



University of Washington



Role of Wind Energy in Attaining Energy Resilient Society

Prepared By

Team 4

Aakashi Kapoor

Joseph Wiltrot

Jocelyn Yue Zhang

For

Thomas Schmidt

University of Washington

G TTL 502

June 8th, 2009

Table of Contents

	Page (s)
Concept of Energy Resilience.....	3
Wind Energy Overview	3
Economic Benefits.....	5
Challenges and Limitations.....	7
Analysis of Wind Power in Washington State.....	8
Economic catalyst for prosperity in Kittitas County – Firms	9
Economic catalyst for prosperity in Kittitas County – Consumer.....	10
Property taxes - Property Values. – Land Owner Benefits.....	10
Indirect Economic Benefits.....	11
Employment – Creation of new jobs in Washington State.....	12
Climate benefits - Reduction of pollutants and fewer emissions.....	12
Case Study on Denmark.....	13
Way to Success.....	15
Wind Energy Benefits in Denmark.....	15
Wind power leads to Economic resiliency.....	16
Wind energy as an Economic catalyst.....	17
Indirect Economic Benefits.....	18
Employment Benefit.....	18
Climate benefits - Reduction of pollutants and fewer emissions.....	19
Challenges in Denmark.....	20
Case Study Analysis.....	21
Similarities.....	21
Differences.....	22
Conclusion.....	23
Project References.....	24

Concept of Energy Resilience

The term “Energy resilience” was first proposed by former Intel CEO, Andy Grove, who in his article “Our Electric Future” for *The American* recommends a transition toward using electricity instead of petroleum to power the U.S. transportation system. Regarding the current situation of global energy consumption, he dismissed the term “energy independence” and indicates that it is neither practical nor necessary for a world of interdependent economies. **(1)**

The concept of Energy Resiliency is more realistic than trying to achieve an energy independent society. The objective should be to increase the capability to endure a sudden disruption of an oil supply and energy resources, considering the current situation of over-dependence on foreign energy imports. Grove argues that one feasible alternative of the future US energy strategy would be shifting to electricity as “primary source”, which can be generated from many different sources, such as solar and wind.

To achieve Energy Resiliency using electricity, alternatives like renewable resources in exchange for traditional energy resources are required. We suggest Wind Energy as a successful energy alternative in order to reduce the dependency on non renewable energy sources. While Wind energy is the cheapest alternative, it also provides economic benefits through Energy resiliency and serves as an economic catalyst for industrial development. To support this, we will compare and contrast two case studies; Denmark and Washington State.

Wind Energy Overview: Application, Technology & Clean Energy Renewability

Wind is a source of renewable energy produced from air flowing across the earth’s surface. Technically, wind is dependent on the sun as it heats land masses and oceans at differing rates, causing portions of the atmosphere to warm differently. As hot air rises, atmospheric pressure causes cooler air to replace it, thus resulting movement in the air is wind. The kinetic energy of

wind is captured by wind turbines and is converted to mechanical energy by the turbine blades, which turn a drive generator to produce electrical energy. **(2)**

Application & Technology: Simply stated, a wind turbine works the opposite of a fan. Instead of using electricity to make wind, wind turbines use wind to make electricity. The wind turns the blades, spins a shaft, which connects to a generator and generates electricity. Electricity is then sent through transmission and distribution lines to homes, businesses and schools. **(3)**

As technology has improved, turbine blades have grown wider and towers have reached higher into the air. Today, wind turbines can weigh hundreds of tons and reach over 100 meters into the air. The blades, which are similar in size to large airplane wings, are attached to a 50 ton box holding the generator, gearbox and controller. Innovative designs and variable speed turbines can rotate at 10-20 RPM, which allows generation with lower wind speeds than in the past. A 2 ½ megawatt turbine produces nearly 3,500 horsepower and requires an electronic switch that can handle this type of power. These kinds of switches did not exist 10 or 15 years ago but improvements in technology have led to more advanced applications today. In the mid-1980s, wind towers were operating at 35% reliability; today, operating reliability has reached 98%. Increased reliability means more uptime, and less cost spent towards maintenance. **(4)**

Clean Energy: Wind energy is a preferred energy source in response to global warming caused by greenhouse gases. Greenhouse gases like CO₂ is produced naturally in our environment through volcanic activity, organic-matter decomposition as fossil fuels like coal and natural gas are burned to generate electricity. Fossil fuel plants emit toxic mercury, nitrous oxides that cause smog, sulfur dioxide and large quantities of carbon dioxide as greenhouse gases rise.

In contrast to traditional resources, wind energy operations do not generate air or water emissions or any type of hazardous waste. Wind Operations do not deplete natural resources like coal, oil and gas or cause environmental damage through resource extraction and transportation. These non renewable sources also require significant amounts of water during

operation. Hence, wind energy is defined as clean and renewable energy source that causes minimal harm to the environment and human health. In spite of limited use of Wind Energy, its impact on our environment is already noticeable. In 2007, nearly 17,000 megawatts of clean generation provided by the U.S. wind power prevented the emission of approximately 28 million tons of CO₂. **(5)**

Economic Benefits of Wind Power

As mentioned earlier, Wind Power can be an economic catalyst and provide benefits to support the industrial development and bring prosperity to any region.

- **Wind Energy is one of the cheapest energy resources-** Wind Energy is known as affordable and inexhaustible source. The cost of wind-generated electricity dropped by more than 80% since the early 1980s. A modern wind turbine can generate electricity at 4 cents per kilowatt-hour, which is competitive with fossil fuels. The increasing economic feasibility of wind energy can be also attributed to better technology in generation and wind prediction, as well as policies that have helped wind energy develop such as subsidies and tax credits. In regard to renewable energy policy, Denmark leads all countries in wind energy policies, a leader in percentage of installed capacity, wind energy technology, and turbine manufacturing. Denmark aims to become the “Wind Power Hub” of the world as this country encourages others to join the wind energy movement. **(6)**
- **It creates large number of Employment Opportunities** – Clean Energy can expand job opportunities by stimulating economic growth, stabilizing the price of oil, and making significant strides toward fighting global warming and building a green, low-carbon economy. Wind Power has emerged as a spate industry in recent years and the majority of jobs are created in the construction field which appears to be in a rapid decline during recent years in US. **(7)** Categories range from component manufacturing, turbine maintenance, turbine installation, operations and project management and R& D positions. It offers large amount of opportunities for those who are specialized in civil engineering,

environmental planning, electricity and other relevant technical skills. The impact is expected to spread over to a normal range of service activities—including accountants, lawyers, office clerks, human resource managers, cashiers, and retail sales people in order to support the process of clean energy expansion.

- **Wind Energy increases the influx of industries in the region.** As mentioned earlier, the cost of electricity generation using Wind energy has reduced drastically, which in turn decreases the cost of utilizing the energy resources. This may result as an incentive for industries especially in manufacturing to set up their industry in the region which has lower energy prices.

Impact of the current recession on Wind energy industry

The most recent highlight of wind energy focuses on the topic of economic recovery in the context of current recession. A lot of big industries like the automobile and financial sectors have suffered a severe setback due to the credit crunch that began in 2008. According to study conducted by Pike Research, "Wind Turbine Opportunities and Outlook", in spite of the current crisis, the Wind Energy industry will continue to grow with wind generation capacity reaching 320 giga watts in 2015 which is 165% increase since 2008. It also states that the growth would be at a 20% lesser rate than anticipated prior to 2009(8). Due to lower land prices and investment rates during the recession, it may be a wise idea to invest in wind energy as it has long term benefits as the industry continues to grow.

Use of clean energy is considered to be the core part of developing a resilient economy in the future. This strategy of developing renewable energy resources, which expands job opportunities by stimulating economic growth, stabilizing the price of oil and making significant strides toward fighting global warming, while building a green, low-carbon economy is what our resilient pursuit will become. As Wind power provides electricity at a stable, competitive cost, the result is a balance of energy prices to stabilize our economy in these times. Wind

energy can be beneficial to the economy to help it become resilient as wind energy can spur our economic recovery by creating more jobs, providing financial incentives to landowners and tax monies for government to spend back in these same communities. The fundamental value of wind to a utility's portfolio is the ability to provide energy to displace fossil fuel consumption, limit exposure to uncertain and volatile fuel prices, and hedge against greenhouse gas control costs.

It is widely believed the most serious concern of the US economy falls on an increase of unemployment, a direct result from the collapse of the housing market bubble, the destabilizing effects of this housing implosion on financial markets and the sharp rise in oil prices. At the same time, we are facing a growing climate and environmental crisis that will require a new vision for the economic revitalization of the nation by investing in new energy infrastructure, cleaner sources of power and more efficient use of electricity and fuels in order to cut pollution. Wind energy as a renewable alternative can help in increasing employment along with reducing the carbon emissions and supporting the nation to be energy resilient.

Challenges & Limitations:

In spite the many strengths of wind power, the limitations of its application are a concern along with its rapid growth and development.

Firstly, wind facilities can only be located where there is adequate wind. These high-wind areas may not be easily accessible or near existing high-voltage lines for transmitting the wind-generated energy. Wind is unpredictable, thus resulting in unreliable energy resources. Today, more research has been conducted to be able to forecast wind which would help in reducing the randomness in the system.

Secondly, the demand for electricity varies with time as electricity production must follow the demand cycle. Since wind power is unpredictable and random, it may not be available when

needed. The storage of electrical energy is difficult and expensive, thus the wind power must be used in parallel with some other type of generator or with nonelectrical storage. Wind power teamed with hydroelectric generators is an attractive solution because the water can be used for energy storage followed with the option of operation with underground compressed-air storage. Hence, without a solution for intermittent production, it is impossible for wind power to become a primary source of electricity generation and permanently replace other more polluting methods.

A **Third** factor is raised by environmentalists who are concerned about the collision of birds with the turbines. The existence of big wind turbines bears much complaint that it causes fatalities of birds and bats through collision as turbines occupy land resources. However, it is not yet proved if this is an alarming situation or if this actually causes deaths and injuries.

Lastly, but not the least issue facing wind energy use is the uncertainty of future government subsidies. Much of the recent growth of wind energy around the world has been made possible through government subsidies. While there is strong support in many nations, shifting political winds can create uncertainty for both manufacturers and utility companies.

Case Study Washington State - Kittitas County

Current Status of Wind Power in Washington State

Washington is currently the fifth-top producer of wind power nationally as Washington's wind power production grew by more than 33 percent in 2007 alone. However, American Wind Energy Association concludes, Washington State does not appear in the "Top 20" states with the most wind energy potential. Washington's greatest prospective is not related to our potential for generating wind energy, but from providing technology, innovation, and components of wind energy systems. **(9)**

Wind energy firms in Washington cover the entire spectrum of the wind power industry, including production of turbine parts, turbine technology development, wind-related consulting and turbine installation. Wind-related construction and management projects are predicted to create an additional 1,400 jobs within WA State. The wind industry has a strong basis in Washington due to transmission infrastructure, financial incentives and comparatively cheap real estate. The most significant drivers are regional Renewable Portfolio Standards and California's large market demand. Although the future of wind in Washington is looking good, the economics are not entirely stable and are affected by a number of assumptions listed below: **(9)**

- Continuation of the federal production tax credits
- Greenhouse-gas emissions reduction framework
- Decreasing production costs of wind energy
- Ability to integrate intermittent wind into the existing power system at reasonable costs
- The availability of large areas for development with access to transmission infrastructure in Washington

Wind energy as an Economic catalyst for Firms in Kittitas County

Kittitas County is home to Puget Sound Energy's Wild Horse wind farm and Chicago-based Invenergy Wind North America's wind project. PSE views renewable energy, particularly wind power, as an effective way to help address global warming and meet the future energy needs of a growing region. In 2003, PSE voluntarily set a goal of procuring 10 percent of its customers' power supply from renewable sources within 10 years. In 2005, PSE became the Northwest's first utility to solely own and operate a wind farm: the 83-turbine Hopkins Ridge Wind Facility in Columbia County, near Dayton, WA. Together, Hopkins Ridge and Wild Horse produce enough power to serve about 100,000 households. **(10)**

Over the next 20 years, PSE plans to acquire more than 1,000 MW of additional wind power. The utility seeks to boost Wild Horse's current 229-megawatt (MW) generating capacity by

approximately 40 to 50 MW as the expansion project was recently approved by the state. Completed in 2006, Wild Horse today produces enough electricity to serve approximately 60,000 households. The expansion will provide enough power to serve approximately 10,000 additional homes when the expansion project is complete. **(10)**

New transmission will be needed to support growing loads and resource additions which can help support and open up new areas for wind development for PSE and others. Creating wind diversity helps smooth variability and therefore lowers the cost of wind integration. A more economical and efficient approach for a resource such as wind is to provide a mix of firm, non-firm, and conditional firm transmission that achieves a balance between the cost of transmission capacity and the value of delivered wind energy. Continued cooperation among transmission planners and regulators is essential to create a workable model for financing and marketing transmission of wind energy in the future.

Wind energy as an Economic Catalyst for Consumers in Kittitas County

The price of wind power has dropped faster than the cost of conventional electricity generation. As wind energy is added to a utility system, its natural variability and uncertainty is combined with the natural variability and uncertainty of transmission loads. As a result, there is an increase in the need for system flexibility required to maintain utility system balance and reliability. The cost of wind integration services can be reduced through generally four types of actions: **(11)**

1. Developing more cooperation between regional utilities
2. Developing markets that will reward entities market their surplus flexibility
3. Producing more low-cost flexibility like hydroelectric resources
4. Development and application of new flexibility technologies

Property Taxes & Values – Land Owner Benefits

In Washington, property tax revenues are in the range of \$10 to \$15 per \$1,000 investment. (Tax revenues were estimated from the input-output model results based on tax rate and

spending information obtained from Kittitas County.) Today, Wild Horse is county's largest property-tax payer, generating more than \$1.5 million in annual tax revenue for local schools and government services, while the Wild Horse expansion should increase these employment and tax benefits by approximately 15 percent. The wind farm also produces significant spin-off investments in local businesses and infrastructure in the area. This new tax revenue of over one million dollars includes \$480,000 for the Kittitas School District, \$402,000 for the state school fund, and \$162,500 for the county general fund. **(11)**

Because wind power projects have a much larger footprint than conventional power plants, they generate comparatively greater landowner revenues through leases and direct purchases of land. (Leases and royalty payments typically run \$2,000 per turbine). As wind projects are usually sited in rural communities, these payments provide an additional source of revenue for rural landowners and farmers as farming and ranching operations are not greatly affected. **(12)**

Farmers and ranchers who lease their land to wind developers receive annual royalty payments averaging between \$3,000 and \$6,000 per year for each turbine sited on their property. For comparison, each turbine sits on roughly an acre of land, while that same acre would earn \$319 per year if used to cultivate winter wheat. Wind turbines are compatible with farming operations, with landowners farming and ranching around them. **(13) (14)**

Indirect Economic Benefits

1. Additional household earnings from employment growth
2. Increased diversification of the county and state economic bases that ensures greater economic stability
3. Increased taxes should result in additional government spending for schools and infrastructure
4. Beneficial effect in agriculture as turbines provide farmers with reliable revenues
5. Wind turbine-related business-Great Opportunities for Washington Ports in the case of Long View where ships are able to offload parts of the tower and turbines for construction

Employment – Creation of new jobs in Washington State

Construction of either a wind energy facility will generate jobs for local communities and the state as a whole. In general, the employment opportunities associated with a wind power plant are in construction, operation, maintenance and manufacturing. Compared to conventional generation options, wind development creates more jobs per dollar invested and per kWh generated. Compared to conventional energy projects, wind energy projects generate slightly more jobs per dollar invested and significantly more jobs per million kWh of energy generated. A study by the New York State Energy Office found that 10 million kWh of electricity produced by a wind energy project would generate 66 percent more jobs than a similar output natural gas CCCT. **(15)** The existing Wild Horse wind farm created up to 250 jobs during its construction and more than 50 permanent jobs in Kittitas County as it became operational in late 2006. The Wild Horse expansion should increase these employment and tax benefits by approximately 15 percent. The wind farm also produces significant spin-off investments in local businesses and infrastructure. **(16)**

Climate benefits - Reduction of pollutants and fewer emissions

Wind power plants can reduce fuel usage by conventional power generation, which will in turn reduce emissions of NO₂, SO₂, and other pollutants, depending on the fuel involved. The economic benefit of the emission reduction induced by the wind plant can be estimated using a range of monetary values for the various pollutants studied.

Wind energy projects have sizable environmental benefits relative to conventional energy projects. Compared to natural gas fired CCCTs, which are the cleanest fossil fueled energy electricity generation, wind energy projects, produce very small amounts of air pollutants. In addition the greenhouse gas emissions associated with wind energy are very low compared to conventional generation technologies. A 2002 RAND report presented the amount of carbon monoxide, nitrogen oxides and sulfur dioxide emissions that would be avoided by replacing 20 percent of future CCCT generation with renewable energy resources, such as wind power. **(17)**

Case Study on Denmark

Status of Wind Energy in Denmark

Even though the first electricity generating wind turbine was developed in the United States in 1887, Denmark had emerged as a leader in not only generation of electricity but also of sustainable energy infrastructure planning. It is thought to be successful due to flat and windy geography but the main reasons can be summed as Long term market stimulation methods, an environmentally concerned and engaged population, an extensive grid system and a well established planning system for turbines [18].

The 1973 oil crisis was a huge disruption to the energy system in Denmark as it imported 90% of its energy requirements. This was alarming for the Danish government which instantly made self-reliance the main goal to make Denmark resilient to the supply disruptions. The need for alternative resources initiated a debate on use of nuclear power but it lost the public debate in 1885 when government banned its testing and research. This was due to the opposition from the academia and Danish people, it was also backed up by the research and testing done in areas of alternative energy source specifically Wind energy.

Way to Success

The wind favorable Danish climate is due to the country's long coastline characterized by consistent and strong winds. As Denmark is not equipped with other natural energy sources such as coal, water falls for hydropower, it naturally turned to alternate sources like Wind and became one of the first countries in which a dedicated effort was put in to experiment with and implement wind technology as basis for electrification.

Besides Denmark's climate, the investment stimulation and future planning is the one of the most influential reasons that Denmark is the leader in Wind Energy. The most crucial decision

was a 30% investment subsidy for renewable energy which took place in 1979. As it was easy to finance the initial capital cost of a turbine, new turbine projects by small cooperatives and group of families started growing and created employment and economic benefits for Denmark. Because these ventures were based on the ideals of social cooperation, community and self reliance, people accepted and encouraged the construction of turbines, rather than opposing them for their noise and the visual interruption in the landscape [18].

Due to state funded efforts for research and development of conservation strategies and more efficient energy technologies, “on the international level Denmark is at the cutting edge with regard to utilizing renewable energy sources” [18].

According to Meyer 1995, Wind Energy was developed in California as well but US turbines were not as reliable as Danish turbines [18]. As a result of the technical lead Danish turbines were reliable and built a huge export market around the globe with US as one of its biggest markets. This also initiated a competition among the Danish companies to decrease the cost of electricity production. The increased quality increased exports to California, and emerging markets like Germany, Sweden. With the increase in demand and successful testing on small scale turbines; Denmark removed the investment subsidy to increase the size of the Wind Turbines but it continued the increase in electricity generation by Wind energy which reached around 20% in year 2003 according to Danish Energy Association. [18].

The Danish Energy Association (DEA), created in 1976 under the ministry of Economic and Business Affairs, is in charge of ensuring a secure and responsible production and consumption of energy from both an economical and environmental point of view [18]. One of the main “secrets” behind the development was the Danish tradition for co-operative neighbor ownership of energy technologies. This was supported by co-operative ownership model in 1996 with around 120,000 individual wind turbine owners. This model had a positive effect on the local acceptance of wind power projects, and ultimately resulted in the political acceptance of wind power gradually.

Since 2000 Denmark proposed to use of green certificate quota system and implements the Feed-in-Tariff system which is based on an obligation for the regional or national utilities to buy a certain share of electricity from renewable source. This helps the market to stabilize the demand, reduce uncertainties and also create simulated investments for increase in wind energy markets. The basic support mechanism for wind energy in Denmark is essentially a fixed price system, with an environmental premium per kWh in addition to the market electricity price. The premium is financed as an addition to the electricity price per kWh, shared equally among all electricity consumers in relation to their electricity use [19].

Wind Energy Benefits in Denmark – Overview

The potential **Economic** benefits of local wind turbine manufacturing include:

- 1) Economic development opportunities through sales of new products, job creation, and increased local tax base
- 2) Opportunities for the export of domestically-made wind turbines to international markets, further enhancing the prospects for local economic development
- 3) Cost savings that result in lower-cost wind turbine equipment, a lower cost of wind-generated electricity, and therefore higher growth rates in domestic wind capacity additions [20].

Similarly potential **Social and Environmental** benefits include

- 1) It supports creating an Energy resilient and self sustainable society.
- 2) Wind energy has been proved to help in reduction of CO₂ emissions and improvement of health index in the nation.

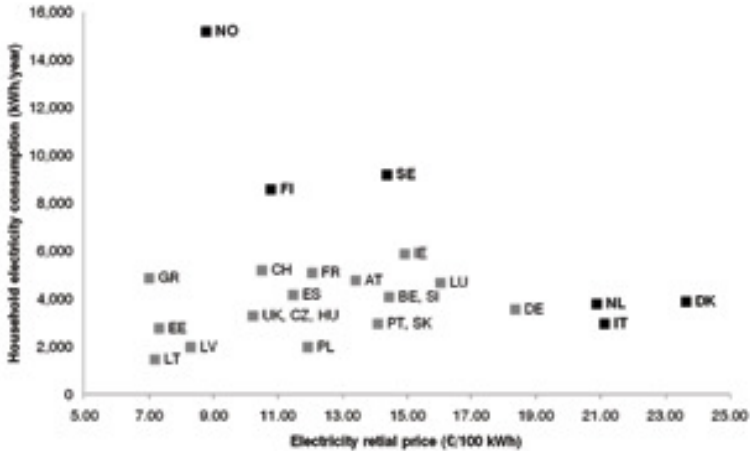
Wind power leads to Economic resiliency

Till 1970, Denmark was dependent on Middle East for oil and imported 90% of its energy requirements where it suffered a huge disruption due to the 1970's oil crisis. Denmark started

its search for alternatives and after a lot of effort put in to find alternative resources, Since 1999 Denmark has emerged as a self sufficient society [18]. With the exploration of oil and gas and increased research and initiative in alternative energy sources, Denmark has not only become self reliant but also at present it earns tremendous profit by exporting energy sources. Vestas is the leading wind turbine manufacturers in the world and 99% of its local production is exported. The wind energy produces around 20% of the total electricity generated in Denmark and the target is to reach 30% by year 2020.

Sansoe Island in Denmark which is a small island with 4000 inhabitants is 100% self sufficient for electricity through bio mass and wind energy. It has 100% carbon offset for transport and Net-Zero Carbon for the energy consumed on the Island [21].

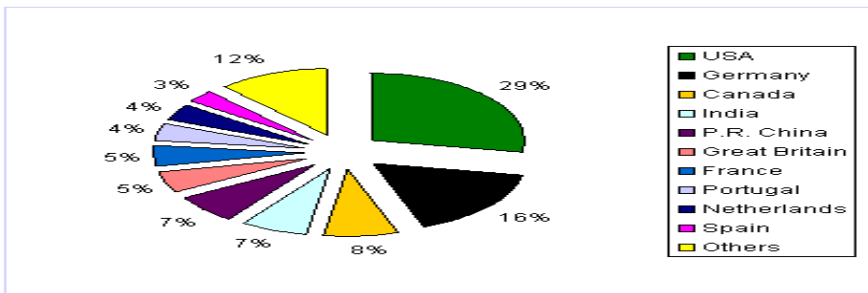
Denmark’s Wind Industry success is credited to a well planned government policies and support for research and innovation. But also Denmark has strict policies to encourage consumers to reduce energy consumption which plays a huge part in making Denmark energy resilient. Long lasting competition among the Danish industries have reduced the cost of production using Wind energy to a huge extent but in the European Union, Denmark has the highest tax level in the retail price of energy for consumers. This is implements to reduce the total household energy consumption as shown in the figure below. Denmark has high energy taxes and there exist almost 120% gap between retail prices in Denmark and UK [22].



Household electricity consumption vs electricity retail price for European countries [21]

Wind energy as an Economic catalyst

Since 1999, Denmark has emerged as a leader of green energy technology. The export market for the green energy technology grew significantly to 5.5 billion Euros in 2004 from 50 million Euros in 1992 [23]. At present, Denmark is a world market leader for Wind turbine manufacturing with production of more than 50% of the world's wind turbine. It has an export rate of 90% with Denmark's Vestas, the largest turbine supplier in the world, selling over 99% of its turbines outside of Denmark in 2004 [20]. The export is shown in the graph below which shows power sold in each year. According to the Danish Wind Industry Association, in year 2006 Denmark exports from the wind industry was 27 billion kroner. Manufacturers in 2006 sold around 5.4 MW as shown in the graph which corresponds to 33% of the global market [24].



Source Danish Wind Industry Association

Wind Energy has catapulted Denmark's economy to be defined as "high income economy" by the World Bank and it generates around \$7 billion annually [25].

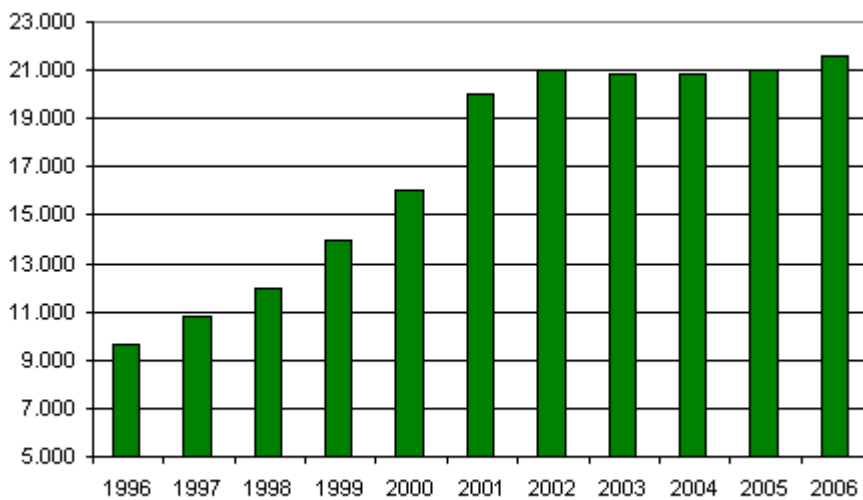
Denmark exports Wind turbines all over the globe with US being its largest market as shown in the graph above. According to the latest figures from Denmark's Wind Energy Association, which represents some 200 companies, in year 2007 revenues for wind industry were up almost DKK 10bn (USD 2.1bn) to DKK 42.2bn (USD 8.8bn), and including the industry's foreign activities the revenue increased from DKK 16bn (USD 3.3bn) to DKK 65bn (USD 13.5bn) in 2007 [26]. Rune Moesgaard of the Wind Energy Association told financial newspaper Børsen: "These figures show an amazingly strong growth rate of over 25% in a year, and the good news is that it looks set to continue" [26].

Indirect Economic Benefits

1. As a technological leader in Wind Energy, Denmark has attracted Wind energy companies from countries which lack expertise like Suzlon has one of its headquarters in Denmark to utilize the technical exposure in Denmark. This helps Denmark's economy by attracting foreign investment in forms of Wind farms and offices.
2. Cooperative ownership models in the Wind Energy sector create opportunities for small families and small business that result in enhancing living standard
3. The cost of health has reduced since Denmark became self sufficient and Wind energy is said to improve the quality of life index.

Employment Benefit

Direct jobs in Wind Energy sector are typically created in three areas: manufacturing of wind power equipment, constructing and installing the wind projects, and operating and maintaining the projects over their lifetime [20].



[Source- Danish wind Industry association]

Wind energy has been economically beneficial for Denmark's economy by creating direct and indirect jobs. 75% of the jobs in the EU are in Denmark, Germany and Spain. Wind Energy sector is growing at the tremendous speed and in year 2007 European Union directly employees 108,600 people and including indirect employment the figures reach 154,000[ref . The direct employment in wind sector has increased 125% since the year 2003 [27].

According to the Danish Wind Industry Association, Denmark employed more than 20,000 people in Wind energy sector in year 2006 as shown in the graph above.

Climate benefits - Reduction of pollutants and fewer emissions

The biggest indirect benefit from Wind Energy is the impact on environment and health. According to the Energy statistics from the Danish Energy Agency for 2007 coal production has fallen by 40% since 1994 to 2007 while natural gas production has increased by 203%. And around 20% of Denmark's electricity output is met by wind power.

According to the Danish Wind Industry Association, Denmark has committed to reduce the emission of greenhouse gases with an average of 21% during 2008-2012 compared to emission level in 1990 under the Kyoto Protocol [18]. Generation of electricity through Wind energy does not produce emissions and benefits the environment. Wind Energy results in indirect health and environmental benefits. It improved the health index of Denmark and reduced the CO2 emissions.

According to the Danish government, average carbon dioxide emissions (emissions adjusted for weather and exports) from coal-fired power generation fell 41% 1990-2007 [28].

Challenges in Denmark

The Denmark success is considered to be the result of cooperative ownership model, government support and long term planning. But in the late nineties the co-operative

ownership model were abolished for a new wind power capacity of 0.5–1MW turbines. The owners of these turbines were mostly single owners, typically farmers which resulted in lack of support from the local political base. Due to the decreased importance of the co-operative ownership model and a large wind power production, the Danish energy system has been facing some challenges.

- Increasing political resistance to wind power, i.e. due to the fact that surplus electricity is being sold at unprofitable low prices on the Scandinavian Nordpool market
- Increasing local opposition to wind power projects¹ caused by an increasing density of wind turbines at inland sites and a change in ownership structure. This development has been supported by the association of large Danish industries and the association of large energy companies which have always opposed the development of green energy technologies, such as wind power [23].

Case Study Analysis

Based on our case studies; we can state that wind power development in Washington and Denmark results in resiliency and potential economic sustainability. It is clear that harvesting a region's renewable energy resources not only generates clean, homegrown, renewable energy, but also creates a robust regional economy by bringing new jobs and revenue to communities in WA State and Denmark respectively. The comparisons drawn from the two case studies include;

Similarities

- ***Significantly greater landowner revenues land leases***

In WA State, the revenue from wind farms is money to the landowner that can help promote agricultural crops or livestock growth. This revenue is pumped back through local rural economies in most cases as a resilient benefit of wind farms. In Denmark, cooperative model benefits the local communities and families by helping them establish a wind farm and earn income from their land.

- ***Generation of local jobs***

Hundreds of jobs have been created directly and indirectly during the development of wind farm projects both in Washington State and Denmark. Denmark employs more than 20,000 people in Wind energy Industry alone as Washington has built a workforce in the industry that comprises over 1400 employees from 11 different wind projects in the state.

- ***Significantly greater local tax revenues for the community***

Kittitas County has seen millions of dollars come from wind projects that are distributed back to the county towards local schools. The Wild Horse Wind Project managed by Puget Sound Energy pays in excess of one million dollars to the county which has been a resilient resource for a rural community. Similarly, wind development is supposed to have a huge share in increasing the quality of life index and standard of living of the Danish people.

- ***Potential revenues from sale of “green power”***

Puget Sound Energy is selling to renewable energy to California, while Denmark companies have cornered the market in Wind Technology applications in the World. Both Denmark and Washington benefit from geographic conditions that promote Wind Farms which are drawing on direct investment into their economy's' as well.

Contrasts

- ***Integration of intermittent wind into the existing power system at reasonable costs***

In the United States, the focus is on the method to integrate wind into the existing system with minimal impact on traditional rules and procedures. The environmental and social impact of the system is suppressed by the belief that current system is efficient.

While in Denmark, the focus is to integrate Wind energy within the existing power system in an environmentally preferred way which results in an accelerated growth. However, Texas is considering a two billion dollar wind farm which might rival Denmark's elitism.

- ***Social acceptance of Wind farms on the natural Landscapes.***

The western parts of WA State are heavily populated and naturally enticing. Even though surplus wind is available due to beneficial geographic conditions, it may not gain social acceptance due to hindrance in natural landscapes.

However in Denmark, the government subsidies and cooperative ownership model presented humongous benefits for small families and communities which resulted in social acceptance of turbines in their backyard.

- ***Government policies, regulations and infrastructure planning***

To support an energy resource alternative, a paradigm shift in culture and policies is required. This can only be achieved by Government support. In US, policies related to Wind energy require to be modified to support it as in Denmark where the policies like feed-in-rate and Energy21 has accelerated the growth. Also, Wind energy requires a proper infrastructure planning which is considered to be the reason of Denmark's success.

Similarly, Denmark has higher environment regulations as compared to US. Even though they produce cheap energy by using wind the high energy taxes increase the cost to be highest in Europe. This is to control the energy consumption which may result in paradigm shift. Where as in WA State, energy consumption costs have reduced which has increased per capita consumption.

- ***Wind Energy Generation Cost***

Currently, Washington State does not have a competitive Wind Energy generation market as Denmark. The competition among industries to capture the market has resulted in lower cost of production in Denmark. Washington imports its technology where as Denmark has locally manufactured turbines which reduces cost. Cost of Land is lower in Eastern Washington as compared to Denmark, but the biggest investment in Wind Energy remains to be the Turbine blades and nacelle which are manufactured in Denmark.

Conclusion

In recent years, wind energy has been gaining both economical and environmental acceptance in the United States as a renewable energy source. In the current context of recession, the development of wind energy serves as an important economic catalyst for both local and national economies in terms of generating job opportunities, local tax and property revenues, as well as stimulating the new “green power” businesses. As an alternative energy resource, Wind Energy is definitely environmental friendly. Most importantly, as analyzed Wind Energy can lead to an emerging Energy Resilient society by stabilizing the economy from disruption in energy sector by increase in fuel prices, energy supply uncertainty and depletion of non renewable resources. Despite a promising prospect of wind energy application, further development and popularization rely largely on the continuous improvement of wind technology as well as developing wind integration into the existing energy structure.

As a conclusion to our study, we make following **suggestions** to accelerate growth in Wind sector in Washington State

- Better Government Policies to support wind energy by providing wind integration subsidies.
- Stricter regulations to reduce emissions as a part of Western Climate Initiative.
- Contributing in paradigm shift by reducing Energy consumption through regulations like energy taxes.

“Energy Conservation is the Foundation of Energy Independence” – Thomas H. Allen

Project References:

- (1) www.mckinseyquarterly.com/Energy_Resources_Materials/Environment
- (2) American Wind Energy Association: Wind Energy Today
[http://www.nhsec.nh.gov/2006-01/documents/39_awea.pdf]
- (3) American Wind Energy Association: Wind Energy Today
[http://www.nhsec.nh.gov/2006-01/documents/39_awea.pdf]
- (4) IEEE website: [<http://www.ieee.org/web/emergingtech/discourses/windpower/tech.html>]
- (5) American Wind Energy Association: [http://www.awea.org/faq/wwt_environment.html]
- (6) American Wind Energy Association: Wind Energy and Economic Development: Building Sustainable Jobs and Communities; [<http://www.awea.org/pubs/factsheets/econdev.pdf>]
- (7) Center for American Progress: Green Economic Recovery Program:
[http://images2.americanprogress.org/CAP/2008/09/peri_mt.pdf]
- (8) Pike Research, [<http://www.pikeresearch.com/>]
- (9) American Wind Energy Association (www.awea.com)
- (10) Peugeot Sound Energy (www.pse.com)
- (11) “Wild Horse Wind Power Project Tax Impacts.” Economic Development Group of Kittitas County)
- (12) <http://www.cted.wa.gov/energy>
- (13) Renewable Northwest Project [www.rnp.org]
- (14) Kittitas County Assessor’s Report 2005 Assessed Valuations Levies and Taxes to be Collected 2006,
- (15) Danish Energy Association [www.dea.com]
- (16) Renewable Northwest Project [www.rnp.org]
- (17) <http://www.mrsc.org>
- (18) Planning for Wind energy success : Lessons from Denmark – Rebekkah Ann Cobum.
Thesis for Master of Urban planning, University of Washington 2003.
- (19) Case study- Wind Energy in Denmark EPU –NTUA, Greece.

- (20)** Fostering a Renewable Energy Technology: An international comparison of Wind Industry Policy Support Mechanism - Joanna Lewis and Ryan Wiser; November 2005
<http://eetd.lbl.gov/ea/emp/reports/59116.pdf>
- (21)** Wind Energy: Opportunities for Prince Edward Island - Yves Gagnon Université de Moncton
- (22)** High Energy expenditure drives the adoption of intelligent metering Tobias Ryberg; 2007
<http://www.berginsight.com/media/MI-1-2007-SMART-METERS-PG64-65.pdf>.
- (23)**Renewable Energy and the need for the local energy markets – Frede Hvelplund
Department of Development and Planning, Denmark 2006
- (24)**Danish Wind Industry Association <http://www.windpower.org/EN/core.htm>
- (25)**Economic Advantages of Community Power - Khlaire Parré, MA, PMP Ontario Sustainable Energy Association.
- (26)**Growth Boom for Denmark’s Wind Energy industry for Ministry of Foreign Affairs of Denmark
<http://www.ambottawa.um.dk/en/servicemenu/News/Growthboomfordenmarkswindenergyindustry.htm>
- (27)**European Wind Energy Association - <http://www.ewea.org/index.php?id=1638>
- (28)**http://www.ens.dk/graphics/UK_Facts_Figures/Statistics/yearly_statistics/2007/Figures2007.xls,