

## Wind Energy Roadmap

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**Abstract**—Wind Energy has been existent for many centuries and has advanced in both products and technologies. We illustrate how Wind energy has evolved and its predicted future in a form of a graphical Technological Roadmap. We considered the following aspects as the basis of our research: - Environment, rising cost and dependency of oil, the availability of profitable and natural wind resources in the Pacific NW, business opportunities and government involvement. Our research is angled from a business perspective with interests discussed in detail later in this report. We predict, as implementation and the shift towards renewable energy, specifically wind energy occurs, there will be considerable reduction in the fluctuation and high cost of utilities, efforts towards the alarming concern of global warming and the increase of awareness of wind energy and its products as a dependable natural alternative energy resource. We used multiple analytical tools and Technology Roadmaps to drive our research and to draw comparisons, demands and predictions amongst Market Drivers, Products and Technology levels, all in respect towards a set timeline. The design of the roadmap was created with importance emphasized on flexibility to change and comprehension of the objectives driving the roadmap. Various designs of objects and color codes representing products, resources and technologies were used in the design of the roadmap. An in-depth analysis of Wind Energy at present and its forecasted future potential in the next 20 years was analyzed. Technology Roadmaps were created for each stage of our analysis, which constantly changed depending on collective data and scope refinement through a process of elimination and importance. Our report can be used as a foundation for future entrepreneurs in the energy sector that wish to explore new business opportunities and wish to diversify their current energy portfolio with a energy efficient portfolio. It could also serve as an educational tool to consumers and be able to assist governmental organizations to achieve their set target to increase the wind energy usage by 20% by the year 2020. Our objective is to identify and present the benefits in utilizing Wind energy to Residential, Commercial and Industrial consumers within the Pacific NW, with a basis on renewable energy as a whole with a specific focus on Wind Energy. Considering the climate and geographic location we feel that wind energy has the most potential in the Pacific NW.

### I. INTRODUCTION

Our objective is to identify and present the benefits in utilizing Wind energy to Residential, Commercial and Industrial consumers within the Pacific NW, with a basis on renewable energy as a whole and a specific focus on Wind Energy we present our findings based on research and analysis that we have conducted from multiple resources. What is being done to lessen the dependency on oil and the shifting to renewable energy sources. Considering the climate and geographic location we feel that wind energy has the

most potential in the pacific NW, we give a general overview of the current situation, products and technology as well as future speculations. Increasingly, solar power is gaining popularity with individual homeowners and businesses that want to generate their own power, but it isn't used much as a utility. Geothermal energy is limited by geography, and biomass is still being developed as a reliable fuel source [1]. About 50 percent of electricity comes from coal, 20 percent from nuclear power, 17 percent from natural gas, 7 percent from hydroelectric and 3 percent from oil, according to the U.S. Energy Information Administration [1].

- The earliest known windmills were in Persia (Iran) and looked like large paddle wheels.
- Today, the largest wind turbines in the world have blades longer than a football field.
- A typical horizontal wind turbine stands as tall as a 20-story building and has three blades that span 200 feet across.
- One wind turbine can provide enough electricity for about 300 homes.
- U.S. wind farm installations totaled more than 16,800 megawatts in 2007, enough power to serve approximately 4.5 million average American households.
- Wind energy is generated in 30 different states. Those with the most wind production are Texas, California, Minnesota, Iowa and Washington.
- The U.S. ranks third in the world in wind power capacity, behind Germany and Spain. [5]

With all of the above taken into consideration we present our Market Drivers, Products, Technology, Analysis and Roadmap in the following report.

### II. LITERATURE REVIEW

#### Market Drives

Much effort has been conducted to identify market drivers and subcategorizes. Some where intuitive, others required some brainstorming. We identified the following four main categories as market drives:

##### *A. Increases in Fossil Fuel Cost:*

Steve Taub, an alternative energy analyst at Cambridge Energy Research Associates states that "Rising fossil fuel prices are making renewable energy more competitive in the power market"[1] Not only does wind have a fixed cost to produce, it is also more efficient. As an example, A 60 watt Incandescent light burning for non-stop for one year requires 427 pounds of coal. As opposed to a single 600 kW wind turbine would only have to spin for 2.94 hours to power that

light bulb for a year [4]. Another point to take into consideration is Price Stability: "The price of electricity from fossil fuels and nuclear power can fluctuate greatly due to highly variable mining and transportation costs. Wind can help buffer these costs because the price of fuel is fixed and free." [4]

#### B. Environmental Issues:

Water is a valuable resource to human survivor, with increase world population and climate change use of water need to be wise, one major advantage in using non-fossil based fuel is water saving in full generation. 29% of the saving would come from the west side of the country.

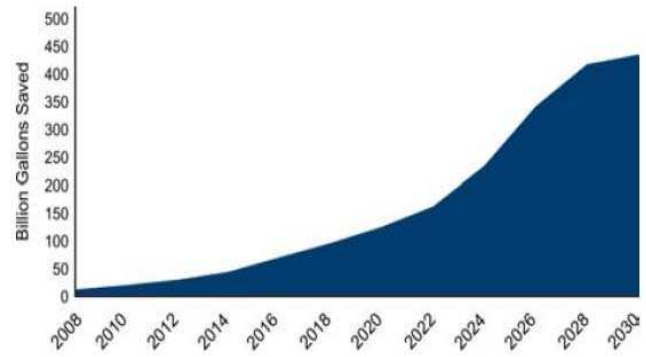


Figure-1 Annual water consumption savings due to deployment of wind energy

The following graph demonstrates the avoided Co2 annual emissions once wind energy objective is achieved by 2030.

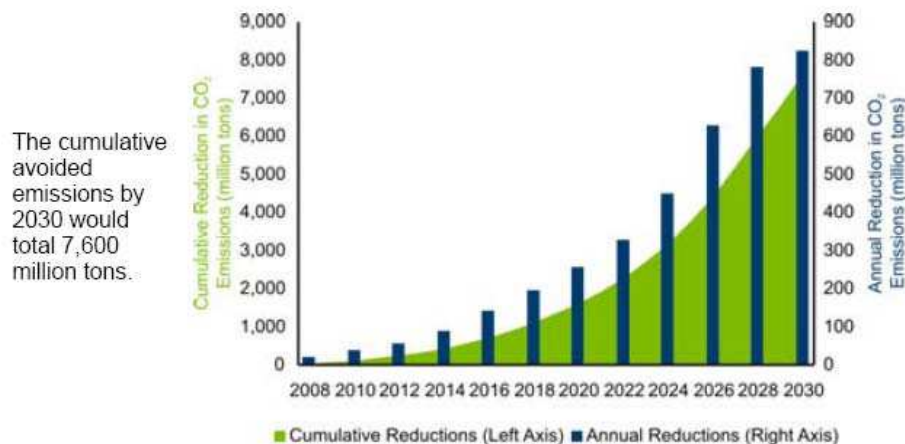


Figure-2 Annual CO<sub>2</sub> emissions avoided (vertical bars) would reach 825 million tons by 2030

For a concrete example as to reducing emissions of pollution and greenhouse gases: "A single 660-kW wind turbine will displace emissions of 1,100 tons of carbon dioxide (the leading greenhouse gas), 6 tons of sulfur dioxide (the leading component of acid rain), and 4 tons of nitrogen oxides (the leading component of smog) every year, based on the U.S. average utility fuel mix. 375 acres (more than half a square mile) of forest would be needed to absorb the same amount of CO<sub>2</sub>." [4]

#### C. Government Policy:

We found that federal and local governments in the NW are legislating Energy Companies as well as giving incentives for cooperation and individuals.

**"Mandatory Utility Green Power Option:** Oregon enacted legislation (S.B. 838) in June 1999 that requires all electric utilities to offer customers an optional green-power program. A "significant portion" of the electricity sold by a utility as green power must be generated using qualifying renewable, including wind energy, solar-thermal energy, solar-electric

energy, ocean energy, geothermal energy, hydropower and/or certain forms of biomass energy. Each utility must inform customers of the sources of the electricity included in its green-power program.

**Renewable Portfolio Standard:** As part of the Oregon Renewable Energy Act of 2007 (Senate Bill 838), the state of Oregon established a renewable portfolio standard (RPS) for electric utilities and retail electricity suppliers. Different RPS targets apply depending on a utility's size. Electricity service suppliers must meet the requirements applicable to the electric utilities that serve the territories in which the electricity service supplier sells electricity to retail consumers." [3]

Large utility companies (those with 3% or more of the state's load) must ensure that a percentage of the electricity sold to retail customer's in-state is derived from eligible renewable energy resources according to the following schedule:

- 5% by 2011
- 15% by 2015

- 20% by 2020
- 25% by 2025

As for Incentives the government gives a few options to individuals as well as cooperation's. The following is a list of few as an example:

Personal Tax Credit: \$1,500 except that the maximum for PV, Fuel Cells and Wind Turbines is \$6,000 (\$1,500 per year for 4 years), up to 50% of installed cost.

Corporate Tax Credit: 50% of eligible project costs, distributed over five years (10% per year) Maximum Incentive:\$20 million for renewable energy equipment manufacturing facilities \$10 million for other projects.

Grant Program: Using revenues generated from the sales of Green Tags, Bonneville Environmental Foundation (BEF), a not-for-profit organization, accepts proposals for funding for renewable energy projects located in the Pacific Northwest (OR, WA, ID, MT). Any private entity, organization, local or tribal government located in the Pacific Northwest may participate.

Low interest loans: Typically \$20,000 - \$20 million Maximum Terms vary, generally in the range of 5 to 15 years. The loan term must be within the expected life of the project.”\* [3]

To give a quick summary of the incentives in the four states the following table summarizes:

State	Amount	Duration	Max
Oregon	60c/kwh	1 year	\$1500
Washington	15c/kwh	10 years	\$2000/year
Idaho	20%	4 years	\$5000
Montana	2c/Kwh	7 years	N/A

A complete list can be found at: <http://www.dsireusa.org> where all legislations and incentives are listed for all states.

#### D. Business Opportunities:

In the past energy generated from wind wasn't economical; however as oil prices continue to increase, wind energy becomes an attractive source in the power market. Catering to increase demand in electrical energy, as well as replacing existing sources of non renewable energy.

The following graph illustrates employment impact as to manufacturing, construction, and operations. Important to note the numbers indicate the maximum employment provided by the wind industry, nation wide. Another note is that the numbers are projected number based on a model included in Department of Energy report.

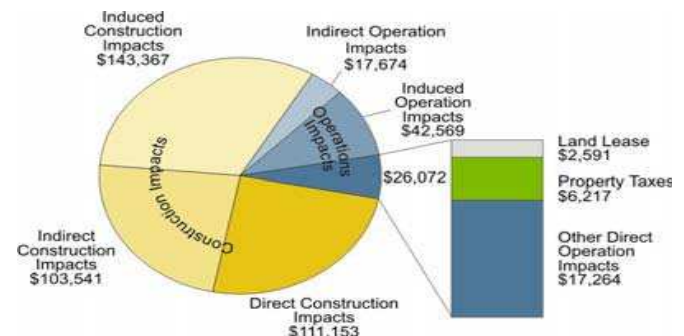


Figure-3

When building a new infrastructure as was the case for the railroad industry in the early 1900s and the Highway infrastructure in the sixties. A lot of opportunity arise and much works need to be done. We found that for the wind industry the following outlines the supply chain:

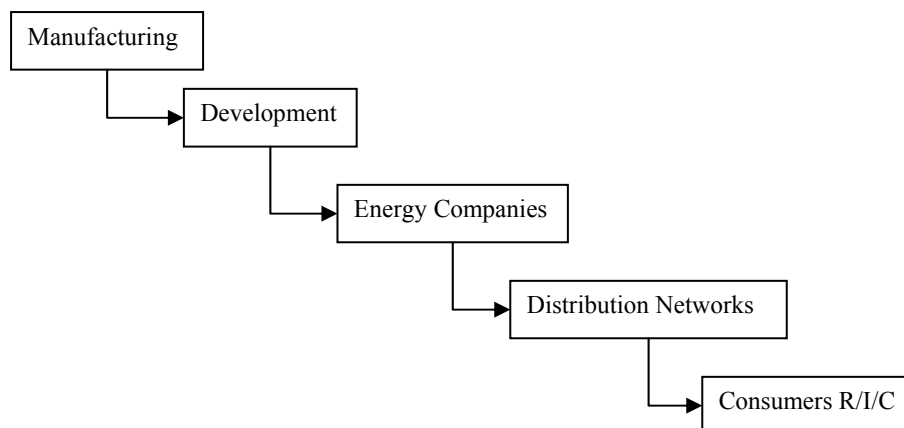


Figure-4

Manufacturing: Companies that introduce and manufacture parts for wind turbines as well as complete turbines from US and global suppliers, such as GE, Vestas, Mitsubishi, and Bonus.

Development: Where land is acquired by the state or purchased by investors to install wind turbines. These lands can be offshore as well as not very usable land such as wet land in areas with good wind speed. The development and site preparation can also be done by energy companies, rather than individual developing companies.

Energy Companies: Most common to the NW are Portland General Electric, Budget Sound Energy, and Idaho Power.

Distribution Networks: Most of which are owned and operated by energy companies, as well as Federal agency, such as Bonneville Power Administration.

Consumers: Residential, Industrial, and Commercial.

As illustrated in the final roadmap Energy companies and distribution companies would reduce their operations up to the point where consumer demands increase due to increase in NW population as well as industrial and commercial increased operational needs. We speculate the first phase demand would be met by 2018, and a second phase of demand would be scheduled around 2024 or 2026.

Looking at small wind turbines we also find economical benefits in rural residential areas as well as backup source in existing urban areas. A list of certified companies can be found at <http://www.awea.org/smallwind/smsyslst.html> including Bergey, Wind power Co, Aero Vironment. As the technology for small wind advances entire residential and commercial towers can become more sustainable and possibly external power independent.

### III. PRODUCTS

For this project we have focused on acquiring data on products that we believe are proficient in both the industrial and residential sectors. For industrial we have discovered that General Electric (GE) has two, the 2.5MW for onshore and the 3.6MW for offshore. In residential we have found that for off-grid the Bergley XL.1 and the quiet revolution (qr5) for on-grid have demonstrated promise.

#### A. Industrial

In North America, all commercially available, large wind turbines are horizontal axis wind turbine (HAWT). This configuration uses a horizontal axis, three-blade rotor, an upwind orientation (powernaturally.org). Generally found in areas with turbulent winds, grouped together in large clusters, and grid connected. The rotor diameters and rated capacities of wind turbines have continually increased in the past 10 years, driven by technology improvements, refined design tools, and the need to improve energy capture and reduce the

cost of energy. For example, the average turbine rating for turbines installed in the U.S. in 2001 was 908 kW, while turbines installed in 2003 had an average capacity of 1.374 kW. In 2005, turbines with rated capacities of 1.5 MW to 1.8 MW present the cast majority of the turbines sizes installed in North America (powernaturally.org).

GE 3.6 MW is engineered for high-speed turbulent wind sites and the harsh marine environment, for off-shore applications. *See Appendix B.1 for specification.* Whereas, the GE 2.5 MW is similar but designed for on-shore environment applications. *See Appendix B.2 for specification.*

#### B. Residential

Small wind turbine industry slowly developed into a major player due to the success of the large wind turbine industry. They are installed as single units and include a greater variety of technology. Bergley XL.1 is a horizontal axis wind turbine (HAWT), 8.2ft high with a rotor diameter of 2.5 meters and a peak output of approximately 1,600watts. It is indented for off-grid home market, as well as for rural electrification programs in developing countries (1). *See Appendix B.3 for specification.*

Quietrevolution (qr5) was designed for the urban environment, areas of constantly changing wind direction and low wind speeds. The qr5 stands at 5meters high and 3meters in diameters and has a peak output of 6,000watts to 10,000watts depending on wind speeds. The qr5 is an on-grid vertical axis wind turbine (VAWT); this unique and elegant helical design is compact and easy to integrate with the environment. *See Appendix B.4 for specification.*

### IV.. TECHNOLOGY

In North America, all commercially available large wind turbines use the 'Danish concept' turbine configuration. This configuration uses a horizontal axis, three-bladed rotor, an upwind orientation, and an active yaw system to keep the rotor oriented into the wind. The drive train consists of a low-speed shaft connecting the rotor to the gearbox (a 2- or 3-stage speed-increasing gearbox) and a high-speed shaft connecting the gearbox to the generator. Generators are typically asynchronous, induction, and operate at 550-690 V (AC). Some turbines are equipped with an additional small generator to improve production in low wind speeds. The second generator can be separate or integrated into the main generator. Each turbine for utility/industrial scale applications is equipped with a transformer to step up the voltage to the on-site collection system voltage. The on-site collection system typically is operated at medium voltages of 25 to 35 kV. [7] *See Appendix C for major turbine components.* Generally, most of the United States has implemented horizontal axis wind turbine (HAWT) design for utility and/or industrial scale energy production, but for residential space are limited and therefore, a vertical axis wind turbine

(VAWT) design. Typically, HAWT will produce more power output than the VAWT, due to the fact that as rotor diameter goes up so does its peak power output.

The rotor diameters and rated capacities of wind turbines have continually increased in the past 10 years, driven by technology improvements, refined design tools, and the need to improve energy capture and reduce the cost of energy. For comparison, the average turbine rating for turbines installed in the U.S. in 2001 was 908 kW, while turbines installed in 2003 had an average capacity of 1,374 kW. In 2005, turbines with rated capacities of 1.5 MW to 1.8 MW present the vast majority of the turbines sizes installed in North America. [7]

As the rotor diameters and rated capacities have increased, so has the hub height of the wind turbines. There is no standard hub height or ratio of hub height to rotor diameter. Wind resource characteristics, terrain, turbine size, availability of cranes, and visual impacts are but a few critical items that are used to determine the most optimum hub height for a given project. Current utility-scale wind turbines can employ hub heights that range from 50 m (164 ft) to 80 m (262 ft). Maximum tip heights (the highest point of the rotor) depend on the hub height and rotor diameter. Table 1 provides an example of the range of tip heights common in 2003. As of May 2005, the tallest wind turbine in the U.S. utilizes an 80-m (262-ft) hub height and an 82-m (279-ft) rotor diameter with a resulting maximum tip height of 121 m (397 ft). [7] *See Appendix D for illustrations.*

The control system employed to operate the turbine to produce grid-quality electricity varies among turbine manufacturers. Each has advantages and disadvantages; however, they all productively deliver energy into utility grids. For example, variable speed turbines produce energy at slightly higher efficiencies over a wider operational range of wind speeds than constant-speed turbines. The power electronics necessary in variable-speed turbines to produce grid-quality electricity consume slightly more energy than capacitors used to condition the power from constant-speed turbines. Variable-speed turbines also provide the ability for the turbine to supply reactive power to the grid and dynamically control the reactive power supply (power factor) to the grid. This feature can be advantageous to the operation of the transmission system particularly in remote portions of the transmission system where voltage control can be difficult and costly for the system operator to maintain. Typically, reactive power and its effects are managed through the use of larger conductor sizes, capacitor banks and special reactive power supply equipment. Remote wind energy projects that have the ability to produce or consume reactive power with either a static or dynamic power factor can mitigate costly equipment on the transmission system.

Turbines that do not utilize variable-speed technology provide close to unity power factor by using switched capacitors at the turbine and, in some cases, at the project substation. The effect of constant-speed systems on the grid

results in the consumption of reactive power. This reactive power must be supplied from other transmission system resources. Transmission system operators are increasingly interested in using remotely located wind energy projects to assist in providing voltage support and control. Fixed-pitch turbines generally have fewer moving parts and are less complex than variable pitch turbines, resulting in lower manufacturing costs. Variable-pitch turbines are able to optimize blade pitch and adjust it for changes in air density or blade contamination. For these and other reasons, the energy output from variable-pitch turbines is somewhat higher than fixed-pitch turbines, thus offsetting the higher system costs. In locations with large variations in temperature, and thus air density, fixed-pitch turbines can experience difficulties with excessive power production during periods of high air density if the blades are pitched in a manner that optimizes production throughout the year. The specific wind and climate characteristics at a given site ultimately determine which type of control scheme generates energy most cost effectively. [7]

In general, the technology lies within the components of wind turbines themselves. Be it large wind or small wind, component technology within wind energy is a mature commodity. Currently, there are no disruptive technologies out to change the way we will harness energy from wind, although through our research we have found NVS or Nano Vent-Skin.

Nano vent-skin (NVS) is a disruptive technology which will change the way we harness energy from the earth. Many believe bigger/larger turbines are the way to go, but designer Agustin Otegui thinks exceptionally small, at the nano scale, with his idea for Nano Vent-Skin, the ultimate green wall. "Using nano-manufacturing with bioengineered organisms as a production method, NVS merges different kinds of micro organisms that work together to absorb and transform natural energy from the environment. What comes out of this merging of living organisms is a skin that transforms two of the most abundant sources of green energy on earth: Sunlight and Wind. There is another advantage of using living organisms: the absorption of CO<sub>2</sub> from the air." The outer skin of the structure absorbs sunlight through an organic photovoltaic skin and transfers it to the nano-fibers inside the nano-wires which then are sent to storage units at the end of each section. Every turbine on the section generates energy by chemical reactions on each end where it makes contact with the structure. Polarized organisms are responsible for this process on every turbine's turn. The inner skin of each turbine works like a filter absorbing CO<sub>2</sub> from the environment as wind passes through the NVS.[9] Otegui told CNN: "Instead of trying to build these huge turbines which are always getting bigger and bigger, I thought, why not do something on a small scale and use it on existing objects and buildings. I wanted to try to cover them like a crawling plants you see on facades." [8]



So what make the NVS so disruptive than traditional wind turbines? Basically, every component of the wind turbine is shrunk down to one billionth of a meter. For example, each of the turbine blades for the NVS is 25 millimeters in length and 10 millimeters in width; whereas, the largest wind turbine in the world has a rotor blade diameter of 126 meters. The designer states that roughly each NVS turbine will produce 0.2 watts of energy and a square meter grid of turbines could produce around 90 watts of power. Compared with the world's largest turbine the Enercon E-126, which produces roughly 7+ megawatts per unit. The fact that the NVS has merged bio-engineering and manufacturing at the nano level for the means of production is what has made the NVS so disruptive. The designer [Agustin Otegui](#) has radically changed the concept of harnessing wind energy. Imagine if every building is covered with this NVS, we would be harnessing energy in two ways (solar and wind) rather than just one, and we would also be filtering out CO<sub>2</sub> from the environment. Also, he has shown us a new industry, the nano-wind industry, for future applications.

## V. WIND ENERGY ROAD MAP OVERVIEW

Attached you will find a Technology Roadmap for Wind Energy. This roadmap has three different levels with each having sub child levels associated to elaborate key points of our focus. We then linked all the different levels Market Drivers, Products and Technology Level together to display a connection and advancement in each area, based on a 20 year timeline. The linkages and connections are derived from functionality, facts and future assumptions based on detailed research in this area.

We designed the technological level in a cluster format which makes it easy to add and remove components as they advance and change. Color-coding the technology level as well as the sub-categories makes it easy for reading this roadmap and for the layman to understand this roadmap without detailed study. Numerous arrows are used throughout the roadmap to guide the flow and direction of the roadmap against the linkages and timeline. We used bright red arrows to identify the future products and where we envision this roadmap for the future.

## VI. CONCLUSIONS

Now we are at cross roads where all of the previous factors are going behind the scene. Human Population as such has a growing need for the Energy with the population increase and the power required to meet the comfort of the people. Both the above factors show a clear direction to the

Country to lead the way again to both bring the Non-Renewable Energy to the Forefront as well as lead the way in the next revolution. Sitting in the Northwest is like a Goldmine with plenty of potential for Wind Energy Industry. The Technology has crossed the initial teething problems and making it a very alternative source of Energy. Today it is the second cheaper source to produce power. In the coming years with the expansion of distributive networks and other forms of delivery method of Wind Energy, like the Nano Technology would bring Wind Energy in par with Fossil Fuel which is both good to the Environment as well as improve the Energy Security of our Country.

As stated in the beginning, the Objective of this report is to develop a roadmap for the Northwest Wind Energy Industry. Based on the Objective stated in the beginning, the research report meets the goal by integrating various tools into the research data, analyzing them and presenting them into a roadmap

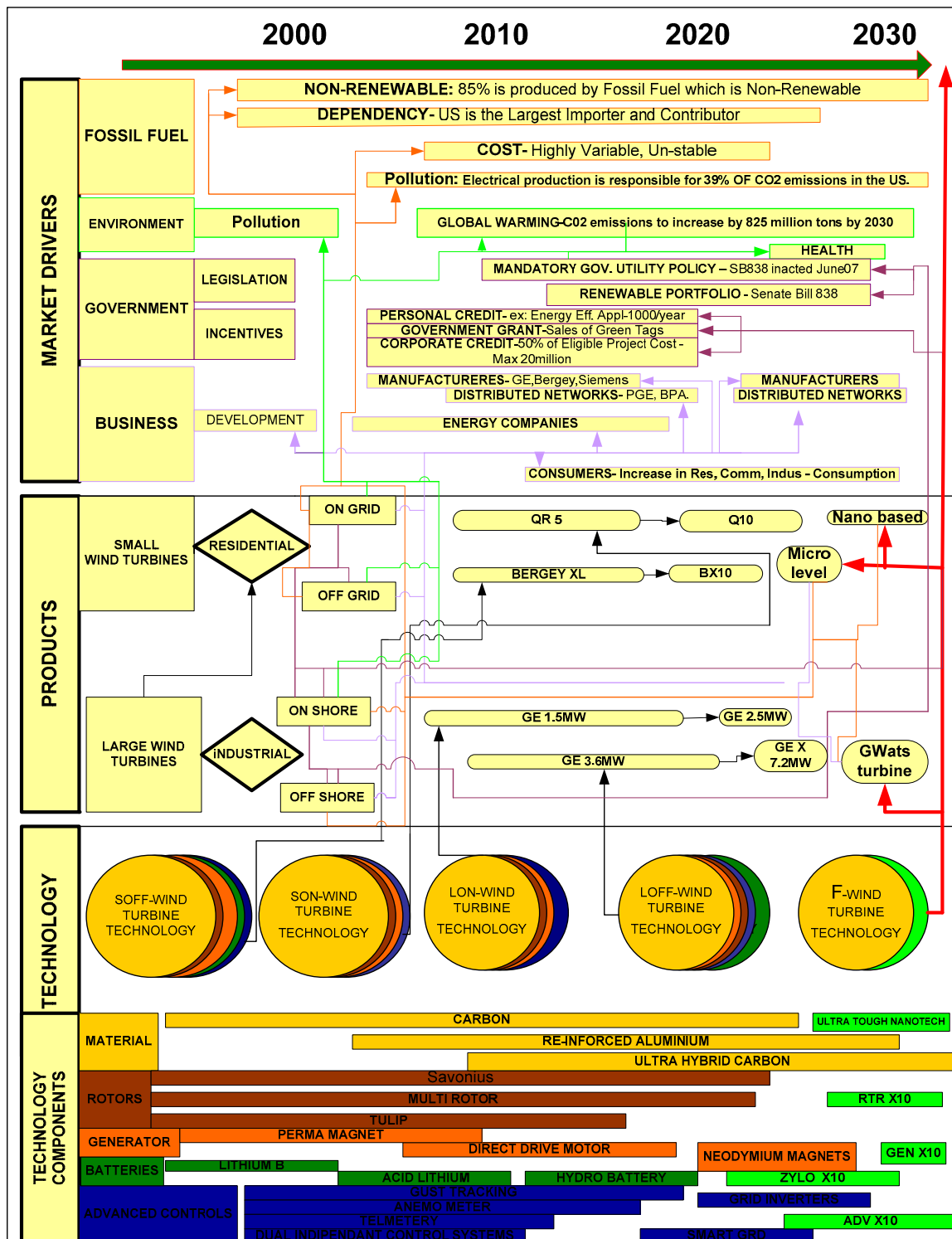
The report presents the current state of the Industry and where the Industry should and will be heading the next 20 years. Various factors like how Technology improvements could reduce the cost of producing Wind Energy, its efficiency in the market place, the Government incentives and regulation which aid the Industry were well presented with the various tools learned in the class. The gaps in the Product and Technology are clearly highlighted with a SWOT analysis. The Force 5 analysis helped to understand the threat level possessed by Suppliers, Potential Entrants, Buyers and Substitutes in order to include them into our roadmap accordingly.

This report is a reflection of the current state and predictions as such on how the Industry is heading. Road Mapping process is always based on current data and a guesstimate of how the future looks from that time. However the data keeps changing in future due to changes in Government Regulations, Technology advancement and improvements made in Distribution. These changes must be added appropriately into the roadmap as new improvements and challenges would make the roadmap closer to real.

The Wind market is not for every one who is looking to wholesale the Electrical Industry.

Lot of regions in the country does not have enough land to create Wind Farms, or just too far from the Power Grid. Northwest as such doesn't fall under the category as it has lot of Wind and Land for harvesting in the Wind Energy. You will not only find the occasional Business or a homeowner who intent to live off the grid to have a greener power source, but also for businesses who are looking at investing in new areas. Wind Energy Industry as such could be the answer for those businesses.

# VII. ROADMAP



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## APPENDIX-A NW CURRENT & POTENTIAL WIND CAPACITY

The following Tables summarize each of the NW states as to current capacity, and potential capacity. Each table also includes a list of all wind projects in operation.

Data was obtained from AWEA website, where same data can be found for each state.[6]

### A.1 Oregon:

Power Capacity - Existing projects (MW):	887.79
Power Capacity - Projects under construction (MW):	201.6
Rank In US (by Existing Capacity):	7
Rank In US (by Potential Capacity):	23
Potential Capacity (in MW):	4870
Annual Energy (in billion kWh):	43

Name	Location	Capacity MW	Unit	Turbine Mfr	Developer	Power Purchaser	Year online
Elkhorn Valley (08)		3.3	2	Vestas	Horizon Wind Energy	Idaho Power	2008
Klondike III		2.4	1	Mitsubishi	PPM Energy	PG&E/PSE/EWE B/BPA	2008
Biglow Canyon Wind Farm		125.4	76	Vestas	Orion/PGE	PGE	2007
Elkhorn Valley (07)		97.35	59	Vestas	Horizon Wind Energy	Idaho Power	2007
Klondike III		101.2	44	Siemens	PPM Energy		2007
Klondike III		120	80	GE	PPM Energy		2007
Leaning Juniper		100.5	67	GE	PPM Energy	PacificCorp	2006
Klondike II		75	50	GE	PPM Energy	PGE	2005
Combine Hills		41	41	Mitsubishi	Eurus	PacificCorp	2003
Condon Wind Project, phase II		25.2	42	Mitsubishi	SeaWest	BPA	2002
Stateline Expansion	Umatilla County	39.6	60	Vestas	FPL Energy	PPM Energy	2002
Condon Wind Project	Gilliam County	24.6	41	Mitsubishi	SeaWest	BPA	2001
Klondike	Wasco County	24	16	Enron Wind	PRM Energy	BPA	2001
Stateline Wind Project	Umatilla County	83.16	126	Vestas	FPL Energy	PPM Energy	2001
Vansycle Ridge	Helix	25.08	38	Vestas	FPL Energy	PGE	1998

### A.2 Idaho

Power Capacity - Existing projects (MW):	75.32
Power Capacity - Projects under construction (MW):	0
Rank In US (by Existing Capacity):	20
Rank In US (by Potential Capacity):	13
Potential Capacity (in MW):	8290
Annual Energy (in billion kWh):	73



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Name	Location	CapacityMW	Unit	Turbine Mfr	Developer	Power Purchaser	Year online
Hydrogen pilot project	South of Boise	0.1	2		Idaho Synthetic Fuels		2006
Fossil Gulch	southeast of Idaho Falls	10.5	7	GE Energy	Exergy Development Group/United Materials	Idaho Power	2005
Wolverine Creek	near Hagerman	64.5	43	GE Energy	Invenergy	PacificCorp	2005
Lewandowski Wind Farm	southeast of Boise	0.22	2		Bob Lewandowski		2003

## A.3 Washington

Power Capacity - Existing projects (MW):	1195.38
Power Capacity - Projects under construction (MW):	94
Rank In US (by Existing Capacity):	5
Rank In US (by Potential Capacity):	24
Potential Capacity (in MW):	3740
Annual Energy (in billion kWh):	33

Name	Location	CapacityMW	Unit	Turbine Mfr	Developer	Power Purchaser	Year online
Nine Canyon III		32.2	14	Siemens	Energy Northwest/RES Americas	Energy Northwest	2008
White Creek Wind Power Project	Klickitat County	204.7	89	Siemens	Last Mile Electric Cooperative	Last Mile Electirc Cooperative	2007
Marengo Wind Farm	near Dayton	140.4	78	Vestas	RES America	PacificCorp	2007
Big Horn Wind Power Project	Klickitat County	199.5	133	GE Energy	PPM Energy	Modesto-Santa Clara-Redding Public Power Agency	2006
Wild Horse Wind Power Project	Kittitas County	2286	127	Vestas	Horizon Wind Energy	PSE	2006
Hopkins Ridge Wind Farm		149.4	83	Vestas	RES America	PSE	2005
Nine Canyon Wind Farm, phase II	Benton County	15.6	12	Bonus	Energy Northwest	Energy Northwest	2003
Nine Canyon Wind Farm	Benton County	48.1	37	Bonus	Energy Northwest	Energy Northwest	2002
Stateline Wind Energy Project	Walla Walla County	176.88	268	Vestas	FPL Energy	PPM Energy	2001

## APPENDIX-B WIND TURBINE TECHNICAL SPECIFICATIONS

### B.1 GE 3.6mw specifications

<b>Operating Data</b>	3.6
<b>Rated capacity</b>	3,600 kW
<b>Cut-in wind speed</b>	3.5 m/s
<b>Cut-out wind speed</b>	27 m/s
<b>Rated wind speed</b>	14 m/s
<b>Rotor</b>	3.6
<b>Number of blades</b>	3
<b>Rotor diameter</b>	104 m
<b>Swept area</b>	8,495 m <sup>2</sup>
<b>Rotor speed (variable)</b>	8.5 – 15.3 rpm
<b>Tower</b>	3.6
<b>Hub height</b>	Site-dependent
<b>Power control</b>	Active blade pitch control
<b>Gearbox</b>	Three step planetary spur gear system

<b>Generator</b>	Doubly-fed asynchronous generator
<b>Converter</b>	Pulse-width modulated IGBT-frequency converter
<b>Braking System (fail-safe)</b>	Electromechanical pitch control for each blade Hydraulic parking brake
<b>Yaw System</b>	Electromechanical driven with wind direction sensor and automatic cable unwind
<b>Control System</b>	Programmable logic controller (PLC) Remote control and monitoring system
<b>Offshore Container</b>	Protecting converter, low and medium voltage switchgear, transformer and control system
<b>Noise Reduction</b>	Impact noise insulation of the gearbox and generator Sound reduced gearbox Noise reduced nacelle Rotor blades with minimized noise level Onshore version: Noise-reduced operation (optional)
<b>Lightning Protection System</b>	Lightning receptors installed along blades Surge protection in electrical components
<b>Tower Design</b>	Hybrid tower made of pre-stressed concrete and tubular steel segment, tubular steel tower (offshore design according to location)
<b>Hoisting System</b>	Optional integrated hoisting system to service major, making external cranes unnecessary

## B.2 GE 1.5mw specifications

<b>Operating Data</b>	1.5sle	1.5sl	1.5s	1.5se
Rated capacity	1,500 kW	1,500 kW	1,500 kW	1,500 kW
Cut-in wind speed	3.5 m/s	3.5 m/s	4 m/s	4 m/s
Cut-out wind speed 600 s average	25 m/s	20 m/s	WZ II: 22 m/s WZ III, IEC II: 25 m/s	25 m/s
Cut-out wind speed 30 s average	IEC s: 28 m/s	WZ II: 23 m/s	WZ II: 25 m/s WZ III, IEC II: 28 m/s	IEC I: 28 m/s
Cut-out wind speed 3 s average	IEC s: 30 m/s	WZ II: 25 m/s	WZ II: 27 m/s WZ III, IEC II: 30 m/s	IEC I: 30 m/s
Cut-back-in wind speed 300 s average	IEC s: 22 m/s	WZ II: 17 m/s	WZ II: 19 m/s WZ III, IEC II: 22 m/s	IEC I: 22 m/s
Rated wind speed	12 m/s	12 m/s	12 m/s	12 m/s
Rotor	1.5sle	1.5sl	1.5s	1.5se
Number of rotor blades	3	3	3	3
Rotor diameter	77 m	77 m	70.5 m	70.5 m
Swept area	4,657 m <sup>2</sup>	4,657 m <sup>2</sup>	3,904 m <sup>2</sup>	3,904 m <sup>2</sup>
Rotor speed (variable)	10.1 - 20.4 rpm	10.1 - 20.4 rpm	11.1 - 22.2 rpm	11.1 - 22.2 rpm
Tower	1.5sle	1.5sl	1.5s	1.5se
Hub heights (m)	61.4+ / 64.7+ / 80+ / 85+	61.4* / 64.7* / 80* / 85* / 100*	64.7* / ** / 80* / ** / 85* / ** / 100* m	52.6*** / 54.7*** / 64.7***
* for WZ II **for WZ III/IEC II ***for IEC I + for IEC s				
<b>Power Control</b>	1.5sle	1.5sl	1.5s	1.5se
Power control	Active blade pitch control	Active blade pitch control	Active blade pitch control	Active blade pitch control

<b>Operating Limits</b> (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
<b>Control System</b>	Programmable logic controller (PLC) Remote control and monitoring system
<b>Gearbox</b>	Three-step planetary spur gear system
<b>Generator</b>	Doubly-fed three-phase asynchronous generator
<b>Braking System</b> (fail-safe)	Electromechanical pitch control for each blade (three self-contained systems) Hydraulic parking brake
<b>Yaw System</b>	Electromechanical driven with wind direction sensor and automatic cable unwind
<b>Converter</b>	Pulse-width modulated IGBT frequency converter
<b>Tower design</b>	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)
<b>Noise Reduction</b>	Impact noise insulation of the gearbox and generator Sound reduced gearbox Noise reduced nacelle Rotor blades with minimized noise level
<b>Lightning Protection System</b>	Lightning receptors installed on blade tips Surge protection in electrical components

### B.3 Bergley XL.1 specifications

<b>Rotor diameter</b>	2.5 m
<b>Type</b>	3 Blade upwind
<b>Start-up wind speed</b>	3 m/s
<b>Cut-in wind speed</b>	2.5 m/s
<b>Rated wind speed</b>	11 m/s
<b>Rated Power</b>	1,000 Watts
<b>Max Power</b>	~1,600 Watts
<b>Cut-out wind speed</b>	None
<b>Furling wind speed</b>	13 m/s
<b>Max design wind speed</b>	54 m/s
<b>Blade pitch control</b>	None, fixed-pitch
<b>Overspeed protection</b>	AutoFurl
<b>Gearbox</b>	None, Direct-drive
<b>Temperature range</b>	-40 to +60 degrees C
<b>Generator</b>	Permanent Magnet Alternator
<b>Output form</b>	24 VCD Nominal
<b>Functional features</b>	Low-end boost, Slow-mode, Electric brake, 30A solar regulator, 60A dump load, Timed battery equalization, Watt meter display mode, Polarity checker

### B.4 Qr5 specifications:

**Physical dimensions** - 5m high x 3.1m in diameter

**Generator** – Direct drive, mechanically integrated, weather sealed permanent magnet generator

**Power control** - Peak power tracking constantly optimizes turbine output for all sites and wind speeds

**Operation mode** - Max wind speed: 16m/s; Min wind speed: 4.5m/s

**Design life** - 25 years (annual inspections recommended)

**Rotor construction** - Carbon fiber and epoxy resin blades and connection arms

**Brake and shutdown** - Over speed braking above 14m/s wind speed, auto shutdown in high wind speeds (above 16m/s)

**Roof mounting** - 3.5m/6m masts

**Tower mounting** - 9m/15m masts

Demountable models are also available for temporary installations

**Remote monitoring** - Event log can be accessed via PC. Remote monitoring stores operation, average wind speeds and kW hours of electricity generated

**Peak power** - 6kW

**Output** - Around 10,000 kWh/yr at an average wind speed of 5.9 m/s

**Availability** - Current lead time is approximately five months

**Electrical Requirements** - Three phase supply - turbines must be grid connected

**Color** - White rotor, galvanized steel mast (silver)

**Coatings** - Coastal sites may require coatings at additional cost. Masts can also be coated different colors.

**Cost of turbine** - £25,000

**Cost of mast** - £2,950 - £5,150 depending on height and finish

**Cost of controls** - £4,600 for a single turbine, reducing for multiple installations

**Installation cost** - Around £3,000 - £6,000 per turbine depending on the site - please note this cost does not include foundations

#### APPENDIX-C MAJOR TURBINE COMPONENTS

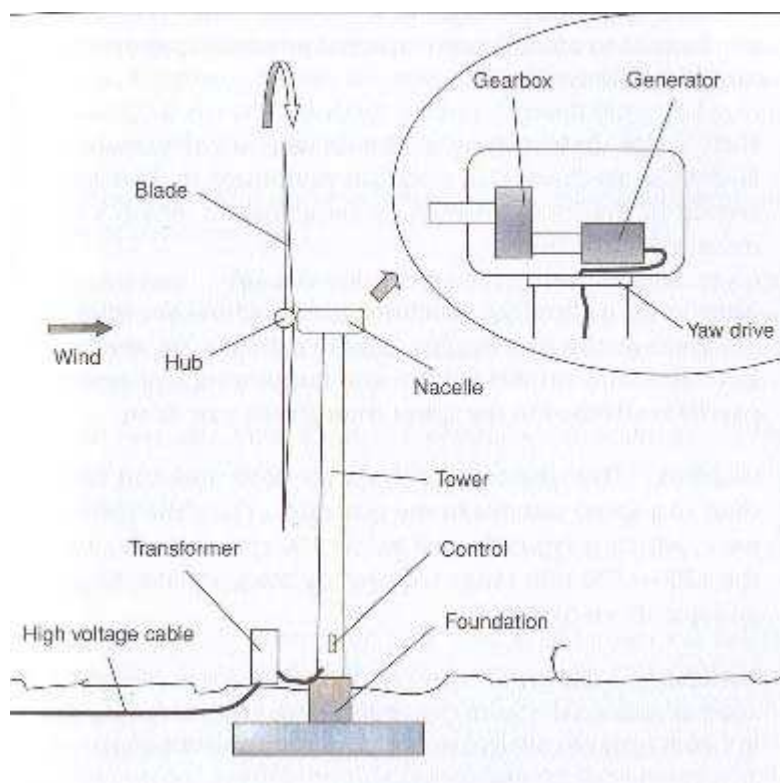
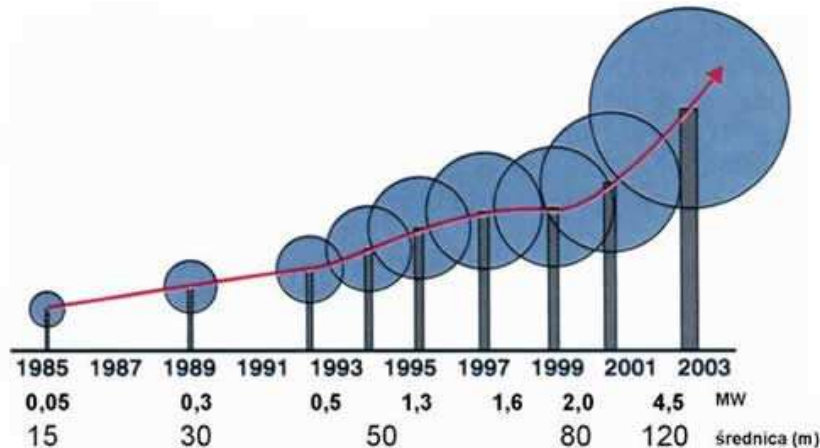


Figure-5

#### APPENDIX-D ROTOR SIZE



#### APPENDIX-E QR5 GAP ANALYSIS

##### *Qr5 Gap Analysis*

### VAWT's

#### Basic advantage

1. You may place the generator, gearbox etc. on the ground, and you may not need a tower for the machine.
2. You do not need a yaw mechanism to turn the rotor against the wind.

#### Basic disadvantage

1. Wind speeds are very low close to ground level, so although you may save a tower, your wind speeds will be very low on the lower part of your rotor.
2. The overall efficiency of the vertical axis machines is not impressive.
3. The machine is not self-starting (e.g. a Darrieus machine will need a "push" before it starts. This is only a minor inconvenience for a grid connected turbine, however, since you may use the generator as a motor drawing current from the grid to start the machine).
4. The machine may need guy wires to hold it up, but guy wires are impractical in heavily farmed areas.
5. Replacing the main bearing for the rotor necessitates removing the rotor on both a horizontal and a vertical axis machine. In the case of the latter, it means tearing the whole machine down. (That is why EOLE 4 in the picture is standing idle).

### Composite Material

#### Where we are?

- Qr5 currently uses carbon fiber as its composite material for;
  - blades, spars, and torque tube
  - Rotor construction
- Chose carbon because of the products 25 year design life.

#### Where we want to be?

- reinforced aluminum
  - aluminum and composite materials, not only stronger than carbon-fiber composites, it's 20 percent lighter and virtually impervious to fatigue
- Ultra hybrid Carbon (UHC)
- Ultra-Tough Nanotech Materials
  - Researchers have used clay nano-particles to modify a polymer material, making it 20 times stiffer, 4 times tougher, and able to withstand temperatures that are more than twice as hot.

## Active control system

### Where we are?

- Patented Gust Tracking
  - learns how the wind behaves in the installed location. Information is then used to gain maximum power from the wind during gusts, optimizing turbine performance.
- Turbine is equipped with an anemometer. It determines that sufficient wind exists for operation, the turbine is actively spun-up to operating conditions at which point it enters lift-mode and starts extracting energy from the wind.
- Dual, independent control systems providing redundant fail-safe operation. It has active sensors and intelligent control system to detect anomalous events.

### Where we want to be?

- Smart grid application
- Advanced control, enable small wind turbines to interface directly with the utility grid without the use of a battery bank
- Inverters with direct directly with the utility grid without the use of a battery bank.
  - now available to directly interface with a machine's controller and synchronize with utility voltage and frequency with very little conversion losses

## Other Technology

### Where we are?

- Helical blade design
- Direct –drive motor
  - No gearbox

### Where we want to be?

- airfoil design advancement
- Neodymium magnets used in modern alternator design for small scale wind turbine.
  - resistant to demagnetization, and have a much higher flux density than plastic, ceramic, or alnico magnets.

## APPENDIX-F WIND INDUSTRY ANALYSIS

We have used three methods to better understand wind industry from an internal and external perspective. SWOT, Five Force, and PEST analysis have been conducted.

### F.1 SWOT Analysis

Strengths	Weaknesses
<ul style="list-style-type: none"> <li>• Renewable</li> <li>• Cost Effective</li> <li>• Mature</li> <li>• Fossil Free</li> <li>• Environment Clean</li> </ul>	<ul style="list-style-type: none"> <li>• GRID structure (i.e. old)</li> <li>• Smart GRID integration needed</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>• Energy Independency</li> <li>• Climate Change</li> <li>• Need for sufficient R&amp;D funds</li> <li>• Possible new markets (Nano-Industry)</li> </ul>	<ul style="list-style-type: none"> <li>• Slow planning</li> <li>• Delayed action</li> <li>• Short term support</li> <li>• Traditional Energy</li> <li>• Political deals</li> </ul>

Figure-6



## F.2 Five Force Analysis

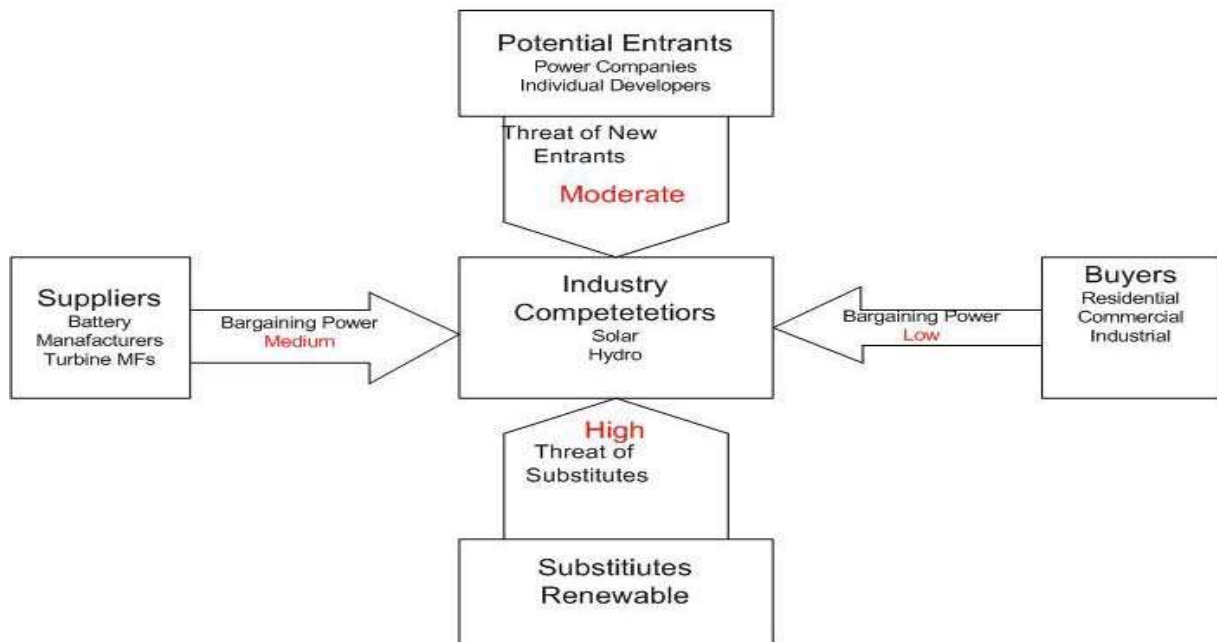


Figure-7

## F.3 PEST Analysis

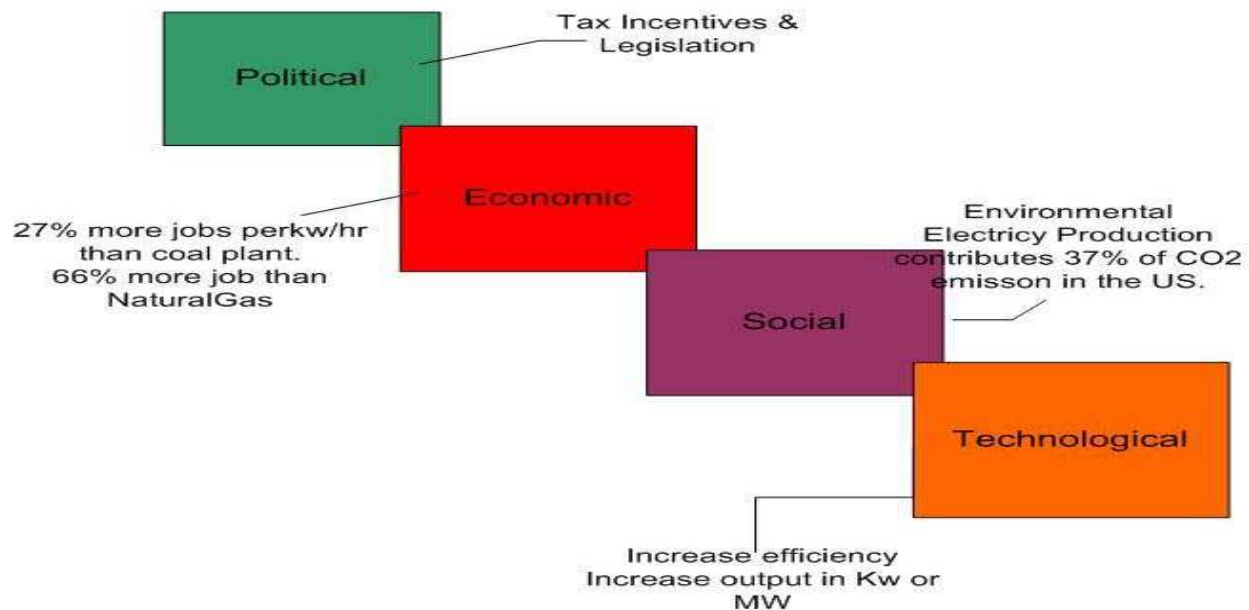


Figure-8

The motivation behind choosing PEST analysis was that the market is a considerable portion of our business, In order to be able to understand our consumers/clients we need to comprehend the Market pull and push. PEST analysis stands for "Political, Economic, Social, and Technological analysis" and describes a framework of macro-environmental factors used in environmental scanning. It is a part of the external analysis when doing market research and gives a certain overview of the different macro-environmental factors that the company has to take into consideration. It is a useful strategic tool for understanding market growth or decline, business position, potential and direction for operations.