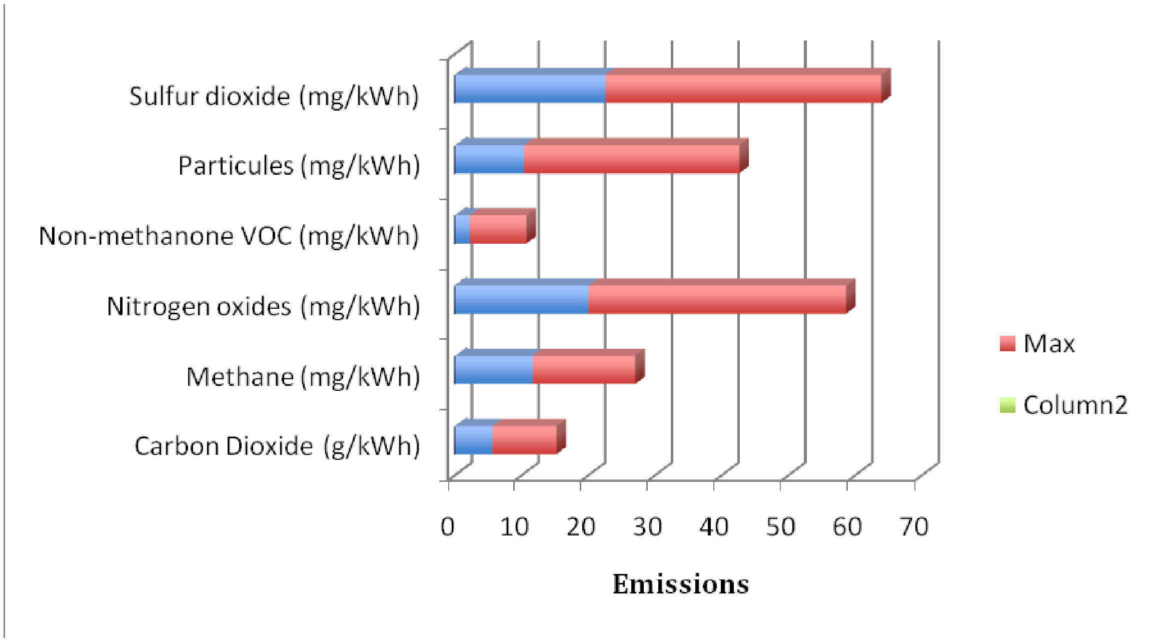

Figure II.2.8: Emissions from production of a 1 kWh Onshore Wind Farm [17]

As discussed in the inputs and outputs section, wind farm construction is the most crucial phase because it generates the biggest environment impacts. These impacts are due to the production of raw materials, mostly steel, concrete, and aluminum which are very intensive in energy consumption. The figure below illustrates the contribution of different LCA phases to the emissions

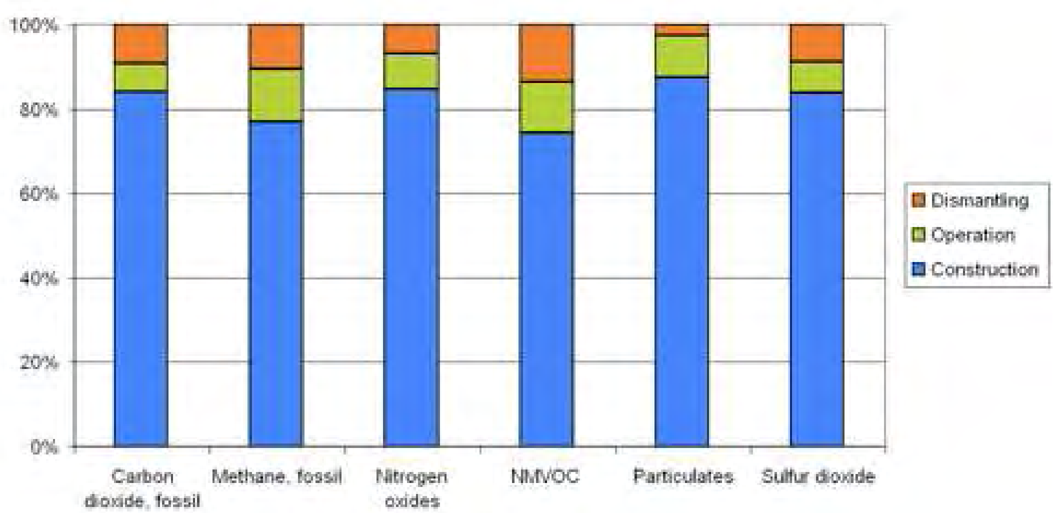

Figure II.2.9: Contribution of Different Life Cycle Phases to Emissions [17]

Since it is such a major player in the emissions, the construction phase is broken down further to illustrate each component of the construction phase and how it relates to emissions. Generally, constructing the tower is the largest contributed to carbon dioxide emissions. The figure is shown below.

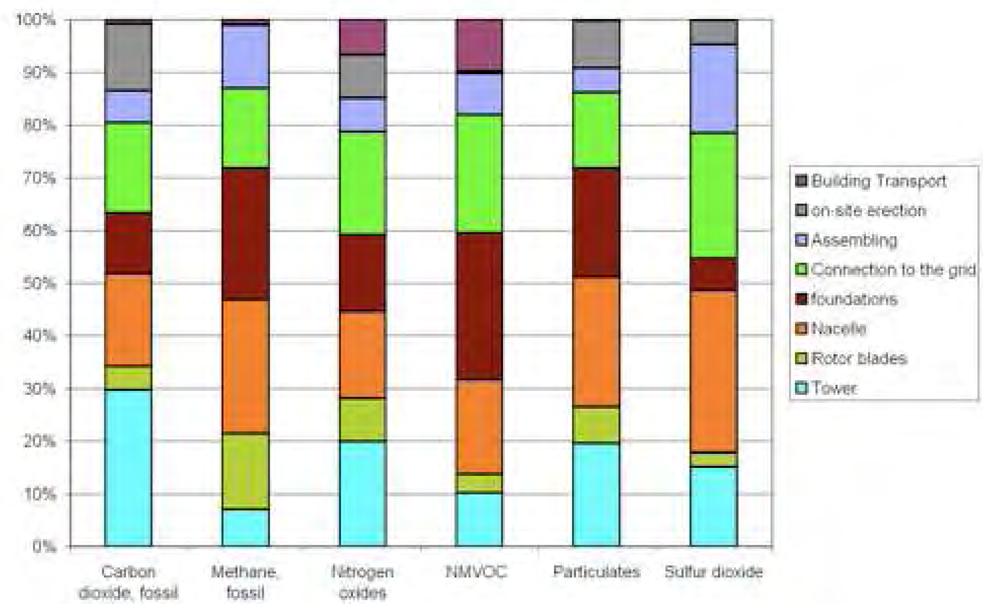

Figure II.2.10: Contribution of components of the construction phase to emissions [17]

Not all phases of the wind turbines life have the amount of emissions as the construction phase. In fact, the energy production phase from wind is clean because no emissions are released from the turbine. Additionally, the environment impacts from the transportation and operations stages are not significant in comparison with the total impacts of the wind energy. Finally, at least 90% of turbine steel is recyclable at the end of the turbine life. This high percentage of recycling leads to a decrease in the waste from the dismantling and disposal stage [18].

II.2.5.4 Energy Consumption and Generation from a wind turbine

The energy production phase of the wind turbine is the longest phase by far and it produces no emissions. Based on the Vestas LCA, a Vestas V80 2.0MW wind turbine will generate about 113,000 MWh during a 20 year period sparing the environment approximately 93,000 tons of Carbon Dioxide [17]. Vestas uses a conservative 20 year period for the lifespan of a wind turbine. The expected lifespan of a turbine ranges from 25 to 50 years.

The LCA also found that the most energy-intensive part of a wind turbine's lifetime involves metal extraction and processing, which accounts for about 50% of the total energy consumption and Carbon Dioxide Emissions. The graph below illustrates the different phases of the LCA and their relevant CO_2 emissions.

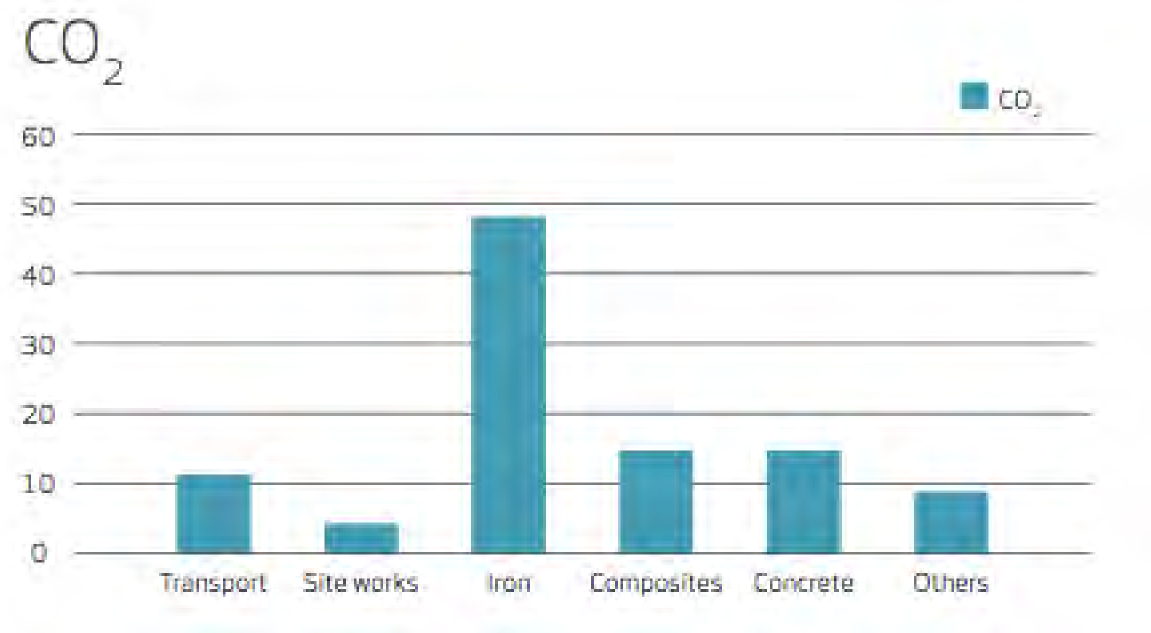

Figure II.2.11: Carbon Dioxide Emissions of the wind turbine in its expected lifetime [17]

It is important to look at the entire life cycle of a source of energy to determine the environmental impacts. Although there are some emissions from a wind turbine, the emissions are much less than the alternate energy sources that can be included. The graph below compares the CO_2 emissions per 1kWh produced by a 2.0 MW onshore turbine to a gas and coal fired plant.

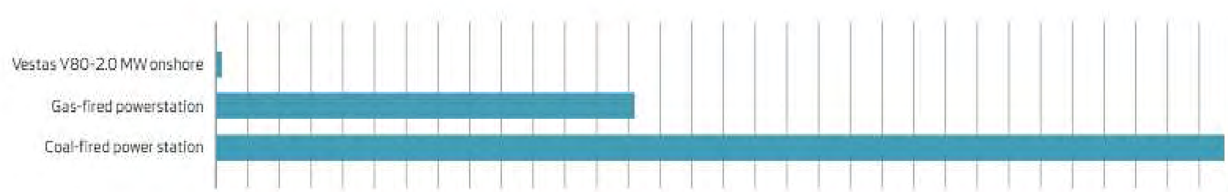

Figure II.2.12: Carbon Dioxide Emissions from 1kWh Energy Produced [17]

As illustrated above, in general the environmental impacts of 1kWh of energy from a 2MW wind turbine is less than 3% compared to the impacts of 1kWh average electricity [19]. The graph below illustrates the avoided emissions from the entire energy sector based on the 20% wind energy by 2030 plan.

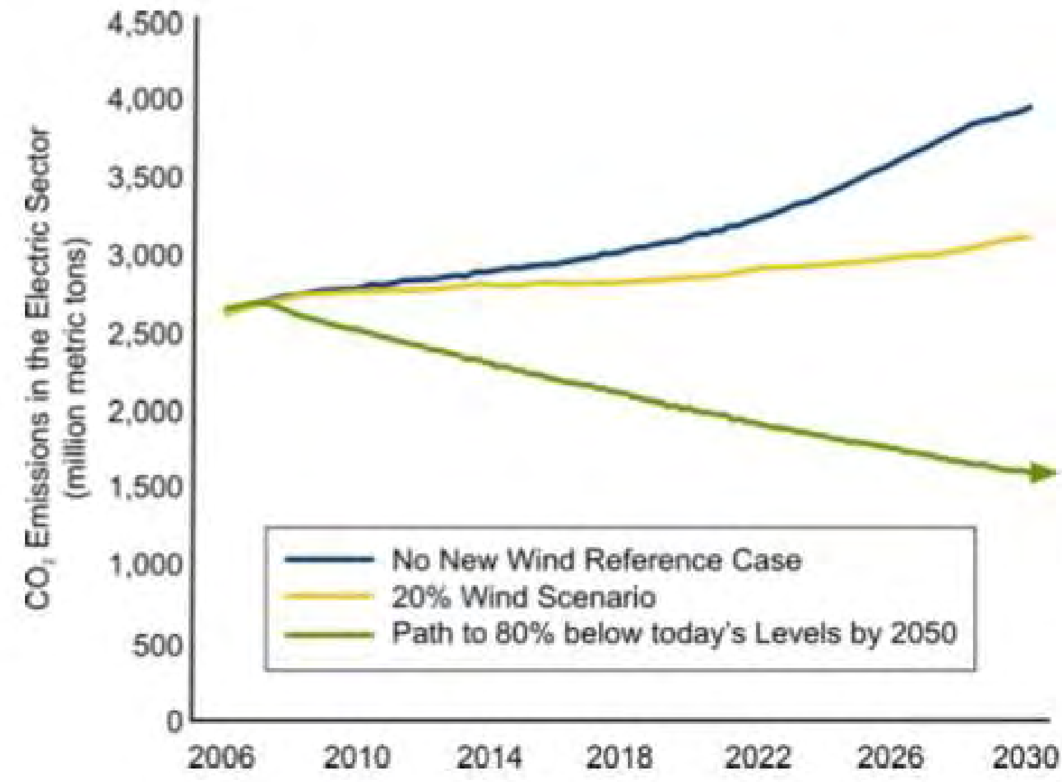

Figure II.2.13: Carbon Dioxide Emissions from Electric Sector [20]

II.2.6. Manufacturing and Installation of Off-Shore Turbines

II. 2.6.1 Manufacturing Considerations of the Current Offshore Wind Industry

The two most pertinent issues affecting offshore wind farm construction are the availability of wind turbines, and (to a slightly lesser extent) the availability of large installation vessels needed to transport turbine and turbine foundation components to offshore sites [21]. Other developers have cited difficulty in locating proper interconnection sites with onshore grid networks, but this problem is not universal and can be dealt with on a site-by-site basis [21].

Luckily, raw materials and technical know-how are not shortcomings of the offshore industry. The largest turbines currently in use are as large as 5 MW, and successful projects have already been installed throughout the Baltic and North Seas of northern Europe. However, the 2-3 year long waiting periods for turbines is causing a major delay in the installation of new offshore projects [21]. GE has even estimated that the backlog for turbines as of April 2008 is on the order of $12 billion [22]. The popular onshore market directly competes with offshore projects for turbine components, as the designs of both types are very similar. Since the capital costs of onshore farms are generally lower than offshore ones, many developers and manufacturers are choosing to solely support onshore structures, leaving even less resources for those interested in installing offshore farms.

Offshore wind farms can utilize larger wind turbines than their onshore counterparts because transporting large equipment over water is considerably less complicated than doing so on land. However, this creates a higher demand for large ocean vessels required to move these parts. In addition to actual turbine pieces, massive steel foundations for the offshore turbines need to be build onshore and then transported to the project site for installation, further increasing the need for such vessels. The availability of these ocean vessels can be problematic because arranging such transportation must be made years in advance. Not only are such vessels in high demand for wind projects, but for other manufacturing and transportation industries as well [21]. A common problem has been that vessel owners feel as if they are treated like "taxi drivers" whose clients expect them to be ready to go the minute they decide they need the transport's services [21]. However, unlike the turbine shortage, there is hope in the near future for alleviation of this problem. Proper planning and a change in perception about the availability of such vessels is all that is needed to ensure that a project's progress is not hindered by a lack of oceanic transport vehicles.

In terms of which companies have the highest penetration in the offshore wind market, according to BWEA, only Siemens Wind Power and Vestas have "built a credible offshore pedigree" due to the established use of their 3.6 MW and other sized models [21]. Other companies are becoming more popular (in fact Ireland's first offshore wind farm at Arklow Bank uses seven GE 3.6MW turbines), but current developers are still relatively limited in terms of turbine model choice, as entry into the turbine manufacturing market by new companies is very difficult due to high startups costs [23]. Government intervention and/or economic incentives are suggested to even make this a possibility. However, the rising popularity and reputation of smaller companies in the offshore industry such as REpower (owned by India-based Suzlon) and Multibird (Germany), who produce larger-capacity wind turbines (i.e. 5MW) is promising to providing more diverse offshore designs [21]. These smaller companies have been able to gain market share by building larger-scale turbine models, which can produce more energy due to their higher nameplate capacity and are generally more cost effective than smaller sized models since fewer need to be installed to produce an equivalent amount of electricity. For a more thorough overview of offshore wind power, see the Offshore Wind Overview section in the Offshore Site Study section.

II. 2.6.2 Manufacturing Considerations of the Future Offshore Wind Industry- Floating Turbines

The wind energy industry is growing fast and one of the results is that the number of possible sites on-shore and in the shallow water offshore is decreasing. There are a number of places (California, Japan, and Norway) that do not have a shallow continental shelf. Deep water floating wind farms could be the future of the wind industry considering that the wind resources are even better in the open sea. Due to higher average wind speeds further offshore, wind power production is normally more efficient in deep water locations (Fig. II.2.14). As Alexandra Gjorz, head of New Energy at StatoilHyrdo puts it, “50 km off the coast of Norway, where the water depth is typically between 100-300m, the power production from each wind turbine is 30% higher than for the Horn's Rev installation some 15 km off the west coast of Denmark due to the higher average wind speed further offshore off the Norwegian coast” [24]. And Horn’s Rev farm is already very productive, with capacity factors recorded as high as 45% [25].

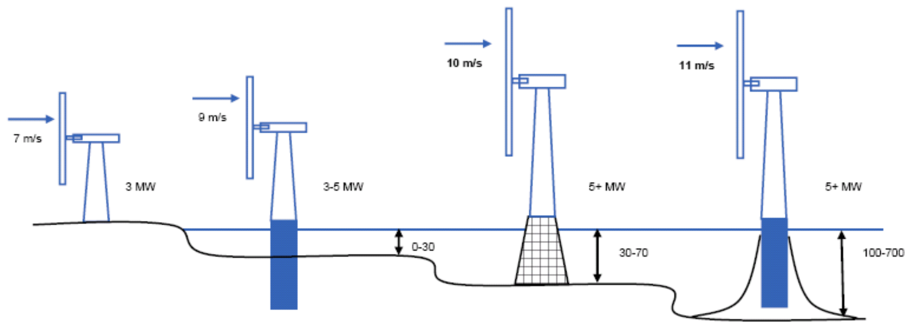

Figure II.2.14: Average wind speed is higher further offshore. [24]

Current fixed bottom foundations have limited offshore wind farm installation beyond sea water depths of 30-40 meters. Advancing into deeper water would require floating platforms due to economic costs associated with larger and deeper turbine foundations.

Floating platforms for installation of offshore wind turbine have been suggested for over 35 years but only recently the technology has developed enough realistically to address technical challenges of such an endeavor [26]. Numerous floating oil rigs around the world have proved that they are technically workable solutions for operating heavy floating structures. These solutions however are economically not viable for offshore wind. New technical solutions are required to overcome the economics hurdles.

Following the oil rigs, there is great variety of design approaches and platform configurations. The primary goal is to achieve static stability which could be done following different strategies based on different physical principles. These approaches can be classified into three broad groups (Figure II.2.15): ballast, mooring lines and buoyancy [27].

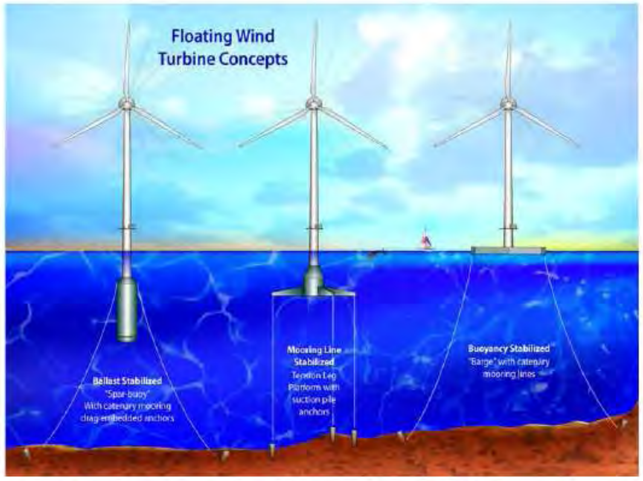

Figure II.2.15: Floating Wind Turbine concepts. [27]

There are a few companies actively try to deploy floating wind turbines – Blue H Technologies (Netherland), StatOilHydro (Norway), Principle Power (USA) and SWAY (Norway).

Blue H Technologies BV is located in the Netherlands but is incorporated in the UK (2004). The company is converting deepwater platform technology developed for oil and gas rigs to place large wind turbines in economically viable ways. The company tested its capabilities by launching the world's first large scale prototype built in Puglia (Fig. II.2.16) in Southern Italy in 2007. The platform is tension-leg type (the middle one in above Fig. II.2.15) with a 80 kW turbine. Blue H is using a two-blade turbine which reduces the total turbine weight significantly. This type of turbine is usually much noisier but this might not be an issue considering the remote location of the farm. The first commercial deepwater wind farm is under construction at the Tricase, Italy site. The farm will have 25 turbines with a total capacity of 92 MW [28].

Figure II.2.16: Blue H full scale prototype in Puglia (Italy). (picture from www.theoildrum.com)

StatoilHydro is a Norwegian company specialized in offshore oil and gas exploration and production. As such, the company has enormous expertise in designing, building, and operating offshore rigs. StatoilHydro is the world's largest deep water operator and the world's third largest net seller of crude oil. The company decided to use its expertise in this field and together with Siemens are building a floating deep water wind farm. The initial stage is to put a 2.3 GW Siemens turbine on a rig about 6 miles offshore from Karmoy, Southern Norway. The turbine is expected to be operational in the fall of 2009 [29].

(a)

WTG:	2,3 MW
Turbine weight:	138 tonnes
Turbine height	65 m
Rotor diameter:	82,4 m
Draft hull:	100 m
Displacement:	5300 m^3
Diameter at water line:	6 m
Diam. submerged body:	8,3 m
Water depths:	120-700 metres
Mooring:	3 lines

(b)

(c)

Figure II.2.17: (a) Location of the future StatoilHydro floating offshore wind farm. (b) Some characteristics the company floating construction. (c) StatoilHydro floating offshore turbine [24].

SWAY (Norway) is a renewable energy company, with world leading technology and competence in floating wind turbines located in deep water. They are developing floating platforms based on an elongated pole design with ballast at the bottom part. This foundation can support a 5 MW turbine in water from 80 to 300 meters in depth. The system is designed to withstand extreme weather conditions. The company expects to have a deployed prototype by 2010 [30].

Figure II.2.18: SWAY offshore wind turbine [30]

Principle Power is developing a project to build a deep-water offshore wind farm next to Portugal in 50 m deep water. They are also considering sites in Oregon and Maine [31].

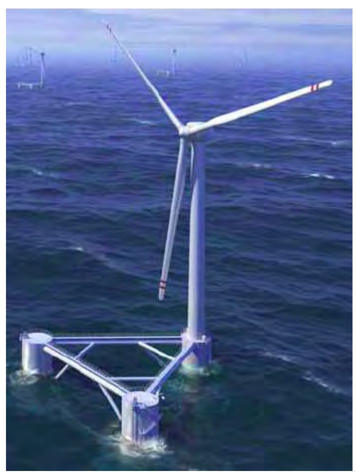

Figure II.2.19: Principle Power floating offshore turbine [31].

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PART III: SITE CASES STUDIES

III.1. INDUSTRIAL-SIZE WIND FARM: KLONDIKE III

III.1.1. General Information about Industrial Wind Farms

The Klondike III site is located in Sherman Country, Oregon (see Figure III.1.1), a north-central area of the state near the border of Washington State. The project lies approximately nine miles south of the Columbia River and seven miles east of the town of Wasco, Oregon. Klondike III is the third installment to the location, after the initial 24 MW Klondike I farm in 2001 and the 75 MW Klondike II Expansion in 2005 [1]. The site features 80 1.5 MW GE turbines and 44 2.3 MW Siemens turbines, with an installed capacity of 221 MW and an actual output of 66 MW year-round average [2]. The site possesses a commercial Class 4 wind grade categorization (a "Good" resource under Renewable Energy Atlas of the West standards), with average wind speeds ranging between 4.78 m/s and 5.12 m/s at an elevation of 50 meters about the ground surface based upon the Wind Data maps. According to Klondike data, the site receives wind speeds of 7.47 m/s at 50m off of the ground. The Klondike data was used in the expected power generation calculations.

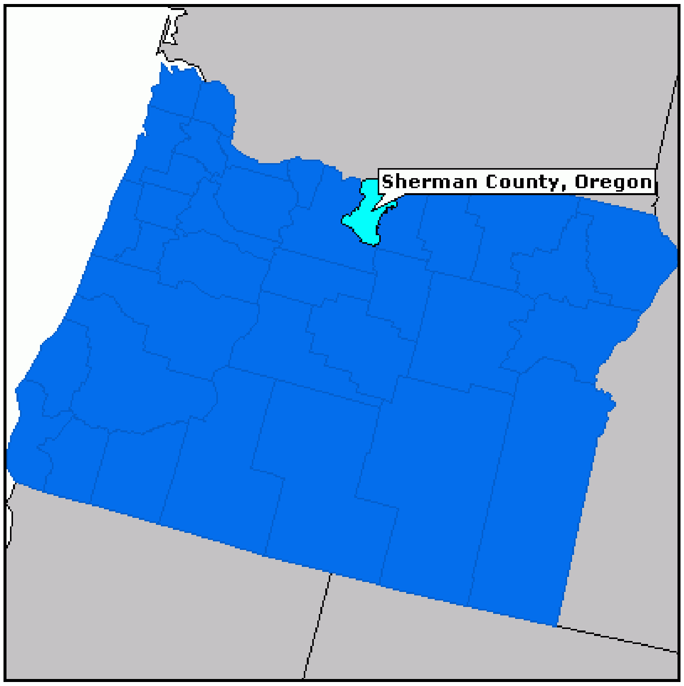

Figure III.1.1: Klondike III Location Map 1 (source: Google Images)

III.1.2. Expected Power Generated

III.1.2.1. Calculating Average Wind Speed at Hub Height

The expected power output by the entire wind farm was generated by combining the power curves for each of the turbines with the wind speed at ground level. The average wind speed had to converted to the wind speed at the turbine hub height. Using the equation below from Vanek Energy Systems Engineering the wind speed at hub height was found for the two different turbines.

$$U(z)= U(z_r)(z/z_r)^{\alpha} \qquad (1)$$

where z is the height desired above the ground, z_r is the reference height, where the wind speed is know and alpha is the wind shear coefficient. For the Klondike calculations, alpha was assumed to be about 0.2 because of the flat terrain of the wind farm.

III.1.2.1.1. GE 1.5 MW Turbine Average Wind Speed

The GE 1.5 MW Turbine has a capacity of 1500 KW, with a cut in wind speed of 4 (m/s), a cut out wind speed of 25 (m/s) and a rated wind speed of 12.5 m/s. The hub height for the turbine is about 65 m, and the measured wind speed of 7.47 m/s was taken 50 m off of the ground. Using Equation 1 above, the wind speed at the hub height for the GE 1.5 MW Turbine was calculated to be 7.86 m/s. Since the GE Turbines are about 15 meters lower than the Siemens turbines, the average wind speed is much less.

III.1.2.1.2. Siemens 2.3 MW Average Wind Speed

The Siemens 2.3 MW Turbine has a capacity of 2300 KW, with a cut in wind speed of 4 (m/s), a cut out wind speed of 25 (m/s) and a rated wind speed of 12.5 m/s. The hub height for the turbine is 80m, and the measured wind speed of 7.47 m/s was taken 50 m off of the ground. Using Equation 1 above, the wind speed at the hub height for the Siemens 2.3 MW Turbine was calculated to be 8.20 m/s.

III.1.2.2. Calculating the Power Generated for each turbine

Since the wind speed bin data was not available, the "Rayleigh" distribution was used to model the wind speed throughout the year. Using the cumulative distribution function (CDF) of the Rayleigh distribution, a corresponding curve was generated. The CDF of the Rayleigh distribution was then written in terms of average wind speed (U_{avg}),

$$F(x)= 1\text{-}\exp[(-\pi/4)(x/Uavg)2] \text{ for } x \geq 0 \qquad (2)$$

Using the properties of the Rayleigh distribution, the probability that the wind speed was at or below the given wind speed was calculated in terms of average wind speed.

$$p(\text{windspeed} \leq U) = 1\text{-}\exp[(-\pi/4)(U/Uavg)2] \qquad (3)$$

The probability functions for both the Siemens and GE Turbines were calculated and plotted below. As shown by the graph, there is the greatest probability that the wind speed will be around 6 m/s, which is slightly lower than the average wind speed for both turbines, due to the nature of the Rayleigh Distribution

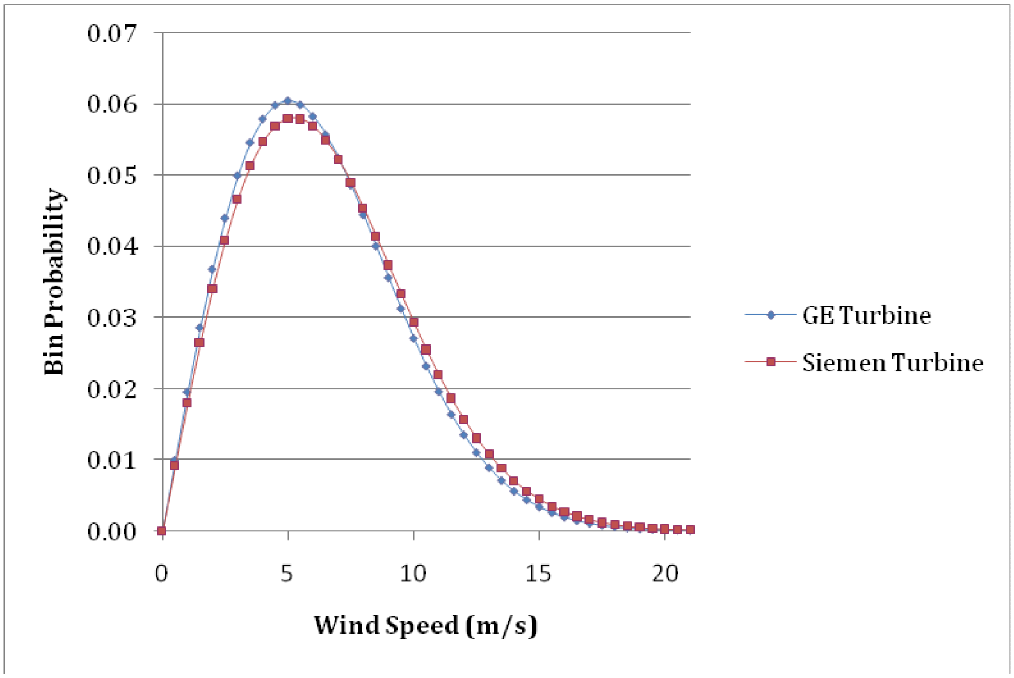

Figure III.1.2: The Probabilities of Wind for a given wind speed, up to 21 m/s.

III.1.2.2.1. GE 1.5 MW and Siemens Turbine Power Curve

Using the power curve supplied by GE (available at http://www.gepower.com/prod_serv/products/wind_turbines/en/downloads/ge_15_brochure.pdf) , the power for one 1.5MW turbine is illustrated below.

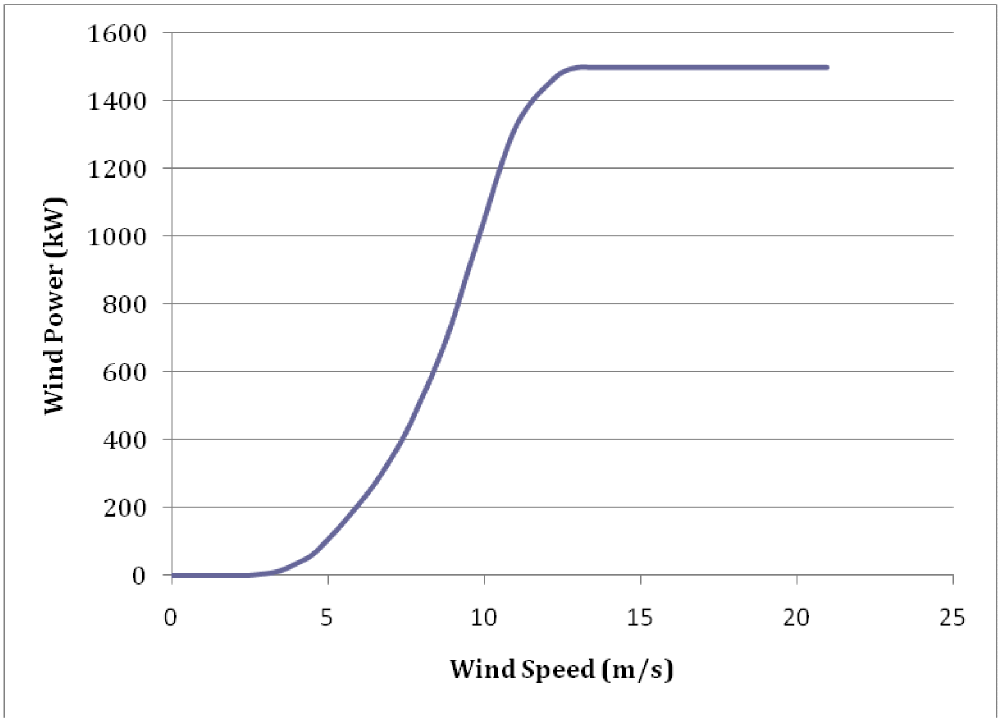

Figure III.1.3: Power Curve for a 1.5 MW Wind Turbine

Siemens does not supply a power curve for their 2.3 MW Turbine, so the power produced per turbine was estimated by modifying the GE Turbine power curve. Since the two turbines have the same cut-in, cut-out and rated wind speed, the power curve for the Siemens turbine only had to be scaled to 2300 MW instead of 1500 MW. The two power curves are shown below

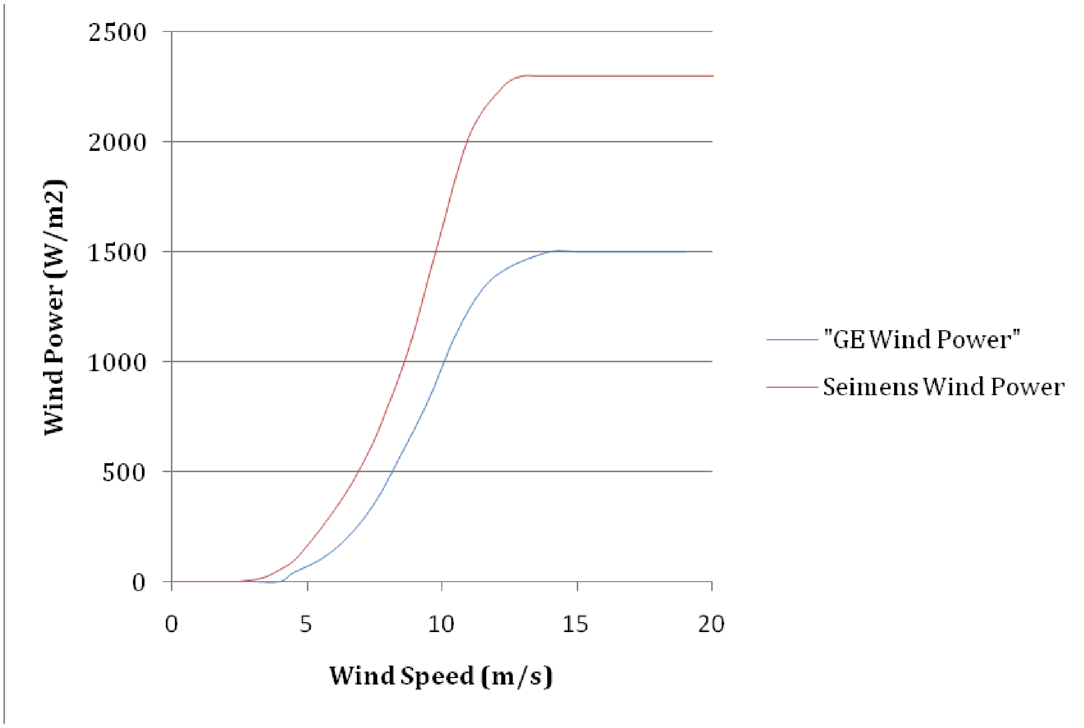

Figure III.1.4: Power Curve for Siemens and GE Turbines

III.1.2.2.2. Estimating the total output from the wind farm

The probability that the wind was at each speed, as shown in Figure III.1.2, was multiplied by the number of hours in a year (about 8766 hours/year) to find the amount of time per year that the wind is at the given speed. Using the data from the power curves, Figure III.1.4, the estimated energy output per turbine was calculated by multiplying the power at a given wind speed by the number of hours per year that the wind was at that speed. The energy per year per wind speed was summed over all of the wind speeds to calculate the total energy per year per turbine. The table below illustrates that the GE turbine has an energy output of almost 4,000,000 kWh and the Siemens has an output of almost 6,000,000 kWh.

The capacity factor for each turbine was calculated by taking the ratio of the estimated energy per year to the energy per year if the turbine were at its maximum power output per year. The table below illustrates that both turbines had a capacity factor around 30%.

Turbine	Energy/Year (kWh)	Max Energy/Year (kWh)	Capacity Factor
GE 1.5 MW	3,926,389	13147500	29.86%
Siemens 2.3 MW	5,739,065	20159500	28.47%

Table III.1.1: Energy Output and Capacity Factor of GE and Siemens Turbine

Using the energy output for one turbine, the energy output for the entire farm was then calculated by multiplying by the total number of turbines. The total yearly output of the Klondike III wind farm is estimated to be about 570,000,000 kWh.

Turbine	Energy/Year (kWh)	#Turbines	Total Energy (kWh)
GE 1.5 MW	3926389	80	314111116
Siemens 2.3 MW	5739065	44	252518851
		Total	566,629,967

Table III.1.2: Energy Output for the Klondike III Wind Farm

III.1.2.3. Project Costs

The Klondike sites are currently owned and operated by Iberdrolas Renewables, and energy is sold through multiple power-purchase agreements to Bonneville Power Administration (BPA), Portland General Electric (PGE), and Puget Sound Energy (PSE) [1]. Additionally, the 25,000-acre Bigelow Canyon Wind Farm (currently 76 turbines, 126 MW capacity) is located to the north of the Klondike sites (see Figures III.1.6 and III.1.7) and is also a property of Iberdrolas and their power-marketing subsidiary, PPM Energy. As of 2008, the site composed on of the 10 largest wind farms in the World and was a testing ground for the new Mitsubishi MWT92 2.4 MW turbine [1]. The project is composed of privately owned farmlands that have historically been cultivated for wheat farming; harvesting activities continue to take place directly adjacent to the installed turbines. Table III.1.3 summarizes the development of the site.

Project	Construction	Capacity (MW)	Turbine Specifics	Number of Turbines
Klondike I	2001	24	Enron Wind, 1.5 MW	16
Klondike II	2005	75	GE Energy, 1.5 MW	50
Klondike III	2007	120	GE Energy, 1.5 MW	80
		101.2	Siemens, 2.3 MW	44
		2.4	Mitsubishi, 2.4 MW	1

Table III.1.3: Klondike Site Summary (source: wikipedia)

The Klondike III site is rated at 221 MW of installed capacity with an estimated actual average output of 66 MW. As a reference, the Klondike III's average daily production is capable of serving 13,125 homes. BPA operates under an agreement with PPM Energy for a reduced cost contract for energy, contingent on BPA funding and constructing a new a 19-km long, 230-kilovolt (kV), double-circuit transmission line between the Klondike projects and BPA's new 230-kV John Day Substation. As a result of the agreement, BPA has a 20-year power-purchase contract for 22.36 percent of the project's output [1]. Similarly, PGE operates under a 30-year contract for power produced by the Klondike II site. The site is advantageously situated both with respect to the level topography, predictable soils, and the existing transmission infrastructure, within which power can be easily transmitted to areas of high demand in the state while avoiding the congested transmission lines in the eastern part of the state.

Construction of the Klondike III site affected 295 acres of land, and project facilities ultimately occupy 74 acres [1]. The construction process was subject to an incident in which one of the 74 meter tall turbine towers buckled, killing one construction worker who was working on the tower and injuring another who was on the ground. Beyond this incident, the Klondike sites have enjoyed measurable success in Sherman County, having minimal environmental effects and numerous economic effects that will be discussed in later sections of this document. Figure III.1.5 illustrates turbine elevations for the Klondike I, II, and III projects, as well as Bigelow Canyon. Figure III.1.6 provides a spatial depiction of the turbine locations within the project site.

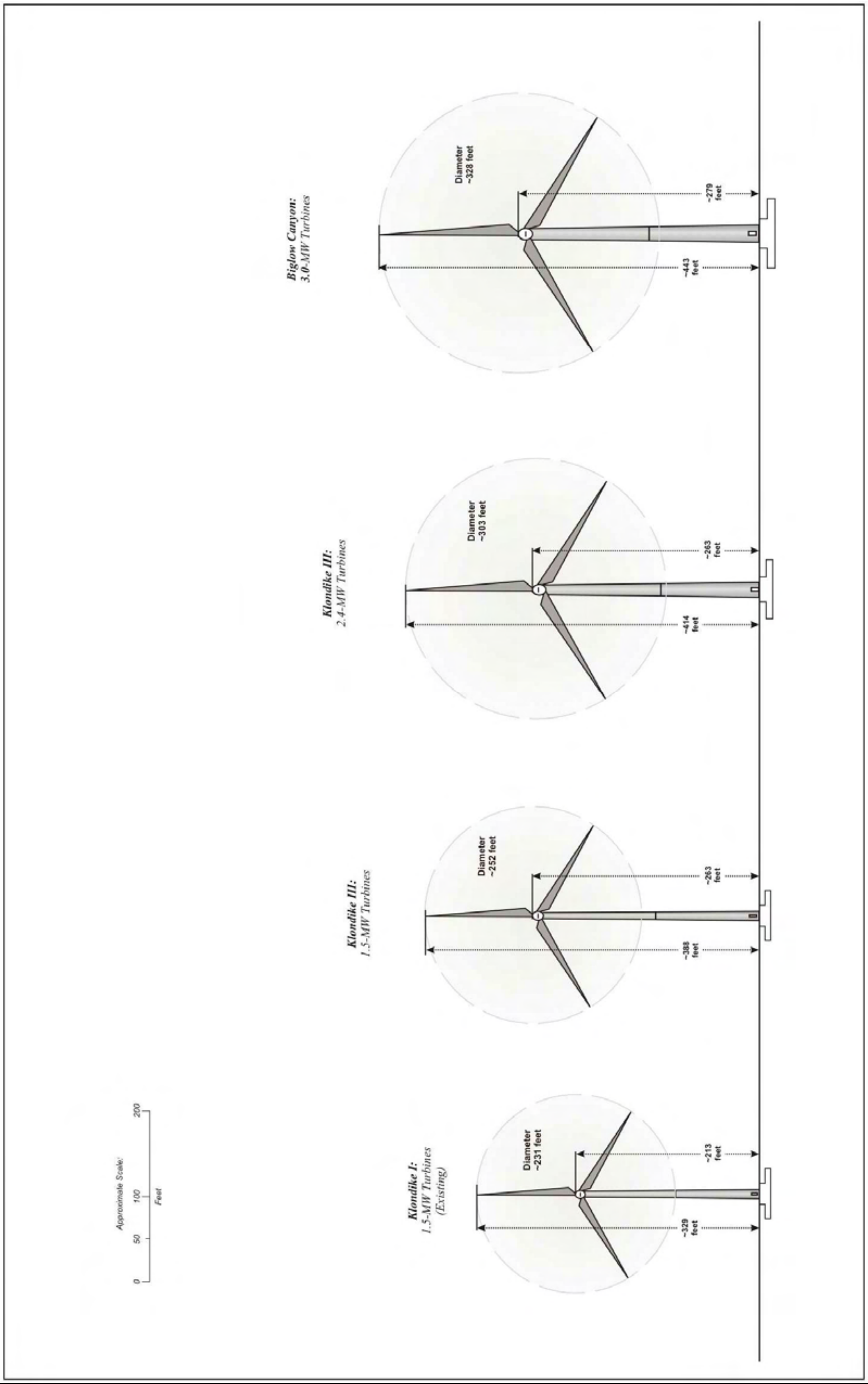

Figure III.1.5: Klondike III Turbine Elevations (Source: BPA)

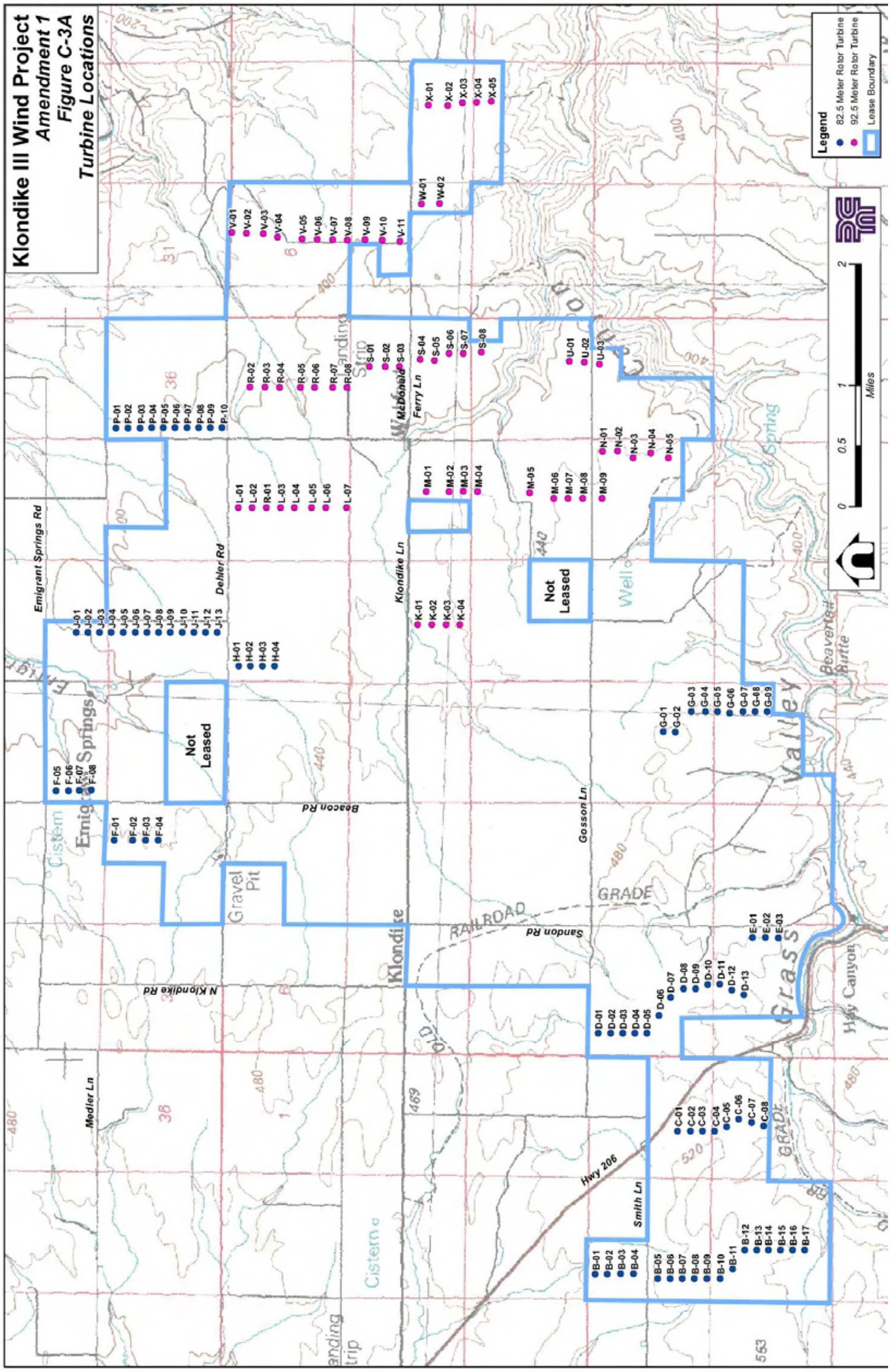

Figure III.1.6: Klondike III Site Overview (Source: BPA)

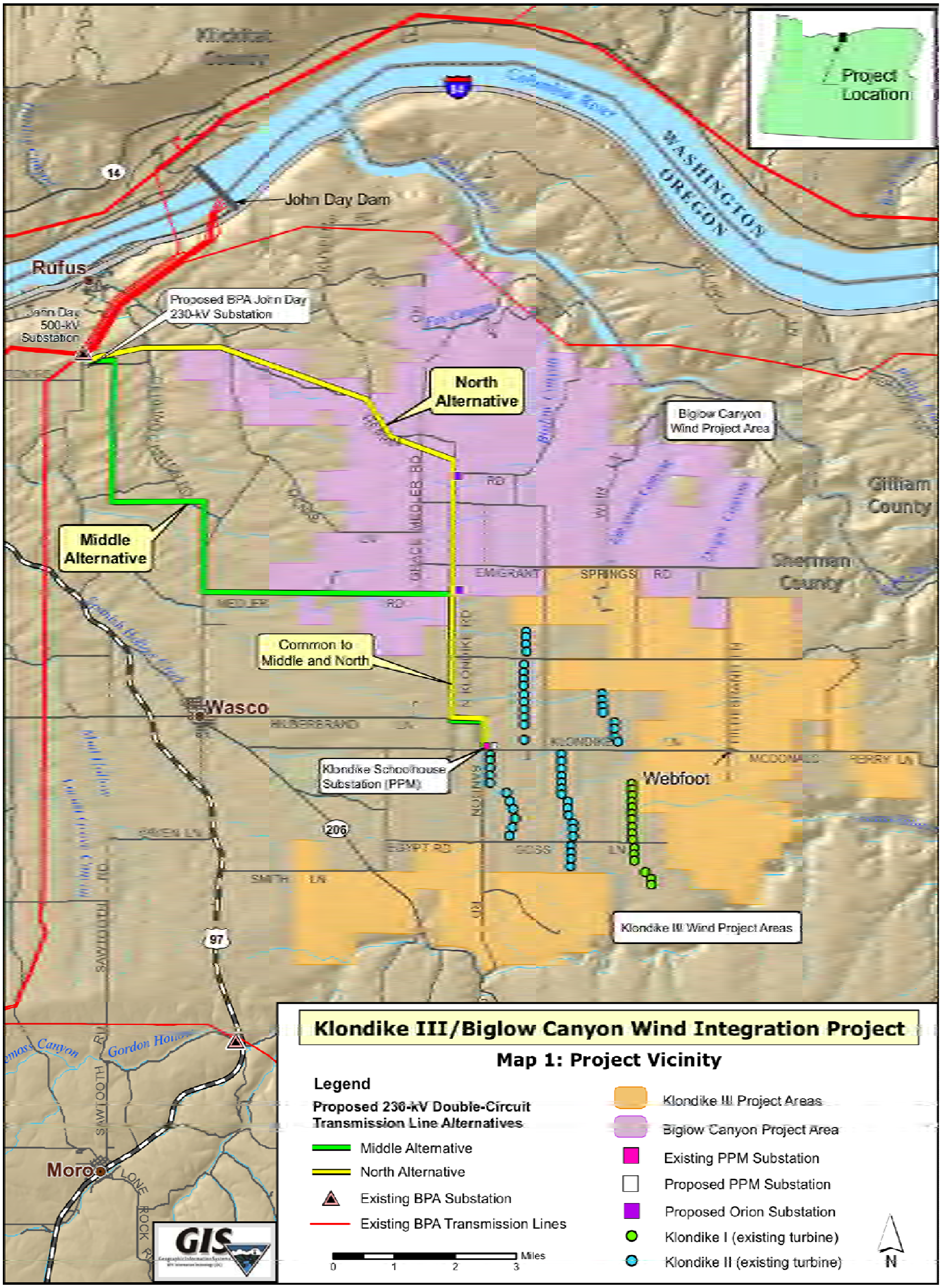

Figure III.1.7: Klondike III Transmission Line Alternatives (Source: BPA)

Figure III.1.7 summarizes the transmission line alternatives considered during design of the facility. In September of 2006, BPA finalized the Environmental Impact Statement (EIS) for the transmission line alignments. The Record of Decision (ROD) was released in December of 2006. BPA found utility in the construction of this transmission line for the reason that it serves both the Klondike output and the Bigelow Canyon site as well, allowing them to negotiate agreements for reduced rate purchases of energy. BPA is a federal agency that owns and operates the majority of the high-voltage electric transmission system in the Northwest and they offer transmission connection to all eligible customers on a first-come, first-serve basis pending the results of an environmental review per National Environmental Policy Act (NEPA) guidelines.

III.1.2.3.1. Construction Costs

One element of this study is to develop a general cost estimate outline for inland wind farms that covers the project from planning and permitting through design, construction, and commissioning. Determining true costs for each phase of the project present some difficulty since wind farms are typically privately owned and thus construction and capital costs are closely guarded for competitive purposes [3]. The values in Table III.1.4 represent methods used by the National Renewable Energies Laboratory (NREL) to estimate wind farm development in conjunction with public cost estimates, bid tabs, and contractor quotes related to similar facets of work such as roadway and substation construction.

The EIS is a critical component of the project development process because it defines design alternatives, potential environmental impacts, and outlines potential mitigation strategies. It has also become necessity, as stated earlier, in the event that a customer wishes to connect to a transmission line operated by BPA or the Western Area Power Administration (WAPA). EIS documents are typically prepared by private consulting firms under the direction of the owner and a ROD is later issued by the appropriate governing body once it is clear the public comments have been addressed, environmental aspects defined, and NEPA guidelines have been followed. The cost estimate for the EIS stage was developed from previous publicly available EIS studies performed by private consulting firms and are represented in \$/turbine installed. Estimates for the O&M facilities, the substation, and substation upgrades were also estimated from publicly available cost estimates and it is noted that specific details regarding these specific components of the project were not readily available and thus these estimates shall be treated as ROM costs. The cost envelope for the turbine itself has been constructed from NREL research and studies published by Engineering-Procurement-Construction (EPC) firms such as EOS Ventures, LLC.

NREL's *Wind Turbine Design Cost and Scaling Model* was referred to for the remaining estimates and the following equations were used and results were escalated to account for inflation. It is noted that NREL's cost equations do not take into account transport distance, length of roadway constructed, or length of transmission line when calculating project costs. The equations were originally developed around the model of a 50 MW wind farm in the Midwest, for which site designs are relatively standard and thus, there is more variability in turbine design, than site-civil work. The equations were aimed at framing rough order-of-magnitude (ROM) costs around turbine characteristics to minimize the metrics used within the calculations. For the exercise, although the wind farm is much bigger than 50 MW, these equations are assumed to be acceptable for ROM costs since the site is relatively simplistic in topographical aspects and the installed turbines were of standard size and specification.

Transportation Cost:

$(0.00001581*(\text{Turbine Rating})^2 - 0.0375*(\text{Turbine Rating}) + 54.7)*(\text{Turbine Rating})$

*Turbine Rating entered in KW [3]

Roadway Cost:

$(0.00000217*(\text{Turbing Rating})^2 - 0.0145*(\text{Turbine Rating}) + 69.54)*(\text{Turbine Rating})$ [3]

Turbine Foundation Cost:

$303.24*(\text{Hub Height} * \text{Rotor Swept Area})^{0.4037}$ [3]

Transmission Connection Cost:

$(0.00000349*(\text{Turbine Rating})^2 - 0.0221*(\text{Turbine Rating}) + 109.7)*(\text{Turbine Rating})$ [3]

Turbine Assembly/Installation Cost:

$1.965*(\text{Hub Height}*\text{Rotor Diameter})^{1.1736}$ [3]

Yearly Operating Costs – The yearly operating costs were developed from studies conducted on the effects of Klondike I and II on Sherman County, which allowed for tax revenue, O&M costs, and Land Lease costs to be extrapolated.

Project Component	Average Unit Cost	Klondike III Project Cost (estimated)	% of Total Project Cost
EIS	$15,000/turbine	$1,830,000	0.63%
Site Design	$25,000/turbine	$3,050,000	1.05%
Turbine	$900,000- $2M/turbine	$170,000,000	58.5%
Transportation	$50,000 - $120,000/ turbine	$10,000,000	3.44%
Roads	$50,000 - $100,000/turbine	$7,500,000	2.58%
Expand Existing Substation	$5,000,000 LS	$5,000,000	1.72%
New 230 kV Substation	$40,000,000 LS	$40,000,000	13.76%
O&M Facilities (2)	$20,000,000 LS	$20,000,000	6.88%
Turbine Foundation	$50,000/1.5MW turbine $110,000/2.3MW turbine	$8,840,000	3.04%
Transmission Connections	$130,000/1.5MW turbine $180,000/2.3MW turbine	$18,320,000	6.30%
Turbine Assembly/ Installation	$50,000/turbine	$6,100,000	2.10%
	Total	**$290,640,000**	**100%**
	Cost/MW	**$1.321M / MW installed capacity**	
Yearly Operating Costs			
Land Lease	$2,000 - $6,000/turbine/yr	$610,000	8.33%
O&M	$30,000/turbine/yr	$3,660,00	50%
Property Taxes	$25,000/turbine/yr	$3,050,000	41.67%
	Yearly Operating Cost	**$7,320,000**	**100%**

Table III.1.4: Rough-Order-of-Magnitude (ROM) Turbine Costs

While the Klondike site is representative of a conducive wind farm site, the best wind conditions are often found in remote areas that have little or no infrastructure. Therefore, wind farms generating high capacity factors also have respectively high construction, development, and

O&M costs. The roadway/transportation infrastructure, length of construction season, and distance from transmission system play critical roles in the cost and feasibility of a wind farm.

Rated output	221	MW
Capital cost	$ 270,640,000	
Capacity factor	29.24%	
Theoretical output @ 100% CF	1,938,000	MWh
Actual annual output	566,600	MWh
Annualized Cap. Cost	$ 19,200,000	per year
Operating Cost	$ 7,320,000	per year
Total annual cost	$ 26,500,000	
Levelized cost	$ 0.0468	per kWh
Discount Rate	5.0%	
Investment Time Horizon	25	years

Table III.1.5: Levelized Electric Cost

III.1.3. Local Economic Impacts of Industrial-sized Wind Farms

Figure III.1.8: Klondike, Sherman County (source: RNP)

In 2001, Klondike I came on-line with 24 MW of capacity provided by 16 turbines. This was the first wind project in Sherman County, being followed by Klondike II and III. The Renewable Northwest Project, a Non-Profit organization promoting the development of renewable energy in the area, published a study about the local economical impacts of Klondike I [5]. We can extend their results for the new projects, and we will complement this information with a more general discussion about local impacts of wind projects in different locations, under different circumstances.

The first important issue of study is the land use and direct impact of the turbines location on the uses of it. Sherman County is strongly dominated by the wheat monocultures, with big landowners (average farm size above 2,500 acres) and industrial-type agriculture practices. Land ownership is important in order to determine the relative proportion of fertile land affected by the turbines. With a modest impact, each turbine affects up to half an acre, plus the necessary roads, substations and transmission infrastructures. Small farmers would effectively feel a bigger impact than those in Sherman County.

On top of the land ownership, industrial agricultural practices are positively impacted by the development of roads and general infrastructures, providing a better access for tractors and other machinery. Farmers rarely live near the lands, so noise and residential land value decline due to the wind project are of little importance. This, of course, would be very different in other circumstances with small farmers' community. Sherman County is highly reliant on wheat production, which is vulnerable to adverse weather seasons, market prices, and provides few opportunities for job creation, demographic growth or local development. These conditions make wind farms a very attractive project for the local community, as proven by the growth of wind farms' extension in Klondike II and III. Landowner royalty payments are typically \$2,000 - 6,000 per turbine each year.

People QuickFacts	Sherman County	Oregon
Population, 2007 estimate	1,677	3,747,455
Population, percent change, April 1, 2000 to July 1, 2007	-13.3%	9.5%
Population, 2000	1,934	3,421,399
High school graduates, percent of persons age 25+, 2000	84.3%	85.1%
Bachelor's degree or higher, % of persons age 25+, 2000	19.0%	25.1%
Households, 2000	797	1,333,723
Median household income, 2007	$39,954	$48,735
Per capita money income, 1999	$17,448	$20,940
Persons below poverty, percent, 2007	15.5%	13.0%
Business QuickFacts	**Sherman County**	**Oregon**
Private nonfarm establishments, 2006	41	110,6841
Private nonfarm employment, 2006	326	1,461,664[1]
Private nonfarm employment, percent change 2000-2006	13.2%	7.8%[1]
Retail sales, 2002 ($1000)	18,4	37,896,022
Retail sales per capita, 2002	$10,285	$10,756
Federal spending, 2007 ($1000)	35,614	25,241,842[1]
Geography QuickFacts	**Sherman County**	**Oregon**
Land area, 2000 (square miles)	823.21	95,996.79
Persons per square mile, 2000	2.3	35.6

Table III.1.6: Quick facts Sherman County, Oregon (source: Sherman County Census)

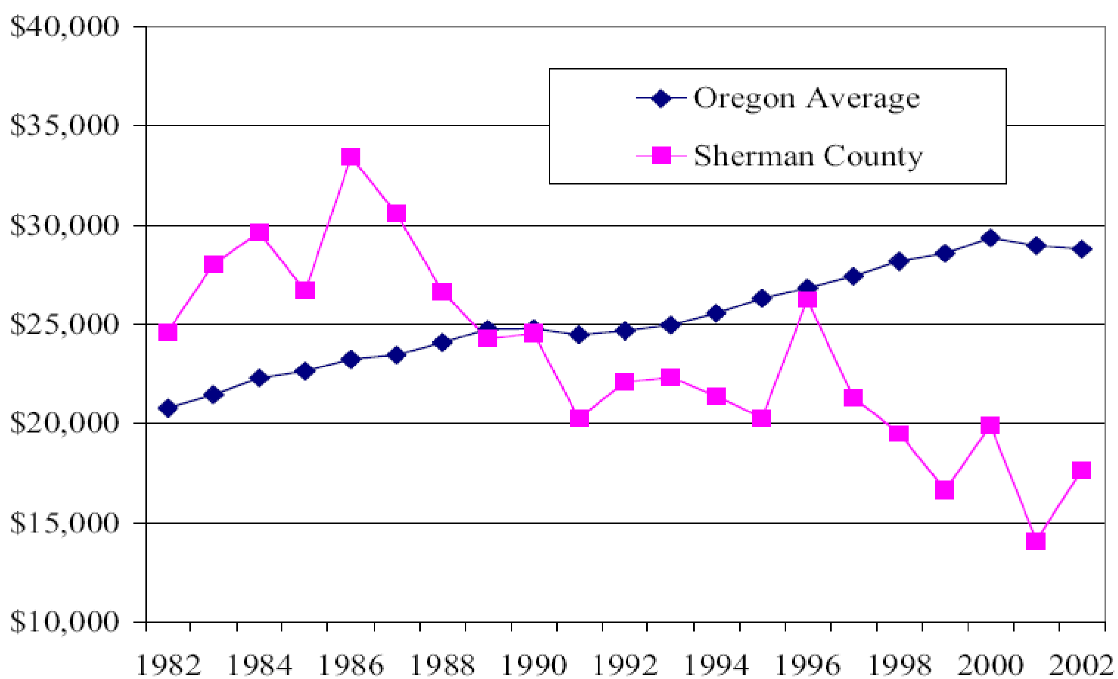

Figure III.1.9: Per Capita Income in Sherman County and Oregon State (source: RNP)

Klondike Wind Farm was chosen for this study because it represented the general characteristics of local communities around the Mid-West, where most of the wind resources are present. This economical impact is easily adapted for wind farms in North and South Dakota or Nebraska. Most of the opposition for industrial-size wind farms comes from states such as Vermont, where economical and social environments radically change, and wind farms may interfere with tourism and other industries

An important aspect of the promotion of new projects is the social participation. In Sherman, the process was a cooperative one, the success of which can be attributed to a wide variety of factors. The Oregon Solutions process was implemented in order to expedite development of the project. Oregon Solutions, a program started by Governor Kitzhaber, has been described as "a collaborative process in which government, private interests, and the local community could work as a team to address the issues and find a solution." This process allowed the project to go from conception to construction in only 12 months, a necessity due to the expiration of the production tax credit on December 31, 2001 [5].

Environmental, aesthetic, and community issues were brought to the fore through public forums and stakeholder meetings, which also contributed to the ease and speed of the development process. Routine meetings with landowners and other members of the community, as well as circulation of The Wind Farmer, a publication designed to keep landowners and members of the community informed, were essential for education and communication. After two years of operation, PPM Energy (owned by Iberdrola Renewables), a power marketing company located in Portland, OR, purchased Klondike in January 2003 for $16.8 million. Due to the quality wind resource and supportive local community, PPM announced in December 2004 that they would expand the project by an additional 75 MW (Klondike II) [1].

As with all wind farms, environmental concerns at Klondike were at the forefront of the planning process. An Environmental Site Assessment performed by WEST, Inc., revealed minimal impacts resulting from the wind farm. The land had been previously disturbed, as the location for the access road and foundations was tilled farmland.

Lacking trees and water sources, the local environment is not well suited to avian life, and the immediate area is not home to raptor nests or migrating birds. A post construction operations study conducted for one full year reported minimal avian mortality. In addition, the turbines do not have an effect on local deer and antelope populations. Compared to other renewable energies, Wind Power has a minimal water use, which is of critical importance for development in arid or remote zones. Thermal-Solar energy, for example, requires large amounts of water, adding pressure on the eco-system on top of the land grab.

North-western Wind Power invested approximately $26 million on the Klondike I Project, an all inclusive amount that includes sitting, permitting, development, tower construction, and electrical work. This equals $1.083 million per installed megawatt, which is on-line with other projects, as reported by a product average of $1 million per installed megawatt of wind power. Larger projects typically experience some economies of scale, which explains the slightly above average cost for the 24 MW Klondike I project compare to Klondike II and III. Also, extra costs were incurred as line and substation work was intentionally designed to accommodate future expansion of the project [1].

To assess the full impact of Klondike capital investment, ripple effects must be considered alongside initial expenditures. Typically, the effects of the expenditures fall into three categories namely direct, indirect, and induced impacts. Direct effects are the immediate payments to primary firms such as consultants, contractors, and the labourers employed to develop and build the project. The indirect effects result from firms linked to the primary firms to complete their contract, which would accrue to firms such as fuel suppliers, equipment rental companies, accountants, and lending banks. The final category, induced effects, encompasses the dollars spent by the firms and employees involved in the project as a result of the increased income. Aggregated together, this ripple through the economy is known as the multiplier effect. The size of the effect varies depending on the size and diversity of the economy.

Sherman County, Oregon is likely to have a fairly small economic multiplier. The small population and lack of economic diversity would cause a large portion of any capital investment to leak outside the local economy rather quickly. For Klondike, this meant that significant benefits from the project were generated for people in the region more than in the county (as with the development and construction contractors).

Most impact studies of wind projects employ input-output data to estimate the indirect and induced benefits. For purposes of comparison, reasonable assumptions can be made as to the size of the local multiplier. A study of the Vansycle Ridge Wind Farm in Umatilla and Morrow Counties in Eastern Oregon reported a multiplier of 1.48 [5]. These counties are far larger in both population (over 80,000 compared to 1,700) and in economic diversity. The lower bound of the multiplier is 1.0, meaning that none of the dollars spent remained in the local economy. Therefore, the multiplier for Sherman County is estimated to be in the range of 1.1 to 1.3.

According to RNP, the entire development process generated significant regional employment throughout 2001 during sitting, permitting, environmental assessments, and design work. Construction began in October 2001 as equipment arrived on site and local contractor KC Construction worked on the access road. Many of the contractors employed by the project are from locations in Oregon. The major phases of construction included roads and grading, excavation and foundations, electrical systems, and erection of the towers (which are general civil and electrical works, requiring no skills specific to renewable energies technologies, being difficult to differentiate these ‘green jobs’ from others in the industry). Construction efforts totalled an estimated 32,000 labor hours, not including manufacturing, fabrication, and transportation of the turbines.

Indirect benefits resulted from those firms linked to the principal contractors. Equipment rental companies received income from the primary contractors. Local oil and gas supplier provided on site tanks of gas and off-road diesel for machinery operations. Additional income and employment includes manufacturing and transportation of parts and equipment to the site. Manufacturing occurred in numerous locations both within and outside the United States.

The cooperation of the community has paid off for Sherman County. In addition to the direct and indirect benefits to regional companies from construction, induced benefits accrued locally, as workers patronized local establishments and dollars flowed through the economy. The local motels, RV/Trailer parks, cafes, and grocers experienced a boost in business during construction.

With only three landowners at the Klondike project, each one is receiving an estimated $15,000 per year. Tax revenues represent the most important lasting benefit to the local community. The Klondike project is the first major capital investment in Sherman County. In the first year of operations, property tax revenues totalled $321,206 from the wind turbines, or slightly over $20,000 per turbine (we can extrapolate this to Klondike III resulting in more than $2.5 million in taxes paid annually) [1]. The figure shows the dollar allocation of Klondike tax revenue in the 2002-2003 fiscal years:

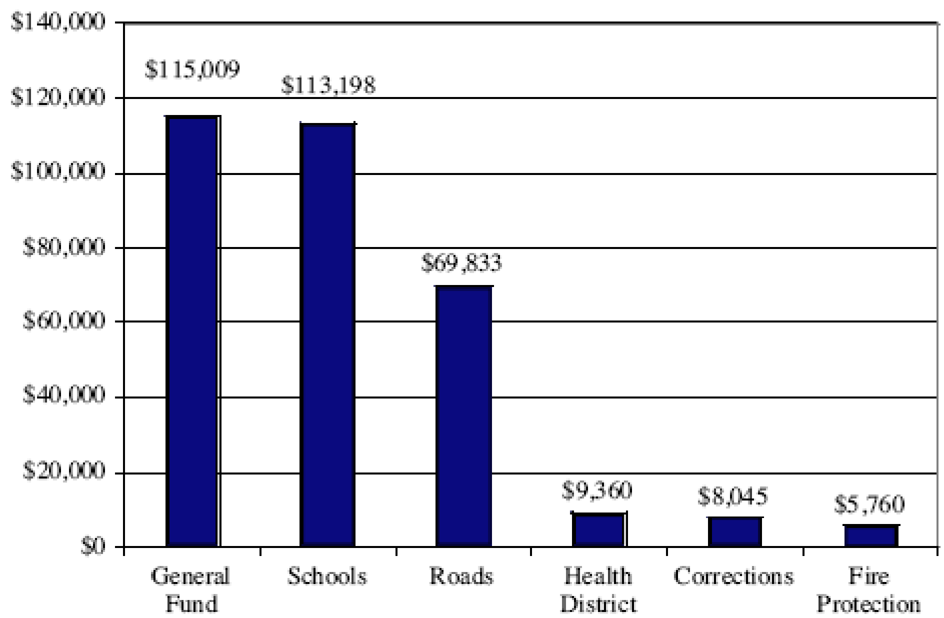

Figure III.1.10: Allocation of Klondike tax revenue (2002-2003) (source: RNP)

Part III.1 Klondike References

1. Bonneville Power Administration (April 2009). "Klondike III/Bigelow Canyon Wind Integration Project" Web resource available at http://www.efw.bpa.gov/environmental_services/Document_Library/Klondike/. Accessed April 2009.
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III.2. GENERATION FOR DIRECT USE: GREEK PEAK PROJECT

III.2.1. Power Production Analysis

Greek Peak Ski Resort is a facility in Central New York that offers down hill skiing in the winter months as a day attraction, currently with minimal lodging and dining options (although extensive expansion is planned to be opened in Fall 2009). Located in the Town of Virgil, in Cortland County, they are near the Finger Lakes region, known for its tourist destinations. As demonstrated by Jiminy Peak Mountain Resort in Hancock, Massachusetts, wind power generation can be a viable option for reducing energy consumption from the grid while also reducing green house gas emissions. Jiminy Peak provides a valuable model for comparison with Greek Peak Ski Resort, allowing for evaluation of capital cost, power production, and environmental benefits. At Jiminy Peak, a 1.5 MW General Electric (GE) turbine was installed and began production in August of 2007 at a cost of $3.9 Million with an estimated investment return period of eight years. With 220 skiable acres and 184 acres accessible to snow making equipment, Greek Peak is a physically larger resort than Jiminy Peak (170 acres skiable terrain and 158 acres of snowmaking coverage)[8,9]. However, Greek Peak consumes only 3.3 million kWh a year, less than half of the power Jiminy Peak consumes in a year (7.5 million kWh). This is primarily due to the fact that Greek Peak's energy consumption is driven by those items directly related to ski operations (lifts, snow making, and lighting), while Jiminy Peak operates a more complex infrastructure with considerably more buildings that draw energy over a larger portion of the year. Jiminy Peak serves more broadly as a year–round vacation area and boasts the restaurants, shops, and rentable condominiums to support it, while.

This study provides an assessment of the economic feasibility and environmental considerations realized through the implementation of a wind turbine at the Greek Peak Ski Area in Cortland, New York. The construction and operation of a 1.5 Mega-watt (MW) turbine at the peak of the resort is compared to the existing condition in which electric is purchased directly from NYSEG. A recommendation is provided based on the long-term economic impacts of the wind turbine and its projected performance. It is important to note that the wind data used in this analysis was taken from a ski fan website. This data is reasonable for a preliminary feasibility study, however, before considering a project for construction, it would be prudent to pursue a more rigorous wind speed study at Greek Peak using an anemometer installed on site.

III.2.1.1. Site Selection

Greek Peak Ski Resort is in a unique position to reduce their annual operating costs by investing in wind power generation. A combination of two factors makes them unique in their ability to harness wind power and use it effectively. As we will show in this section, the seasonal electricity demand by the resort coincides with the seasonal wind speed. When their demand is highest in the winter, 3000 MWh on average, they are able to displace 74% of the energy purchased from the grid.

Sites such as Jimmy Peak Ski Resort in Massachusetts have already installed and been benefitting from their own wind turbines. The Greek Peak resort is comparable in size and snowmaking capacity to Jiminy Peak and typically consumes 3.3 thousand MWh per year. Greek Peak's energy consumption comes mostly from operations directly related to skiing (lifts, snow making, and lighting). However, with the addition of a hotel and summer water park, Greek Peak's consumption is expected to increase due to air conditioning loads in the summer months. This increase in summer load will actually allow the turbine to pay for its self earlier, since without the summer resort facilities it is producing more than is being consumed during that period. Net metering laws say that excess electricity produced will only be purchased from Greek Peak at the bulk electricity rate, versus the retail rate that is paid for consumption from the grid. This difference may be a factor of two between the price paid to the supplier and the price paid to Greek Peak when they are acting as a supplier.

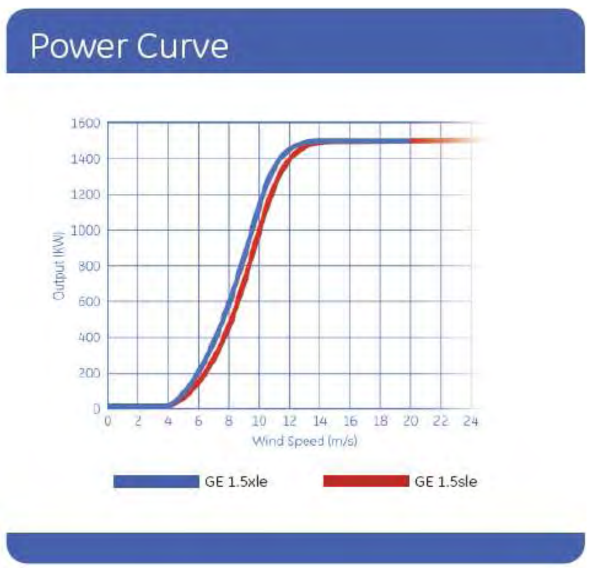
The location of the Greek Peak resort, upon preliminary inspection, appears conducive to wind turbine operations with land that allows for tower placement in areas with minimal turbulence from surrounding terrain features and wind patterns that average 11.7 meters/second during the months of November through April.

III.2.1.1.1. Turbine Selection

GE's 1.5MW 'sle' turbine was chosen because it has emerged as one of the industry's standard turbines and is a readily available model for a project of this size. Similar projects which ended up using GE turbines, (such as Jiminy Peak) noted long waiting periods for turbine parts from other companies, and thus chose to go with GE because of their experience and willingness to support small projects. The GE 1.5 MW turbine has a rated output that can adequately deliver one-third of Greek Peak's current peak winter demand, and its cut-in speed (minimum speed required to turn the blades) measures in at 3.5 m/s. With an average yearlong wind velocity at Greek Peak of 9.9 m/s at an 80 meter hub height, the turbine is an acceptable fit for the site. Technical specifications for the turbine and the corresponding power curve (relating wind speed to power output) for the turbine are presented in Figure III.2.1. For further information on the turbine, please refer to the appendix at the end of this section.

Technical data

Operating Data		1.5sle	1.5xle
Rated Capacity:		1,500 kW	1,500 kW
Temperature Range: (with ColdWeather Extreme Package)	Operation: Survival:	-30°C – +40°C -40°C – +50°C	-30°C – +40°C -40°C – +50°C
Cut-in Wind Speed:		3.5 m/s	3.5 m/s
Cut-out Wind Speed (10 min avg.):		25 m/s	20 m/s
Rated Wind Speed:		14 m/s	12.5 m/s
Wind Class — IEC:		IIa (V_{e50} = 55 m/s V_{are} = 8.5 m/s)	IIIb (V_{e50} = 52.5 m/s V_{ave} = 8.0 m/s)
Electrical Interface			
Frequency		50/60 Hz	50/60 Hz
Voltage		690V	690V
Rotor			
Rotor Diameter:		77 m	82.5 m
Swept Area:		4657 m^2	5346 m^2
Tower			
Hub Heights:		65/80 m	80 m
Power Control		Active Blade Pitch Control	Active Blade Pitch Control



1.5sle — *Classic workhorse, an efficient and reliable machine with proven technology*
1.5xle — *Built on the success of the 1.5sle platform, captures more wind energy with 15% greater swept area*

Figure III.2.1: Technical specs and power curve for GE's 1.5MW "sle" model wind turbine
Source: GE Energy 1.5MW Wind Turbine brochure

For an incremental increase in wind speed, the power that can be taken from the wind increases by the cube of the wind speed. Based on this relationship, a slight increase in wind speed can cause significant increase in power output. From the calculated average winter (November through March) wind speed of 11.7 m/s, an approximate wintertime output of 12,400 kWh per day is expected. However, this is only an average. With recorded wind speeds reaching 16.7 m/s, power output near turbine's maximum capacity (1500 kW) will be reached at numerous times during the skiing season. This is advantageous because, with the highest peaks in wind speeds occurring through the winter months, it can be expected that periods of peak energy generation will occur alongside winter storm events.

III.2.1.1.2. Wind Data

We were able to find four sources of wind data for the Greek Peak site. Three of those sources only gave an average annual wind speed, while one source recorded wind speed three times daily for one year. We chose to use the source with daily wind speed data for our primary analysis. Data from the other three were used to corroborate our estimated annual wind capacity numbers from the primary analysis.

From an online ski enthusiast website (Snow-forecast.com, 2008) we have collected historical wind speed data recorded three times daily in kilometers per hour. We assumed the wind speeds were recorded at an instrument height of 20 feet, or 6.07 meters. Averaging this for each day, then month, we are able to calculate a rough idea of the average wind speed at Greek Peak for the two seasons in the year. Because they are averages, we apply a correction factor of $6/\pi^{1/3}$ and arrive at practical wind speed estimates as shown in Table III.2.1 (Albright & Vanek, 2008). This then has to be adjusted to a hub height of 80 meters to remove the wind shear effect of the ground surface.

Month	Average speed at instrument height (6.07 m) [m/s]	Season Average [m/s]	Season Average with Correction [m/s]	Hub Height (80 m) Average [m/s]
January	6.4	5.62	6.97	11.67
February	6.1			
March	5.8			
April	4.3			
May	4.9	3.91	4.85	8.12
June	4.0			
July	3.5			
August	3.2			
September	3.6			
October	4.1			
November	4.9			
December	6.2			
Annual	4.8	4.76	5.91	9.89
	Winter			
	Summer			

Table III.2.1: Snow-forecast.com Wind Data for Greek Peak

In addition to the data described above, three other sources of wind speed data for Greek Peak were found. They are available to the public from online resources. The data from each is summarized in Table III.2.2 below. It should be noted that the first two sources below, Wind Navigator and 3 Tier Group, are for-profit entities that offer wind energy planning and consulting services. As a free service, they offer a less accurate assessment of wind speed for a given geographic area. These values are comparable to the annual average wind speed in Table III.2.1 above.

Source	Average speed at instrument height (6.07 m) [m/s]	Average with Correction [m/s]	Hub Height (80 m) Average [m/s]
AWS True Wind	3.60	4.47	**7.48**
3 Tier Group	4.05	5.02	**8.41**
NREL	4.39	5.45	**9.13**

Table III.2.2: Supplemental Wind Speed Data for Greek Peak (Wind Navigator, 2009) (Online Power Assessment, 2009) (United States-Wind Resource Map, 2009)

Wind speeds vary both daily and seasonally. The reason for this is the temporal heating cycles of the earth's surface. Wind speeds are the highest very early in the morning, coinciding well with snowmaking activities, and are lowest in the afternoon; wind speeds at Greek Peak pick up as the region cools and slow as the site warms.

III.2.1.1.3. Energy Production

Using the Rayleigh distribution to approximate annual wind speed distribution (Albright & Vanek, 2008), we were able to apply the power curve from a GE 1.5 MW turbine to determine power and energy production over the course of the year. Due to the seasonal nature of Greek Peak's electricity usage as seen in Figures III.2.2 and III.2.3, the analysis is actually looking at the year in two periods, from November 1 through April 30 for the winter season, and May 1 through October 31 for the summer season. The majority of Greek Peak's energy use in the winter season is due to snow production. By comparing the relative amount of energy demand, a small effect can be seen between winters where higher snowfall results in lower energy demand from snow production. Data was not available for March and April of 2009 or for May-July of 2006. A projection is made in Figure III.2.3 for the remainder of each season's usage.

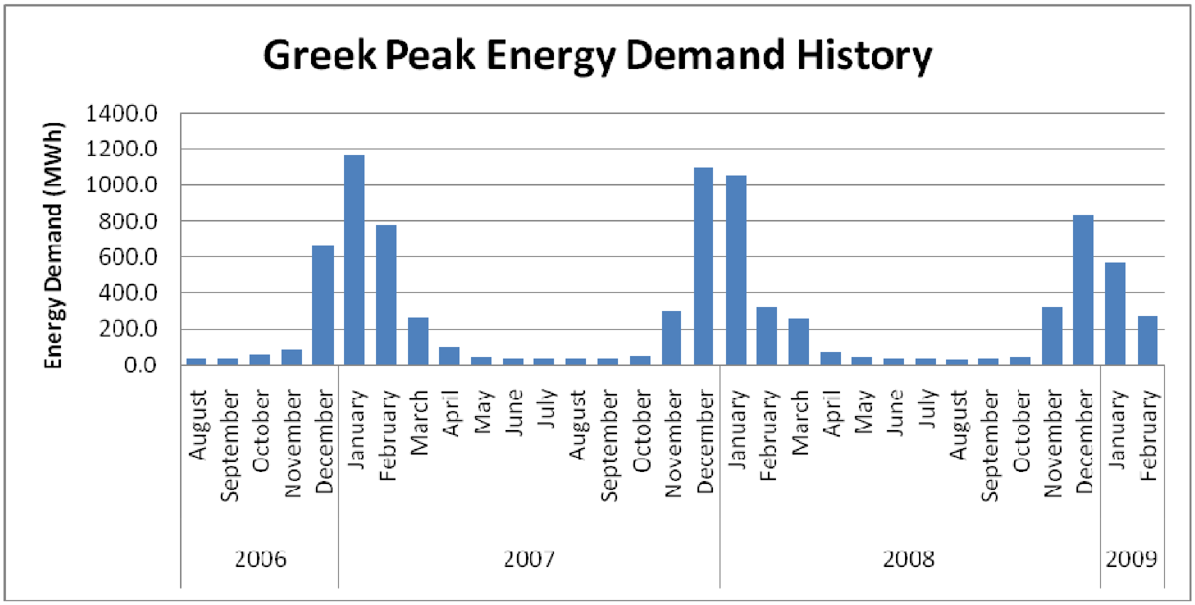


Figure III.2.2: Monthly Energy Demand

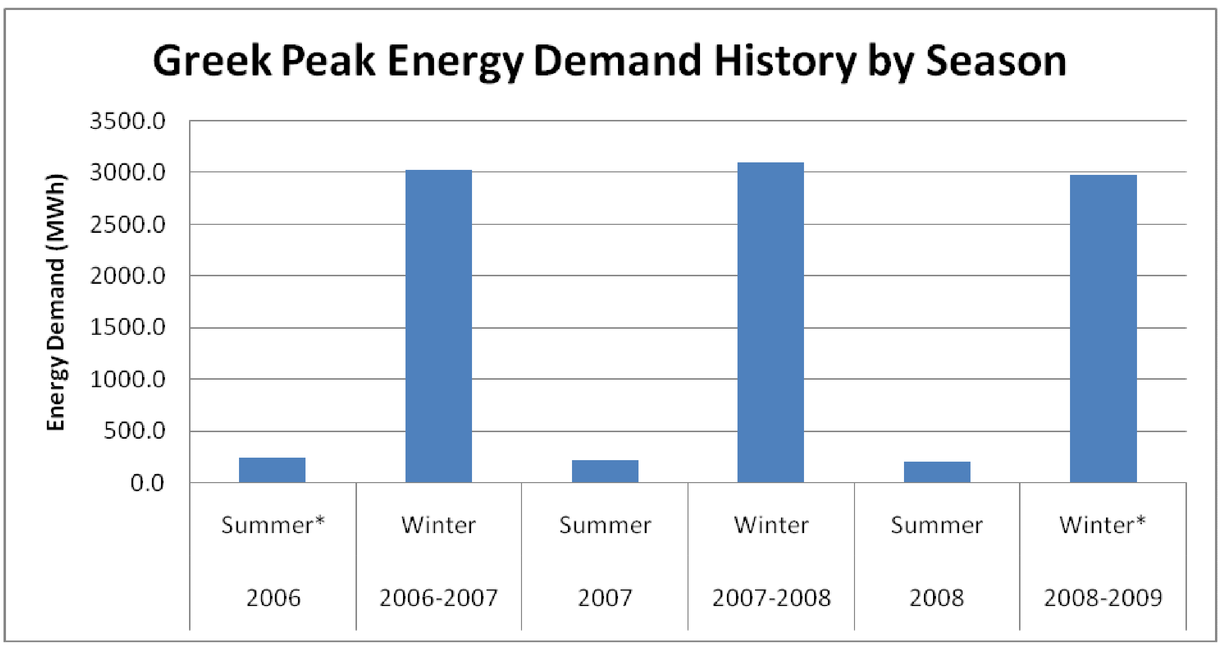


Figure III.2.3: Seasonal Energy Demand (*Projected total)

Based on the season electricity usage and generating capacity, a 1.5 MW turbine will be able to displace approximately 75% of the winter season's purchased electricity and all of the summer season demand with approximately 800 kWh sold back to the grid via net-metering. A graphical representation is shown in Figure III.2.4, with average demand for each season and the associated generating capacity during that portion of the year.

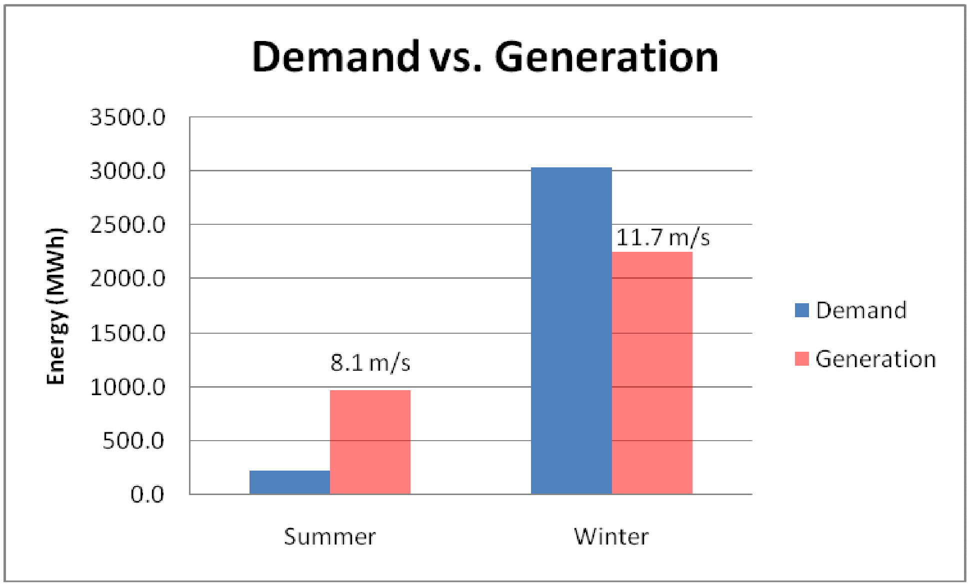


Figure III.2.4: Seasonal Energy Demand and Generation

Greek Peak is currently constructing a summer resort and swimming facility that is scheduled to open in the Fall of 2009. An estimate of electrical demand for the summer air conditioning load for this facility was not available, but it is clear the operation of this facility will raise the summer electrical demand. This will only make the construction of a wind turbine a more viable economic solution to Greek Peak's needs as the demand for that season nears the turbine's generating capacity.

III.2.1.1.4. Sensitivity Analysis

In order to analyze the importance of each factor used in the estimate of electricity generation at the Greek Peak site, a sensitivity analysis was conducted. In keeping with the energy production analysis, the sensitivity analysis was conducted based on the same two seasons. Using equations III.1 and III.2 shown below, we assumed a base case for each season given the average wind speeds shown in Table III.2.1 shown above, an 80 meter hub height, and a surface roughness coefficient of 0.2.

$$\textbf{Power} = 0.5 * \rho_{air} * A * C_p * V^3 * N_g \quad \textbf{(Equation: III.1)}$$

P = power in watts

ρ_{air} = air density (estimated at 1.15 kg/m^3)

A = rotor swept area exposed to the wind (4657 m^2)

C_p = Coefficient of performance (estimated at 35%)

V = wind speed in meters/sec

N_g = generator efficiency (estimated at 86%)

$$V = V_r(z/z_r)^{\alpha} \text{ (Equation: III.2)}$$

V=Wind speed at height z (m/s)

z=Height above ground (such as desired hub height, m)

V_r =Wind speed at reference height z_r (m/s)

z_r=Height of measured wind speed (m)

α=Surface Roughness Coefficient

Wind speed was the first parameter analyzed since we know that our data is not as precise as we would like to have for a full engineering analysis. The sensitivity analysis shows for a 5% change in average wind speed there is a corresponding change in energy output of approximately 1000 MWh in the winter and 200 MWh in the summer. Based on this analysis, it is evident that before going ahead with construction of a wind turbine, Greek Peak should erect an anemometer to measure wind speed over the course of a year under known conditions.

The surface roughness coefficient (alpha) is a measure of the roughness of the terrain surrounding the wind turbine site. Terrain features such as trees and buildings lead to higher wind shear, reducing the wind speed at a given height above ground. We are only able to assume a typical value of 0.2 without direct study of the effect of wind shear at the Greek Peak site. In order to see the effect on energy out put at Greek Peak from errors in this factor, we conducted the alpha variation sensitivity analysis in both seasons. For small changes in alpha, there is a correspondingly large effect on the amount of energy output from a turbine at this site, further making the point that it is important to accurately measure wind data at the site before going ahead with turbine construction.

Finally, for a given wind profile at a location, the builder can choose to raise their turbine height to take advantage of higher wind speed at higher elevation. GE offers two standard tower heights with the 'sle' turbine, 80 meters and 65 meters. Our sensitivity analysis was based at 80 meters, with the low end at 65 meters, and high end at 120 meters for comparison purposes. Further analysis needs to be done to determine the marginal cost of increasing turbine tower heights to discover the optimal height.

The sensitivity analysis shown in Figure III.2.5 was conducted assuming the wind was blowing at a constant speed during the entire season. In order to determine the actual levels of energy output for given season and accompanying variable's uncertainty, a Rayleigh distribution should be applied at each data point for the given wind speed in that scenario.

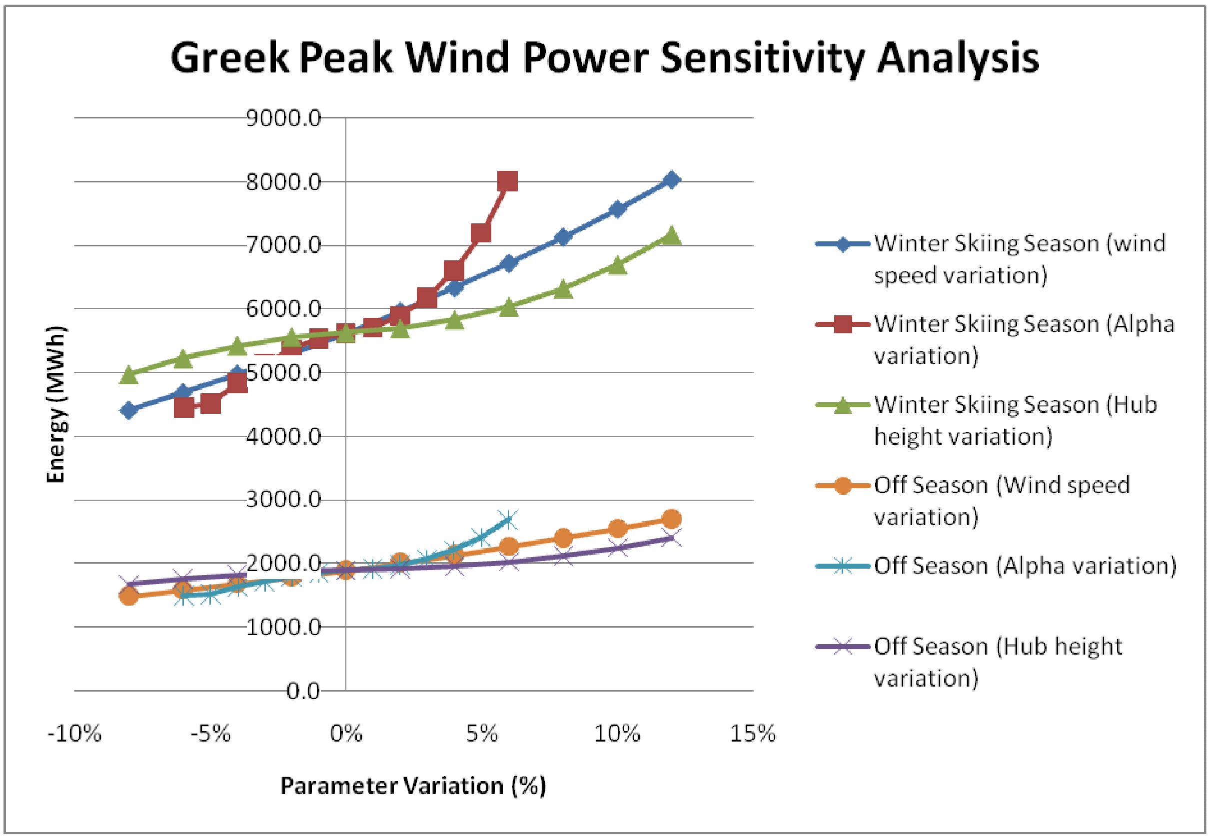


Figure III.2.5: Greek Peak Wind Power Sensitivity Analysis

III. 2.2. Construction Analysis

III.2.2.1. Town of Virgil Zoning Laws

Included in the zoning laws for the Town of Virgil is a section wholly dedicated to wind power facilities. The latter are defined as "all necessary devices that together convert wind energy into electricity, including the rotor, nacelle, generator, tower, electrical components, foundation, transformer, and electrical cabling from the tower to the substation(s)".

The relevant point from the code to our placement analysis is that the sum of the hub height plus the rotor radius should be greater than 1.5 times other private or public property. To see other relevant points outside the scope of our analysis, please check section 626 of the zoning laws in Appendix B. Since, according to the GE specifications, the rotor radius is 38.5m, and the hub height is 80m (we take the longest case), the minimum distance between the base of the tower and nearest property line should be 178m.

The following map, Figure III.2.6, taken from Google Maps, shows the elevation terrain for Greek Peak site. The locations where it is possible and reasonable to place a wind turbine are marked in red.

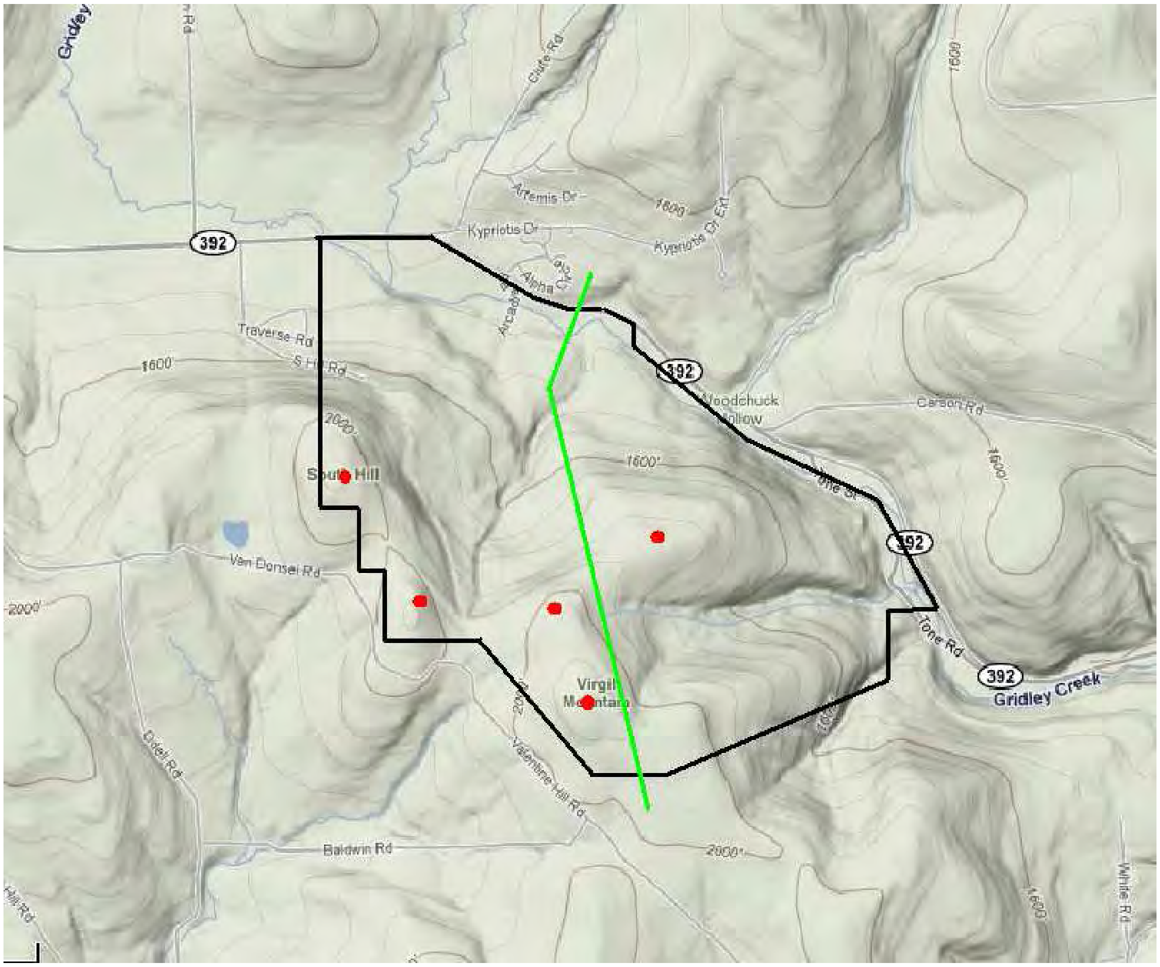


Figure III.2.6: Map of Greek Peak Skiing Facility (boundary in black) with Potential Turbine Sites (Google Maps)

Based on the area topography and proximity to property lines and transmission line right of way, we recommend the western most location on South Hill as the best location to erect a turbine. This location allows the best exposure to north and west winds and is located at one of the highest points on the property. In Figure III.2.6, the approximate boundary of Greek Peak's skiing facility property lines are shown in black with the transmission line location in green. A comprehensive property plan is shown in the appendix of this section.

Adjacent to the southern property boundary is Van Donsel Road. This road would provide excellent access to the proposed turbine sites to bring in construction vehicles and turbine components. Access from the north across the skiing slopes would be significantly hampered by the steep grade.

III.2.2.2. Grid Connection

For this study it was assumed that the nature of connection for Greek Peak to the grid system would be via a high voltage line vice a distribution line. A high voltage transmission line crosses the Greek Peak property on a right of way adjacent to the ski lodge facility and proposed turbine sites. This places a potential grid connection within approximately 1 mile of any potential turbine site on the Greek Peak property. This transmission line carries both 115 kVolt and 230 kVolt cables. In order for Greek Peak to connect to this transmission line, three basic systems must be in place. First, near the transmission line a substation facility will be constructed to increase the output voltage of the turbine to line voltage. This is the majority of cost associated with interconnection as seen in Table III.2.3 below. Second, from this substation a connection must be made to the high voltage transmission line. Third, an underground medium voltage transmission system to connect to the turbine must be installed. Underground cables are used to improve aesthetics, as dictated by the Town of Virgil zoning laws. Cost estimates for the grid interconnection are summarized in Table III.2.4.

Estimated Costs for Substation Construction and Connection to Wind Energy Project (in 2007 $000s)		
Voltage (kilovolts)	Construct New Substation	Connect with Substation
69	1064	355
115	1532	511
138	1702	567
161	2000	667
230	2510	837
345	4000	1333
500	6211	2070

Table III.2.3: Estimated Substation Connection/Construction Costs (Office of Coal, Nuclear, Electric and Alternate Fuels , 2001)

Estimated Costs of Single Circuit Alternating Current Transmission Lines	
Voltage (kilovolts)	2007 Installed Cost ($000s per mile)
115	207-620
138	207-620
230	248-620
345	578-1157
500	661-1322

Table III.2.4: Estimated Transmission Line Costs (Office of Coal, Nuclear, Electric and Alternate Fuels , 2001)

Based on the 115 kV system near Greek Peak and this data, the cost to connect to the high voltage transmission line could be between $1.74 and $2.15 million. This is a relatively high cost compared to the actual cost of the turbine. In order to justify this relatively high capital cost, it would be worthwhile to study the feasibility of installing multiple turbines on the Greek Peak property, or adjoining properties, to realize an economy of scale in the fixed cost of the substation and transmission cost compared to the lower marginal installed generation cost. In order to utilize the net metering system allowed in New York, Greek Peak would also have to reconfigure its connection to the distribution system. The resort's primary energy meter would have to be connected to the generator side of the newly constructed substation. This would allow them to utilize the energy produced by the turbine, as well as utilize energy from the grid when wind speed was not sufficient to fully supply the demanded level of energy.

There is a potentially lengthy process that is involved to get permission to connect to the transmission system. The New York Independent System Operator (NYISO) facilitates an agreement between the generator (Greek Peak) and transmission operator. This is actually an 11 step process beginning with a simple inquiry, a preliminary investigation, a detailed technical feasibility study, turbine construction, interconnection, and finally testing and acceptance by the utility. In order for the required studies to take place, Greek Peak must be placed in an interconnection queue with the other generators requesting connection in the state early in the process. Currently, there are approximately 150 generator connection requests in the queue.

III.2.2.3. Federal and New York Incentives

III.2.2.3.1. Production Tax Credit

The production tax credit (PTC) is a federal incentive for renewable projects. It basically means that people who generate electricity from renewable sources will be eligible for the PTC, which would provide them 1.9 cents per kWh for the first 10 years of the renewable facilities production. The PTC has been a major driver in the development and growth of wind energy. However, it needs to be regularly extended by the Congress. This has caused lapses when it wasn't renewed, and thus wind development has stagnated during these periods. In addition to that, obtaining an acceptance from the Federal Government may take up to two years, which makes people hesitant sometimes, especially if the PTC law is nearing its end. The PTC is also adjusted for inflation, and the amount received from it may be diminished if the owner of the property receives other kinds of grants. Overall however, the PTC reduces the cost of generating electricity from wind by 2 cents per kWh on a 20-year levelized basis. In February 2009, the Congress extended the PTC until 31st December 2012.

In addition to that, wind farms developers can choose to receive a 30% investment tax credit (ITC) rather than a PTC. However, this applies to facilities built in 2009 and 2010. After that, the ITC is converted to a grant from the Department of Treasury. Other federal policies support Wind development. As an example, Wind power property can be depreciated during a 5-year period.

III.2.2.3.2. NYSERDA Grant

New York State established the New York Renewable Portfolio Standard (RPS) to increase the energy independence of the state. Presently, the goal of the RPS is to expand New York's electricity consumption from renewable sources to at least 25% by 2013. This is also expected to result in more than $1.4 billion in direct economic benefits in the state over the next 20 years in the form of long-term and short-term jobs, new property tax-related payments, and purchases for fuels and landowner lease payments.

III.2.2.4. Aesthetic considerations

Shown in Figure III.2.7 is an edited version of a panoramic view of the Greek Peak resort, showing what a turbine would look like at the top of South Hill.

Figure III.2.7: Greek Peak with Proposed Wind Turbine

III.2.3. Economic viability

III.2.3.1 Wind Turbine Economic Model

The economic analysis provides a net cash flow model accounting for the average yearly energy consumption of the resort, the estimated yearly output of the turbine, operations and maintenance (O&M) costs, net-metering benefits, and state and federal incentives. The model assumes the use of a loan of adequate size to cover the installed cost of the turbine less an initial capital cost (estimated at five percent of installed cost) and a $150,000 grant supplied by NYSERDA. Furthermore, the repayment of the loan is assumed under a constant annuity over a 10-year period at an interest rate of eight percent. The interest rate is discounted by NYSERDA's New York Energy $mart^{SM} Loan Fund, which deducts four percent of the interest rate off of the first $1,000,000 of the loan.

The model assumes that a net-metering system will be installed, allowing excess energy produced by the turbine to be redirected into the grid, subsequently generating a credit (or “avoided cost”) for each kWh of excess energy to be stored and used to offset energy bought from the grid at a later date. Additionally, it is assumed that credits are time sensitive and thus unused or expiring credits will be purchased by the electric utility at an “avoided-cost” rate of 7.4¢/kWh (5.5¢/kWh for alleviating demand and a tax rebate of 1.9¢/kWh).

The analysis of a 1.5 MW turbine at Greek Peak relies on available site and weather data, the resort’s utility bills from the past two years, construction costs of similar projects, and turbine performance data from GE. The average cost per kWh, based on the utility bills, was determined to be 16¢/kWh and includes peak charges and late fees; effectively, it is the total resort-wide cost of electricity for 12 months of operation divided by the total kWh used in those 12 months. Electric costs are inflated at a rate 3.13 percent per year and “avoided-cost” rates are escalated at 1.00 percent per year. O&M costs are estimated at 0.5¢ per kWh and are inflated yearly at a rate of 2.85 percent. The GE turbine’s life cycle is estimated to be 50 years. In general, the aim of the model is to compare the capital cost of construction and maintenance with the potential cost savings generated by the turbine.

The cost to purchase and install the turbine has been derived from similar projects, namely Jiminy Peak, with the assumption that an Engineering, Procurement, and Construction (EPC) firm would be employed to perform the turbine selection, site design, installation, and commissioning (typical of the industry). The cost breakdown for the potential work (estimated from industry standards) is detailed in Table III.2.5 below and shows both turbine cost and a lump sum for design, permitting, construction, commissioning as well as the connection cost estimate. Costs are shown in 2008 dollars.

	Percentage of Total Cost (%)	Cost of Project Phase
Design	10%	$618,825
Permitting	3%	$206,275
Construction & Materials	48%	$2,887,850
Commissioning	7%	$412,550
Connection cost	32%	$1,945,000
Total	100%	$6,070,500

Table III.2.5: Summary of Greek Peak Turbine Project Costs

The externalities for the turbine (the benefits and negative side-effects that are not directly monetary) are excluded from the economic model, and are considered separately for their environmental affects, community impacts, and social costs. Avian studies, wetlands assessments, endangered species studies, and visual/noise impact studies are beyond the scope of this report, but are acknowledged as critical elements of a wind turbine design at the Greek Peak ski area.

III.2.3.2 Evaluation Results

III.2.3.2.1 Economic Model Results

The 1.5MW GE turbine at the Greek Peak site is estimated to produce 3227 MWh over the course of a year, satisfying the resorts demand (3.3 MWh). 128,000 kWh worth of unused credits are generated and resold to the utility at the "avoided-cost" rate of 7.4¢ per kWh. Table III.2.6 summarizes the input values for the economic model. Figure III.2.8 graphically displays the net cash flow during the turbine's 50-year life cycle.

Total Installed Cost ($):	**$6,070,500**
Annual Energy Output (kWh):	**3,227,000**
Additional Energy Demand (kWh):	**2,210,347**
Annual Energy Input to Grid (kWH):	**128,000**
Electricity Cost ($/kWh):	**$0.1600**
Electricity Resale ($/kWh):	**$0.0740**
Electricity Inflation Rate (%):	**3.13%**
Resale Inflation Rate (%):	**1.00%**
Loan Downpayment (%):	**5.00%**
Down Payment ($):	**$303,525**
Amount of Loan ($):	**$5,616,975**
Interest Rate (%):	**8.00%**
Loan Term (Years):	**10**
Month Installed:	**0**
O & M Cost ($/kWh):	**$0.005**
O & M Inflation Rate (%):	**2.85%**
NYSERDA Grant:	**$150,000.00**

Table III.2.6: Economic Model Inputs

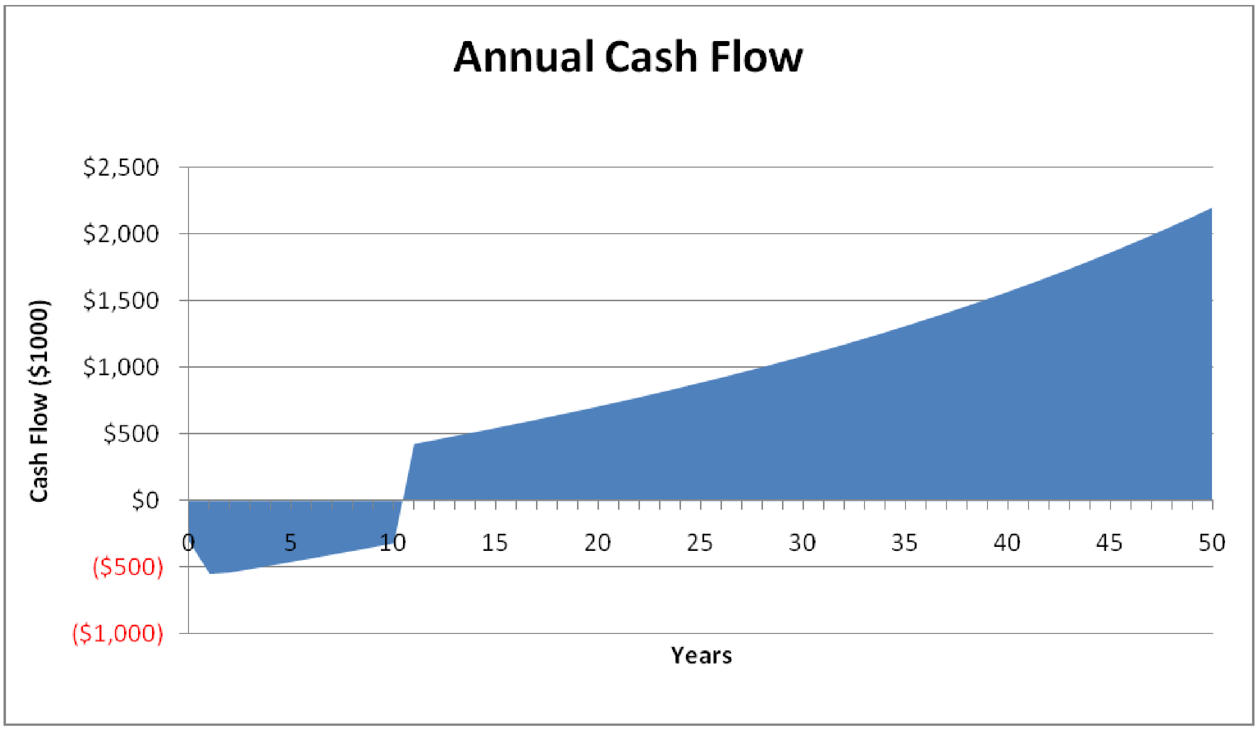


Figure III.2.8: Net Cash Flow Diagram

An initial capital cost of $303,525 (5% of the total investment) is assumed and with the total amount of the loan for the turbine being $5,616,975 with yearly payments of approximately

$717,674 over a 10-year period will be required. The annual cash flow becomes positive in year 10 due to the turbine's production and the loss of the yearly loan payment. However, the project does not fully pay for itself until its 40th year of operation.

Part III.2 Greek Peak References

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Appendix A: GE 'sle' 1.5 MW Wind Turbine Technical Specifications

Operating Data

Rated capacity	1,500 kW
Cut-in wind speed	3.5 m/s
Cut-out wind speed 600 s average	25 m/s
Cut-out wind speed 30 s average	IEC s: 28 m/s
Cut-out wind speed 3 s average	IEC s: 30 m/s
Cut-back-in wind speed 300 s average	IEC s: 22 m/s
Rated wind speed	12 m/s

Rotor

Number of rotor blades	3
Rotor diameter	77 m
Swept area	4,657 m^2
Rotor speed (variable)	10.1 - 20.4 rpm

Tower

Hub heights (m)	80

Power Control

Active blade pitch control

Operating Limits (outside temperature)

- Cold weather light: -4 to 104 °F (-20 to 40 °C)
- Cold weather extreme: -22 to 104 °F (-30 to 40 °C)/-40 °C to +50 °C survival without operation

Control System

- Programmable logic controller (PLC)
- Remote control and monitoring system

Gearbox

- Three-step planetary spur gear system

Generator

- Doubly-fed three-phase asynchronous generator

Braking System (fail-safe)

- Electromechanical pitch control for each blade (three self-contained systems)
- Hydraulic parking brake

Yaw System

- Electromechanical driven with wind direction sensor and automatic cable unwind

Converter

- Pulse-width modulated IGBT frequency converter

Tower design

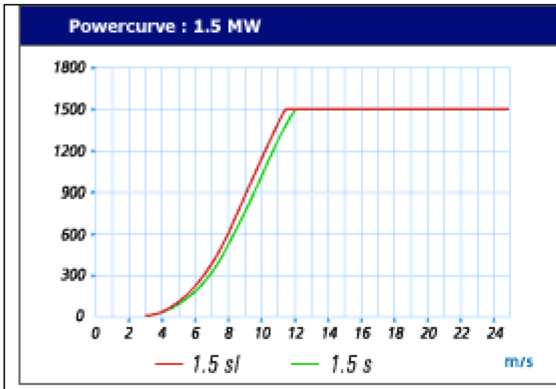
- Multi-coated, conical tubular steel tower with safety ladder to the nacelle
- Load lifting system, load-bearing capacity more than 441 lbs (200 kg)
- Service platform for 100 m hub height (service lift optional)

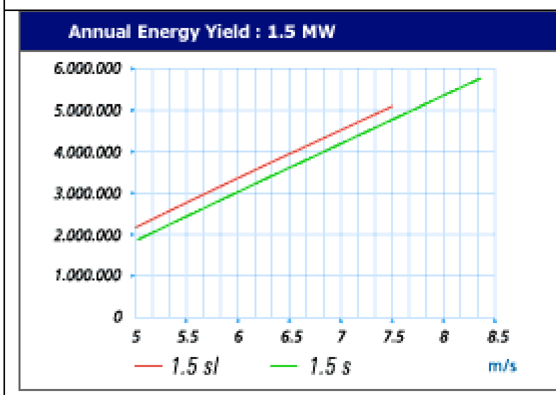
Noise Reduction

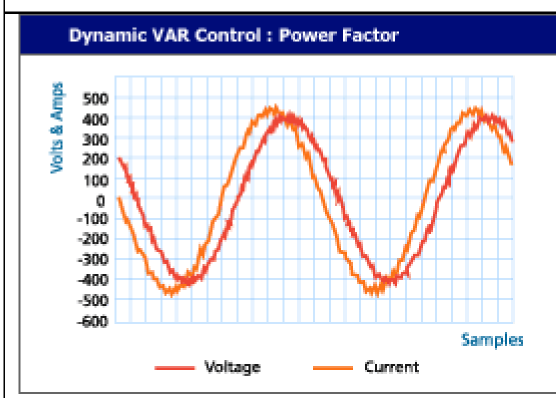
- Impact noise insulation of the gearbox and generator
- Sound reduced gearbox
- Noise reduced nacelle
- Rotor blades with minimized noise level

Lightning Protection System

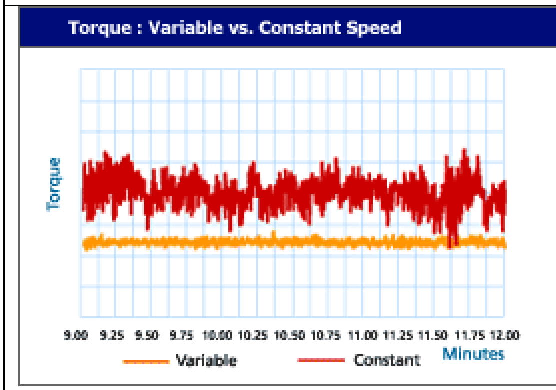
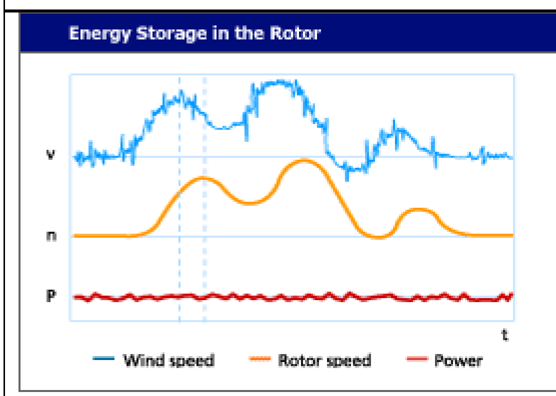
- Lightning receptors installed on blade tips
- Surge protection in electrical components
- 1.5 MW Wind Turbine Technical Data







GE's patented dynamic power conversion system with VAR control technology enables the wind turbine to generate reactive power (current leading voltage),

providing transmission efficiencies and enhanced voltage stability, which is particularly beneficial in weak grid applications.

GE's variable speed operation provides reduced mean torque loads and smaller torque excursions for a given power output compared to constant speed wind turbines.

The energy of a gust is stored by accelerating the rotor. This leads to reduced loads, improved transmission efficiencies and performance.

Note: specifications subject to possible modification.

Appendix B: Section 626 of Town of Virgil Zoning Laws, Wind Power Facilities

A. The minimum setback distance between each production line commercial wind power electricity generation unit (wind turbine tower) and all surrounding property lines, public road rights-of way, overhead utility lines, any dwellings, and any other generation units, above-ground transmission facilities, electrical substations, and separate meteorological facilities, shall be equal to not less than 1.5 times the sum of the proposed tower height (hub height) plus the rotor radius. No experimental homebuilt or prototype wind turbines shall be allowed without documentation by the applicant of their maximum probable blade throw distance in the event of failure and determination by the Planning Board of appropriate setback distances on the basis of that documentation.

B. No individual tower facility shall be installed in any location along the major axis of an existing microwave communications link where its operation is likely to produce electromagnetic interference in the link's operation.

C. No individual tower facility shall be installed in any location where its proximity with existing fixed broadcast, retransmission, or reception antenna (including residential reception antenna) for radio, television, or wireless phone or other personal communication systems would produce electromagnetic interference with signal transmission or reception.

D. Use of nighttime, and overcast daytime condition, stroboscopic lighting to satisfy tower facility lighting requirements for the Federal Aviation Administration may be subject to on-site field testing before the Planning Board as a prerequisite to that Board's approval as it applies to existing residential uses within 1500 feet of each tower for which such strobe lighting is proposed, on property belonging to anyone other than the owner of the property where the tower is located.

E. Individual wind turbine towers shall be located with relation to property lines so that the level of noise produced during wind turbine operation shall not exceed 50 dbA, measured at the nearest neighboring residence at the time of special use permit application.

F. No wind turbines shall be permitted that lack an automatic braking, governing, or feathering system to prevent uncontrolled rotation, overspeeding, and excessive pressure on the tower structure, rotor blades, and turbine components.

G. The minimum distance between the ground and any part of the rotor blade system shall be thirty (30) feet.

H. All power transmission lines from the wind electricity generation facilities to on-site substations shall be underground.

I. Prior to issuance of a Building Permit, the applicant shall provide the Town proof, in the form of a duplicate insurance policy or a certificate issued by an insurance company, of liability insurance, of a level to be determined by the Town Board in consultation with the Town's insurer, to cover damage or injury which might result from the failure of a tower or towers or any other part(s) of the generation and transmission facility.

J. In addition, the following material shall be submitted to the Planning Board for commercial wind power electricity generation and/or transmission facilities:

- Digital elevation model-based project visibility map showing the impact of topography upon visibility of the project from other locations, to a distance radius of three miles from the center of the project. Scale used shall depict 3-mile radius as no smaller than 2.7 inches, and the base map used shall be a published topographic map showing cultural features.
- The applicant shall provide color photos taken from locations within a 3 mile radius from the proposed tower location(s), and computer-enhanced to simulate the appearance of the as-built aboveground site facilities as they would appear from these locations.

K. Prior to receiving siting approval under this Law, the Applicant, Owner, and/or Operator must formulate a Decommissioning Plan to ensure that the Wind Power Facility is properly decommissioned. The Decommissioning Plan shall include:

1. Provisions describing the triggering events for decommissioning the Wind Power Facility.
2. Provisions for the removal of structures, debris and cabling, including those below the soil surface;
3. Provisions for the restoration of the soil and vegetation;
4. An estimate of the decommissioning costs certified by a Professional Engineer;
5. Financial Assurance, secured by the Owner or Operator, for the purpose of adequately performing decommissioning, in an amount equal to the Professional Engineer's certified estimate of the decommissioning costs;
6. Identification of the procedures for the Town of Virgil access to Financial Assurances;
7. A provision that the terms of the Decommissioning Plan shall be binding upon the Owner or Operator and any of their successors, assigns, or heirs; and
8. A provision that the Town of Virgil shall have access to the site, pursuant to reasonable notice, to effect or complete decommissioning.

Appendix C: Greek Peak Property Plan

III.3. OFFSHORE WIND FARM: CAPE WIND PROJECT

III.3.1. Offshore general study

III.3.1.1. Offshore wind advantages over onshore wind

Wind power is the fastest-growing energy source worldwide with growth rates of about 20-30% per year [15]. While an overwhelming majority of current and future wind farms are constructed for onshore sites, a substantial amount of resources have also been used to develop wind turbine projects in offshore locations. Over the past 20+ years, onshore wind energy technology has matured to the point where it can finally provided electricity at prices competitive with classic electricity production technologies. Offshore wind farms have the potential to repeat the success of their onshore counterparts by using similar technologies and benefitting from the advantages associated solely with offshore wind sites [1, 2]. In general, offshore wind sites feature:

- Better wind resources since the average wind speeds are higher and more consistent due to sea level flatness causing less turbulence.
- Closer proximity to densely populated urban coastal cities
- Less aesthetic concerns, since the farms can be barely seen (or not seen at all) from the shore and are not actually placed in anyone's backyard
- Larger turbines can be utilized since transportation of parts is easier over water, which means more efficient capture of the wind resource
- Extensive offshore areas are available, encouraging the development of large projects
- Low lifetime CO_2 emission per unit of electricity generated
- Shorter towers can be used because of lower wind-shear (smaller friction on the interface water-air than air-earth surface)
- Regional development and the creation of new job opportunities in manufacturing and construction

Figure III.3.1 shows the US wind energy resource measured/estimated by the National Renewable Energy Lab. It can be seen that the US has vast wind resource potential in the central part of the country, featuring many extensive locations with winds that average 7-8 m/s average wind speed at elevation of 50 m. However, while these onshore sites are classified as “good” and “excellent” resources, offshore wind energy resource potential is often ranked as “outstanding,” with 8-9 m/s average wind speeds in many locations. Key areas ripe for wind farm development include the coasts of the Great Lakes, New England the Mid-Atlantic states, Virginia and the Carolinas, the West Coast near Oregon, Puget Sound, and California. These locations coincide significantly with the location of many major metropolitan cities, such as New York City, Los Angeles, Chicago, San Francisco, etc, as is shown in the inset of the Figure III.3.1. Since half of the US population resides within 50 miles from the coasts and from the Great Lakes substantial offshore development could provide significant power sources for areas that historically draw the highest demand in the country.

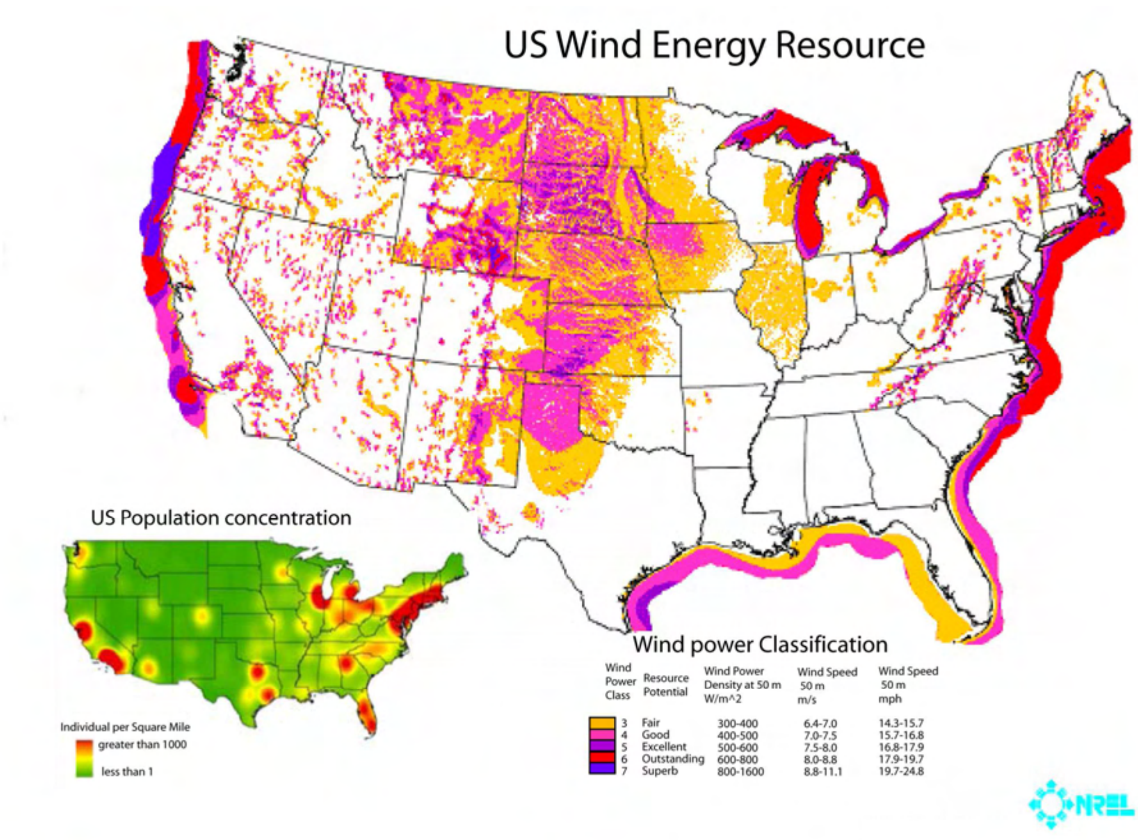


Figure III.3.1: Map of the US wind resource [3]

(The inset shows the population concentration distribution)

In addition to noting the huge potential for offshore wind by region, the same potential can be classified by seafloor depth. In general, deeper water generates higher turbine installation costs. The deepest current installation is the Beatrice Wind Farm Demonstration Project off the coast of Scotland, which features wind turbines installed in 45 meters of water [9]. Beyond this depth, 50 meter is estimated to be depth at which the costs to secure the foundation of the turbines to the seas floor become prohibitive [10]. However as technology improves, deeper waters will become accessible. The possibility of floating turbines is currently undergoing research for use in waters up to 200 meters deep, so producing energy from far-offshore sites may indeed be a possibility in the future [10]. In the US, the potentially available wind energy capacity for different sea depth for select regions is shown in Figure. 2. As can be deduced from the graph, a large portion of the wind resource in the U.S. is currently unavailable for utilization due to seafloor depth restrictions:

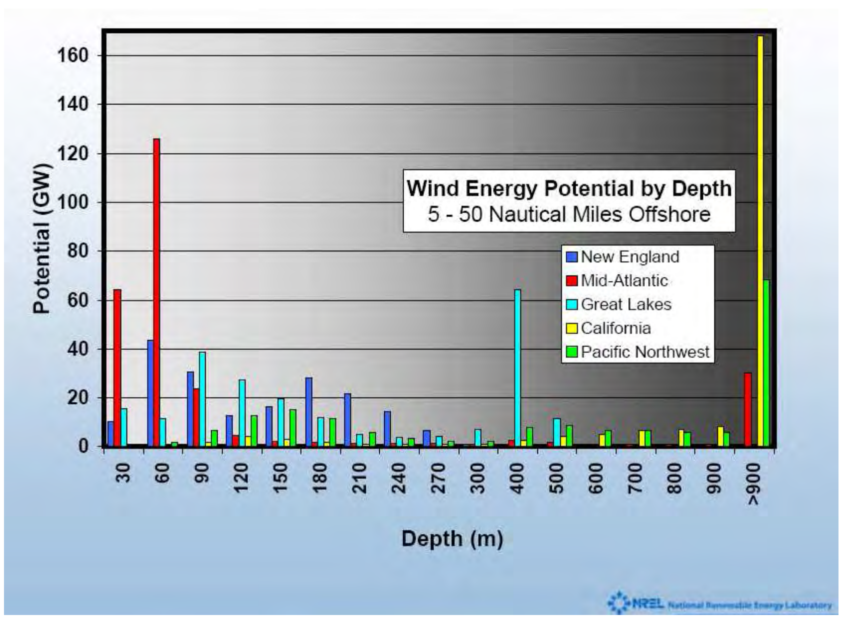


Figure III.3.2: Potential wind energy available verses sea depth for five US regions [1].

III.3.1.2. Offshore wind energy challenges

While offshore wind in theory initially appears to be a much better alternative than onshore wind development, developing offshore farms is actually far more challenging than developing and constructing onshore ones. There are a number of technical challenges that translate into higher economic cost resulting in overall higher capital requirements which can and have hindered widespread offshore development.

III.3.1.2.1 Economic aspects

Offshore wind turbines are mounted on massive foundations that must be constructed completely on land and shipped to the offshore site. Erection of a foundation and installing the turbine on top of it is more complicated and more expensive than on on-shore sites. Connecting from the grid to the farm is through underwater cables, for which installation is also more expensive. In general, access to offshore turbines is more difficult and therefore the maintenance is more expensive. As a result of the enumerated reasons, the construction of offshore farms takes longer time and the payback period is longer.

III.3.1.2.2 Technical aspects

Offshore wind farm construction is technically more challenging than on-shore construction, as is highlighted in the following list of difficulties:

- Design and mounting of stable foundations suitable for the seabed is required and in, in the future, in deep water, special floating platforms will need to be developed and built for locations that are too deep for sea bed-mounted foundation.
- Offshore wind turbines operate in more complex and adverse environments and the structures and must have a high resistance to corrosion.
- Turbines and supports must be design to operate effectively at high waves, tides, and sea currents.

- The turbine structures must withstand extreme waves, hurricanes, and severe weather conditions such as icing. Because the access is limited, turbine must be able to operate with less frequent maintenance.

For some countries that have offshore shelves with limited regions of shallow waters suitable for sea-bed mounted offshore wind farms or other issues limiting the development of offshore wind farms with sea-bed foundation, floating wind farms might become their choice if the offshore wind energy could provide a substantial source of energy. Also due to the high cost and technological challenges of offshore wind farm foundations, floating wind farms may be advantageous. Appendix A includes more detailed information regarding the current status of the development of floating offshore wind farms.

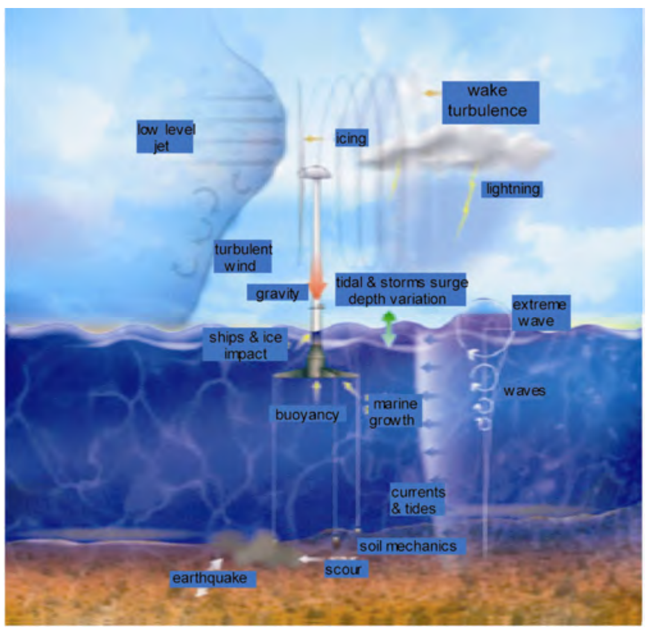


Figure III.3.3: Offshore wind technical challenges [4]

III.3.1.2.3 Manufacturing Aspects

With regards to manufacturing aspects of wind turbines, the two most important problems affecting offshore wind farm construction are the availability of wind turbines, and (to a slightly lesser extent) the availability of large installation vessels needed to transport turbine and turbine foundation components to offshore sites. Other developers have cited difficulty in locating proper interconnection sites with onshore grid networks [11].

III.3.1.2.4 Social and Environmental Aspects

Where offshore wind projects are visible from the coast, coastal residents may complain about the aesthetic appearance of these structures and their disturbance to the natural landscape. While this issue is a valid one, the installation of on-shore wind turbines is considered to be even more aesthetically unpleasing, thus offshore wind power has an advantage in this case over on-shore power.

The placement of offshore wind turbines has the potential to disrupt shipping routes, and thus can pose a danger to ocean vessels. This problem, in most instances, can be solved through strategic placement of turbines, rerouting of shipping routes, and improving the safety of the turbines by adding lights which ship captains can easily avoid.

Commercial fishing may be disrupted due to wind farm installations, which has drawn much outrage in certain instances. While the issue is currently being studied, the restricted areas around the bases of the turbines have also been shown to create new habitats for wildlife [16]. Still problems linger.

Finally bird kills have been observed via the turbulence associated with wind turbine blade rotation. It has been found however that this is an insignificant cause of death among birds. Still, wind farms should be placed out of the way of major migration paths of bird flocks.

III.3.1.3. Existing offshore farms and planned projects

Although recently U.S. has made some significant steps towards planning future offshore wind projects, Europe currently leads the world in offshore wind power development due to strong wind resources located in the shallow waters of the North and Baltic Seas.

Denmark was the first country to install an offshore wind farm, which it completed in 1991. The Vindebay project features 11 turbines (450 kW capacity each, see the inset in Fig. 4c) which have been working continuously for 18 years [6]. Since then, the offshore wind power has been increasing steadily in Europe to achieve capacity of 1471 MW (Fig. III.3.4a) at the end of 2008 [6]. Considering all the projects which are planning and designing phase, the projections is for capacity of 37.4 GW in 2015 (Fig. III.3.4b) [6].

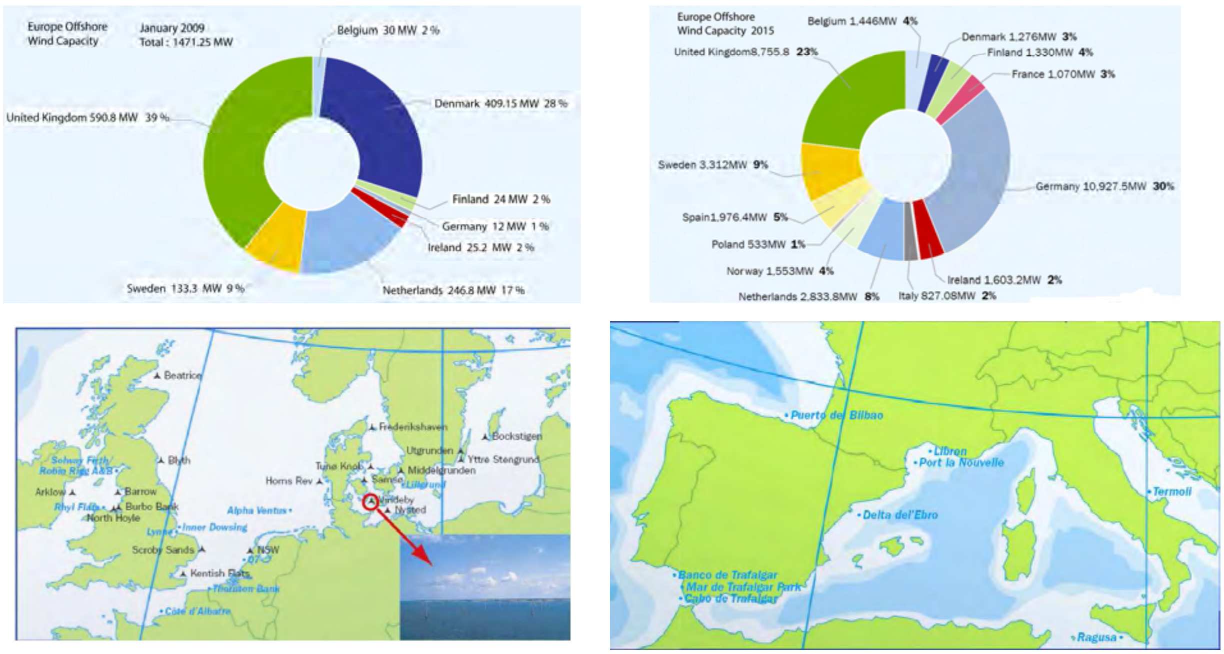


Figure III.3.4: (a) European offshore wind energy capacity in 2009 [5] and (b) in 2015. (c) and (d) operational offshore farms (in black, red circle denotes the first offshore wind farm Vindebay) and planned farms to be completed in 2009 (in blue) [6]

Denmark's dominance in installed nameplate capacity was eventually surpassed in October 2008 when the UK set a new benchmark of 590MW of installed capacity [11]. Since then, (as of January 2009), the 194 MW Lynn and Inner Dowsing Wind Farm off the coast of Lincolnshire, the UK has become the world's largest offshore wind farm capacity [12]. Many offshore wind farms are under construction and the largest of these is the 500 MW Greater Gabbard Wind Farm in the UK [13]. New offshore wind farms which are proposed include the 1,500 MW Atlantic Array and the 1,000 MW London Array, both in the UK. [14].

From the experiences of existing wind farms in Northern Europe, it has been determined that site survey work is more time consuming and costlier than initially expected in the pre-construction phase. Appropriate wind farm project scheduling is much more important than previously thought due to the difficulties associated with commissioning farms in the autumn under disruptive weather [24].

III.3.2. Site study

III.3.2.1. Cape Wind Project in Cape Cod, MA

III.3.2.1.1. Project descriptions

The offshore site study is modeled after an existing project named the Cape Wind offshore wind farm. The Cape Wind Project is a $900 million endeavor proposed for installation on a part of the Nantucket Sound called Horseshoe Shoal, in Cape Cod, Massachusetts [17]. It is being developed by Cape Wind Associates, and if completed on schedule, will be the first offshore wind energy project in the US. The site study is heavily based on the findings of previous work done on assessing the practicality and validity of this project. However, this study differs from the Cape Wind Project because 100 - 5MW Repower turbines are used instead of 130 3.6MW Vestas turbines. Thus the area covered, electricity produced, and many other factors will be different from the Cape Wind Project. Still, it is important to first lay out the design of the proposed Cape Wind Project to learn about the pertinent site information, the relevant interconnection aspects, and how the project will fit into the overall energy plan of the Cape Cod region.

The footprint of the Cape Wind project will cover 64.7 km^2 (24 mi^2), and will be situated 25.4km (15.8 mi) from Nantucket [17]. The 130 horizontal-axis 3.6 MW Vestas turbines will have a hub height of 86.9 m (285 ft), a blade diameter of 111 m (364 ft), a lowest blade tip at a height of (75 ft) above the water surface, and a highest blade altitude of 134.1 m (440 ft) above sea level [17]. The turbines would be situated between 4 and 11 miles (6.4 and 17.7 km) off the shoreline and at peak generation will produce 420 MW of electricity (enough to power 420,000 homes) [17]. On average, 170 MW will be produced, which is substantial to cover about 75% of the demand for

Cape Cod, Martha's Vineyard, and Nantucket Island [17]. The project will produce enough energy to offset the equivalent of almost a million tons of carbon dioxide a year, and will produce enough energy to offset the equivalent of 113 million gallons of oil annually [17].

Currently 45% of the area's electricity comes from the Canal Power Plant in Sandwich, which burns #6 bunker oil and natural gas [18, 19, 20]. Although exact statistics on the percentage of each used are unavailable, it has been stated by the manger of the Canal station plant, Parker Koopman, that the facility has to ability to switch fuel sources between oil and natural gas at any time, but that the oil-burning unit is considered the primary unit and the one most often used [20]. So, unlike most wind energy resources, the offset fossil fuel in the case of the Cape Wind project will primarily be oil instead of coal. The project can benefit the cape due to the fewer required shipments of oil into the power plant, which has experienced two major oil spills since 1976. During the first event, the *Argo Merchant* ran aground and spilled 7.7 million gallons of oil off the coast of Nantucket in 1976 [21]. During the second, a barge full of oil meant for the Mirant Canal Generating Plant ran aground spilling 98,000 gallons of oil, killing 450 birds and shutting down 100,000 acres (400 km^2) of shell fishing beds [22].

In terms of current progress, Cape Wind received final environmental approval from the Commonwealth of Massachusetts in March 2007 and from the US Minerals Management Service (regulatory authority for offshore projects) in January 2008. Construction is expected to take 18 months, and be completed in 2010, assuming financing is obtained, which is due to happen some time after March 21, 2009 [19].

There has been much public outcry over the wind farm, with longtime residents complaining of the visual effects the project will have on the horizon. However, more and more people are starting to support the project [17]. The obstacle faced now is dealing with the effects of the project on the local fishing industry, which claims that 60% of fishermen's income is generated from fish caught in Horseshoe Shoals [23].

III.3.2.1.2. Project advantages and concerns

III.3.2.1.2.1 Advantages

It is expected that Cape Cod wind farm will reduce GHG emissions by 7,374,000 tons per year and air pollution emission by several thousand tons per year. The electricity produced by the farm would replace 113 million gallons of oil per year, and the volatility of electricity cost due to changes in fossil fuel cost will decrease. During the construction, about 1000 jobs will be created, with 150 attributed to operations and maintenance activities.

III.3.2.1.2.2 Project concerns:

There are number of public concerns about this project. One such concern is that the builder of the farm is taking 64.7 km^2 (24 mi^2) of public trust land without competitive bidding. Additionally, there are concerns regarding the effect of the farm on fishing and tourism, and the wildlife ecosystem. Local aesthetic issues highlight the potential use of flashing light and horns, while fisherman and recreational boaters have navigational concerns.

III.3.2.1.3. Location

Horseshoe Shoal is a region of \ Nantucket Sound, located off Cape Cod, Massachusetts (41°32′31″N, 70°19′16″W). While the Cape Wind farm is proposed to cover 64.7 km^2 (24 mi^2), our project will encompass 29.6 km^2 (11.4 mi^2).

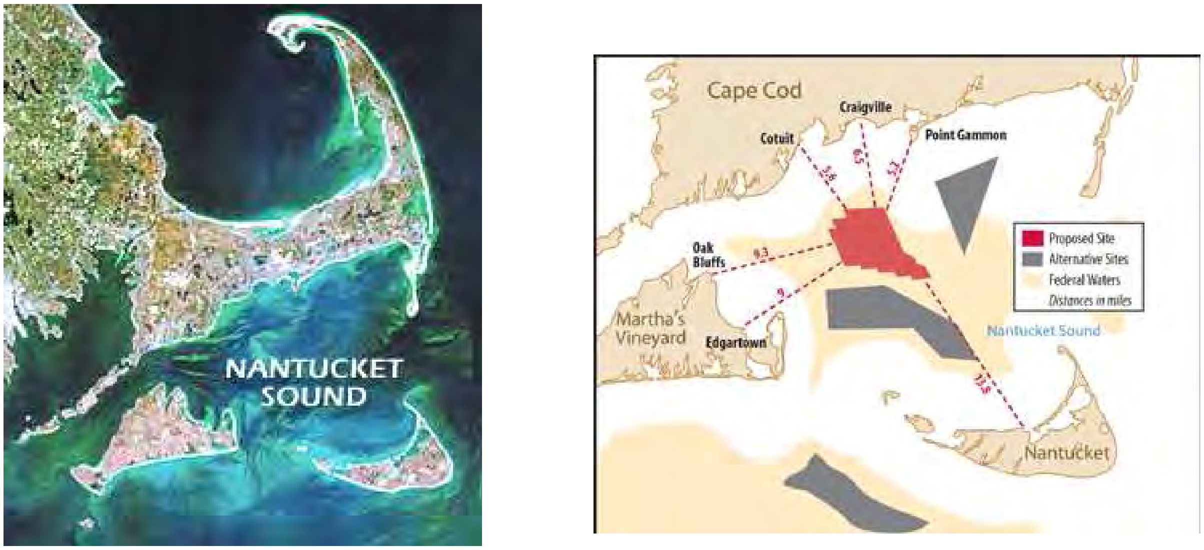


Figure III.3.5: Site Location [36]

III.3.2.1.4. Physical Characteristics

III.3.2.1.4.1. Sea depth

The sea depth in Nantucket Sound is highly variable, ranging from 0.3 to 21 meters (1 to 60 ft) at Mean Lower Water. The farm is going to be built on Horseshoe Shoals with shallow northern and southern legs and deep water in between. Within the proposed project location, the depth varies between 2.5 meters at the southern leg of the Horseshow shoal and 21 meters at the southwest boarder of the farm [7, 8].

III.3.2.1.4.2. Currents and waves

Because of the shadowing effect the islands of Nantucket and Martha's Vineyard, the wind-driven sea currents are of moderate strength. The tidal flows are stronger and typical tidal rise is between 0.3 to 1.2 meters. The water currents in the sound are primarily directed to the east and the average speed is around .6 m/s. Because of the closed nature of the sound, it is difficult to develop very high wind-driven waves. In open waters, they can reach as high as 3.7 meters but they break before reaching the wind farm area because of the shallow water [7, 8].

III.3.2.1.4.3. Weather

The weather in Nantucket Sound changes significantly in short periods. Fog and strong winds create dangerous conditions. Visibility is as low as 3.2 km during the foggy season, which runs from April until August. There are thunderstorms in the spring and summer as well as gale force winds in about 5% of the time in the October-March period [7].

III.3.2.1.4.4. Wind Resource

The wind resource of the site was determined from the NREL map for the state of Massachusetts.

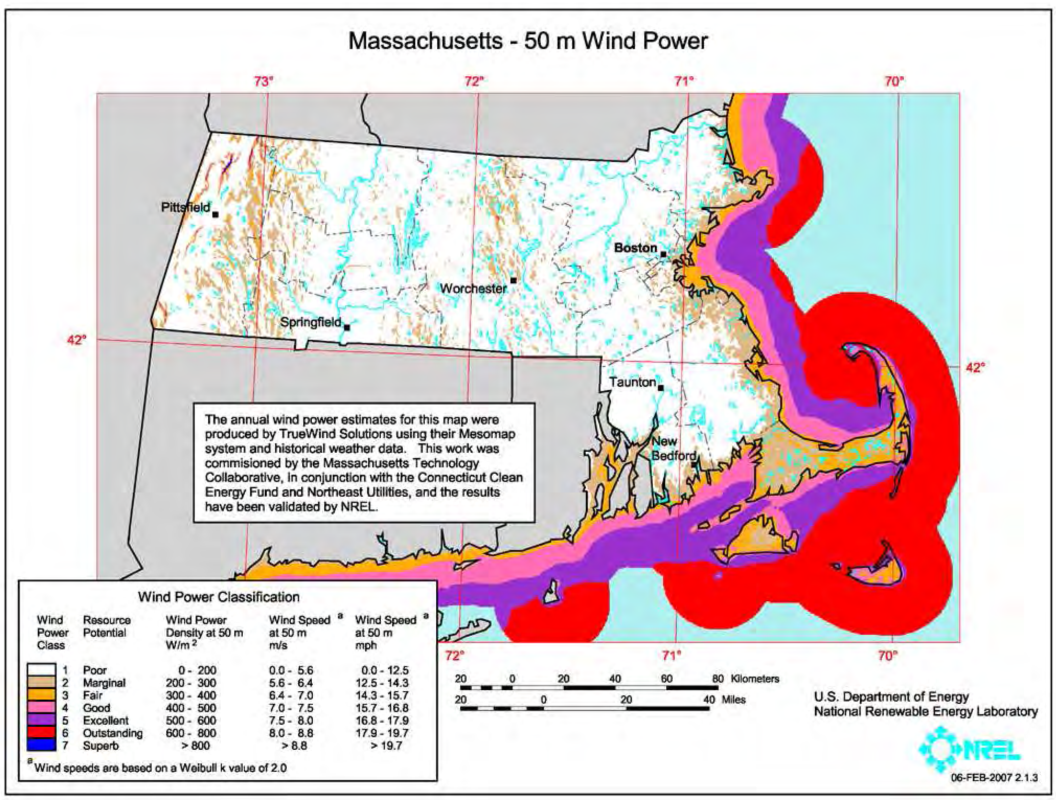


Figure III.3.6: Wind resource of state of Massachusetts at elevation of 50 m. [3]

Most of project area has “excellent” wind resources (7.5-8.0 m/s) while the southeast part of the area has “outstanding” wind resources (8.0-8.8 m/s). More detail data for the wind resource is presented in the site efficiency section of the paper.

The actual wind speed data distribution is measured at a radio tower in Nantucket, and analyzed by Renewable Energy Research Laboratory at University of Massachusetts, which gives us a sense of how wind speed varies at the Nantucket area. The following figures present a group of wind data at Nantucket from September 2005 to August 2006 [26].

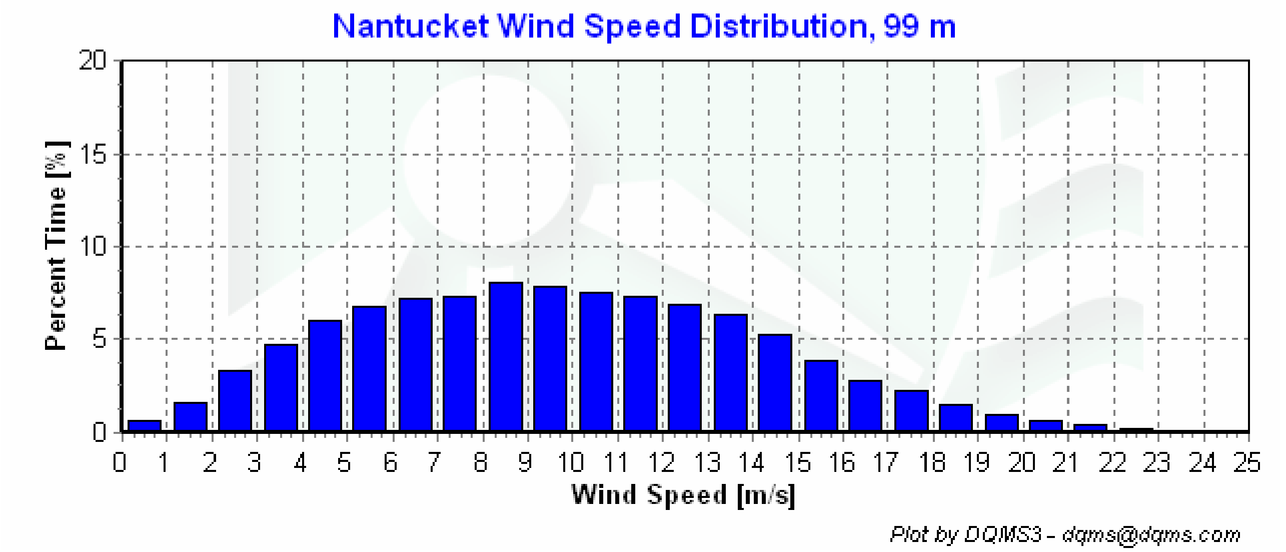


Figure III.3.7: Wind Speed Distribution [26]

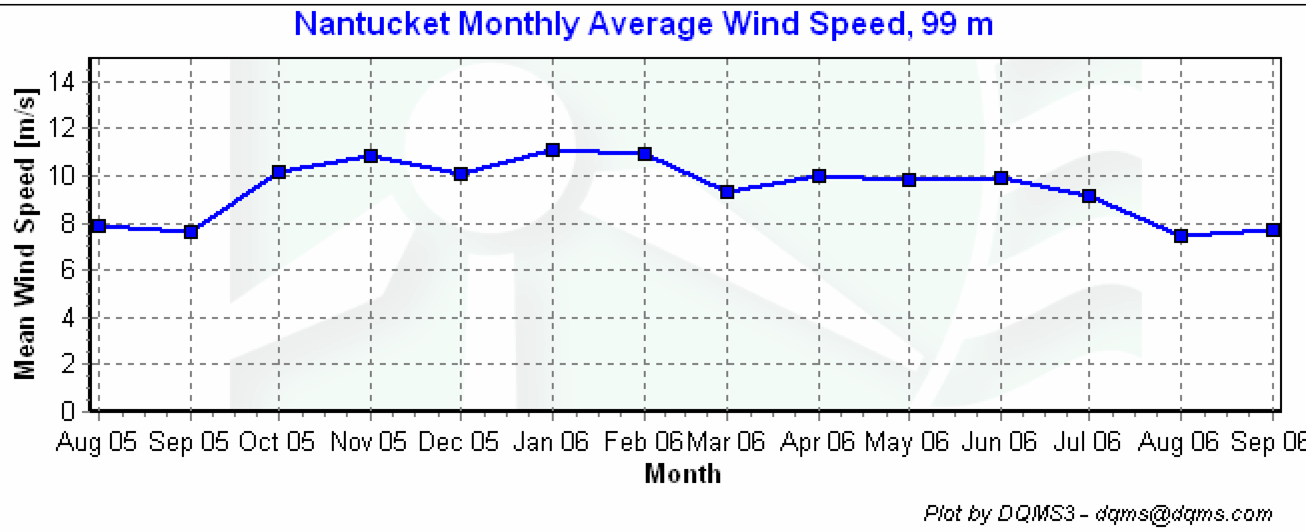


Figure III.3.8: Monthly Average Wind Speeds [26]

III.3.2.2. Modifications

III.3.2.2.1. Output Analysis

Estimation of the output of Repower 5 MW turbine at Nantucket Sound site

Based on the wind resource map, most of the farm is “excellent” and “outstanding” resource area. Assuming that the average wind speed at 50 m is 8.5 m/s, the estimated average wind speed was calculated at the REpower 5 MW turbine hub height of 95 m. Using the following equation, an estimating average wind speed of 9.7 m/s was found at the hub height.

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

Where z = 95 m, $z_r = 50$, $U(z_r) = 8.5\, m/s$ and $\alpha = 0.2$. We used Rayleigh distribution to estimate the probability of the wind speed to be in a given range when the average speed is 9.7 m/s. The results are summarized in Table 1. The turbine cut in speed is 3.5 m/s, cut-out speed is 30 m/s and rated wind speed is 13 m/s (data from Repower turbine brochure). The output of the turbine for a given range of wind speed is determined from the power curve (Figure III.3.10).

bin	min speed	Max speed	hour/ year	frequency, %	bin aver speed, m/s	prob to be in bin	Power, kW	Energy kWh for 1 year
1	0	0.5	18.4	0.210	0.25	0.002100072	0	0
2	0.5	1.5	145.8	1.664	1.00	0.01664258	0	0
3	1.5	2.5	284.3	3.246	2.00	0.032457114	0	0
4	2.5	3.5	409.0	4.668	3.00	0.046683841	0	0
5	3.5	4.5	514.1	5.869	4.00	0.058691729	126	64781.58275
6	4.5	5.5	595.9	6.802	5.00	0.068024391	352	209754.5712
7	5.5	6.5	652.0	7.443	6.00	0.074426882	648	422482.7048
8	6.5	7.5	682.0	7.785	7.00	0.077851447	1081	737218.9443
9	7.5	8.5	687.2	7.844	8.00	0.078443122	1638	1125570.939
10	8.5	9.5	670.2	7.651	9.00	0.076508517	2335	1564951.108
11	9.5	10.5	634.9	7.247	10.00	0.07247293	3170	2012515.295
12	10.5	11.5	585.4	6.683	11.00	0.066831808	4017	2351739.129
13	11.5	12.5	526.5	6.010	12.00	0.060102511	4755	2503497.985
14	12.5	13.5	462.4	5.278	13.00	0.052781499	5000	2311829.667
15	13.5	14.5	396.9	4.531	14.00	0.045310572	5000	1984603.056
16	14.5	15.5	333.4	3.805	15.00	0.038054152	5000	1666771.854
17	15.5	16.5	274.1	3.129	16.00	0.031287883	5000	1370409.294
18	16.5	17.5	220.7	2.520	17.00	0.025197454	5000	1103648.502
19	17.5	18.5	174.2	1.989	18.00	0.019885564	5000	870987.7188
20	18.5	19.5	134.8	1.538	19.00	0.015384479	5000	673840.2012
21	19.5	20.5	102.2	1.167	20.00	0.011671565	5000	511214.5633
22	20.5	21.5	76.1	0.869	21.00	0.008685492	5000	380424.5464
23	21.5	22.5	55.5	0.634	22.00	0.006341324	5000	277749.98
24	22.5	23.5	39.8	0.454	23.00	0.00454332	5000	198997.4026
25	23.5	24.5	28.0	0.319	24.00	0.003194854	5000	139934.6033
26	24.5	25.5	19.3	0.221	25.00	0.002205363	5000	96594.91838
27	25.5	26.5	13.1	0.149	26.00	0.001494583	5000	65462.72634
28	26.5	27.5	8.7	0.099	27.00	0.000994542	5000	43560.92008
29	27.5	28.5	5.7	0.065	28.00	0.000649884	5000	28464.91645
30	28.5	29.5	3.7	0.042	29.00	0.000417062	5000	18267.30739
31	29.5	30.5	2.3	0.026	30.00	0.000262878	5000	11514.06024
32	30.5	No limit	3.5		31.00		0	0

Table III.3.1: Repower 5 MW turbine output estimation.

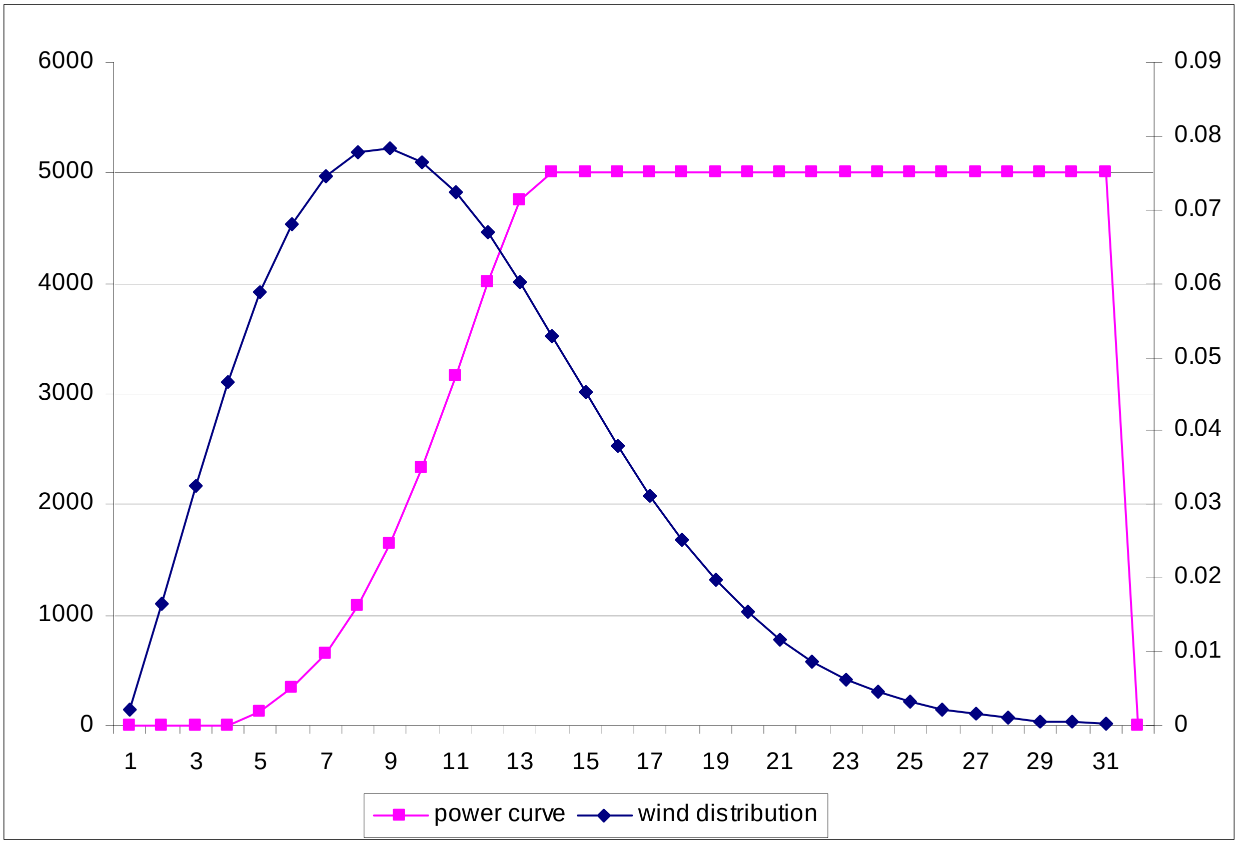


Figure III.3.9: (a) Wind speed Rayleigh distribution for average speed of 9.7 m/s. (b) Output curve for Repower 5 MW turbine (from REpower turbine brochure)

The rated capacity of this turbine is 43.8 GWh for one year. From Table III.3.1, the output of the turbine for 1 year is 22.7 GWh with a capacity factor is 51.8 %. However, based on transmission losses, this number is expected to be closer to 40%. The Cape Wind project assumes a capacity factor of 36%, so our project is slightly more efficient due to our use of larger turbines that are more efficient in converting the wind resource into electricity [16].

III.3.2.2.2. Navigation Concerns

As seen in Figure III.3.10, the site is not being built along any current shipping routes, and is thus not expected to cause any disturbance to the shipping industry.

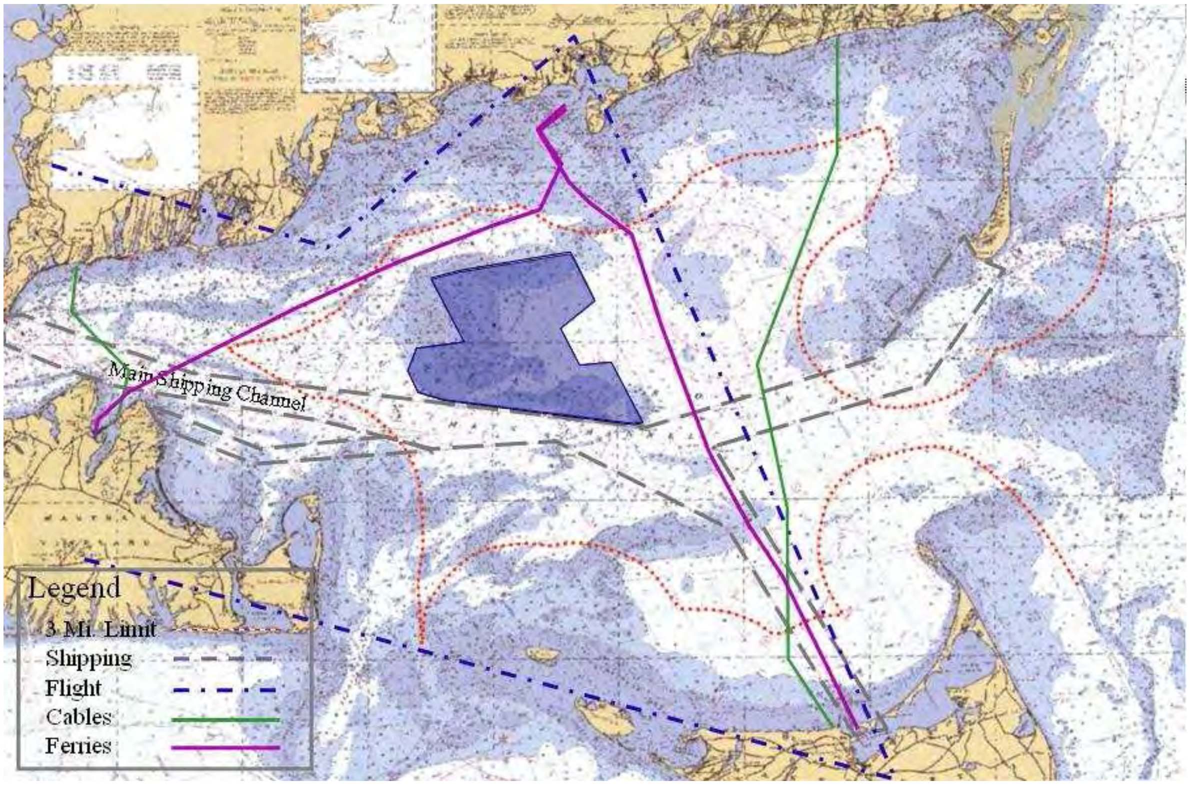


Figure III.3.10: Proposed Cape Wind Project site with nearby flight and shipping routes [17]

III.3.2.2.3. Farm Layout

While the Cape Wind project is proposing to set-up 130 3.6MW GE turbines in a grid with a minimum spacing of 0.34 nautical miles by 0.54 nautical miles, our project will compare and analyze several layout choices from the layout forms suggested in energy estimation by consulting company "Royal Haskonning" for West Rijn Project in Netherland [27]. The turbines will be connected to an electrical service platform located in the middle of the farm. The service platform will be connected to the shore with submarine electrical transmission cables buried 6 feet beneath the seabed.

III.3.2.2.4. Wind Turbine Spacing

From the online NREL calculator [28], the wind farm area was calculated as the number of turbines times the area required per turbine. This approach however ignores the turbulence impact among turbines. In the current international standards, no recommendation exists on how to take the wake and partial wake encounter into account. Henry Seifert and Jürgen Kröning have investigated the wake effects on the turbine spacing in wind farms onshore [30]. For the offshore wind turbine spacing, it could be assumed that more spacing would be needed due to ocean wave and other effects and the requirement that the wind turbines need to be able to rotate to any direction. The turbine spacing would also depend on wind direction distribution at the specific site. Using the Garrad Hassan Group's requirements for wind farm erection as a reference, we conservatively assume a distance of 8 turbine blade diameters for inter-rows and 3 diameters for in-rows, which means for each turbine the area is approximately 8 diameters × 3 diameters [29]. The numbers of turbines in each row should be determined based on transmission line and construction optimization. From Garrad Hassen's large offshore Wind Farm Wake Model, one potential layout of our farm is to place 10 turbines in a row with 10 rows in total. Using the length of turbine blade as one diameter of turbine rotor, the total area required for our wind farm is approximately 29.6 km^2. This assumes a square grid of turbines, which may not work ideally on the site due to elevation differences and ecological concerns. This information is unavailable however, and thus a more detailed design of our turbines on the site would be needed for further analysis. However it is still likely that our site will encompass a smaller area than Cape Wind's proposed layout because we will be installing 30 less turbines, and the Repower turbines have only slightly large diameters (7 meter difference) and thus will only be slightly further apart from one another.

III.3.2.2.5. Interconnections

With a few minor adjustments, the site will employ the same interconnections system as the Cape Wind project. The only differences will be cable requirements for the inter-turbine network, since fewer turbines will be installed than the amount employed in the Cape Wind project. The energy collection system begins at each turbine, where transformer equipment steps up the generation voltage (660 volts for Repower 5MW) to a medium voltage of 33 kV [32, 33]. A series of cables then connects each turbine to a network that eventually leads to the wind farm substation. These cables are typically buried 1-2 meters below the seabed, but do not always have to be [31]. The idea is that if they are buried, there is far less risk of damage from dropping anchors or debris [31]. However, since our site will not allow commercial fishing within its borders, this may not be an issue, and money can be saved by not having to bury the cables.

At the wind farm substation, which will be located near the center of the wind farm, the voltage is further stepped up to 115kV for the purposes of long-distance transmission to the onshore receiving facility. The main reason for increasing the voltage is to prevent losses and save money by using smaller-diameter cables [31]. From this substation, buried cables bring the electricity ashore, where the voltage can travel in above or below-ground cables and may even be stepped up again before reaching the receiving facility [31]. For our site, and for the Cape Wind design plan, the voltage will not need to be stepped up once ashore, since it already matches the voltage of the existing NSTAR Electric overland utility transmission lines [33]; all onshore cables to be buried underground [33]. Since the turbines produce AC power, and the onshore transmission system is AC, the connecting cables will also be High Voltage AC cables, which are widely available and have proven practical for similar purposes [33]. Also, AC cables have been shown to be cost-effective for offshore farms that are less 50 km (31 miles) from shore, which is the scenario we have in Nantucket Sound [33]. The proposed farm-to-shore interconnection system will utilize four (4) three-conductor XLPE (cross-linked polyethylene) insulated cables with diameters of 800 mm^2 installed in pairs in two separate trenches [33]. Four cables are needed because 800 mm^2 is the largest capacity, commercially available, solid dielectric AC cable that can be installed in two sub-sea trenches [33]. Also, each cable uses three conductor lines instead of a single larger one because using a single larger cable would significantly increase the costs of the interconnection system [33]. The total length of the connection system from farm to shore will be 17 miles (11 submarine and 6 on land) [33].

Cost data is difficult to estimate for any offshore wind project since cables are usually custom-made for each scenario and depend heavily on external demand, inflation and commodity pricing, and the policies of the cable supplier [31]. However, NREL was able to find estimates for cable, transformer, and substation costs, and their findings are shown in Figure III.3.11.

Costs for cables with specific conductor sizes from two companies. Highlighted costs were extrapolated from known costs.

Conductor Size mm^2	Company A	Company B
	Cost ($/m)	Cost ($/m)
Collection System		
95	152	455
150	228	494
400	381	609
630	571	635
800	600	731
Transmission System		
630	755	860

Transformer unit costs.

Location	Voltage & Capacity	Unit Cost
Wind Turbine	690/34 kV 3.16 MVA	$50,500
Offshore Substation	34/138 kV 187 MVA	$2,618,000
Onshore Substation	138/345 kV 560 MVA	$5,600,000

Installation cost breakdown.

	East Coast	West Coast
Marine Route Survey & Engineering	$1,500 K	$2,000 K
Cable Transport Via Freighter from Europe ($/m)	$58	$85
Mobilization/ Demobilization	$5,000 K	$6,000 K
Cable Laying Operations ($/m)	$94	$103

Figure III.3.11: [Modified from 33]

The substation cable from the farm will come ashore at West Yarmouth and will connect to NSTAR Electric's transmission grid at its substation in Barnstable. From there, the electricity will flow along with the existing electrical current to nearby consumer's homes on the Cape and

Islands. Figure 12 shows the wind farm's connection with NSTAR's overall electric grid, while Figure 13 shows a schematic of the farm-Barnstable substation interconnection system.

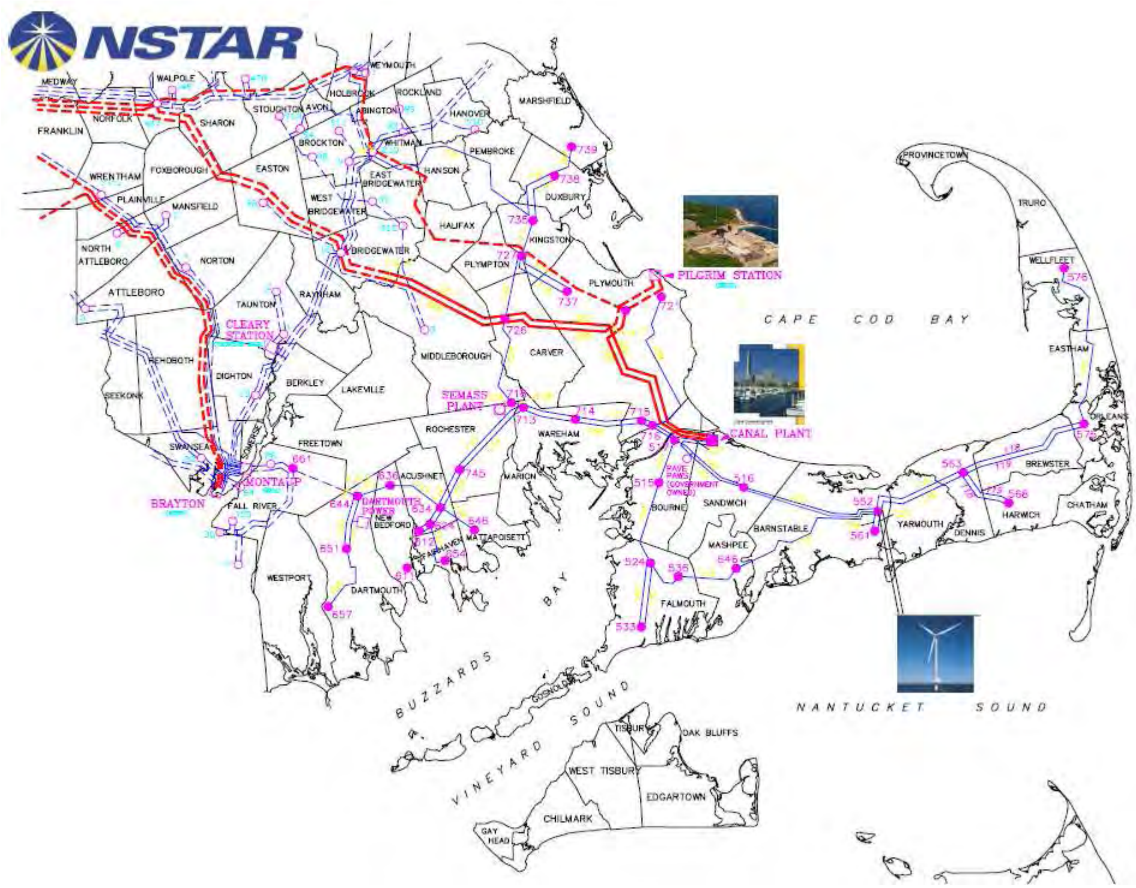


Figure III.3.12: NSTAR Electrical Transmission System. [18]

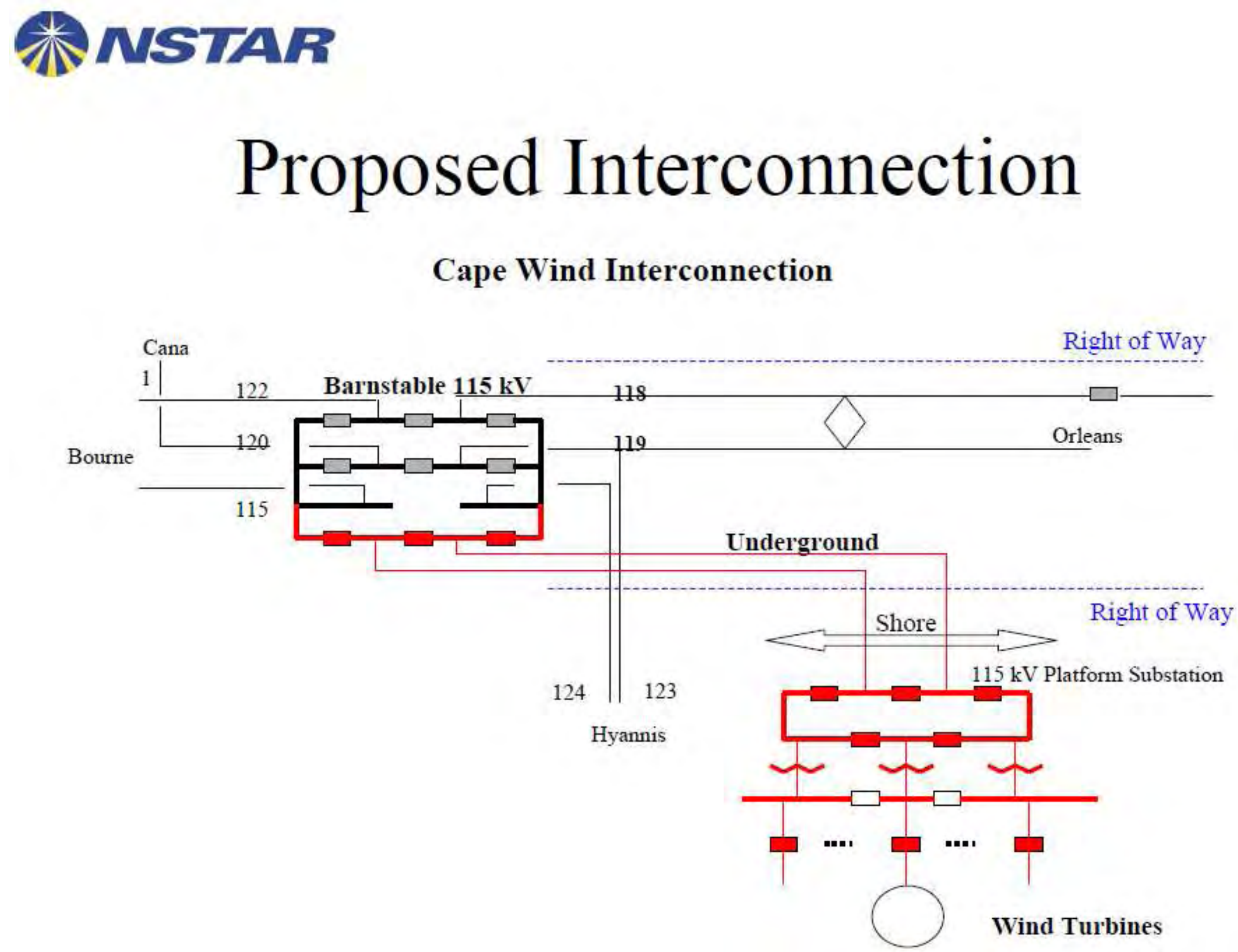


Figure III.3.13: Wind Farm – Barnstable Interconnection Schematic [Modified from 18]

III.3.2.2.6. Economic and Financial estimates

Based on previous projects and studies from, average shallow offshore capital costs range from \$2000/kW – \$2900/kW (1500€/kw - 2200€/kw) [1]. Given the value from the 2002 Horns Rev project (1650€/kw ≈ \$2175/kW) and accounting for inflation, a reasonable estimate of \$2600/kW of capacity was used in our analysis [1]. So, given our installed capacity of 500MW, our total capital costs are estimated to be in about \$1.3 billion. Given additional costs for decommissioning of \$25,000,000 (\$50,000 per MW) and annual operation and maintenance costs of \$43,800 (1¢/kWh) for 25 years of operation, this figure is expected to rise to 1.326 billion for the total life cycle cost of the wind farm [34, 35]. Using the breakdown of project capital requirements presented by the Offshore Wind Energy Organization, the majority of costs are from the turbines (45%), followed by the support structures (25%), and interconnection considerations (21%) [2]. See Figure TT for a more detailed breakdown of how capital is invested during the typical construction operations of an offshore wind farm.

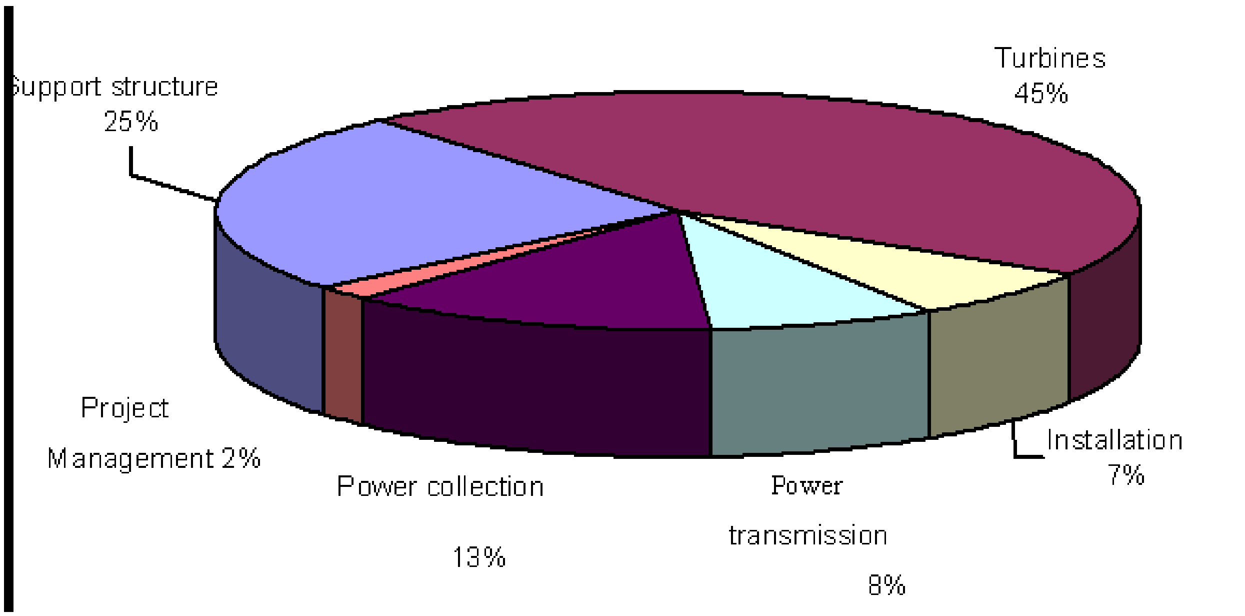


Figure III.3.14: Breakdown of capital requirements for offshore wind projects [2].

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PART IV: MAJOR FINDINGS AND SUGGESTIONS FOR FURTHER WORK

IV.1. Summary of major findings from throughout the research project

With global warming serving as the main motivation behind the growth of the wind industry, the majority of the world's leading nations have developed policies and goals to facilitate the shift in the proportion of their energy use acquired from renewable resources. While the initiatives and targets vary by country, the main goal, to reduce greenhouse gas emissions, remains the same.

Focus on the United States' policies in particular reveal that there are significant incentives as well as barriers that impact the wind industry's successful penetration into the energy market. The current US government's support for wind energy has lead to a significant demand for wind turbines, which has overloaded the current capacity of wind turbine industry to meet demand. Our analysis found that there are five major leaders in the turbine industry, but many other smaller companies have been developing innovative designs to increase their turbine output to help meet the demands.

The three site studies illustrated the diverse scenarios that the wind industry can successfully be implemented in. The Klondike III site analysis found that large-scale wind farms can create a considerable amount of power, which have the opportunity to supply thousands of homes yearly with clean energy. The analysis also found that there are certain costs relating to the construction of the wind farm, but overall the benefits outweigh the costs. The county in which the Klondike III wind farm resides also benefits from the tax incentives as well as the additional job market the wind farm creates. So, large-scale wind farms not only provide clean energy to meet rising demands but also positively impact the economic aspects of the surrounding community.

The individual-use turbine analysis at Greek Peak proved that it can be beneficial for energy savings on the direct use level, but the cost of connecting to the nearby grid may prove too high for one turbine to be cost effective. The local zoning laws as well as Federal and New York Incentives were taken into consideration when completing the analysis.

The offshore site analysis, which examined aspects of the Cape Wind Project, has many technical aspects similar to those around already installed and operating in the North and Baltic

Seas of northern Europe. This site differed from the Klondike site because the wind speeds were much greater and more consistent which provided a greater power output. Additionally, modifications to the interconnections and turbines themselves were considered for the estimate. The designed farm has the opportunity to supply the surrounding Cape Cod Area with clean energy, but many concerns such as aesthetics and environmental have yet to be addressed before installation can begin.

Overall, the demand for wind energy is increasing as technology is providing more efficient turbines and wind farms. Given the current political push towards renewable energy, the wind energy will continue to grow as a contributor to the energy industry, and will serve to lessen our country's dependence on foreign oil while creating jobs for thousands of people.

IV.2. Recommendations for further research

Based on the project findings, the team came up with a number of topics for future research:

1. Size (in terms of capacity) of Wind Turbines

   Current largest turbine is 5 MW, the vendor REpower claims that with small modifications it can reach 6 MW. Other companies are trying to design from the scratch 7 MW turbine. Some of GE engineers think that 20 MW is not out of questions.

2. Floating Offshore Turbines

   Although the offshore group briefly scratched the surface of this technology, it would have been fun to delve more into the technical aspects of this technology to figure out what the bottlenecks to its implementation are. Even though near-shore farms are the big thing right now, the potential for floating turbines is immensely higher, since they can be installed further offshore and all along the west coast, which has many coastlines that are too deep for current wind energy installation technology. It is also interested to see how much technology is borrowed from the offshore drilling industry, and it would be neat to see if any of these companies can enter the offshore wind market based solely on this aspect.

3. Integration of Offshore Turbines with Wave Energy technology

   Producing energy from waves is also considered a form of renewable energy, so it would have been interesting to study if current designs in this field could be combined with wind turbine technology to produce pieces of equipment that can harness energy from both. This may not even be possible, but the possibility is there, and it would be interesting to see if it is even practical.

4. Decommissioning and Recycling Aspects

   Wind farms claim they have useful lives of 25 years, but how much would it cost to double this? In what shape are these turbines in after that time? Do the turbines have to be completely replaced? Or can we replace a few key parts and keep everything else moving along? How does this differ for offshore sights? These are so intriguing questions future groups can look at.

5. Variations between states regarding local regulations and policies for the installation and operation of wind turbines.

   This is a subject that we initially hoped to cover in greater detail, but ultimately did not have time for. The numerous zoning restrictions, tax credits, and energy policies make for an interesting landscape with respect to wind power and it would be valuable to know which states are most conducive for the installation of wind energy and which states are more difficult. A correlation between growth in installed capacity and easy of wind farm installation is of interest to see if strong, advantageous site conditions overcome difficult policy, or vice versa.

6. Research the Issues faced by landowners who are involved with wind farm developers

   The land owner is typically a third party member to the production and sale of electricity. Their land makes it all possible, but it is not widely known if there are trends in the way land owners work with wind farm developers. An analysis of the types of land owner associations or terms desired by a land owners in their agreements might provide insight into the types of contractual agreements that are made with major developers. This could provide the ground work for setting a baseline in the negotiations between those who have the raw resource, strong wind, and those who have the means to develop it.

IV.3. Reflections

IV.3.1. PERSONAL EXPECTATIONS FOR CEE 591 WIND POWER PROJECT

Christine Acker

I am very excited to be a part of the wind energy project. Over the past year, I have followed various forms of renewable energy and take every opportunity I have to learn more about it. This semester I am also taking a course on biofuels, which will focus on ethanol produce from corn, cellulose, and sugar cane. It will be interesting to compare the sustainability of wind energy and ethanol over the course of the semester.

Coming into this project I know very little about wind energy, but I'm excited learn. I hope not only gain knowledge of the scientific side of the industry (how high the towers should be, the most effective blade design, etc) but I also hope to investigate the economic and business side. An interesting research area is finding the industries that would financially benefit the most and target them in marketing campaigns. Another topic of interest would be to complete the cost analysis of the wind turbines and calculate the number of years before the cost of the turbine breaks even.

In addition to exposure to a new topic, I have never worked in a group with such diverse backgrounds and experiences. This project will provide a crucial lesson on how to work efficiently with many different people as well as the best way to utilize the strengths of each group member. These lessons cannot be taught in the classroom and they will serve to strength team management skills. I look forwarding to gaining education as well as management experience while completing the project this semester.

Yash Agarwal

My idea to work on this project is to gain knowledge on the current topics in Wind energy and see how the markets are for this source of power. By the end of the project, I would like to see myself perfectly talking in the literature of that of a professional person working in an energy field. I would like to see more new innovative ideas that would drive the people to invest in energy (wind) related industries. Wind energy being a green energy or a pollution free energy resource would have no contributions to global warming and hence it's a healthy area to invest in but at the same time, I would like to know the ways of eliminating the downsides of investing in this business model.

Apart from this, I think that our team is comprised of various members from different backgrounds. I would like to see how these team dynamics like efficiency orientation, leadership skills, use of influence, conceptualization, spontaneous actions, logical thoughts and various other skill sets from the individual members emerge as we move along this project.

Nael Aoun

I hope to learn from this project about the different aspects of wind energy. Some background about the technology used for wind energy, how it works, in which environments or parts of the globe it can be implemented, and its limitations. I also hope to know more about the feasibility of wind farms and how construction projects of wind farms are implemented and coordinated with the government and their economic advantages or disadvantages for the national economy, taking into account what environmental improvements they may produce. Finally, I hope to become more familiar and up-to date with current trends and events happening in the energy sector internationally, meaning that I would become more familiar with the names and works of wind energy companies and different legislations that governments take individually or in concert. As for group dynamics, I hope to improve my communication skills. I also would gain experience from interacting with people from different nationalities or culture than mine, and learn from them. Finally, concerning team management, this project offers the chance to do basic task division coordination and reviews that happen in a more complex way in real life, so I hope to get some initial experience that would be useful when I begin work

Stephen Clark

My main motivation for choosing the Wind Energy Project as my MEng project is because, to me, the concepts of renewable energy and sustainability are key ideas which I feel will be crucial to the development of the U.S. and the world for centuries to come. The more I can learn about our current infrastructure and the current design and construction of wind turbines, the more capable I will be to assess where the technology is going and what needs to be done to make the substantial use of wind power a reality. I may be a fool, but I have faith that mankind can kick its habit of relying on fossil fuels before it's too late, because civilization as it is now will not survive if we don't. The implementation of renewable energy must happen, and I've actually been pretty pleased with how far we as a country have come within the past decade, and I'm pretty excited for the future. Given the new Administration has made promises to support the growth of renewables, I feel as if getting involved in this field couldn't have come at a better time.

At the same time I'm looking forward to the management/team aspects of the project, since I've never been part of a project team at Cornell and I'm interested to see how it will work out and what our final product will be. I'm also looking forward to getting to know some great people before I graduate, and to just have fun and really enjoy everything I learn.

Alejandro Hernandez

The reason I came to Cornell as a non-degree student was, in the first place, my need to experience the live in the USA and get to know how Americans live and work. Of course, I value the opportunity I have in Cornell for my education and that's why I'm taking so many courses in different schools even if I don't get any credit for them. My principal areas of interest in the academics are the sociology and politics, even though I'm an engineer. That's probably why I'm trying to focus my career in the sustainable development in general and the renewable energies in particular.

I'm applying for a job in Iberdrola (number one in wind power), and there're many possibilities I could end working for them in the US, as 40% of their international business is here, and it is sure there'll be a huge expansion of the sector in the next years.

With this little background, it will be easier for me to explain that my principal goal in the project is getting to know the people in the group, both Americans and internationals, and work together sharing our different approaches and habitudes. I hope we'll get the opportunity to work enough hours together, at least in small sub-groups, so our relation will be greater than an exchange of emails. I also hope we'll give particular importance to the group / team formation, above the final topic on wind energy.

About the project itself, it is not a new topic for me, as I had the opportunity to learn about the technology and industry situation in Europe before, but I hope I'll get to know better the situation in the US. I hope we'll be able to monitor the actions of the new administration in this field during the next months, assuring our best knowledge of updated policies and evolutions once we graduate in May. I also expect we'll focus in the problems associated with wind power (grid update, local disturbance, need of infrastructures, countryside industrialization, noise…), and our project won't merely reflect a basic economic-technical calculation.

My final expectation is forging a relation with Prof. Vanek, as I highly value his personal implication with sustainable development and I hope we'll learn from him much more than a technology.

Nancy Lin

For the project content:

1. The current wind energy use around the world;
2. Pros and Cons that wind energy has as an alternative energy, how much feasible it could be to make it at least over 10% of total energy production;
3. The possibilities to improve the current technology for mass production;
4. Its possible use combination with other energy resources;
5. Cost and economic estimate.

For the project management perspective:

1. As a relatively large team, what is the effective way to make the team through the storming period as short as possible;
2. Practice project management skills taught in class;
3. Experience in an international team (we have members from different countries).

4. Project documentation and data management skills.

Jesse Negherbon

There are multiple objectives that I hope to accomplish over the course of this term project in wind energy. The immediate objectives revolve around developing my understanding of the energy market and wind technology's place within it, and employing the teamwork and project management skills that I learned over the course of last term in Project Management, Managerial Decision Making, and Negotiations.

With respect to the energy market and wind power, I am interested to know more regarding the major turbine manufacturers, how much of the technology the US imports versus exports, and what software and models are commonly used to evaluate turbine sites and performance measures. I also intend to develop my knowledge of the general energy market and how different energy sources factor into the grid and consumer consumption. The federal/state incentives and regulations for wind energy have appeared convoluted in my previous studies and I would like to obtain a firmer grasp on such matters to further understand the policy side of the subject.

Regarding the teamwork and management goals, I would like to enhance my communications skills by working with a diverse group of students from varied backgrounds. The scheduling aspect of the project is also of interest to me as I am unsure of my abilities to accurately judge an estimated-time-to-completion for a process or document such as the one we are working on. I think it will be a challenge to find topics for each individual to pursue, while maintaining group cohesion and motivation. I look forward to the process of getting to know each of my teammates and learning about the subject as group.

Dimitre Ouzounov

The goals are broadly in three different fields: technical, economics and managerial. From technical part, I am expecting to get familiar of all aspects of wind energy generation: underlying physical principles, design (not in great details) and operation of wind turbines, efficiency, and integration into the power grid. I would like to now the capabilities of current technology and especially the future perspectives: what is going to happen in near future? I am expecting to find out what is the standing of the wind energy approach compared with the other alternative energies (solar, hydrogen, etc). I am especially curios about possible disadvantage and downsides of wind energy. I have heard a lot about benefits but somehow the disadvantages are not “advertised” at the same level.

It is also important to know the economics side of wind energy business. I know that this sector still needs government help (tax or otherwise). What is needed to make wind energy generation economically viable on pure market principles? Could this happen in near or more distant future? How an appropriate site is chosen and what other factors should we consider to estimate the cost?

I took last semester the Project Management class and I am expecting to observe and apply some of the knowledge acquired. I am curious to see how the group goes through life-cycle stages (forming, storming, and performing). I am expecting to practice competencies for successful project management.

Reginald Preston

My primary interest is to study the economics of wind farm operations, from site selection through construction to operation. I find it interesting to learn how the government production tax credit is helping to drive a lot of wind farm projects and would like to have a deeper understanding of the costs and risks involved with renewable energy production from wind. It’s my personal belief that if this country is going to grow wind farms at the rate needed to both curb emissions and supply the demanded energy, it is either going to require significantly more involvement from the government or a drop in cost to allow this sector to compete with coal in the private sector. The industries that support wind energy production with their associated supply chains and the foreign countries that are developing their own wind energy supply are also of interest. As energy supply for the future is a global concern, I think there is a lot that can be learned from other regions of the world that could possibly be adapted for this country’s benefit and proliferation of renewable wind energy.

On a team level, I don’t feel that I can learn as much as others might from a leadership role as I am fairly versed in team leadership through my time in the Navy. I would like to focus on being a contributing member of the group, and helping the group to succeed by learning from the team dynamics that arise from our membership. Having the opportunity to learn from the leadership style of others that are different from my own will give me a great perspective on future group/team opportunities that I may encounter.

IV.3.2. End of project reflections

Christine Acker

On a technical level, this project was very interesting for me. I knew very little about the wind industry coming into this project and I am not a big supporter of it. It was very interesting to not only see what environmental benefits the wind industry provides, but also the number of jobs it is creating and the economic benefits as it continues to grow. I enjoyed doing the wind calculations for the Klondike III farm because it allowed me to incorporate mathematical computations into a project focused mainly on research.

Some things I would change or address next year are to have a more specific topic with concrete points to achieve. We were given a very broad topic that allowed us to explore many different parts of the wind industry, but I do not feel that any one of us went extremely in-depth, enough to become mini "experts" because the topic was so broad.

As far as a team management process goes I learned a lot about managing a team with 9 individuals who were not all familiar with each other before beginning the project. The group was very luck to find a time each week that the majority of the team could attend, sources such as wiggio provided to be a great help, but as in any group there were definite some points where we faced communication issues. Overall, I feel that the group really pulled together in the end to provide a very interesting and diverse research project.

Yash Agarwal

Wind energy project was a really well managed project. I have learnt a lot of things that will be applicable to me in my life. Firstly, the topic itself was interesting to me because I would like to explore future opportunities possible with wind energy. A very fine quality of research was done by our group and the areas of research extended into various fields. This was possible because of the large diversity and member of our group. I have never worked on any project which had nine members in a team. The support of Professor Vanek was very strong from the start which gave us the motivation and interest for the topics we worked on. Scheduling of time for meetings with a group composed of nine members was another important concept to notice. Everyone was updated with the information and other people's work which was a very trivial point to keep in mind to avoid duplication. The tasks of the project were accordingly split up. A data base (Wiggio) was well established under the guidance of our group member and everyone got accustomed to it to upload and compile everyone's work, even though Wiggio was a little frustrating in the start. Overall I had very high expectations from the project and they were met. The best surprise I got was that there were no disputes in the project in spite of the fact that we were so many members all from different backgrounds. Everyone managed to follow the timeline and the work went on very smoothly. I would love to work again with this team on a different project in future if possible.

Nael Aoun

In this project, everything worked well mostly. The relationships in the team were all good, we had constructive discussions and the environment was healthy. Also, we researched many interesting topics. What surprised me was how people from different cultures work and communicate differently. For example Yash and I work very similarly and collaborate much more on tasks than Americans do since they divide tasks and work individually on them. Finally, I think team coordination could have been better.

Stephen Clark

Overall, I was glad to be a part of such a diverse group of people, and I really got a thorough first-hand view of what it is like to work on a project team. Unfortunately, some of the things that often plague project teams also appeared in our group as well. Some people ended up doing a lot more work than others, which is something I was hoping wouldn't be the case. But as it stands now, the project is near complete, and the final product is something we can be proud of. If I were to go back and do it again, I think it would have been better to elect sub-group leaders in the groups, which do no overlap with overall group leaders, to ensure that everyone has a role, and that everyone has someone to answer to. This will not only keep people on track, but it will be easier to pinpoint where problems are.

In terms of the work we did, I think the presentation went well, and our report is robust and full of useful information about the current state of wind energy. It's surprising to see how quickly the industry has developed in the past decade, and I can't wait to see how everything unfolds in the future. I hope future MEng groups can use our report for the basis of further study, or Greek Peak can use it to make informed decisions about whether or not to consider installing a wind turbine at their resort.

Alejandro Hernandez de Toro

The project has being very interesting as a way to discover some particulars of the wind energy and the energy sector in the US. It has also being specially remarkable for me to know some other students really interested in the sustainability and renewable energies. Perhaps some more interaction with the director of the project, and a more detailed work in some areas could have done it a even better project. In terms of project management, it's also being interesting as a way to know and compare different roles and personalities in the group.

Nancy Lin

Before I worked on the wind project this semester, I always thought over 5% of wind energy in a country's energy consumption was costly and impossible, solar can join as a minority and only bio-chemical and nuclear energy can save the world. However, after a semester's research and study I'm so surprised wind energy can even play a larger part in the future energy market, not to mention those very innovative technologies behind wind projects already running and some in recent plan, such as floating turbine, flying kite, etc. Now I take much more confidence in the world's future energy market. I'm also encouraged by our group member's continuous enthusiasm for the research in wind energy.

As for the project management part, it's not easy to manage a group with 9 members. We have practiced skills taught in project management class but haven't fully used some of them. As I perceive, time is the major constraint for the practice of project management skills.

Jesse Negherbon

On a technical level, this project provided a broad exposure to the wind industry and I know more both about wind turbines and energy in general. The economic aspect of the industry provided the most interest too me and I believe it will be helpful to know how to generate life-cycle costs for a turbine as well as understand the facets of a project, site, or region that may make wind energy feasible. I would venture to say that our group needed to focus more intently on a few of the areas of the industry, rather than exploring all aspects that interested us; such an effort would have led to more detailed research and perhaps would have eliminated some of the overlapping efforts that we had. While some areas of the report are strong and well defined, others are noticeably thin or less structured. Fewer, and more defined, goals would have improved that overall quality of the end product. One choice that seemed to constantly present itself, was the decision whether to research the subject from the technical aspect, remaining as objective as possible, or to approach it from a standpoint of policy in which the discussions surely would present some subjective statements. The subject of energy can be rather controversial topic to address and I thought that it proved to be one of the more difficult challenges in the project.

On the subject of teamwork and group management, there are certainly difficulties present in coordinating a nine person effort both with respect to research and composition of the final deliverable. Ultimately we found a time in which the entire group could convene on a weekly basis and I think that this helped communication; it would have been advantageous to have met weekly as a group for the entirety of the semester. With regards to communication, the use of Wiggio facilitated document control, but to some extent I think it divided the group as some members preferred email or group discussions as media to exchange information. Overall, the group worked well enough, but as in any project, there are lessons to be learned, and more open lines of communication is one of them; I also think that a cap should be installed on the size of the group, with a maximum of perhaps five members. In any case, this project succeeded in exposing me to the wind and energy industries and it is my hope that the final deliverable is effective in educating others on our findings.

Dimitre Ouzounov

This project gave me an opportunity to learn in depth about renewable sources of energy and particularly about the wind power. I have always been curious about that topic but never looked into details before. I did not realize how much the wind industry has advanced. As a person with scientific background, I always pay more attention to the technical aspects. This project helped me to appreciate the significance of the other aspects (political, environmental, etc.).

I worked in two sub-groups in this project: the offshore wind (with Steve and Nancy) one and the group that researched current and future demands of wind power (with Alex and Jesse). Both groups decided to follow different approaches. In the wind power demand group, we separated the topics and each member concentrated on particular issues. In the offshore wind group, we work in parallel constantly updating each other about our findings.
Both approaches turned out to be prolific and resulted in excellent reports.

I enjoyed working with the whole team; every one took a portion of the project and made sure that the work was done on time. Overall, I had very positive experience participating in this project.

Reginald Preston

In looking back at my initial personal goals for this project, the only item that I didn't explore to the fullest was wind farm operation. I learned about some of the monitoring tools available and the integration with overall grid operations, but would like to have had more time to delve into the actual management and operation of a wind farm. The remainder of my goals were met as I was able to study the Greek Peak site to learn about the economic analysis of a given site as well as work with the manufacturing team to see how the industry is working to drop the cost of energy production through innovating technology. Instead of finding the government as only a source of direct stimulus or tax benefit incentives, there is a significant amount of government and private industry collaboration occurring to share technology and work towards the best solution to increase the amount of wind power penetration in the market.

From a team management perspective, the biggest lesson I took away was the importance of laying out the initial team processes before starting work. At mid semester we, as a team, came together to discuss the challenges we were facing such as communication and leadership. Most of our difficulty stemmed from the fact that we did not have group management methods in place that team members bought into before beginning the project. Given the task at hand, we molded group processes around our work already in progress and due to perceived time constraints did not focus on getting everyone to buy into those processes. The result was ultimately poor communication and slow progress.