Czech University of Life Sciences in Prague

Faculty of Economics and Management

Department of Economics

Bachelor thesis

The economy of wind energy in the Czech Republic

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Declaration

I declare that the thesis "The economy of wind energy in the Czech Republic" has been completed by me and only the defined sources and study aids were used; they are cited in the thesis and provided at the end of the thesis.

Prague, the 30th March

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Veronika Nosková

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The economy of wind energy in the Czech Republic

Ekonomie větrné energie v České republice

Summary

The purpose of this bachelor thesis is give to the reader fundamental knowledge about the situation of wind energy and wind plants in the Czech Republic. It begins with a brief description of wind power plants history, followed by the definition of wind. The literature review is focused on the economical aspects of wind plants such as their cost, advantages and disadvantages, but also their ecological benefits and handicaps. It also includes information about the requirements that are needed for their successful installation.

In the analytical part five European countries (the Czech Republic, Germany, Austria, Denmark and the United Kingdom) were compared in terms of the use of wind plants. First of all general information about the situation of wind energy in each country including the European Union are mentioned. Finally the wind plants and wind energy generation development with respect of the future plans and total use of wind energy among other energy sources were qualitatively examined. This research is based on the secondary data provided by Eurostat.

Keywords: Renewable energy resources; Wind energy; Wind plants in the Czech Republic, Present and future of wind power plants; Wind energy in Europe; Wind energy in the world; Ecological aspects of wind energy

Souhrn

Cílem této bakalářské práce je poskytnout čtenáři základní znalosti o situaci větrné energie a větrných elektrárnách v České republice. Začíná se stručným popisem historie větrných elektráren, po níž následuje definice větru. Literární rešerše je zaměřena na ekonomické aspekty větrných elektráren, jako jsou jejich výhody, nevýhody a náklady, ale také jejich ekologických přínosy a omezení. Obsahuje také informace o podmínkách, které jsou potřebné pro jejich úspěšnou instalaci.

V analytické části bylo porovnáno pět evropských zemí (Česká republika, Německo, Rakousko, Dánsko a Spojené království) z hlediska využití větrných elektráren. Nejprve jsou zmíněny obecné informace o situaci větrné energie v jednotlivých zemích, včetně Evropské unie. Nakonec je kvalitativně zkoumán rozvoj větrných elektráren a větrné energie s ohledem na budoucí plány a celkové využití větrné energie mezi jinými zdroji energie. Tento výzkum je založen na sekundárních údajích Eurostatu.

Klíčová slova: Obnovitelné energetické zdroje; Větrná energie; Větrné elektrárny v České republice; Současnost a budoucnost větrných elektráren; Větrná energie v Evropě; Větrná energie ve světě; Ekologické aspekty větrné energie

Table of content

1 Introduction

The energy sources and the production of electricity are quite popular topics at this time. It is getting more obvious that the humans do not have enough natural resources for themselves and their future generations. Many of the resources that provide us energy like coal, oil or natural gas are almost mined out and the humans have not been able to find new bearings of these sources yet. It was needed and still is to think about other resources that can provide us the same as the previous ones.

There is a high potential in natural renewable resources. Power plants that are producing electricity from the renewable resources like the Sun, wind, water and biomass were already invented. The lack of natural resources is not the only thing that contributes to the growth of the meaning of renewable resources. People now started to think about the environment more than ever and they are not satisfied with the old power plants producing pollutants.

Energy has a big influence on our lives. Many things would not be possible without the help of electricity. It does not give us just the light and warm, but it plays a huge role in the whole production. Agriculture and industry is dependent on electricity and without these two economical sectors it would not be possible for humans to survive.

2 Aim and methodology

Aim

The aim of this bachelor thesis is to compare the situation of wind power plants in the Czech Republic with five European countries namely the Czech Republic, Germany, Austria, Denmark and the United Kingdom including the European Union. These countries were chosen, because they play important role in the wind energy industry or they have a unique position among the whole energy sector.

This work concentrates on the issue in general terms, focusing on history of the wind power plants, wind as a resource of energy, economical and ecological benefits and handicaps, condition for their successful installation and present and future of wind power.

Methodology

In the introduction was mentioned the basic knowledge of today's environmental situation considering the energy importance for human life and the possibility of use of renewable resources, which were gained through my studies.

In the literature review were used materials such as books, e-publications and web pages. The first part describes the evolution of use and development of utilization of wind as an energy source and also the wind itself. The technical and natural requirements for installing wind power plants were described.

The second part of the literature review deals with wind power in terms of their importance. The thesis focuses on the environmental and ecological impact through the advantages and disadvantages of wind power utilization.

This part is followed in by myths and facts that are connected to wind energy and create prejudices about wind plants to be harmful for humans or animals such as wind plants being bird killers or producing harmful noise.

In the practical part of this work the wind energy situation of wind power plants in the world, the European Union and chosen European countries is described with focus on the development of wind energy use in the given area, installed power, amount of electricity generated and future plans. Then the qualitative research on primary energy production in the five chosen countries was undertaken, which was based on the data collection from Eurostat.

3 Literature review

3.1 History of wind plants

3.1.1 Origin of wind power plants

The first wind mill was built in 644AD at Persian-Afghan border. Some people say that wind mills were already used in ancient Egypt; however, there is no evidence for this. It had a vertical axis of rotation and was used for milling grain.

These windmills were only used in Orient. The windmills with horizontal axis of rotation were invented in Europe. The first proven one was built in the Duchy of Normandy in 1118. From this place they were spread into other parts of Europe.[1]

3.1.2 The first power plant

The invention of the first wind power plant was made by two men in the same time. The first one was **Charles F. Brush**. He constructed the first electrical wind turbine that was connected to electrical generator in 1888. This machine was built in Cleveland in Ohio. Rotor of the power plant was 17 meters long and it contained 144 vanes.

The second man was from a small city Askov in Denmark. His name was **Paul la Cour** and he was a professor of Math, Physics and Chemistry on public university. In 1891 he constructed the first wind power plant with four to six propellers formed by the stretched sails frame structure that looked like a classic windmill. The wind turbine in Ohio was technically better than the wind power plant in Askov. Paul la Cour was also trying to find a solution how electricity can be saved in the time without wind.

3.1.3 Next development

There are documents where is written that several types of wind power plants have been used in various expeditions. They have saved valuable fuels for the times on the sea.

[1] HAU, Erich. *Wind turbines : Fundamentals, technologies, application, economics*

Already in the first decades of the twentieth century the people have thought not only about the possibilities and ways of using wind energy for electric generators and dynamos considered for performance, but also on how the wind power plants can be improved by development.

The greatest progress was Denmark. Denmark is the only country with unbroken continuity to the development, production and use of wind energy since they were invented till today. The reason for the construction and use of local wind energy resources was the lack of energy resources during the First World War. In 1919, received the Danish engineer Povl Vindig a patent for the first modern wind turbine with a rotor aerodynamic principle. His device, called Agricco has shown that the aerodynamic propellers are twice as effective as the traditional wing with an equal area.

The development was accelerated through the Second World War, because access to fuel was limited and a new possibility for energy development had to be created. In the years 1940 to 1945 by the company of Knud Lykkegaard was built about 70 turbines with a rotor diameter of 14 to 18 meters and 30 to 40 kilowatts of power in Denmark.

In 1950, Ing. Johannes Juul, who attended the classes of Poul la Cour in Askov, built wind turbines for the production of alternating current. These plants, which had a rotor diameter of 27 meters and the installed power of 200 kilowatts, were a springboard for the modern facilities.

Another important wind power plant was built from 1975 to 1977 on its own initiative of students and teachers of a high school in the village Tvinde (Denmark). The construction at this time was the world's largest windmill and represented a great progress in the development of wind power. It has shown how effective the use of their opportunities was. The concrete tower has measured 53 meters on which the engine with three wings, which had a length of 27 meters, was installed. It achieved output was two megawatts (MW), but it had to be limited to 960 kilowatts, because it was connected to the local network. This historic and unique facility

is being used over 28 years. During this time almost no problems have occurred. Only in 1993 the rotor blades were replaced. [2]

3.1.4 Economic importance of historical windmills

The windmills in Europe were only used for milling grain. The country rulers took advantage of this and set wind rights. One of them was the milling obligation. The residents of a specific area could have their grain ground just in the mill area that was assigned to them. Due to this they had to pay fees to the local ruler.

Another example is the milling construction ban, which controlled the number of mills in certain area. These rights were in most countries abolished in the time of Napoleon, when freedom of trade was introduced and many new windmills were built.

In Netherlands the windmills were also used for draining in the 15th century. They dried huge land areas that could not have been used before that. This had big influence on Netherlands's economy and development in the 16th and 17th century. In the 17th century the Netherlands became a central distribution centre for all kinds of goods so the wind mills were used also for industrial processes. Thanks to this it became the export leader of sawed wood.

At the end of the 19th century there were about 9000 wind mills in the Netherlands, 20000 in Germany and 200000 in Europe. This number started to decrease by the invention of steam engine. [3]

3.2 Wind

Wind is in fact caused by solar radiation. Solar radiation warms up the atmospheric air unevenly because of the angle of incidence. When temperature of air increases its density decreases. Lighter air rises up into atmosphere and spreads around. That makes a pressure drop that is filled by cooler air from other region. This movement of air is than called wind.

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[2] Z historie větrných elektráren. *Elektro*: *Odborný časopis pro elektroniku* [online]

[3] HAU, Erich. *Wind turbines*: *fundamentals, technologies, application, economics*

Wind is highly variable resource that is a crucial fact for wind power. Velocity of wind has a cubic relationship to power so even small changes in the velocity can have a huge effect on the energy produced.

Speed and direction of wind varies from place to place. The flow of air is affected by earth surface. These effects can be even natural (ground, vegetation) or human made (buildings). There are also significant differences in the given location dependant on time that is changing not only by day or season, but also every year. The annual change can reach up to 30% of speed, so before building a new wind power plant the average wind velocity and its distribution have to be measured.

Wind energy is a kinetic energy. It has to be converted by the wind power plant into electrical energy to produce power. By aerodynamic forces on the rotor blades convert the turbines that are installed on the column wind energy into rotational mechanical energy. This is then delivered through the gearbox to the generator, where it is finally converted into electrical energy.[4]

Wind plants need a wind speed of 4 to 5 meters per second (m/s) and reach maximum power output at around 15 m/s. When the wind speed is too high (25 m/s) wind turbines shut down.[5]

3.3 Basic conditions required for successful installation of wind turbines

There are several factors that help to decide if a location is suitable for the wind power plant or not. They are both natural and technical.

As it was already mentioned wind speed and its frequency are crucial for a wind power plant. For inland areas like the Czech Republic are convenient locations mainly at higher altitudes, usually 500 meters above sea level. At lower altitudes the average annual wind speed is too low (around 2-4 m/s). A wind measurement should take at least one year. Ideally it is compared with the long-term data from the nearby meteorological stations.

[4] MATHEW, Sathyajith. *Wind energy*: *fundamentals, resource analysis and economics*
[5] Wind energy FAQ. *EWEA*: *The European Wind Enery Association* [online]

Weather conditions are also important. In winter there are numerous shutdowns of power plants caused by massive frost that covers the blades and gauges. Therefore energy production in some places drops during the winter months.

Other important factors are also air density and number of barriers like buildings or trees near the plant. They can cause turbulences which impede natural air flow.

To the technical aspects belongs the possibility of placing appropriate technology. One of them are the geological conditions for the foundations of a power plant like soil bearing capacity, quality of surface and seismic situation.

There is need of an option to build the necessary paved communication for easy maintenance and repair and also short distance from the high voltage or extra high voltage connections with sufficient capacity.

The power plant cannot disturb by noise. The maximum permissible noise levels outdoors in residential areas are 50 db during the day and at night 40 dB. Due to this the plant must by placed away from the dwellings, but it must not be placed in natural parks and reservations to prevent interference with the surrounding nature.

Property relations to land and attitude of local authorities and citizens also have to be observed.[6]

3.4 Wind energy economics and environment

Production of wind energy is considered to be the cleanest and windmills are often a symbol of environmentally friendly production of electricity, although they are sometimes criticized for its negative properties.

[6] Energie větru, *EkoWATT* [online]

3.4.1 Advantages of wind power plants

- A turbine with installed power of 2.5 – 3 MW can produce more than 6 million kilowatt hours (kWh) within a year. That is enough to supply 1,500 average EU households with electricity.
- Wind energy has the lowest emissions of all energy production technologies. Wind turbines produce no greenhouse gas emissions. The turbine needs just three to six months to produce the amount of energy that goes into its manufacture, installation, operation, maintenance. Wind turbines can generate electricity for 20-25 years. After this period they are removed more easily than other types of power plants. During its lifetime it produces 80 times more energy than is used in its production, maintenance and scrapping.
- Wind energy creates no radioactive waste or water pollution and emits no toxic substances such as mercury and air pollutants. By burning fossil fuels emerges huge amount of carbon dioxide (CO_2). So about 666g of CO2 can be avoided by each kWh of energy produced while using wind energy instead of fossil fuels.
- Today, wind energy employs about 190,000 people in Europe and every turbine erected in Europe is also manufactured in Europe which makes European companies the world leaders in wind energy.
- Wind power can lower electricity prices by bringing more competition to the electricity market.[7]
- Wind turbines only have to occupy a few square meters for the base; this allows the land around the turbine to be used for other purposes, for example agriculture. They enable to generate energy in remote locations, such as mountain areas and remote countryside. They are in a range of different sizes which makes supporting varying population levels easier.
- Technological development makes the wind energy much more efficient.

[7] Wind energy FAQ. *EWEA*: *The European Wind Enery Association* [online]

3.4.2 Disadvantages of wind power plants

- The main disadvantage is unpredictability and instability of energy supply, because wind power plants are dependent on current wind conditions.
- Wind turbines produce less electricity than the average fossil fuelled power station.
- Surrounding wildlife can suffer during the build process of a new wind power plant.[8]
- TV signal interference may occur. It depends on the position of the television transmitter, power plants and houses with an antenna, but this concerns only the areas nearby the plants.
- It is said that wind plants disturb the landscape character. It is more question of taste.[9]

3.5 Myths and facts connected to wind energy

3.5.1 Noise

Sound is a pressure change recognizable by human hearing. While talking about wind plants it is important to distinguish between acoustic output of the turbines and the noise level (the so-called acoustic pressure) at the particular location where the sound is perceived or measured.

Acoustic output states the turbine manufacturer based on measurements of the accredited laboratory. By modern power plants with output of 2 megawatts reaches the acoustic output roughly 100 to 106 decibels (dB). This is dependent on the type of turbine and wind speed at which sound is measured. Noise measured at the base of 100 meters high power plant is between 50 to 60 dB. The picture shows different levels of noise encountered around us.

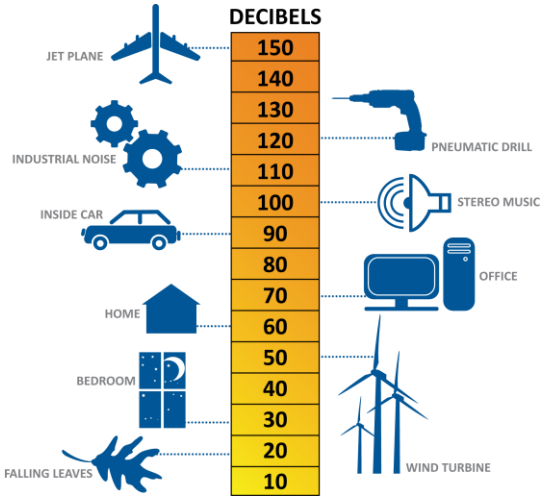

Figure 1 - Noise levels

Data source: AWEA

[8] Advantages & Disadvantages Of Wind Energy. *Clean energy ideas* [online]
[9] Energie větru, *EkoWATT* [online]

Sounds issued by wind plants have two causes: the rotating mechanical components in the engine room (especially gearbox and generator) and air flow around the propeller blades. Reducing noise was one of the main things that the designers focused on. Modern types of turbines already minimized the mechanical noise. Some wind turbines do not even have the gearbox and also the surface and shape of the rotor blades significantly reduced aerodynamic noise.

Frequent reason for concerns about the noise of wind power plants is most probably bad experience with the first prototypes. Thanks to technological developments are the present plants already far quieter. If the wind plants are supposed to be built near residential homes the applicants must have the technical expertise. The result must confirm compliance with hygienic noise limits.

By the construction of wind farms with more power plants the level of noise of the individual turbines does not add. The scale in decibels is logarithmic as well as the human perception of sound volume. By construction of the second wind turbine increases the noise level approximately only by three dB, at the three plants it is about five dB.

3.5.2 Disruption of landscape

Wind power certainly creates new landmarks in the landscape. It must be built where the wind blows enough, mostly on hills or plains. But the fact that they can be seen does not mean that they disfigure the landscape. Simply said some people like them and some not.

Placement of wind turbines in the landscape must be perceived quite differently. Pure resources significantly reduce pollution from other plants. Large coal and nuclear power plants have much greater impact on the landscape: whether by themselves or their consequences. Surface mining of brown coal significantly changes the landscape. Also deforestation in mountain ranges of acid rain due to coal burning has stronger impact on the landscape than the turbines. The same applies for the mining of uranium in nuclear reactors.

Wind turbines can be dismantled and taken away by the end of their life. As renewable resources are inherently small and often close to the place of consumption there are less

demands on the transmission network. Therefore there is not a need for so many electrical poles and wires as for distribution of electricity from large centralized resources to the rest of the state.

Of course there are also places where the wind plants should not be built. The plant designer must consider whether the new power plants would not be located in areas where it would be in conflict with nature and landscape protection or in historical zone. It is certain that the wind plants cannot be built in national parks and protected areas, but the authorities should consider each project individually to support renewable energy sources and protection of valuable landscapes.

3.5.3 Wind power plants kill birds and frighten animals

Wind farms are famous as bird killers, but if wind turbines are well planned and built they do not mean a serious danger for birds and animals. The spinning blades pose to birds just a little risk. The turbine is visible obstacle for them. It is dangerous for them at night or in fog. But even a possible conflict with the rotating blade does not have a fatal ending. A cushion of air around the blades can throw the bird off without being hurt or killed. [10]

There was a study made by Wallace P. Erickson, Gregory D. Johnson, and David P. Young Jr. about the causes of bird mortality in 2005. The results can be seen below.[11]

Table 1 - Causes of bird mortality

Causes of bird mortality	Annual bird mortality estimate
Buildings/windows	550 million
High tension lines	130 million
Cats	100 million
Vehicles	80 million
Pesticides	67 million
Communication towers	4.5 million
Wind turbines	28.5 thousand
Aeroplanes	25 thousand

Data source: http://ewea.org/fileadmin/ewea_documents/documents/publications/factsheets/Factsheets.pdf

[10] SEQUENS, Edvard and Petr HOLUB. *Větrné elektrárny: mýty a fakta*
[11] Wind Energy Factsheet. In: *The European Wind energy Association* [online]

Misleading are also concerns that wind turbines disturb hares, deer, foxes and other animals. This was confirmed by a three-year research conducted by the Institute for wildlife at the Veterinary University in Hannover. A large area with a total of 36 wind power plants was watched and then compared with a similar area with no turbines. Density in the animals with the plants remained the same or even increased. Animals can get used to operation of wind plants so they are not disturbed. This is also confirmed by the experiences of farmers and huntsmen from many countries where wind farms are in operation. Similarly, the turbines are not a problem for agriculture, because cattle, sheep and other animals pasture under the wind plant poles.

3.5.4 Wind plants discourage tourists

The myth that wind plants discourage tourist do not need to be true. Wind turbines on the contrary can attract many tourists. This is a relatively new phenomenon and it can be assumed that they will arouse interest. Some hiking trails just bring visitors directly to them. For example in Jindřichovice pod Smrkem (north Bohemia) about 12 thousand people came to see two 600 kW wind turbines during the first year of operation. Under the plant was established an information centre. This also illustrates how wind turbines can help to develop the nearby village and attract tourists.

3.5.5 Stroboscopic and disco effect

Stroboscopic effect is optical phenomenon where uncomfortable vibration of light and shadow is felt. This emerges while the sun is low at the horizon. If the power plants are planned near residential houses the designer should pay attention to this problem.

By the first wind power plants happened that the sunshine was reflected on the rotating blades and bothered people by its reflection. Manufacturers began to use matte colour on rotor blades to divest the disco effect how this phenomenon is called.[12]

[12] SEQUENS, Edvard and Petr HOLUB. *Větrné elektrárny: mýty a fakta*

3.6 Present and future of wind power plants

Modern wind turbines look different from the older ones. They are getting bigger and also their location changes. Nowadays many of the wind farms are built on the sea above the sea level near the coast. These are so called offshore wind plants.

The size of wind turbines has change over time. At the beginning of wind power generation was the propeller diameter only about 15 meters and nowadays it reaches almost 160 meters. In the picture can be seen the development of wind turbine sizes.

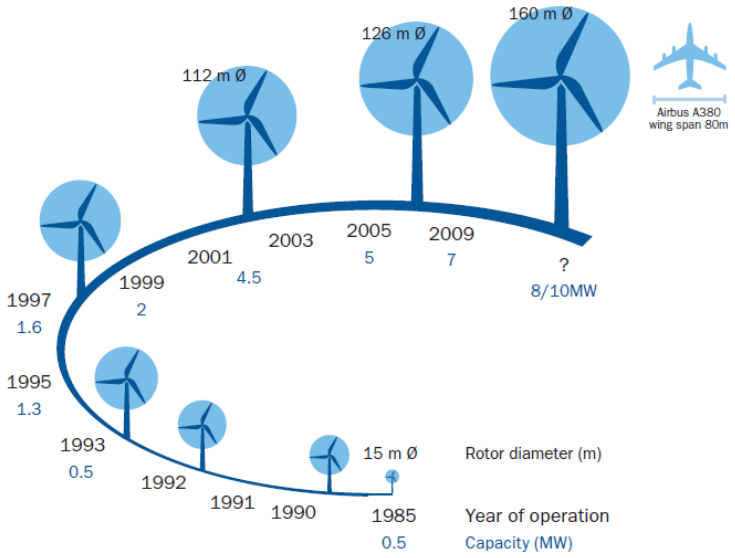

Figure 2 - Size evolution of wind turbines

Data source: http://ewea.org/fileadmin/ewea_documents/documents/publications/factsheets/Factsheets.pdf

3.6.1 Wind turbine costs

Today's average wind power plants have installed power around 3000 kW. The building costs were very high in the 80's of the last century when the production began. It was because of no serial manufacturing. Costs of these power plants were about 5000 $US per kW. Now their costs are about 1000 $US per kW so it is possible to built them also areas with lower wind speed.[13]

[13] HAU, Erich. *Wind turbines : Fundamentals, technologies, application, economics*

4 Results

4.1 Wind energy in the World, in the Czech Republic, European Union and chosen European countries

4.1.1 World

During 2011 there was an increase in installed power in wind plants over the world 41,236 MW, which represents an annual increase of 20.9% and together it accounts for 238.3 GW of installed power. The world's number one is China with its total 62,733 MW of installed capacity in wind power plants (annual growth 18,000 MW), followed by USA with a total of 46,919 MW, Germany (29,060 MW) and Spain (21,674 MW).

A large increase in wind energy during the year 2011 can be seen also in France, Italy and Great Britain. Each of these countries has installed about 1 GW of new wind power, which placed them behind China, USA, India and Germany - the countries with the largest annual increase in installed wind capacity in 2011.[14]

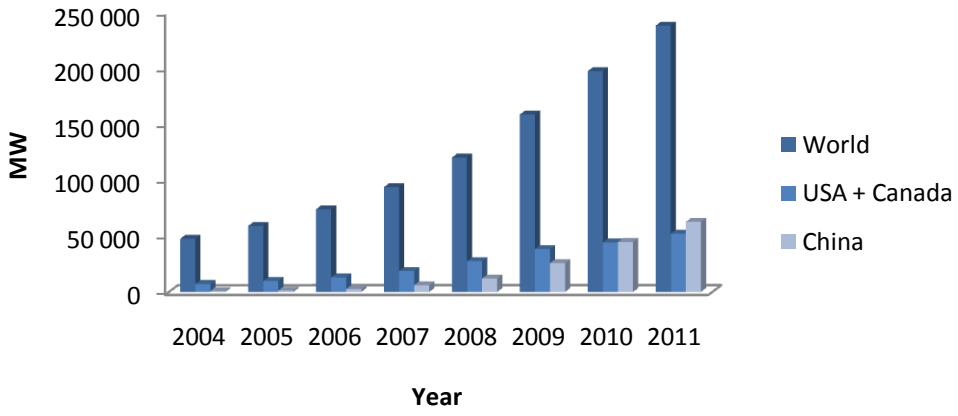

Figure 3 - Installed power - World cumulative, 2004-2011

Data source: ČSVE, own processed

[14] Větrné elektrárny ve světě. *ČSVE*: *Česká společnost pro větrnou energii* [online]

4.1.2 Europe

Wind energy is one of the most growing energy sources in Europe. During the last year 9,616 MW of wind power capacity was installed in the European Union (EU) which accounted for 21.4% of total 2011 power capacity installations and all renewable power installations accounted for 71.3%. The EU's total installed power capacity increased in the last year by 35,468 MW net to 895,878 MW, with wind power installed capacity increasing to 10.5% (93,957 MW), and renewable capacity to 31.1%. The wind capacity installed by the end of 2011 should produce 204 terawatt hours (TWh) of electricity, which represents 6.3% of European electricity consumption.

According to the table below Germany remains the country with the largest installed capacity in the European Union, followed by Spain, France, Italy and the United Kingdom.

Table 2 - Wind power installed in Europe by the end of 2011

	Installed 2010	End 2010	Installed 2011	End 2011
EU Capacity (MW)				
Austria	19	1,014	73	1,084
Belgium	325	886	192	1,078
Bulgaria	322	500	112*	612*
Cyprus	82	82	52	134
Czech Republic	23	215	2	217
Denmark	315	3,749	178	3,871
Estonia	7	149	35	184
Finland	52	197	0	197
France	1,396	5,970	830*	6,800*
Germany	1,493	27,191	2,086	29,060
Greece	238	1,323	311	1,629
Hungary	94	295	34	329
Ireland	82	1,392	239	1,631
Italy	948	5,797	950*	6,747*
Latvia	2	30	1	31
Lithuania	72	163	16	179
Luxembourg	1	44	0	44
Malta	0	0	0	0
Netherlands	56	2,269	68	2,328
Poland	456	1,180	436	1,616
Portugal	171	3,706	377	4,083
Romania	448	462	520	982
Slovakia	0	3	0	3
Slovenia	0	0	0	0
Spain	1,463	20,623	1,050	21,674
Sweden	604	2,163	763	2,907
United Kingdom	1,005	5,204	1,293	6,540
Total EU-27	**9,648**	**84,650**	**9,616**	**93,957**

* Provisional
** Former Yugoslav Republic of Macedonia
*** Figure not communicated

Data source: http://ewea.org/fileadmin/ewea_documents/documents/publications/statistics/Stats_2011.pdf

Wind power was the third most growing source of energy during the past year (21.4% of all power installed) after solar photovoltaic (46.7%) and gas (21.6%). Other types of power plants experienced only a small growth, for e.g.: coal 4.8%, fuel oil 1.6%, large hydro power plants 1.3% and nuclear 1%. All the new installed sources together make 45 gigawatts (GW) of electricity gathering capacity. The graph shows all the new installed and decommissioned power capacity in Europe in 2011.

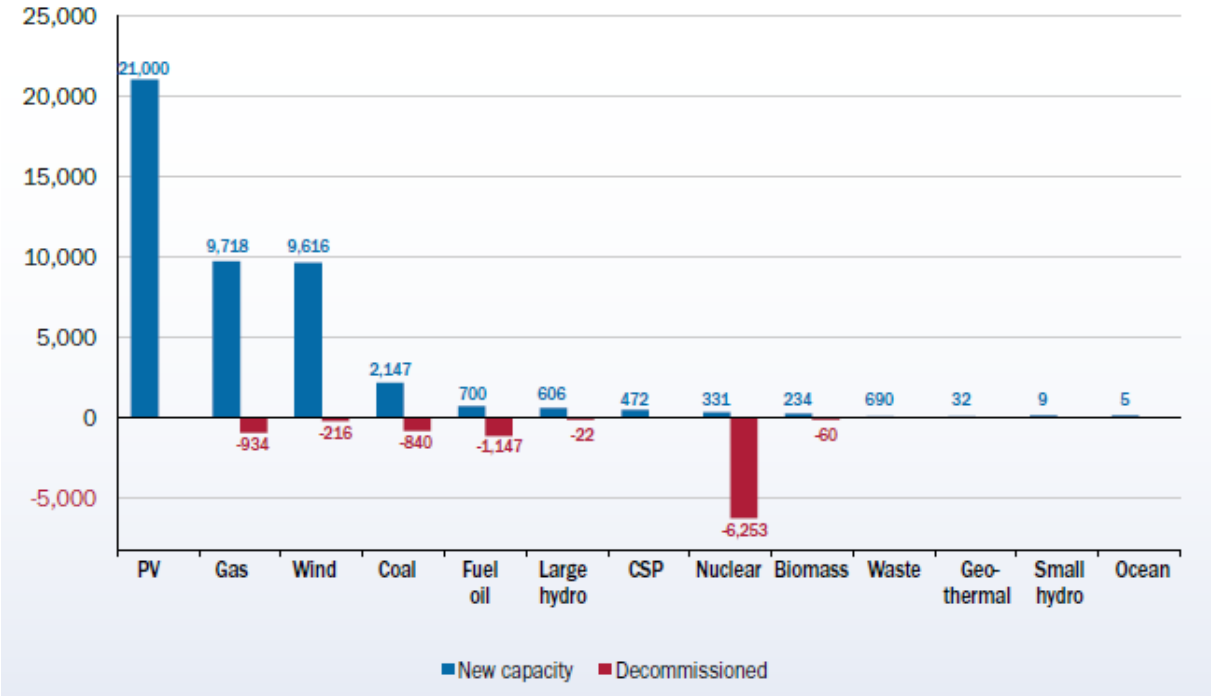

Figure 4 - New installed capacity and decommissioned capacity in MW

Data source: http://ewea.org/fileadmin/ewea_documents/documents/publications/statistics/Stats_2011.pdf

In accordance with the two graphs below, it can be seen, how the electricity mix in the EU changed during the years 2000 and 2011. The wind power itself grew more than four times and all renewable sources by a third.[15]

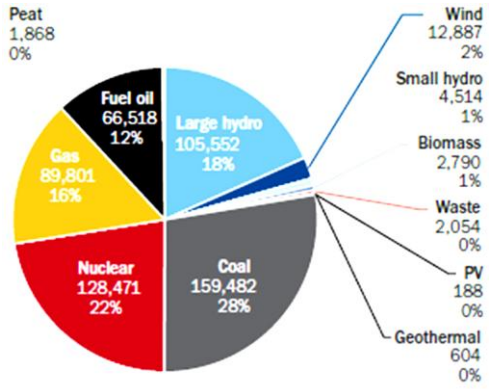

Figure 5- EU power capacity mix 2000

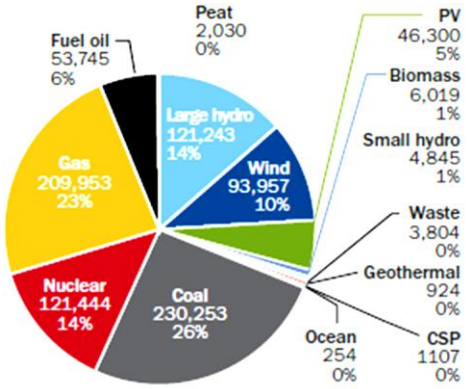

Figure 6 - EU power capacity mix 2011

Data source: http://ewea.org/fileadmin/ewea_documents/documents/publications/statistics/Stats_2011.pdf

It is planned to build more and more wind plants in the future. The European Wind Energy Association plans to have about 230 GW installed power in wind plants in 2020. This should cover 14-17% of European power demand. In 2030 their target is to produce 26-35% of EU's electricity. This would have essential impact on fuel costs and CO_2 production.[16]

4.1.3 The Czech Republic

The Czech Republic as an inland country has not very good wind conditions, but thanks to current technology developed for inland power stations it can well cope with the fluctuating wind speeds. Wind electricity can be converted relatively easily. This fact helps to meet national targets of 13% of final energy consumption coming from renewable sources by 2020.

In spite of the fact that there have been various subsidy programs was the majority of Czech wind power plants were built without subsidies. Thanks to purchase prices a wind plant

[15] Wind in power: European statistics 2011. *The European Wind Energy Association* [online]
[16] Wind Energy Factsheet. *The European Wind energy Association* [online]

can have an acceptable return without additional support. Purchase price is set so that under certain parameters the return is of investment 15 years.[17]

By the end of 2011 was the installed power of wind power plants in the Czech Republic 217 MW. Total production in 2011 amounted to 397 GWh. This allows the coverage of energy consumption of about 113,000 households. The table shows the development of installed power and the output of wind plants in the Czech Republic from 2005 till 2011.[18]

Table 3 - Installed power of wind plants and their output in the Czech Republic

Year	Installed power MW	Output MWh
2005	28	21300
2006	54	49400
2007	116	125100
2008	148	243900
2009	192	289900
2010	215	335600
2011	217	397100

Data source: ČSVE, own processed

Wind power plants in the Czech Republic can be found in 10 of 14 regions. The current largest wind power plant in the Czech Republic is in the village Pchery, near Kladno in central Bohemia. The rotor diameter is 100 meters and the output is three MW on every of the two poles. The pole measures 85 meters to the axis of the rotor. The two plants produce 11-13 GWh of energy annually, which is enough to run 5,000 average households. The most of our wind power plants have installed power of two MW, their the diameter of the blades measure 90 meters and the height of the column to the rotor axis measures 105 meters, which is together 150 meters from the top point.

The largest wind farm in the Czech Republic is in Kryštofovy Hamry in Krušné Hory, north-western Bohemia. There are 21 wind turbines with installed power 42 MW. The diameter of each turbine measures 82 meters. This farm was built in 2007. In the Czech

[17] Větrné elektrárny. *Ministerstvo životního prostředí* [online]
[18] Statistika. *ČSVE*: *Česka společnost pro větrnou energii* [online]

Republic are mostly build loose wind power plants or mini farms with two to five pieces. This differs from other European countries, where is attempted to build several plants together.[19]

The purchase price of electricity coming from wind energy is the cheapest from all renewable sources. In 2011 it was 2.23 CZK per kWh in comparison with 5.5 CZK/kWh from photovoltaics, 3.0 CZK/kWh from small water plants, 4.58 CZK/kWh from biomass and 4.12 CZK/kWh from biogas. The graph shows the development in electricity prices during the years 2005-2012.[20]

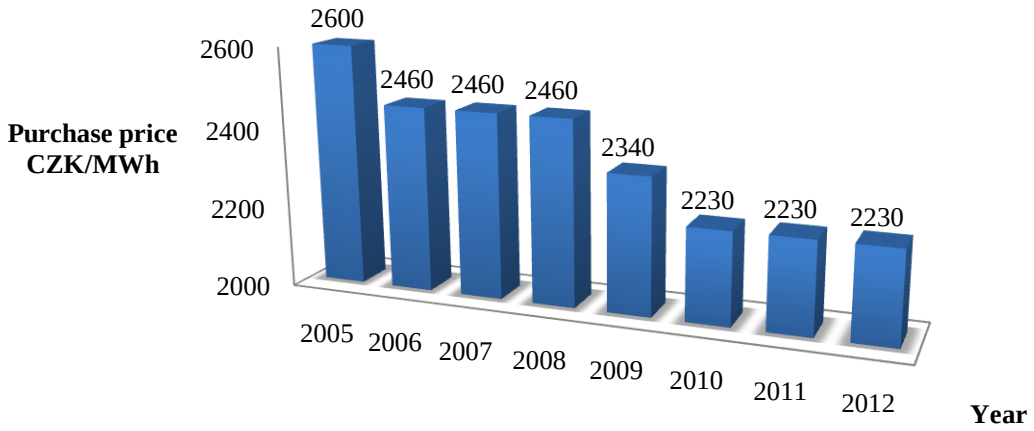

Figure 7- Development of purchase prices of electricity coming from wind plants in 2005-2012

Data source: ČSVE, own processed

4.1.4 Germany

Germany is one of Europe's largest producers of wind and solar energy. Behind the primacy is a law that distributes the costs of purchasing electricity from renewable sources for all customers equally. According to the Federal Ministry for the Environment, each household paid for green electricity 1.5 Eurocents per kilowatt hour in 2009. In comparison the households in the Czech Republic paid about 0.2 Eurocents for renewable energy sources. According to the estimates of the Federal Office of Energy in 2020 a quarter of the energy will by produced by wind turbines.

[19] Aktuální instalace. *ČSVE*: *Česka společnost pro větrnou energii* [online]
[20] Vývoj výkupních cen energie. *ČSVE*: *Česka společnost pro větrnou energii* [online]

For a period of the next ten years, Germany is planning to invest huge sums primarily to the construction of wind farms on the sea. According to the Federal Wind Energy Association there would be about 5000 wind turbines that will supply German coast with energy in 2030.[21]

Total Germany's installed power was 29,075 MW by the end of 2011, which puts it on the third place worldwide after China and the USA and on the first place within Europe. The richest regions for wind turbines in Germany are Lower Saxony, Bavaria, Saxony-Anhalt, Schleswig-Holstein and Nord Rhine-Westphalia. All of them are located in the parts of Germany, where the wind is the strongest.

In 2009, 38 TWh of electricity were generated from wind power. This represented 7% of total electricity consumption in Germany. There are together 22,297 turbines. Most of them have installed power 2-3MW.[22]

4.1.5 Denmark

Denmark is country with the longest history of wind power plant use. According to the history it started to develop wind turbines after the oil crises and the biggest steps in the development were also made here.

Denmark had 3,871 MW installed power in wind turbines by the end of 2011, which puts it on the 7th place within Europe. This accounts for about 20-25% of the whole Danish power consumption that makes a primacy for Denmark, because no other country has its wind power so integrated into the power system. According to the Danish Wind Industry Association, this number should rise up to 50% till 2020. Wind energy industry in Denmark employs around 25,000 people and has 8.5% contribution of whole country's exports. Thanks to about 30 years of experience on designing, developing, building and installing of the wind turbines it has a unique position on the wind market.

The first offshore wind plants were built in Denmark in 1991. This fact made it the leader of offshore wind energy and since that it has been trying hard to keep the position. In

[21] NOVÁKOVÁ, Martina. Solární a větrná energie: Podíl v Německu roste. *Nazeleno.cz* [online].
[22] MOLLY, J.P. Status der Windenergienutzung in Deutschland. *BWE*: *Bundesverband WindEnergie* [online].

2007 there was a study made that says Denmark has an opportunity to install a power about 4,600 MW on the sea. This would cover the whole entire domestic demand for electricity.[23]

4.1.6 Austria

Austria has been building a reputation of a country that cares about ecology and sustainable development. It tries to promote the use of renewable resources and rejects nuclear power. Nearly four fifths of energy produced in Austria comes from renewable sources. Since 2000, the number of green energy increased by almost 80% and over the past 40 years it has tripled.

As well as the Czech Republic is Austria an inland country, but the wind conditions are much different because of the mountainous surface. Thanks to its location it has two energy sources, which are traditionally used in large-scale energy production: water power and biomass; however, wind power is also on important source of energy. The purchase prices of wind electricity are growing every year in accordance to support wind energy. In 2010 they were 2390 CZK/MWh.[24]

Together 31 wind turbines with 73 MW installed power were constructed in 2011 in Austria. There were 656 wind turbines with a capacity of 1,084 MW in operation at the beginning of 2012. During the year 2012 it expected to install approximately 140 wind turbines with a total capacity of 376 MW, which would increase the existing capacity by a third. Annual domestic electricity production from wind power is currently around 2200 GWh and through the expansion it can reach up to 3,000 GWh. This amount covers the power demand for about 850,000 households, which is more than one third of Austrian population. This is an important target for Austria, because thanks to this they can avoid to buy nuclear power from neighbouring countries. During the years 2011 and 2012 740 million Euros were and will be spent on wind turbines construction.[25]

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[23] Denmark: Wind power hub, *Danish wind industry association* [online]
[24] V Rakousku jsou z obnovitelných zdrojů čtyři pětiny tamní energie. *Biom.cz* [online]
[25] 2012 bringt kräftigen Ausbauschub der Windkraft, *IG WINDKRAFT*: *Austrian wind energy association* [online]

4.1.7 The United Kingdom

The United Kingdom (UK) is the windiest country in Europe, so the use of wind energy is a good way how to generate electricity. It has been used since 1991, when the first wind farm was built. In 2007 wind energy become the largest renewable generation source and contributed by 2.2% to the whole UK's electricity supply. The government of the UK has stated a strategy whose target is to generate 15% of all the UK's energy from renewable sources by 2020.[26]

The total installed power was by the end of 2011 6,540 MW. The UK is the world leader in offshore wind, because its installed capacity is the same as in the rest of the world together. Nowadays there are 538 installed offshore wind turbines in the waters of the UK. Their installed power equals 1,708 MW and a similar number of turbines is in construction, which together accounts for 1,233 pieces. The average capacity of an offshore wind turbine is around 3 MW and it is still growing. Each of the installed turbines produces per year an amount of electricity which can satisfy the annual consumption of 2,114 households. According to the latest study there should be 8GW of capacity installed by 2016 and 18GW by 2020. This would have a contribution to the net UK electricity production of 17%.

The wind farm with the biggest output in the world is located in the UK. It is located near the coast of Cumbria shire (central Britain) and its installed power is 367MW. The UK plans to build even bigger wind farm than this one. Its name is London Array and its installed power will be 1 GW.[27]

[26] Onshore Wind, *RenewableUK* [online]
[27] Offshore Wind, *RenewableUK* [online]

4.2 Comparison of primary energy production in chosen European countries

In this chapter diagrams representing the primary energy production in years 2000 and 2010 in the Czech Republic, Denmark, Germany, Austria and the UK are qualitatively examined.

Primary energy is any source of energy, which can be found in nature and used by humans for further conversion or transformation, e.g.: coal, crude oil, sunlight, wind, water vegetation and uranium. These energy resources can be converted on transmitted into heat or electric energy. Unfortunately, it is not possible to be 100 percent efficient, so there are always some losses by these operations.[28]

Primary production of coal includes not only the amount of energy produced, but also the quantities consumed by the producer in the production process (e.g. for heating) as well as supplies to other producers of energy for transformation.

Primary production of crude oil includes production within national boundaries when offshore production is also covered. This production covers all crude oil, condensates and oil from shale and tar sands.

Primary production of natural gas includes quantities used within the natural gas industry, in gas extraction, pipeline systems and processing plants.

Primary production of nuclear energy consists of the electricity made and also the heat produced in a reactor as a result of nuclear fission.

Renewable energy primary production:

- Biomass includes the heat content of biofuels or biogas and heat produced by combustion of renewable waste.
- Hydropower covers potential and kinetic energy of water converted into electricity.

[28] Primary energy. *The encyclopedia of Earth* [online].

- Wind energy covers the kinetic energy of wind which is converted by the turbine and generator into electricity. Wind plants do not produce any heat which makes the percentage of produced primary energy by wind relatively small.
- Solar energy covers the solar radiation which is divided into solar heat and electricity production.

The data are presented in tones of oil equivalent (TOE). This means energy generated by burning one metric ton of oil. This equals 11.63 MWh.[29]

4.2.1 Primary energy in the Czech Republic

In spite of a decrease in amount of energy produced by coal during the years 2000 and 2011 coal remains the most used energy source in the Czech Republic. More than two thirds of whole energy produced in the year 2010 came from coal. This has a significant impact to the environment. The energy production even more focused on coal in the past, mostly in the communistic era. This led to acid rains that damaged the nature mostly in north-western Bohemia.

As a member of the EU, the Czech Republic has to satisfy the EU regulations dedicated to renewable resources. In year 2000 there were no solar or wind plants in the Czech Republic. Until 2010 the change was the percentage change in the production of primary energy 0.09% by wind and 0.2% by solar energy. However, the Czech Republic plans to invest more money in the nuclear power plants as in renewable resources, because it wants to keep the positive power balance, which is sometimes lost by the countries, which try to product only the green power.

[29] Main tables: Energy statistics. *Eurostat* [online]

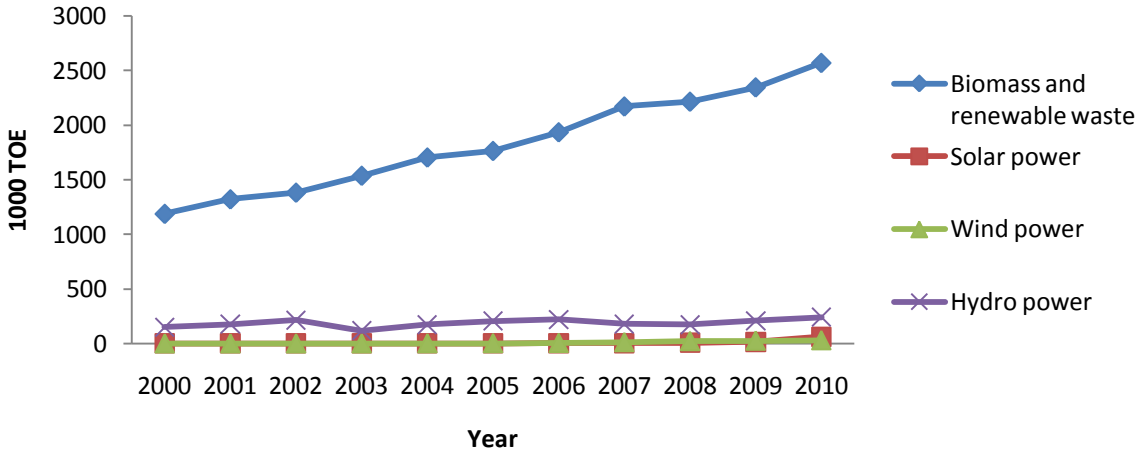

Figure 8 - Primary energy production from renewable resources in the Czech Republic

Data source: Eurostat, own processed

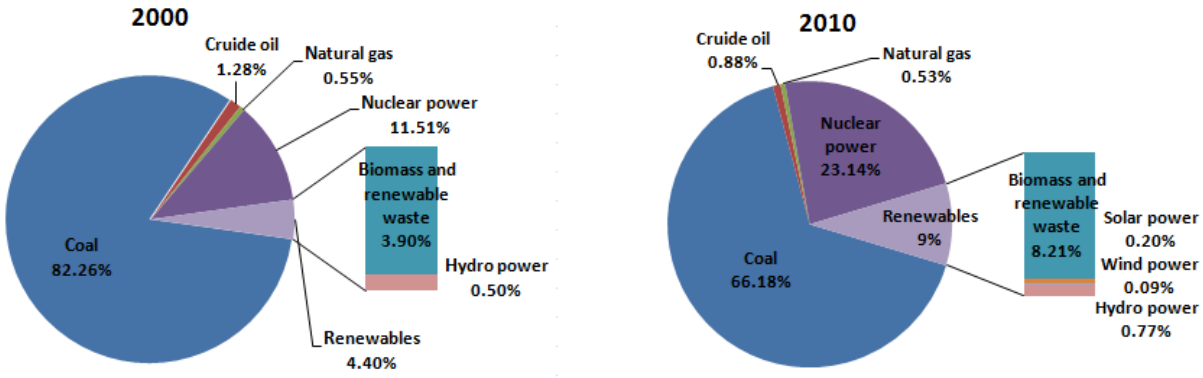

Figure 9 - Primary energy mix - the Czech Republic

Data source: Eurostat, own processed

4.2.2 Primary energy in Denmark

Denmark produces its energy mainly from crude oil and natural gas even if the total amount energy produced by crude oil decreased in the years 2000 to 2011. It uses no heating and nuclear power plants and it plans to be dependant only on renewable resources in the future. That is why the percentage share of renewables in the primary energy production increased approximately by 50% during this period. An interesting fact is that Denmark produced 1.33% of the total energy by wind plants already in the year 2000, thanks to being the developer of wind energy.

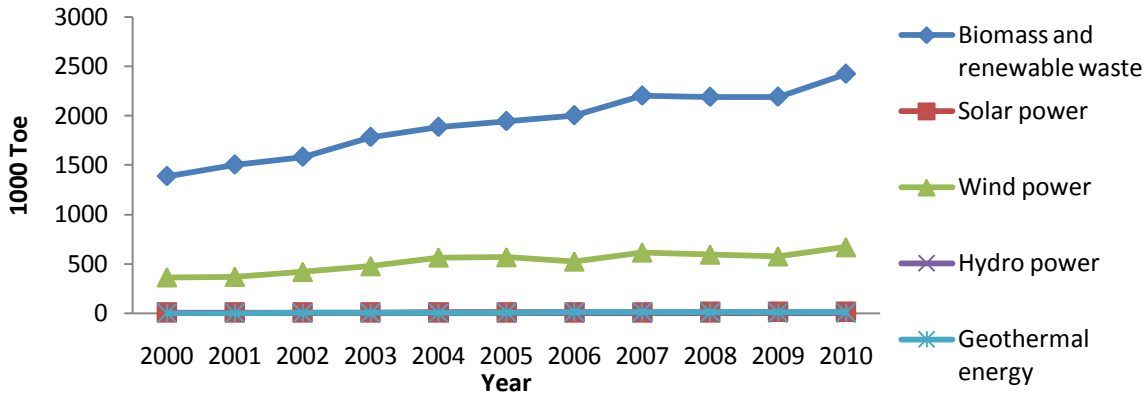

Figure 10 - Primary energy production from renewable sources in Denmark

Data source: Eurostat, own processed

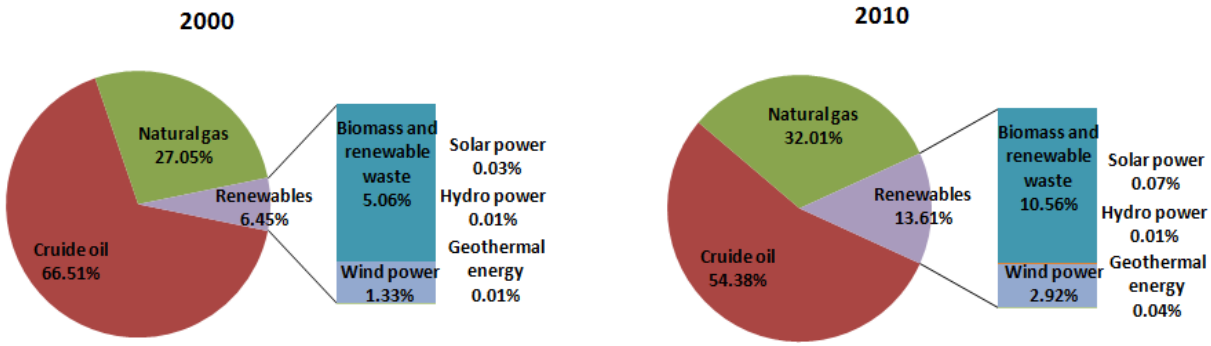

Figure 11 - Primary energy mix - Denmark

Data source: Eurostat, own processed

4.2.3 Primary energy in Germany

Germany is one of the countries that try to implement environmental policies into many parts of their legislative. The share of renewable resources in the total primary energy production has grown four times during the years 2000 and 2011. The biggest changes occurred mainly by biomass and renewable waste, wind and solar power. As it can be seen, Germany tries to avoid producing energy from coal and nuclear power plants, especially after the disaster in Japan's nuclear power plant Fukushima in 2011.

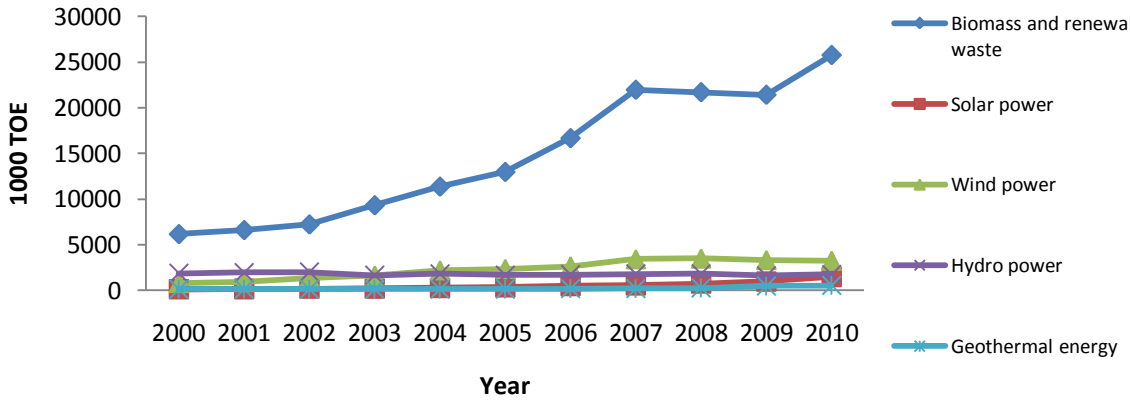

Figure 12 - Primary energy production from renewable sources in Germany

Data source: Eurostat, own processed

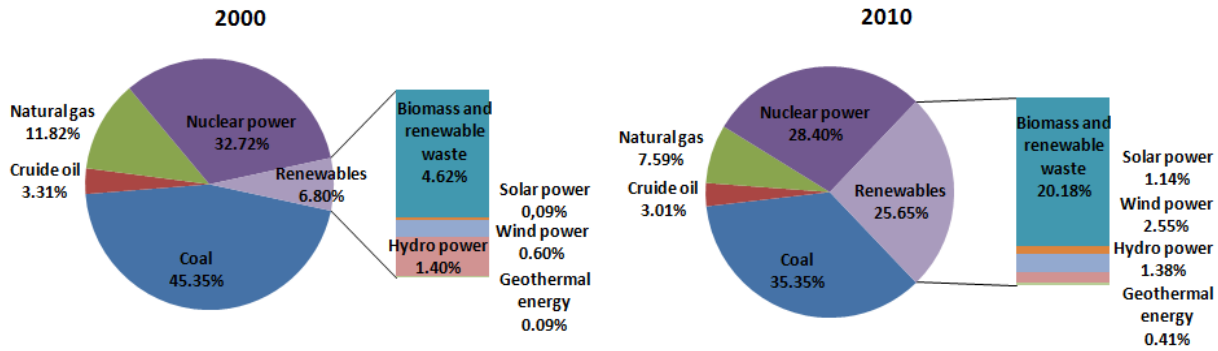

Figure 13 - Primary energy mix - Germany

Data source: Eurostat, own processed

4.2.4 Primary energy in Austria

Almost four fifth of all energy produced in Austria comes from renewable resources. The two main sources are biomass and hydro power plants. During the last ten years Austria was able to remove all the coal power plants. Also it has no nuclear power plants except one nuclear reactor in Vienna that is dedicated for scientific purposes and produces no energy. Unfortunately, due to this fact Austria has a negative power balance, so a significant amount of energy has to be imported.

It can be seen that the amount of energy produced by wind power plants has grown rapidly from 0.06% to 1.59% in the years 2000 to 2010, which represents the highest percentage change from all used sources of energy.

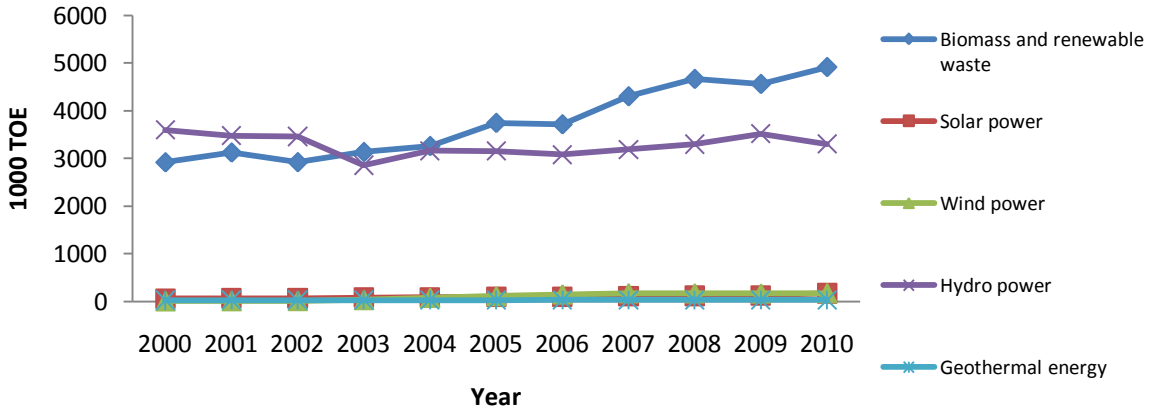

Figure 14 - Primary energy production from renewable sources in Austria

Data source: Eurostat, own processed

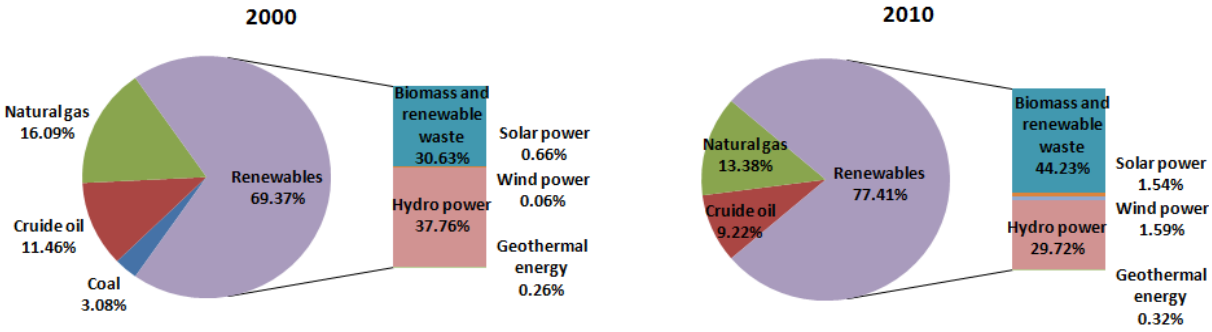

Figure 15 - Primary energy mix – Austria

Data source: Eurostat, own processed

4.2.5 Primary energy in the UK

The UK produces most of its energy by fossil fuels as crude oil or natural gas. Due to the fact that by burning fossil fuels a significant amount of CO_2 is produced, the UK government decided to focus on this while planning a new energy policy.

During the years 2000 and 2010 there was a huge decrease in the total primary energy produced. This change affected mainly the fossil fuels. On the other hand the share of renewable resources in the primary energy production has grown approximately by 80% during the same time. The biggest boom occurred by wind power share which increased from 0.03% to 0.6%.

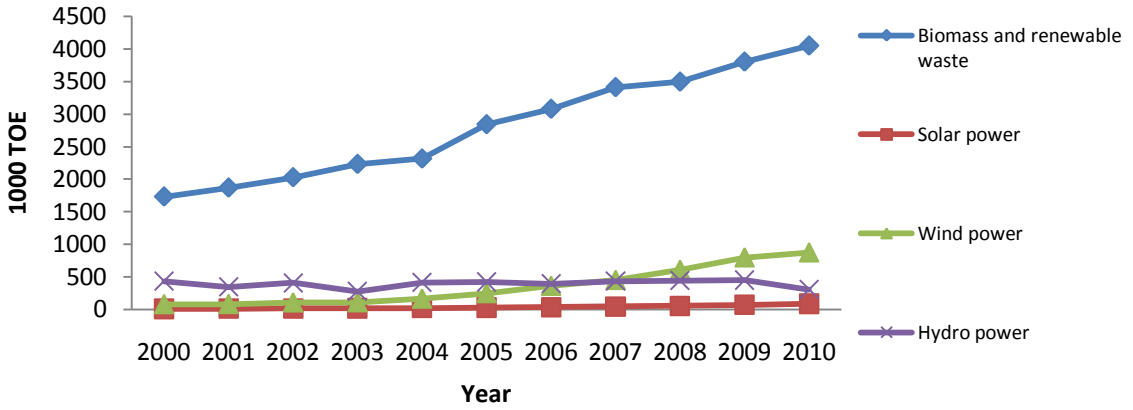

Figure 16 - Primary energy production from renewable sources in the UK

Data source: Eurostat, own processed

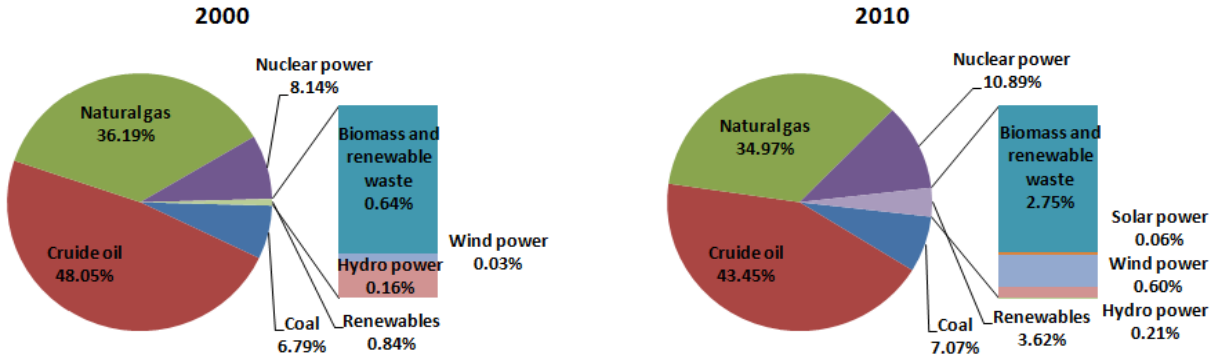

Figure 17 - Primary energy mix - the UK

Data source: Eurostat, own processed

5 Conclusion

The situation of wind energy in the Czech Republic was examined in this thesis by comparing it with other European countries. It concentrated mostly the economical and ecological site of the wind energy problematic and also development of wind energy use in the last decade.

All of the EU countries already started to implement renewable energy into their energy policies to lower the production of harmful substances, some of them more and some of them less. The graph below describes the amount of energy produced by wind plants in the Czech Republic, Denmark, Germany, Austria and the UK from 2000 to 2010.

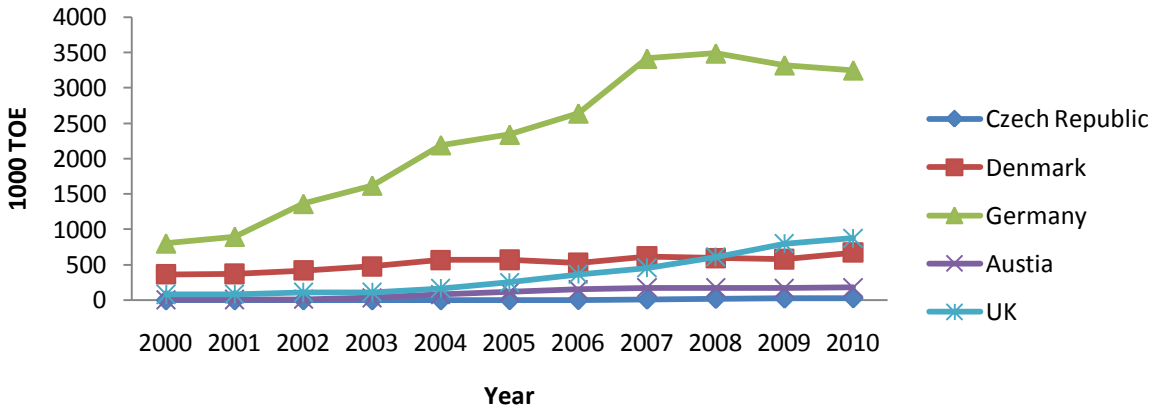

Figure 18 - Energy production from wind power

Data source: Eurostat, own processed

The collected information show that wind energy is not considered being the number one energy source in the Czech Republic. The Czech Republic started to generate energy from wind power plants in 2005, while in other countries the utilization started a few years earlier. However, the Czech Republic was able to install power of 215MW by the end of 2011, which can supply electricity to about 358,000 households.

In other European countries wind energy is supported by various parts of the legislative; e.g.: in Germany every household has to pay about 1.5 Eurocents for every kWh of

green energy in comparison to the Czech Republic, where it is only 0.2 Eurocents. Other countries such as Denmark and the UK spend significant amount of money from the state budget to support wind energy.

Another disadvantage for wind energy in the Czech Republic is that there are not many suitable places where wind plants can be built and also that Czech people are not opened to have a wind plant near to their homes.

On the example of Austria can be seen that using renewable sources in such a huge percentage deepen the energy problematic. As not all the renewable resources are able to provide the same amount of energy, because they are dependent on the weather conditions, Austria cannot satisfy its demand for electricity and has to buy it from abroad, which can affect the purchase prices.

Summarized it is needed to start to produce energy more ecological, but in the way that people's needs can be satisfied.

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6.1 List of figures

6.2 List of tables