SAVONIA

Wind Power

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Bachelor’s Thesis

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Bachelor’s degree (UAS)

SAVONIA UNIVERSITY OF APPLIED SCIENCES **THESIS**
Abstract

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Abstract
With the growing shortage of traditional energy, the development of renewable energy becomes more and more important. Wind power, as an energy which has been used for thousands years, has its new life in the modern society. Wind turbines can convert wind power into electricity which can be used by people through the power grid. According to learning principle of wind turbines, a basic understanding of this conversion can be settled. The example of Denmark will be introduced so that readers can understand how the government can play an important role in developing infrastructure and the whole industry. The current recycling situation will be analysed and problems which should be solved in the future will be pointed.

Keywords
Wind Turbines, Structure, Concept, Principle, Denmark, Market, SWOT

CONTENTS

1 INTRODUCTION

After the first industrial revolution, the demand for energy has been growing rapidly for production and normal life. According to the statistics by IEA, International Energy Agency, the total final consumption was more than doubled since 1971 to 2014, from 4244 Mtoe to 9426 Mtoe (International Energy Agency 2016). At the same time, the traditional energy coursing environmental pollution and the emergence of multiple global or regional energy crisis prompted humans to begin research on sustainable energy development.

Sustainable energy is the energy which is derived from natural resources that are capable of being replenished, and hence can be sustained in the long term (Oxford Dictionary of English 2010). The most important feature of it is being environmental friendly. With the development and popularisation of sustainable energy, energy tensions and environmental pollution problems will be alleviated to a certain extent.

Wind power, as one of the sustainable energy, is showing its development and commercial potential. According to the Figure 1 from 2005 to 2016, wind energy becomes the second largest form of power generation capacity in Europe, and it has surpassed coal. In 2016, 10.4% of the EU's electricity demand was covered by wind power with approximately 300 TWh generated (WindEurope 2017).

The structure of this thesis will include the following:

At first, the technical theory and components of wind power will be introduced. With these aspects, readers will have a relatively clear understanding of the wind power. Secondly, hardware maintenance and recycling of wind power will be explored because maintenance can guarantee the stability of mechanical work and recycling can avoid the impact of waste materials on the environment.

Then, Denmark, as a country which supports developing wind power technology, will be used as an example to analyse and find its successful ways.

Finally, the global wind power market and wind power SWOT situation will be introduced. Readers will have a general understanding of the market, its benefits and disadvantages.

In this thesis, commercial wind turbines are being analysed, and small household wind turbines are not in this range.

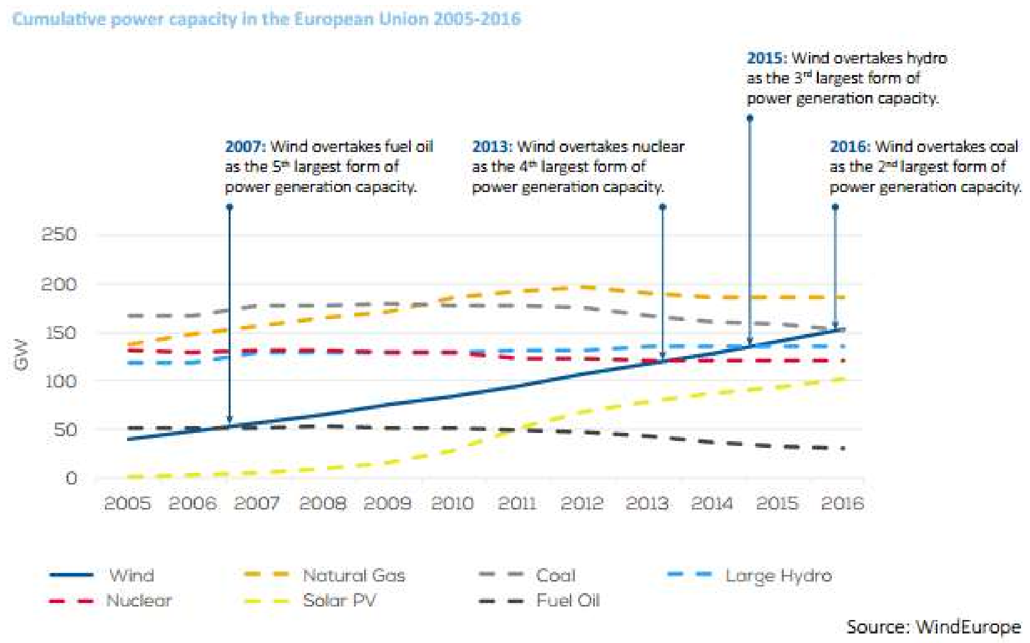


FIGURE 1. Cumulative power capacity in the EU 2005-2016 (WindEurope 2017)

2 CONCEPT AND PRINCIPLE OF WIND POWER

2.1 The formation of the wind

Wind energy is one of the products from solar radiation energy. The atmosphere on earth is equivalent to the water in the ocean. In the ocean, the deeper you dive, the temperature is going to colder and the pressure is going to greater. However, the most different aspect between atmosphere and water is that atmosphere has better thermal conductivity. So that the heat from the sun can be transferred to the atmosphere from high altitude to the surface of the earth.

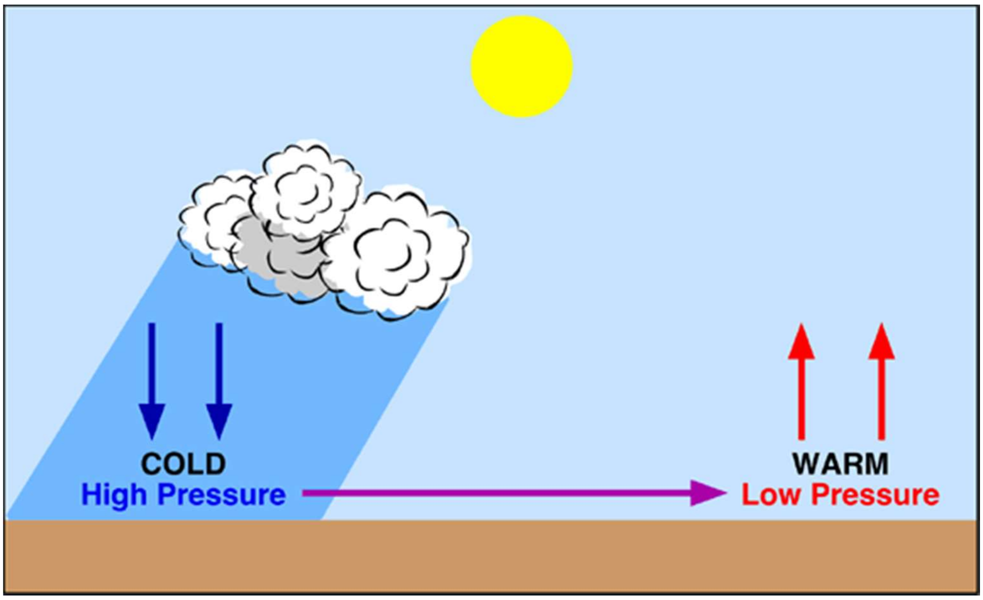


FIGURE 2. Formation of wind as a result of localised temperature differences (Pidwirny 2006)

Figure 2 shows the formation of wind due to localised temperature differences. When the sun shines on the ground, the air will be heated and the warm air will rise because of lighter. Then in that place, the pressure will be smaller than places where it cannot shine, due to cloud cover, water bodies, vegetation, uneven surfaces like mountains and valleys. According to physics, air will want to move from high to low pressure to balance the difference, which is what we know as wind (Met Office 2015). This phenomenon is called convection current.

2.2 Components of wind power

Nowadays, horizontal-axis is the type which most modern wind farms selected. Figure 3 is a side view of a horizontal axis wind turbine with left turbine blades.

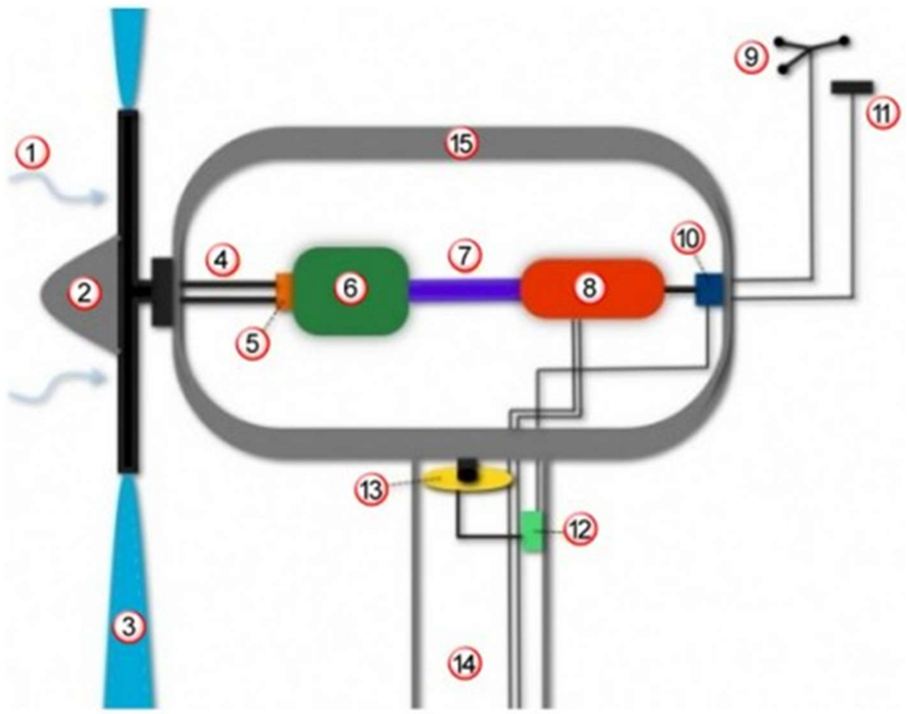


FIGURE 3. Structure of wind turbine (TurbineGenerator 2017)

Number 1 means the direction of the wind.

Number 2 is the wind turbine’s nose. This part is designed with aerodynamic to ensure that the negative impact is the minimum to the wind.

Number 3 means blades. The blades are connected the nose and the rotor. When the ample wind speeds are coming, the blades will be pushed and begin to spin.

Number 4 is the main turbine shaft. It is connecting the blades to the inner components of the machine.

Number 5 is the brake. It can stop the wind turbine when the speed is too high or the turbine is unneeded.

Number 6 is the gearbox. When the gears change, the speed of rotation will change too. It can balance the speed and torque and the generator can work with a suitable situation.

Number 7 is the high-speed turbine shaft. It connects the gearbox and the generator.

Number 8 is the turbine generator. It converts the mechanical energy from the wind into electricity.

Number 9 is the anemometer. It is a device that can measure wind speed. The controller is normally instructed to start or stop the turbine at different wind speeds.

Number 10 is the controller. With anemometer, it can control the rotating blades to start or stop.

Number 11 is the wind vane. It is an instrument to measure the wind direction.

Number 12 and 13 are the yaw drive and yaw motor. They can control the turbine to be facing the wind with the information from wind vane.

Number 14 is the turbine tower. It contains cabling, so the generator can send power to the transformer or battery that eventually distributes the available power. The tower is also an important structural support system, which will keep the turbine height in the air, where the wind speed is more ideal.

Number 15 is the turbine nacelle. (TurbineGenerator 2017.)

2.3 Principle of wind turbine

The principle of wind power is almost the same as the firepower. However, the wind is the resource which replaces the fuel and water（or steam）to become the power source to propel the turbines.

Simply, when a certain wind speed blows through three propeller blades which are specifically arranged in a horizontal manner, it will drive the entire fan rotation. The speed of the fan is generally slow, so it will output faster speed through a gearbox. Then through the generator, it converts mechanical energy into electricity energy. The output electricity energy is alternating current with low voltage. It still needs to go through a rectifier and an inverter to access the power grid.

The direction and speed of wind are always changing. The wind vane can measure the direction of wind and feedback to the controller to rotate the head to face the wind. The anemometer can measure the speed and then feedback to the controller to determine whether to limit the speed of the fan or start the fan.

The blade is the most important component for the wind turbine. Nowadays, all of wind turbines in wind farms are using curved blades.

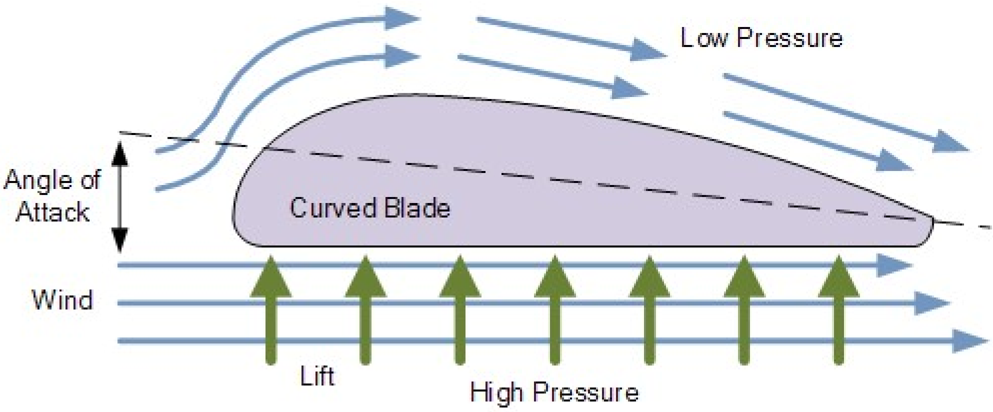


FIGURE 4. Air flow of blade (Alternative Energy Tutorials 2017)

Figure 4 shows the distribution of the cross section of the blade and the airflow. The curved blades are very similar to the long aerial plane wings (also known as aviation foils) with curved surfaces at the top. The velocity of the top flow is faster than at the flat side of the blade, which makes the top pressure lower. The result is that the top pressure is small. That is to create a blade movement. (Alternative Energy Tutorials 2017) This force is the lift force.

However, the blade still has resistance. It is called a drag force, which is basically the friction between the air and the blade surface. The reason of increasing lift force is increasing the angle of attack, but at the same time, the drag force is also increased. So, when the lift to drag ratio is maximum, the wind turbine can give maximum performance.

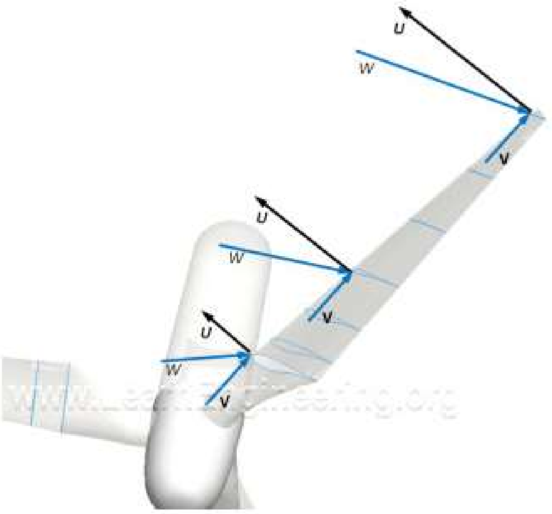


FIGURE 5. Force in different place of blade (LearnEngineering 2013)

When the angular velocity is the same, the farther away it is from the center, the greater the line speed. Figure 5 shows the different force analysis in the blade different places of it. As a result, the modern rotor blades twist 10 to 20 degrees along their length from the root to the tip so that the angle of attack is reduced from where the air is relatively slowly moving closer to the root to a faster movement. This blade twist maximizes the length of the attack along the length to achieve the best lift and rotation. (Alternative Energy Tutorials 2017.)

3 MAINTENANCE AND AFTER-USING

The rapid development of wind power for the wind power equipment manufacturing industry has brought great market opportunities. Denmark, Germany, Spain, India and the United States are the world's largest concentrated areas for the wind power manufacturing industry. In particular, the Europe’s production capacity of wind power equipment manufacturing has exceeded 50 % of the world, making Europe become to the major wind power equipment export area in the world.

However, it has also brought great challenges. The increase of the capacity of the wind turbine increases the size and the scale of the wind turbine. It also puts forward the higher requirements for the safety and reliability of it. The excellent quality and high reliability of wind turbine units are the fundamental requirements of wind power generation. Besides production quality, maintenance is another important part for supporting high reliability.

In order to achieve true sustainability, wind turbine material recycling is also very important. The design life of the wind turbine is about 20 years. After 20 years, the end of the wind turbine will be a huge challenge.

3.1 Maintenance

Maintenance is very important for any machine, and wind turbines are also no exception. Wind farms are normally located in harsh, remote environment, and the cabin is located in the 50 m to 80 m above the altitude. These conditions increase the difficulty and the cost of maintenance. For operating units with a working life of 20 years, operating and maintenance costs account for about 10 % to 15 % of wind farm revenues; for offshore wind farms, wind turbines operate and maintain up to 20 % to 25 % of wind farm income. (Chen et al. 2011.) High operating and maintenance costs increase the operating costs of the wind farms while reducing the economic benefits of wind power.

In order to reduce the costs, many types of research have been done for tracking and investigating the failure of wind turbines. The top ten components which are responsible for most downtime caused from 1997 to 2005 have been counted by Johan Ribrant and Lina Margareta Bertling from Royal Institute of Technology (KTH) in Sweden. The data is quite old and some of them may have changed due to technology improvement. But it is still valuable for understanding.

TABLE 1. Top 10 failure rate components (Ribrant J. and Bertling L.M. 2007)

Component	Failure Rate	Downtime per Failure (h)
Gears	0.045	256.7
Control System	0.050	184.6
Electric System	0.067	104.6
Yaw System	0.026	259.4
Blades and Pitch System	0.052	12.5
Generator	0.021	210.7
Sensors	0.054	49.4
Hydraulics	0.061	43.2
Drive Train	0.004	291.4
Mechanical Brake	0.005	125.4

According to the Table 1, the failure rate for each component is quite small but the downtime is quite huge. However, the full picture needs to add repair and replacement costs, the real influence will be much larger than the paper data.

Reliawind is a project which is running between 2008 and 2011 held by Spain. The main objective is to focus on the design, operation and maintenance of optimized wind energy systems. (RELIAWIND 2013.) In the report, it also has data to count the failure statistics.

The fault statistics in Table 2 are used for key components of wind turbines. The data comes from 450 wind farms, including shore and offshore wind turbines running at different times (Elforsk 2012). As we can see, the pitch system, the frequency converter and the generator assembly are the top three contributing to average time lost. If these faults can be detected by information technology, wind farms will pay less for their loss and maintenance costs.

TABLE 2. Critical components failure rate (Elforsk 2012)

Assembly	Contribution to Total Failure Rate (%)	Contribution to Average Time Lost (%)
Pitch System	21.29	23.32
Frequency Converter	12.96	18.39
Generator Assembly	7.16	10.47
Yaw System	11.28	7.30
Gearbox Assembly	5.13	4.66
MV Switchgear	3.32	3.27
LV Switchgear	5.88	3.03
Transformer	1.71	1.84
Tower	2.66	1.75
Hydraulic System	1.19	1.42

For suppliers, in addition to developing new wind turbines and technology, a comprehensive maintenance program will reduce the incidence of accidents. Siemens Wind Power is a well-known wind power enterprise. Its maintenance profile is a suitable source to learn how to keep the wind turbines in good working condition.

Similarly, as the general mechanical companies, Siemens Wind Power provides scheduled service as well as troubleshooting. Scheduled service is the annual service including routine maintenance tasks, structural inspections, and compliance testing of various components. Troubleshooting is the service that when a wind turbine has some faults which have to be identified, Siemens technicians will visit the turbine to diagnose the problem on-site. In addition, Siemens Wind Power sets up two remote diagnostics centers, which are located in the United Kingdom and Denmark, in order to detect problems early and reduce the downtime. These centers provide diagnostic and monitoring services for Siemens wind turbines around the world, proactively maintaining equipment at optimal performance levels. Through the real-time data, the experts on a 24/7/365 basis will monitor the entire Siemens global team closely and can detect and often solve potential problems remotely before they occur. This initiative can help to reduce the costs associated with wind energy. (Siemens 2014.) Siemens uses a combination of traditional and information technology maintenance method, which not only decreases the downtime caused by faults, but also reduces the wind farm on the maintenance of the expenditure, and further enhance the wind energy economy.

3.2 After using

With the passage of time, the first wind turbines are going to the end of the service life. How to deal with them becomes a more and more important issue. Lots of organizations and institutes are doing many researches and give their opinions.

Scottish Natural Heritage (SNH), is the Scotland government funded organization. The goal of it is looking after all of Scotland's nature and landscapes across all of Scotland. In 2013, this organization published commissioned report No.591. It is also named *Research and guidance on restoration and decommissioning of onshore wind farms*. In this report, not only the standard for determining when infrastructure will/should be removed has been developed, how wind turbines can be reused is also included.

According to this report, many utilities retire old wind turbines after 10 years and then install more efficient equipment. That means even wind turbines can usually operate for 20 years, the last 10 years they will be not serving anymore. However, due to the demand for electricity and the limitation of funding, the market for second hand turbines is growing rapidly. For Eastern European countries, in order to achieve the European Union's carbon dioxide reduction targets, second hand wind turbines are becoming their smart choose. Firstly, they are cheaper than the new turbines. Used turbines cost 40 % less than new turbines, and that is in line with governments' financial situation. Secondly, the second hand turbines are typically smaller. It makes it easier to get local approval for their installation. For other customers from Asia and Latin America, the reason is almost the same. (Welstead et al. 2013.)

In Netherlands, parts of towers and some blades have been set into children's parks as a play equipment. According to this idea, some retired wind turbines can also be transferred to playgrounds or wind energy education facilities. However, the value in this way is limited. It still needs a method to deal with damaged or expired turbines.

As more and more people accept the concept of environmental protection, recycling becomes an important part for every final products including wind turbines. In 2015, Technical University of Denmark published its research report named *DTU International Energy Report 2014 Wind energy - drivers and barriers for higher shares in the global power generation mix*. In its chapter 13, recycling of wind turbines has been discussed, as well as the problems.

TABLE 3. Materials of wind turbines recycling (Technical University of Denmark 2015)

Material	Recycling/Disposal Rate (%)	Disposal Method
Ferrous high alloy	98	Recycling
Ferrous metal	95	Recycling
Steel		Recycling
Aluminium and aluminium alloys	95	Recycling
Copper, magnesium, nickel, zinc and their alloys	98	Recycling
Plastics, rubber and other organic materials	100	Incineration with energy recovery
Precious metals and other non-ferrous metals and alloys	98	Recycling
Electronics	50	Recycling with energy recovery
Batteries	100	Recycling
Concrete, bricks etc.	64	Landfill
Sand and gravel	0	Remains in the ground after wind farm is dismantled
Blades	95	Landfill or recycling
Remaining materials		Incineration or landfill

Table 3 shows the recycling or disposal rate of wind turbines built using current technology. As we can see, metals, alloys and batteries have high rate and their disposal method is recycling. That means these materials can be almost totally recovered and reused. However, 50 % recycling rate for electronic is less, comparing with its value.

The big problem for wind turbine recycling is the blades. Even the disposal method has an option named recycling in Table 3. The real rate for recycling is not perfect. In order to cope with the changing working environment and easy to be driven by wind, high strength, corrosion resistance, light weight, and fatigue resistance are all required. So, composite materials are widely used by manufacturers to create blades. Nowadays the blade shell often uses glass fiber reinforced resin. The tip and the main beam are using higher strength carbon fiber. For example, the blades manufactured by LM Wind Power are using pure glass fiber and polyester matrix (LM Windpower no date).

The challenge is that glass fiber is not easy to be recycled. This is the reason why the first old wind turbine blades were landfilled or as a fuel/material to manufacture cement. According to DTU International Energy Report 2014, glass fiber can be separated with processing temperatures in the range 300 ~ 700 ℃ (different method with different temperature). However, when the heating temperature is above 250 ℃, the mechanical properties of glass fiber will degrade (Technical University of Denmark 2015). As a result, even glass fiber separating is successful, the products cannot be reused. Fortunately, a project named DreamWind run by Aarhus University is processing this puzzle. The goal is to develop a chemical substance to separate composite materials from each other and keep their characteristics (Harel K. 2016).

4 WIND POWER IN DENMARK

Nowadays as one of the first countries to develop wind power technology, Denmark is now in the leading position. According to the statistics, the wind power generation corresponded to 42 % of the electricity consumption in 2015. Following the 39 % in 2014, once again Denmark had the world's highest rate of using wind power. At the same time, wind power industry has become a mainstay industry of Denmark exports. (Energinet 2016.)

The cause of Denmark developing wind power industry is the first energy crisis in 1973. Before the 1970s, 99 % energy consumption in Denmark was depending on imports. Through the energy crisis the economy and normal life of Denmark had suffered a huge impact. From that time, establishing a new energy system was considered by Denmark government. Finally, the Denmark government was determined to use its own geographical advantage — the windy North Sea and the Baltic coastlines to develop wind power.

Somehow the success of wind power in Denmark can be attributed to the government policy guidance. According to a Chinese research (Zhang L. and Ma H. 2011), the impact of policy on the development of wind power will be explained by three parts which are following the timeline below.

The pioneering stage (1973 — 1995)

(1) Wind power manufacturing industry

In the starting stage, Denmark's policy was first supported for wind turbine research and development. The purpose was to reduce the cost of large wind turbines. At the same time, the quality certification and standardized systems were developed to ensure the reliability of the product and to achieve safe operation of the standard. Also, for the better market share, Denmark government supported a project. The project offered a long-term financing and secured loans so that for the wind farms, the risk of choosing wind turbines from Danish companies was reduced.

(2) Wind power generation enterprises

To support wind farms, Danish government did preparatory work to meet the needs of wind farm construction planning. This included, for example, wind resource evaluation and data collection. The cost of the wind farm was large. Since 1979, the government has been providing investment subsidies for installation costs of 30 % for the use of Denmark certified wind turbines until 1989. Then, the policy was changed that the income from wind power enterprises was not taxed and a stable production subsidy was given.

(3) Power grid

The power grid is a transport network for the electricity production and consumption. In Denmark, the wind power development is included in the power grid planning. It means that before the wind farm building the entrance of power grid has been made. It is easier for a wind farm to access to the grid and testing and then producing electricity.

The growing stage (1995 — 2000)

(1) Wind farms

In 1996, the Denmark government introduced the "Twenty-first Century Energy" action plan under the Kyoto Environmental Agreement. The goal was to reduce carbon dioxide emissions by 20 % in 2005 compared to 1998 and by 50 % in 2030. In order to achieve this ambitious goal, Denmark embarked on power system reform. In 1999, the Danish Parliament enacted and adopted a power reform program, which clearly required that the power company was obliged to purchase renewable energy at a fixed price, and planned to gradually change from the fixed price system to the competition and trade-based renewable energy quota system. The plan also provided that, by the end of 2003, renewable energy supplied increased to 20 %.

In 1997, Denmark announced the construction of offshore wind farms, which Denmark would build, with an offshore capacity of 150 megawatts in 20 years and then access the grid with a voltage rating above 100 kV.

(2) Power grid

In 1997, Denmark set up a special group to develop power grid connection guidelines, and in 1999 announced the first grid connection guidelines with requirements of wind turbines control functions, from the early non-voltage level of a provision developed into 100 kV above and below 100 kV voltage level and the two technical regulations.

The mature stage (2000 — Present)

(1) Wind power generation enterprises

In January 2002, Denmark began to implement the renewable energy quota system. According to the policy, power companies had to be the buyers of renewable energy and the price was based on the general market mechanism. It also required the companies had to supply electricity being at least 20 % renewable energy. Otherwise, they would pay the fine, which was based on the missing amount.

In 2004, the Denmark government promulgated *Subsidies for Renewable Electricity Generation*. In a period of 20 years, the subsidies will be given according to the wind turbines accessing the power grid and operating time. Another plan named *Replacement Scheme for Wind Turbines on Land* was implemented in the same year. The aim was scraping all wind turbines with a capacity of less than 450 KW from January 2005 to December 2009.

In 2006, Denmark announced an act that before 2030, the wind power capacity of Denmark would reach 5.5 GW which is including 4 GW of offshore wind turbines, and the proportion of wind power supply should be increased to 50 % of the national power supply.

(2) Power grid

In 2009, *Promotion of Renewable Energy Act* was promulgated by Denmark government. It distributed wind farms accessing cost between power producers and grid companies. The grid companies would invest in decentralized onshore wind farms because of the lower accessing cost and then apportioned to the local users. Due to the higher cost of centralized offshore wind farms access, the power producers would invest first and then the cost would be apportioned to the users nationwide through tariff subsidies.

With these continuity and encouragement policies, the wind power industry of Denmark has been a great success. In 2016, the wind power provided 38 % of total electricity consumption in Denmark. It alleviates the situation of energy shortages in Denmark effectively. Furthermore, the export value in 2014 amounted to 7.2 billion Euros, accounting for 5.2 % of Denmark total exports. (Danish Wind Industry Association no date.)

5 THE CURRENT SITUATION OF WIND POWER

Following Denmark, several countries are developing wind power industry sooner or later. Through the years, the market of wind power is becoming larger.

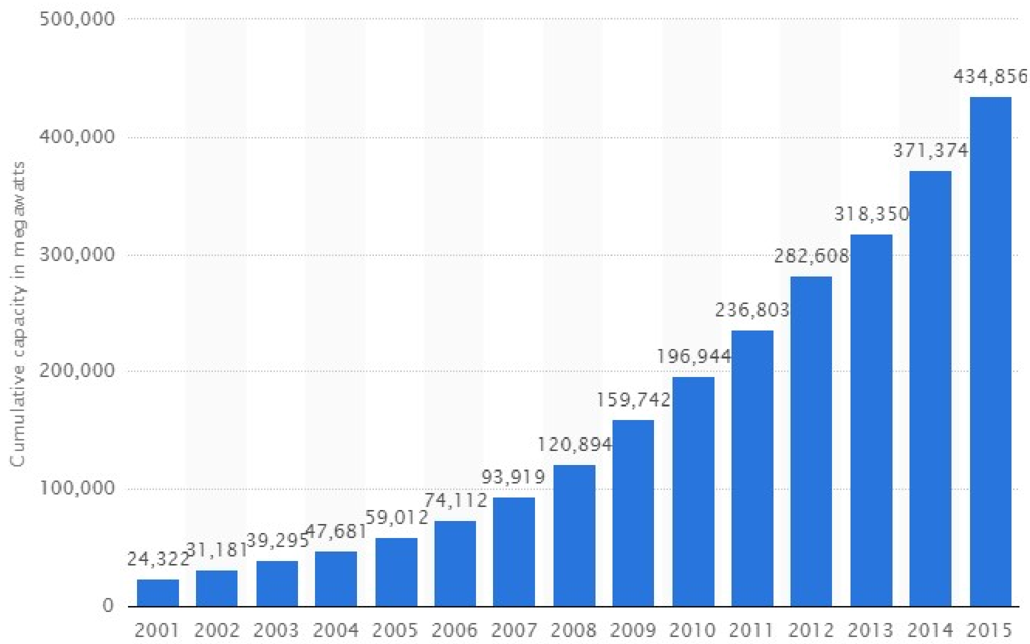
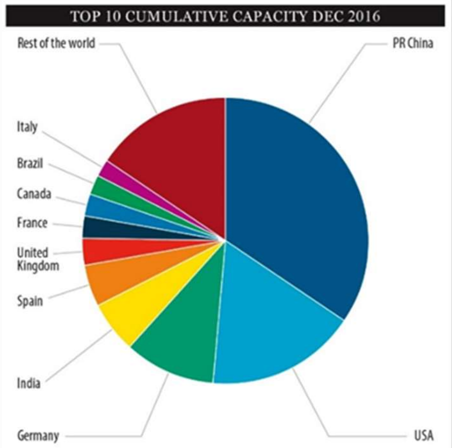


FIGURE 6. Wind power capacity from 2001 to 2015 (Statista no date)

Figure 6 shows the cumulative wind power capacity (MW) installed globally between 2001 and 2015. The number of installation capacity is growing steadily year after year. It is believed that the installation capacity will be still growing step by step in the future.

5.1 The market share in the world

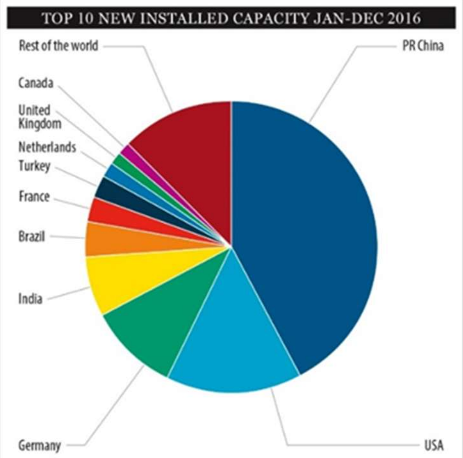
As the concept of environmental protection enjoys popular support, national governments have effectively supported development of sustainable energies. The market share of wind power is a strong evidence to show the investment rate of each country.



Country	MW	% Share
PR China*	168,690	34.7
USA	82,184	16.9
Germany	50,018	10.3
India	28,700	5.9
Spain	23,074	4.7
United Kingdom	14,543	3.0
France	12,066	2.5
Canada	11,900	2.4
Brazil**	10,740	2.2
Italy	9,257	1.9
Rest of the world	75,577	15.5
Total TOP 10	**411,172**	**84**
World Total	**486,749**	**100**

Source: GWEC

FIGURE 7. Top 10 Cumulative Capacity Dec 2016
(Global Wind Energy Council 2017)



Country	MW	% Share
PR China*	23,328	42.7
USA	8,203	15.0
Germany	5,443	10.0
India	3,612	6.6
Brazil* *	2,014	3.7
France	1,561	2.9
Turkey	1,387	2.5
Netherlands	887	1.6
United Kingdom	736	1.3
Canada	702	1.3
Rest of the world	6,727	12.3
Total TOP 10	**47,873**	**88**
World Total	**54,600**	**100**

Source: GWEC

FIGURE 8. Top 10 new installed capacity Jan-Dec 2016
(Global Wind Energy Council 2017)

As Figure 7 shows PR China has the largest part of cumulative capacity of wind power. It takes about 35 % of the world in December 2016. It is nearly twice as much as USA, which has about 17 % share. Also, PR China has the largest growth of new installed capacity in 2016 as shown in Figure 8. (Global Wind Energy Council 2017.)

5.2 SWOT of wind power

SWOT is a tool to analyze strengths, weaknesses, opportunities and threats. With this tool, countries and organizations can make a correct decision to find a right place and policy to develop wind power. The main points of SWOT are in Table 4 and their details are described below.

Strengths

When the wind turbines are working, it does not have any fuel cost and emissions because the power is from the wind. Comparing with other renewable energies, wind power is the lowest cost renewable resource. Furthermore, the location of wind farms is not only on land but also offshore with suitable environmental location.

Weaknesses

It is difficult to predicting the wind and it will cost lots of time to collect several years' data to determine where the location of a wind farm is. The generated electrical energy per year cannot still promise a fixed value. The maximum efficiency of wind turbine is less than 60 %, which less than other renewable energy efficiency. For example, hydropower's efficiency is about 90 %. As easily accessible energy source, fossil fuels still have advantage in price.

Opportunities

With the developing of technology, single wind power capacity will be improved. This means larger and more efficient wind turbines will be installed and larger amounts of electricity with lower cost will be generated. Offshore wind turbines are another opportunity. Higher wind speed, not taking up land resources and not affected by terrain are offshore wind farm's advantages.

Threats

Offshore wind turbine has its benefits, however, its costs still have to be considered. Nowadays, the cost of one offshore wind turbine is twice, even three times more than one onshore wind turbine. It is a huge financial pressure for operators who want to make the offshore wind turbines into a stable power generation. For manufacturers, the rise in raw materials prices increases the final product prices. How to balance market share and profit is a problem, which cannot be ignored.

TABLE 4. SWOT of wind power

Strengths: No fuel costs Clean, renewable Can be located on land/off-land The lowest cost renewable resource No carbon emissions	Weaknesses: Difficult to predict the wind Not ideal for efficiency High cost than fossil fuels
Opportunities: Offshore wind Larger and more efficient turbines to generate larger amounts with lower cost	Threats: Too expensive for offshore wind turbines Raw material prices soar Policy changed

6 CONCLUSION

Wind power, as one of the sustainable energy forms, is a future of electricity generation. However, the cost of early research and development is a serious problem for the enterprises. Fortunately, with the support from government such as Denmark, wind power industry has a health growth and becomes more and more important in the world economy.

Another important issue that has to be focused is recycling. Nowadays some of waste can be re-used or recycled but lots of them cannot be treated as resources. The trend of wind power industry is that more and more wind turbines will be installed. However, the problem how to deal with more and more waste from wind farms needs to be solved. This is the aim why governments, enterprises and scientists have to cooperate to figure out feasible methods in materials choosing and waste treating. This way the wind power can be the truly sustainable energy.

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