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BACHELOR THESIS

Economy of renewable energies in Germany

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Declaration

I declare that I have worked on my diploma thesis titled "Economy of renewable energies in Germany" by myself and I have used only the sources mentioned at the end of the thesis.

In Prague, on date 10th of March 2015

Shevelina Yulia

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Economy of renewable energies in Germany

Ekonomika energie z obnovitelných zdrojů v Německu

Summary

Thesis "Economy of renewable energies in Germany" devoted to alternative types of energy in Germany.

The aim is to analyze the development of various types of renewable energy sources, their advantages and disadvantages, the trend of development in retrospect since 2000 and run until 2050.

Thesis is divided into two main parts, the literature review and a practical part. Review of the literature consists of a description of wind, solar, bio, geothermal energy, as well as the conditions governing the efficiency of wind energy, types of wind in the receiver, evaluate the effectiveness of the use of wind energy from the point of view of the state, problems, goals and prospects of wind energy. The practical part consists of the current situation of wind, solar, bio, geothermal energy in Germany, as there are graphs which show the growth trend of energy in Germany and throughout Europe. In conclusion, summarize, some of the energy will get the greatest acceleration and what kind of energy is the most common.

Keywords

Renewable energy sources, Wind energy, Bioenergy, Solar energy, Germany, European Union.

Souhrn

Práce "Ekonomika energie z obnovitelných zdrojů v Německu", věnovaných alternativních energií v Německu.

Cílem je analyzovat vývoj různých typů obnovitelných zdrojů energie, jejich výhody a nevýhody, trend vývoje ve zpětně od roku 2000 a potrvá do 2050.

Práce je rozdělena do dvou hlavních částí, přehled literatury a praktické části. Přehled literatury se skládá z popisu větrné, sluneční, bio, geotermální energie, jakož i podmínkami, kterými se řídí účinnost větrné energie, typy větru v přijímači, vyhodnocení účinnosti využívání větrné energie z hlediska stavu, problémy, cíle a vyhlídky větrné energie. Praktická část se skládá ze současné situace větrné, sluneční, bio, geotermální energie v Německu, protože tam jsou grafy, které ukazují trend růstu energie v Německu a po celé Evropě. Na závěr shrnuje, jaký typ energie má budoucnost a jaký druh energie je nevýhodný.

Klíčová slova

Obnovitelné zdroje energie, větrná energie, bioenergie, solární energie, Německo, Evropská unie.

Content

1. INTRODUCTION

The scientists warn us that such well-known and available resources as oil and gas might be soon exhausted, that other important resources like iron and copper ores, nickel, manganese, aluminum, chrome, etc. are running out. During 40 years after the World War II people used as much mineral raw materials as people did during the whole human history. It is too early to speak about complete (or absolute) depletion of resources of course: as we extended exploration works the proved amount of some resources even increased, but it gives poor consolation.

Nowadays the world power industry is based on non-renewable energy resources. Our main fossil fuels are oil, gas and coal. Further development of the power industry will be connected with finding of the best energy sources formula and, first of all, with trying to reduce the proportion of conventional energy resources. But we can say that the mankind is already in the transition period: we are moving from power based on organic fossil fuels which are non-renewable to power of almost infinite energy resources.

High hopes are put worldwide on the so-called alternative energy resources; their advantage is that they are renewable and clean energy.

The running out of resources promotes sustainability policy and more extensive waste recycling. In many countries big efforts are made to save energy and resources. Some countries have state energy saving programs.

2. OBJECTIVES AND METHODOLOGY

2.1 Objectives of thesis: Aim of the work is to analyze alternative sources of energy in Germany and their development prospects. The aim is to analyze the development of various types of renewable energy sources, their advantages and disadvantages, the trend of development in retrospect since 2000 and run until 2050.

2.2 Methodology: Metodology is mainly based on the study of the literature, internet resources and comparative analysis. There are used mainly descriptive and comparative methods for ellaboration of the Thesis.

3. LITERATURE REVIEW

3.1 Alternative energy

Alternative energy is becoming more and more popular worldwide. Its advantage is that it is renewable and clean. The alternative energy sources include: wind power, solar power, biopower, geothermal power, tidal power, marine and ocean current power, hydrogen energy, space power (exploration is at the initial level). Among these such sources as wind, solar and bio power have been developed more than the others (Pustovalova, 2005).

3.1.1 Wind power

It appears that primarily wind power was used for sailing, later it was used for pumping water and grinding grain. It is believed that first wind rotors were developed in China, Japan and Tibet more than two thousand years ago. In Ancient Babylon people used them for draining swamps. In Egypt and Middle East people built wind water elevators and windmills (Shefter, 1975).

In Europe wind turbines were widely used in the Netherlands, Germany, Denmark and other countries. (Shefter, 1975).

Wind is one of the most powerful energy sources which under favourable conditions can be widely used in industry. It is produced by permanent movement of air in the atmosphere which happens because the sun heats the earth surface unevenly. (Shefter, 1975).

Wind is a free energy source. That is why some people still think that energy produced by wind turbines is very cheap. The drawback of wind as energy source is that it is inconsistent, it can change its speed greatly, which makes energy also inconsistent. It depends a lot on meteorological factors such as atmospheric disturbance, solar activity and amount of heat emitted on the earth, as well as wind direction and speed can vary randomly because of the local terrain. (Shefter, 1975).

Though wind turbines are capital intensive they are more cost-effective than heating plants due to their low operational costs (they need 6 times lower costs). That is why their costs can be covered in one or one and a half year. Besides, operating life of wind-power units (which are relatively low-speed machines) is longer than of the heating units. So their cost per unit of metal for the whole operating period and amortization expenses are lower too. (Shefter, 1975).

Further development of wind farms construction depends on how quickly we can reduce their cost and amount of metal in wind turbines and how to enhance their reliability. This can be achieved by using reinforced concrete poles, non-metallic rotor blades, alloy steel and light alloys. To make wind farms more competitive it is necessary to reduce their investment cost by 25-30%. (Shefter, 1975).

The following factors which enhanced wide use of wind power can be mentioned: rapid growth of energy demand when fluid and solid fuels and water resources are limited; despite the fact that price for mineral fuels decreases, the threat of their running out still exists; construction of thermal and water power plants requires big capital investment (the costs grow when taking into account energy transmission costs which are considerable as it is necessary to supply consumers who are remote from power lines, dispersed and consume little); enhancement of using coal, oil and gas in chemical industry for production of synthetic materials; considerable breakthrough in aerodynamics, engineering, aircraft industry, chemistry, electric engineering, etc. which allows to create more advanced and cost-effective wind-power units. (Shefter, 1975).

The wind turbines can be widely used in agriculture for battery recharging, water desalination, pumping of drinking water, and water aeration. (Shefter, 1975).

Moreover, along with recharging of batteries low-power wind turbines can power beacons and sea-lights, protect gas-and oil-pipes from corrosion. Stand-alone wind farms which work as isolated generating plants have limited application and can be used for powering water elevators and ameliorative units only. (Shefter, 1975).

The wind turbines preserve freezing of water surface in winter. It is also more economically efficient to use wind turbines in some regions like deserts, semi-deserts, water-short areas. (Shefter, 1975).

3.1.1.1 Feasibility of wind power use

Main factors which define feasibility of wind power use include meteorological conditions, efficient location of the wind turbines, method of converting the wind kinetic energy into electrical power and using it in the power supply system, and economic viability (D. De Renzo, 1982).

The above listed factors are described below with their specific features and role referring to Germany, and also with the corresponding data which was used during the research; wind power resources; natural resources (theoretical resources); resources suitable for practical use (technological capacity); economic resources (economic potential) (D. De Renzo, 1982).

Natural wind power resource is its kinetic energy. The major part of the wind kinetic energy which can be converted into useful power in compliance with the laws of nature and up-to-date technologies makes the resources suitable for practical use. The part of these resources which can be transformed into conventional energy with economically justifiable expenses in comparison with expenses on usual energy sources makes the economic resources (D. De Renzo, 1982).

3.1.1.2 Critetia for identifying efficient location of the wind turbines

Locations most suitable for wind power use have the following characteristics: high annual average wind speed which is the most important factor that influences the annual output of the wind turbine (turbines); rare intensive turbulence of air flows, i.e. on the average minor change of wind direction and speed which allows non-failure work of the wind turbines; main wind flows should have one dominating direction which allows reducing the space necessary for the wind farm.

High annual average wind speed and relatively weak turbulence of air flow are more common for the coastal areas. Because of the even surface of the sea strong winds, which are hold at high attitude, weaken very slightly when going down and they have less turbulence than the onshore winds. But at the coast area land winds and offshore winds may cause a problem. Bottom and top parts of rotor blades can be simultaneously exposed to the air flows which move in different directions and have different speed. That introduces serious technical problems which should be solved (Shefter, 1975).

When the main wind flows have a dominating direction it is possible to minimize the distance between the wind turbines which is necessary to reduce the shadowing effect, i.e. separate turbines can be located closer to each other perpendicular to the main wind direction. Which means it is possible to place more wind turbines which can increase power production on the area unit (Shefter, 1975).

Apart the meteorological factors the final choice in defining location for the wind farms is also influenced by other factors. Among them: available traffic network and opportunity to connect to the existing grid; economic factors such as land price and legislative acts: for instance, nature conservation law, flight safety rules, health and safety care regarding the population of the chosen region; environmental impact such as noise, distortion of landscape and radio- and TV lines noise (Sidorov and Kuznetcov, 1980).

Land price is an important factor for economically efficient use of wind power too. Thus when erecting a big number of wind farms the price for land used for farms increases as it becomes unsuitable for other purposes. But at the same time the price for land between the separate turbines decreases though this land is suitable for use, for example, for agricultural crops (Shefter, 1975).

3.1.1.3 Conditions that define wind power efficiency

Unlike conventional fossil fuels wind power does not require expenses on its extracting and transportation. That is why wind is often considered as the free energy source. Because of that some people think that energy extracted by wind turbines is generally cheap and almost free too. But naturally it is far from it. It is necessary to know the conditions better to define correctly where and how wind power can be more advantageous, and when it is more reasonable and cost-efficient to use other types of power units. It is also necessary to take into account the demands of the consumers, specific features of the wind power, operating mode of the wind turbine and quality of the produced energy. By considering all factors only one can receive objective reasons to define whether it is economically reasonable and technically possible to install a wind turbine in certain conditions (Jarrass and Hoffmann, 1980).

Wind is a random and uncontrolled phenomenon produced by the sun activity and rotation of the Earth. One of the wind power features is its inconsistence which is caused by considerable speed change. It leads to considerable change of the wind kinetic power even during short-term: from zero-point energy in windless conditions to energy which exceeds the theoretically-calculated value many times during storm and hurricane. This results in inconsistency of the capacity produced by the wind turbine. Thus to keep constant capacity of the wind turbine, preserve it from overloading and ensure the preset rotation frequency of the wind wheel and other machines connected to the rotor at certain wind speed (higher than the theoretically-calculated), it is necessary to apply automatic capacity and rotation frequency control systems. Low atmospheric density causes low concentration of energy in the air flow per unit area of the flow section. Thus it is necessary to use turbines with wind wheels of sufficient diameter to get measurable capacity (Jarrass and Hoffmann, 1980).

But wind can change not only its speed, but also its direction. To capture maximum wind power the wind wheel (or any other operating element which transforms wind kinetic power into mechanical energy) should have a certain position toward the wind flow. That is why it is necessary to equip the wind turbines with automatic orientation systems. For vane rotors of horizontal axis type the wind wheel should be installed so that its rotation plane is perpendicular to the wind vector (Jarrass and Hoffmann, 1980).

Finally during a short-term or long-term period there can be lack of energy because the wind speed is not enough for the wind turbine operation. That is why it is necessary to provide storage systems, reserve drivers and reserve units to back up the wind turbine capacity depending on the turbine construction, type and purpose. This will ensure that consumers are provided with mechanical or electrical power, heat, water or processed products (for example, flour, feed-stuff, hydrogen and oxygen produced by electrolysis of water, etc.) without fail and in compliance with the schedule (Jarrass and Hoffmann, 1980).

The principal approach is that to use wind power efficiently in each case it is necessary to ensure several factors: high annual average wind speed and constancy of its direction; maximum invariability of wind speed and direction; the best match of wind capacity and energy demand schedules; available traffic network and convenient locations for erection of wind farms; lack of noise, radio- and TV lines noise during wind turbine operation (Jarrass and Hoffmann, 1980).

3.1.1.4 Types of wind turbines

Many different types of the wind-receiving units have been developed. The number of patents for them is bigger than for any other types of power units. In general these are the devices which construction evokes asymmetrical powers in the wind flow; they can rotate, translate or vibrate. There are the following types of wind-receiving units depending on the orientation of the axis to the direction of the wind: of horizontal axis in parallel to the direction of the wind; of horizontal axis perpendicular to the direction of the wind (like water wheel); of vertical axis perpendicular to the direction of the wind (Shefter, 1975).

There are also known translation wind-receiving devices, among them - a sailing boat with a water turbine mechanically connected to the electric generator. It was also suggested to construct a sailing wind-receiving device which moves around the close-looped rail-track on wheels which are mechanically connected to the electric generator. Another type of translation device was developed for extracting power when wind flow varies. There are also devices developed for converting wind power into electrical power that do not have moving elements. One of them is the device which is based on Thomson heating effect and uses cooling of the wind flow to extract electrical power (Shefter, 1975).

3.1.1.5 Government evaluation of wind energy usage

The government evaluation is mainly based on the principle of production cost minimization and 1 kWh energy distribution in the certain region. However, this problem is more challenging from the government point of view than from the entrepreneur's standpoint (Shefter, 1975).

Firstly, the term "costs" has the wider meaning. Though energy production involves additional costs which do not affect entrepreneurs' budget, they still have an impact on the state economy and after all affect public interests in a whole. Thus, damage to people health by air contamination due to usage of mineral coal as the fuel for power plant operation, leads to increase of health costs and consequently insurance contributions to the sickness funds. In government assessment, these costs relate to energy production cost. In order to take into account such costs when planning capital investments and sales by entrepreneurs/energy suppliers, a certain tax should be imposed on the energy suppliers and thereby affect the selling prices (Shefter, 1975).

It is not the same in case of government costs subject to expected in early future decrease of primary energy resources which is currently are ignored by the market. Thus, the oil deficit is expected in the 80ths of 21th century, and an inevitable adaptation process will cause rise of federal expenditures which is not reflected in oil prices at the moment, and as a result it does not affect the capital investments of the electric energy suppliers. In this case it would be reasonable to outline by the relative taxes the trend of primary energy resources decrease in the current capital investment policy of the energy suppliers in order to make their decisions on size and direction of their capital investments correspondent to the market situation by the moment these new capital investments would have been implemented in production (Shefter, 1975).

In the case of costs minimization according to the government evaluation, one should take into consideration that the competitive production practices are evaluated from the same points. So, construction of coal plants mined in Germany is subsidized by the government, since the domestic primary energy resources are used and thereby reliability of energy supply is improved. Wind power stations should be granted with the relevant funds on the similar basis (Shefter, 1975).

Economic efficiency of wind power usage depends on the plant operation and life whether it operates in-season, from time to time or throughout the year. In the latter case and when the wind turbine is running all-time as long as there is wind of the certain velocity, and the load corresponds to the developed power, the maximum capability may be achieved that reduces specific energy costs (Shefter, 1975).

The most significant factor for wind energy performance is full compliance of the wind turbine specifications to the wind conditions, on one part, and consumer peculiarities, on the other part. In this respect, the main purpose is to define optimal rated wind velocity governing the installed power and flow rate at which the automatic control system of wind turbine developed capacity is launched. Level of cut-in-wind speeds for the turbine must be as low as possible in order to apply wide range of speeds. It is also can be reached by perfect dynamic qualities and acceleration ability of the unit, i.e. the capability of the wind turbine to accelerate quickly and reach the operating condition. It is sure that under otherwise equal conditions the unit with simpler structure and maintenance and having required reliability and high efficiency would be more cost-effective (Shefter, 1975).

To enhance wind power efficiency in the certain region and to improve economic performances it is critical to distribute more proportionally various wind speeds throughout the year and to avoid the possibility for windstorm. Under such circumstances the periods of long energy calm are less. Moreover, the oftener high wind speed repeats, the more manufacturing costs are required for the turbine as it should be more reliable (Shefter, 1975).

3.1.1.6 Aspects, objectives and perspectives

As a rule, wind turbines are widely used in agriculture for wind surge and water desalination for potable needs as well as for water pumping at vertical drainage and out of waterlogged land, for batteries charging, aeration of water reservoirs, etc. Achievement of a final objective depends not merely on successful solving of scientific and technical problems but also on program execution control level, operation coordination, focus on core aspects, cooperation in design and production of machines. Two core aspects are distinguished, namely production and usage of units of rather low capacity for autonomous objects and consumers, and design, production and operation of large-scale wind power stations to be used in systems and jointly with heat and hydraulic power stations. And mission area for achievement of these aspects is essentially different. Difficulties of the first above aspect are connected with arrangement of production, implementation and operation while of the second one is associated with scientific issues (Jarrass and Hoffmann, 1980).

Fully automated wind turbines of higher specific speed and capacity from 1 to 3 kW will be widely applied in pasture water supply as well as turbines of higher power (10-15kW) for well areas watering of which can give addition yield of vegetables and gourds (Jarrass and Hoffmann, 1980).

The critical moment is creation of turbines with hybrid engines which combine advantages of low-speed machine at startup and high-speed machines at operation with various wind speeds (Jarrass and Hoffmann, 1980).

Application of desalting wind turbines will be on wide scale basis. Taking into account wind peculiarities as an energy source, the high-speed wind turbines equipped with desalters can be predicted. Water desalting functions of such the desalters are characterized by quick response, wide range of power unit capacity, current load and sometimes voltage, and allow power interruptions excluding the risk of salt content increase in water. The plants using practices of reverse osmosis, steam compression and vacuum distillation, comply with the above specifications. Desalters will be equipped with batteries if the unit capacity is 7-10 kW while stand-by engines will be applied for desalters consuming 20-25 kW power. Units up to 100 kW mainly with pump electric drives will be required for vertical drainage operations and winter icing (Jarrass and Hoffmann, 1980).

The most significant scientific-technical objectives affecting the wind turbine efficiency are as follows:

1. Design of self-control engines which require no controllers. It can be reached by application of special airfoil sections for wind turbine blades or by braking effect caused by air flows discharged from the channels.

2. Development of the wind turbine with wind wheels of larger diameter, in which the energy is directed to the generators by the so called aerodymanic transfer.

3. Production of fully-variable highly efficient generators operating within the wide range of power and ensuring low current frequency change by automatic disable/enable of number of pole-pairs in relation to frequency of wind wheel rotation.

4. Design of high-speed pistonless compressors with flat efficiency characteristic as a function of power and with low starting torque and engineering of pneumatic power transmission system hereon. As an option, a diaphragm-type compressor can be applied.

5. Construction of direct-drive ultra-high-speed wind turbines equipped with a device for automatic torque increase at startup and maximum torque and rotation rate limitation during windstorm.

6. Determination of practices, methods and devices decreasing the value $_{\text{blade tip velocity}}$ and enhancing wind energy efficiency up to the perfect level (0.85-0.9) (Jarrass and Hoffmann, 1980).

3.1.2 Solar energy

Advanced technologies enable solving the problem of energy supply by photovoltaics. Solar energy is converted to electrical one by photovoltaic silicon cells composing of solar batteries. Solar power stations do not release harmful substances into atmosphere and are environmentally-friendly, and their energy source is inexhaustible. But quantity of energy generated by photovoltaic cells directly depends on solar activity, therefore they are equipped with batteries for day and night usage. They often say that there is nothing new under the sun. Oddly enough, but this expression related to the solar thermal power as well. Archeological excavations proved that in the bath houses and other buildings of the ancient Rome there were channels along which warm air from solar heated part of buildings flew and generated comfort temperature indoors (Byers, 1988).

The method of energy production from sunlight has been known for more than a century. Photovoltaics phenomenon was firstly introduced by Edmond Becquerel in 1839. In the course of experiments he submerged two metal electrodes into conductivity solution and sunlight exposed. Low potential difference occurred between the electrodes. The solar cells developed by the Bell laboratory in the early 50s caused a revolution in electronics. Space industry would have been almost aidless without them. Light solar energy generators could change the approach to creation of artificial satellite. In addition, solar energy can be used in solar house. Solar energy units are designed for heating and hot water supply to houses. Solar energy units allow saving expensive mineral fuel due to reasonable usage of solar radiation power (Byers, 1988).

The solar house (the house with heating and cooling and hot water supply due to solar energy) became very popular. Probably, the ideal example of such the house is a conventional Japanese house. During all seasons there is a comfortable temperature for living. Actually, there are little real solar houses with completed heating and cooling system, and it is not easy to make them economically viable. Though it is obvious, that natural sources of coal and oil are not enough for extended lengths of time, and the future technical program will require energy saving (Syunroku Tanaka, 1989).

3.1.3 Biomass

While coal is globally still very important for power generation it is also very CO_2-intensive. Biomass used, is an in many cases cost-effective option to substitute coal for biomass in electricity production, to mitigate CO_2 emissions. Another advantage is the increased fuel flexibility. In Europe, cost-effectiveness has been enhanced further by the introduction of the EU Emissions Trading Scheme (EU ETS). (LUSCHEN, A., MADLENER, R. 2013).

3.1.3.1 Biofuel

Such type of energy has enormous advantages compared with another types by the reason of relative cheapness and environmental safety. Of course, this fact attracted much attention, and this is an active area for research by many countries (Schulz, Eder, 1996).

There are several technologies for biofuel production. One of them is processing of agricultural wastes. Wood pieces, straw, animal dung, etc. can be the feedstock for the above process. German chemical company Choren Industries supported by groups DaimlerChrysler and Volkswagen was the first who started biofuel manufacturing (FLEGENTOV, 2006).

After drying, the wastes are heated up to 400-500 C, the generated gas is subject to the set of conversions with a catalyst, and the sulphur-free diesel fuel leaves the reactor. More to that, biodiesel fuel is CO_2-free, therefore the same carbon dioxide that was uptaken by growing plants is back to the atmosphere after this fuel combustion. Cleanliness of the biodiesel fuel is as much important as it complies with toxicity standard Euro 4 even for those motors designed for Euro 3. Certainly, the solar biodiesel fuel is still rather expensive (FLEGENTOV, 2006).

According to the project authors, the present European agricultural resources allow to provide this fuel for 50-80% of all car diesels (FLEGENTOV, 2006).

3.1.3.2 Biogas

Biogas is the gas producing by hydrogen or methane digestion of biomass. Methane is decomposed under an influence of three types of bacteria. In the food chain the next bacteria fed metabolic byproducts of the previous ones. The first type is hydrolitic bacteria, the second one- acid forming and the third one- methane forming bacteria. These three types take part in biogas generation. Biohydrogen is one of the varieties of biogas. Hydrogen, its final product, is also the energy source. (Schulz, Eder, 1996).

People have been using biogas for long time. As long ago as the first millennium a.c., the ancient Alamanni living in wetlands of Elba river basin, sewed the leather canvasses, covered swampland and released gas along the leather tubes to their dwellings, then they burned it and used for cooking. In the 17^{th} century Jan Baptista Van Helmont defined that the decomposing biomass generates flammable gases. In 1776 Alessandro Volta made a conclusion on relationship between the quantity of decomposing biomass and quantity of generated gas. In 1808 sir Humphry Davy founded methane in biogas. The first recorded biogas unit was constructed in Bombey, India in 1859, and since 1895 biogas has been applied in Europe for the street lighting purpose (Schulz, Eder, 1996).

Biogas composition: 50-87% of methane, 3-50 CO_2, trace impurities of hydrogen and H2S. But the power is generated by methane only (Schulz, Eder, 1996).

Energy feedstock: animal dung , bird dung, grass, sewages, juice production wastes, starch, etc. In addition, biogas can be produced from specially grown crops such as maize silage and sea grass. Gas release can reach up to 300 m3 /t. Maximum quality of biogas can be produced from fat, up to 1300 m3 with 87% of methane content. The present plants allow gas release from 60 to 95% of theoretically possible (Schulz, Eder, 1996).

Biogas enables decrease of methane release into atmosphere. Methane has an impact on greenhouse effect 21 times more than CO_2 and has been kept into atmosphere for 12 years. Demethanized wastes are applied in agriculture as a fertilizer (Schulz, Eder, 1996).

Biogas is used as a fuel for heat or steam energy production or as a car fuel. Biogas plants can be installed as a treatment stations in farms, poultry factories, distilleries and sugar plants. Germany is the leader in middle and large-scale plants (over 10 000 plants) (Schulz, Eder, 1996).

Biogas price is about 0.5 Euro per liter in gasoline equivalent. Biogas industry in Germany is estimated 100 bln kWh by 2030 that will be approximately 10% of domestically consumed energy. Here are two ways of obtaining biogas (Schulz, Eder, 1996).

Figure 1. Schematic diagram of the production of electricity from biogas produced from agricultural products

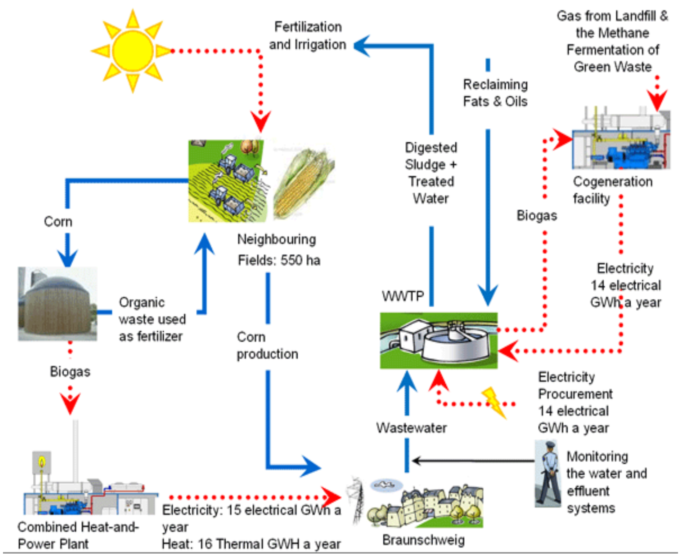
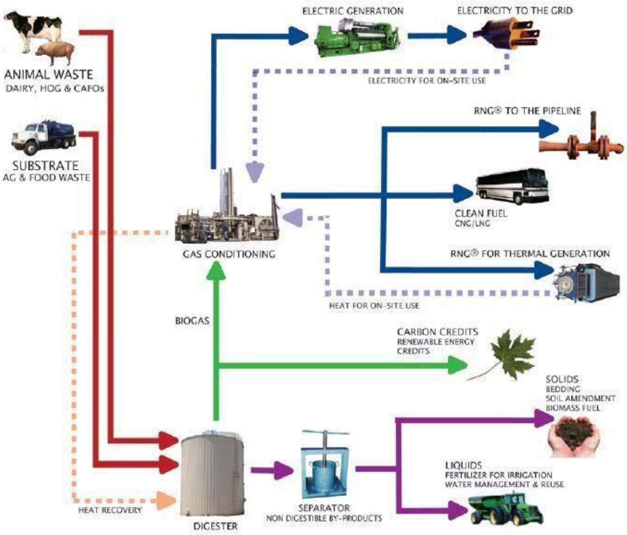


Figure 2. Schematic diagram of the production of electricity from biogas produced from livestock waste



3.1.3.3 Biodiesel production process

In the course of biodiesel production, the oil is pressed out the feedstock and cleaned; the semi-product is heated, cooled and distilled: 1-low-temperature gas generator; 2-high temperature reactor; 3- dust filter; 4- heat exchanger; 5- water supply; 6- separator; 7- multitube reactor; 8- gas compressor; 9- condenser; 10- cooling system; 11- heater; 12- distilling tank; 13-gas generator; 14- finished fuel tank (Flegentov, 2006).

Figure 3. Schematic diagram of the receiving biodiesel

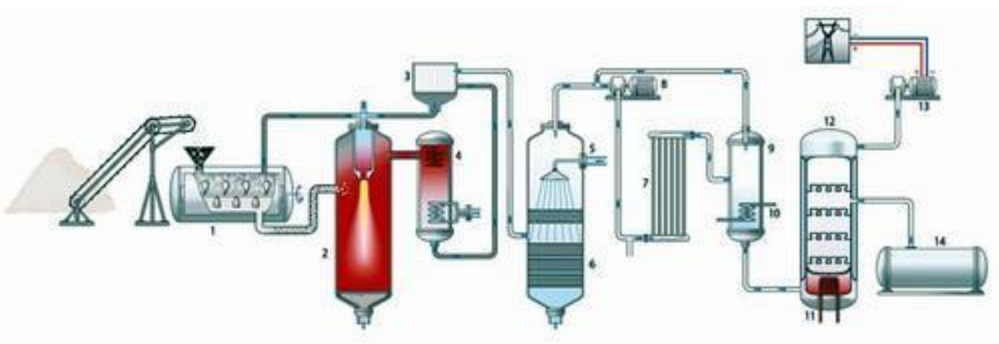


Table 1. Several Characteristics of mineral diesel fuel and biodiesel

	Mineral diesel fuel	**Biodiesel**
Cetane number	42-52	47-58
Pour point, C	-10	-9
Sulphur content, %	0,2	-
Ash content, %	0,03	-
Viscosity at 20 C, mm^2/sec	3,8	7.5
Calorific efficiency, kJ/kg	42 000	37 000

At the moment, the most favorite feedstock for biodiesel production is rape which grows everywhere as a weed. The only nuance is that it should be gathered in time. Rape harvesting capacity is 20-25 centners per hectare. But now it is just added to the diesel fuel, because the pure rape oil is not used as a fuel. Due to the higher viscosity (20 times more than of the diesel fuel), other fuel equipment and modified combustion chamber are required. Oil is mixed up with methanol, and mephyl ether (or oil methanol mixture) is obtained. 350 kg of this mixture can be obtained from one tonne. To produce biodiesel, 30% of oil methanol mixture is added to the diesel oil. Rape oil can be composed with ethyl (potable) alcohol instead of toxical methyl alcohol (Flegentov, 2006).

It is of interest, that as a result of oil conversion into biodiesel, several additional marketable products are manufactured. They are glycerin and potassium sulphate (Flegentov, 2006).

Advantages:

Economical aspect. The countries having little or no oil are ready to pay by green feedstock (rather than dollars) for energy independence. (Flegentov, 2006).

Biodiesel is free from sulphur and cancerogenic benzene. Ingestion of this fuel is in situ and environmentally safe, and combustion emissions of CO_2 is 50-80% lower than if conventional mineral diesel fuel is used; vegetable oil has a good flammability due to cetane number (58), whilst the cetane number of the conventional diesel oil does not exceed 52. In other words, bio diesel fuel is readily ignited but it burned with lower heat release (See the Table 1). Feedstock may be reproduced annually, the crop does not require special care in the course of cultivation. As a result of oil processing, several additional marketable products are manufactured. They are glycerin and potassium sulphate (Flegentov, 2006).

Drawbacks:

Cost of production is higher than that of petrol and diesel oil, additional agricultural land is required, rapeseed oil ethers are of high corrosiveness. This may lead to loss of durability of rubber gaskets and seals, formation of hard deposits in nozzles, plugging of fuel filters and failing of high-pressure pumps, high content of nitrogen oxide in ‘vegetable’ exhaust. NO_X content in exhaust is 10 % more than in regular diesel oil, and as a result of experiment Volvo engineers proved that this difference may reach 40%, toxicity abatement may also result in loss of power which is compensated by higher fuel consumption (Flegentov, 2006).

3.1.4. Geothermal Power

Another prospective energy source that will become the most efficient one in the future. It is geothermics, i.e. thermal processes in the Earth's interior. This heat is available everywhere and all year round. Here are the figures: 99% of the substance that forms our planet is hotter than 1000 degrees Celsius, and the share of substance with the temperature below 100 degrees accounts for 0.1% of the Earth mass. Despite the fact that only a small part of this power can be actually used, it is almost inexhaustible. Using only the power that is close to the surface, it will be possible to cover from 20 to 25% of Germany demand for heat in the nearest future, apart from power production. Explored reserves of geothermal power exceed the energy content of all resources put together in more than 30 times. In Germany, where particular attention is paid to use of renewable resources, geothermics is only beginning to develop. It can be explained by the fact that there is a little number of hot springs in the country. However, some geothermal facilities can be reckoned among large industrial installations. They supply centralized heat for the whole districts. And recently the systems have emerged that make it possible to use geothermics for power production. Today, technologies that can be used not only at the source of thermal waters, but universally, is a vital issue. This theory was called 'hot dry rock'. It is based on a well-known phenomenon – as we go deeper into the Earths' interior, the temperature rises by about 3 degrees every 100 meters. American geoscientists proposed to drill 2 boreholes 4 to 6 km deep. Into one of them cold water will be injected, from another one heated steam will be taken off, as the temperature at such depth is between 150 and 200 degrees Celsius. The steam can be utilized both for heating and power production. Today, this technology is being tested in Alsace, and in Soultz region it has already become possible to obtain geothermal steam, the constructed power station will produce current soon. The power station capacity is 25 MW. And this current will cost less than the current generated by solar batteries. The aim of geothermal technology is to increase the share in power production to 25% (Fradkin, 2003).

4. RESULTS

4.1. Alternative energy sources in Germany

Germany is an European Leader in Alternative Energy in Europe. Germany has adopted particularly ambitious renewable energy targets, and is now implementing an Energiewende e a transition to a nuclear-free and low-carbon energy system (Gullberga et.al., 2014).

Germany has achieved great success in alternative energy and established a lead over the states that set widespread use of solar energy as their strategic priority. The German nation manages not only to maintain world domination in production of solar energy, Germany succeeded to surpass all its previous records in monthly generation of net energy, according to the report for 2013. In July 2013 alone, 5.1 terawatt (TWh) was generated by solar photocells in Germany. It is noteworthy that this country holds to the comprehensive strategy of utilizing generators at alternative natural energy sources, in winter the country has much less light, but this loss is compensated with electricity generated by wind farms. During the first half of 2013 Germany got 19.4 TWh from the Sun, and the output of wind-driven generators made up 24.2 TWh. Thus, these two natural energy sources overtook nuclear power stations. German NPS produced 52.1 TWh, and alternative energy as a whole generated 43.6 TWh. As for the ratio energy generation - consumption, Germany has managed to benefit, i.e. the country produces more electricity than it consumes. In 2012, the Germans supplied 22.8 TWh to the energy market and during the first half of 2013 they exported 12 TWh. These days every second solar power station in the world is a German one Germany is striving for the share of alternative energy to make up 20% of the total power consumption volume in the power balance of the country by 2020. It should be reminded that today, the share of alternative energy consumption in Germany amounts to the half of 2020 target (Zholkver, 2015).

Addressing this issue, Norbert Rottgen, Minister for Environment, stated as follows: "Use of environmentally friendly technologies such as wind, sun and biomass energy is likely to advance faster than expected and exceeds the target growth of 18% in 2020". Rottgen also noted that by 2020, German Government anticipates the volume of energy generated from renewable sources at the level of 38.6%. As for heat production, the share of alternative energy in power generation will have totaled 15.5% by that time. And it will amount to 13.2% in transport (Zholkver, 2015).

Over 10 per cent of heat, power and fuel consumed in Germany in 2009 was supplied to consumers in form of alternative sources. The economic recession did not affect this sphere of German economy (Zholkver, 2015).

The history of renewable sources development in Germany is a story of success. When it comes to available capacities, in 2009 only they grew by 5 GW and reached 45 GW. It is approximately one third of the total power potential of Germany (Zholkver, 2015).

4.1.1. Sun, air and water

One should also take into account German offshore wind farms that will come into service this year. And in 2009 the capacity of biogas producing facilities was increased almost two times (Zholkver, 2015).

The share of alternative energy sources in the total power balance of Germany is more than 10 percent, and more than 16 percent - in power production. In absolute terms, it is 94 bln KWh of power produced by wind farms, solar batteries, geothermal facilities and stations using biofuel. The share of renewable energy sources has grown to more than eight percent (Zholkver, 2015).

These data was announced by Norbert Rettgen, Minister for Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany at press-conference in Berlin. He was very optimistic and convinced that Germany could achieve EU objectives and increase the share of renewable sources in total energy balance from today's 10 percent to 18 percent in 2020 (Zholkver, 2015).

4.1.2. Environmental and Economic Effect

An important side effect for Germany is less dependence on energy carriers import. "As long as renewable sources replace traditional ones, import dependence drops, while import is substituted by domestic production," Rettgen noted (Zholkver, 2015).

Along with enhancement of energy security and lower dependence on oil and gas purchases, fast development of alternative energy sources allows to solve the problem of reduction of greenhouse gas emissions to the atmosphere at the same time. By now, Germany has cut carbon dioxide emissions to 28% compared to the level of 1990, as radio station «Deutsche Welle» informs. The reduction was achieved largely because of the use of renewable energy sources. Without their further development climate protection targets, in Rettgen's opinion, will be unachievable (Zholkver, 2015).

Besides of environmental effect there are also economic benefits. While total volume of German GDP went down by 5 percent, investments in alternative energy sources continued to grow. Last year they increased by 20 percent, that is 18 bln. Euro. ‘This means that renewable energy sources sector keeps growing against the general trend," Minister noted. "This sector augments its potential, while economy in general is in recession" (Zholkver, 2015).

Unlike other sectors of national economy of the Federal Republic of Germany, where employees were fired from the enterprises or shifted-over to a shorter workday, the number of alternative energy sector workers reached 300 ths people last year. This is 20 ths more than one year ago and if compared to 2004, almost the double of workplaces in this sector (Zholkver, 2015).

4.1.3. Argues over NPS

Nuclear Power Stations (NPS) is a touchy issue for German Minister for Environment. The one before last Government of the Germany took the decision to close all NPS stepwise by 2021 and stop building new ones. The Conservatives and the Liberals that formed a new Cabinet of Ministers last year, intend, however, to extend the life of German reactors. The question is, for how long (Zholkver, 2015).

Some Government representatives refer to foreign practices. In some countries the life of nuclear power stations is 60 years and even longer. Within his Christian Democratic Party, Norbert Rettgen belongs to nuclear sceptics. At his initiative, an interagency committee was established in Germany. The committee is charged with assessment of appropriateness and economic efficiency of German NPS life extension for 0 to 20 years. As Minister explained, the committee should calculate the expenses of national economy and define the measures to be taken in case the life of NPS is not extended at all or increased by 5, 10, 15 or 20 years (Zholkver, 2015).

Like Chancellor Angela Merkel, Norbert Rettgen calls atomic engineering a transitional technology, though, Minister wants this transition to be shorter, in contrast to mid-century oriented Head of the Government. “Both in the coalition treaty and governmental philosophy atomic engineering is considered to be a transient stage and not a long-term power perspective," he reminded. According to him, there are no alternatives to renewable energy sources. Refusal of nuclear power stations is unavoidable not least because new ones will not be built (Zholkver, 2015).

"Thus, continuous, consistent, stepwise and reasonable substitution of NPS with other energy sources shall be concerned," Norbert Rettgen stated (Zholkver, 2015).

This can happen sooner than Minister expects it. According to investigation conducted on the order of Energy Watch Group, an American organization, as soon as in 2030, the whole world, including transport sector, will be supplied with the power from renewable sources. Though, according to experts' calculations, to realize this, 3.8 mln big wind turbines shall be installed, 90 large and 1.7 bln smaller solar power stations shall be built, that is, on the roofs of almost all residential and municipal buildings. Estimated cost of the program is USD 100 trn (Zholkver, 2015).

4.1.4. Current situation

The major documents regulating activities in the sphere of RES are: National Renewable Energy Action Plan of 2010, German Energy Strategy 2050 of 2010, and the aforementioned EC Renewable Energy Directive of 2009 (Alternative energy sources, 2014)

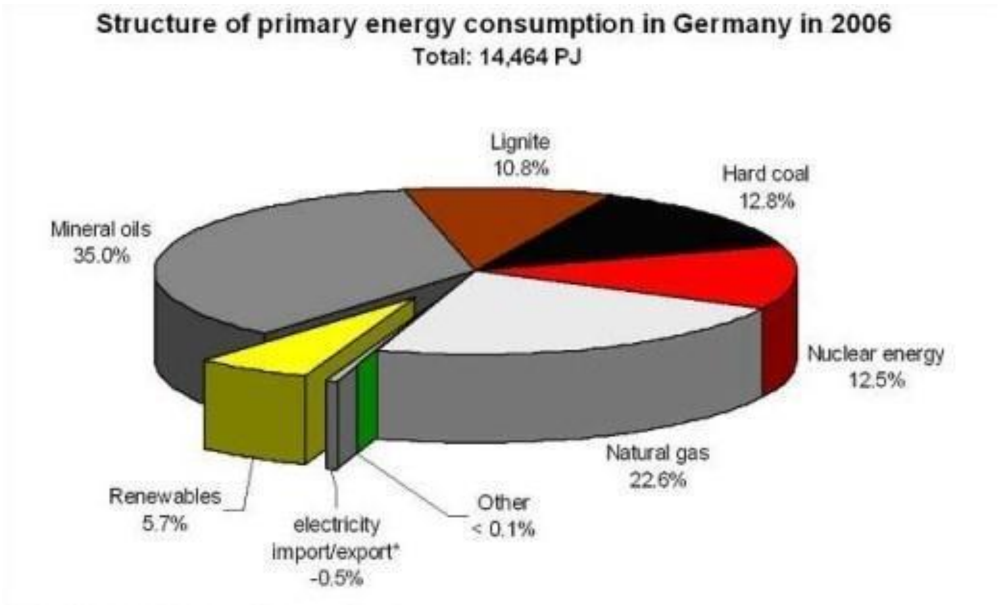
Notwithstanding the optimistic RES development plans already adopted de jure, there are also restrained opinions on the future of alternative energy in Germany and Europe in general (Alternative energy sources, 2014).

"The main problem of renewable sources is big losses when converting one kind of energy into another and the most part of energy produced in such way cannot be saved. The situation will not change in the next 10 years. The future will belong to renewables only then, when we manage to preserve the produced energy. In the meantime they remain a good supplement, but can not become the basis of power supply. I mean efficient and reliable energy sources," Gunther Oettinger, EU Energy Commissioner declared (Alternative energy sources, 2014).

At the same time, Commissioner favors the position on closing of NPS and offers to focus on coal power stations. Thus, it may be concluded that along with its wish to lessen energy dependence and diversify power sources, EU has an absolutely sensible view of RES issues as well as their development prospects (Alternative energy sources, 2014).

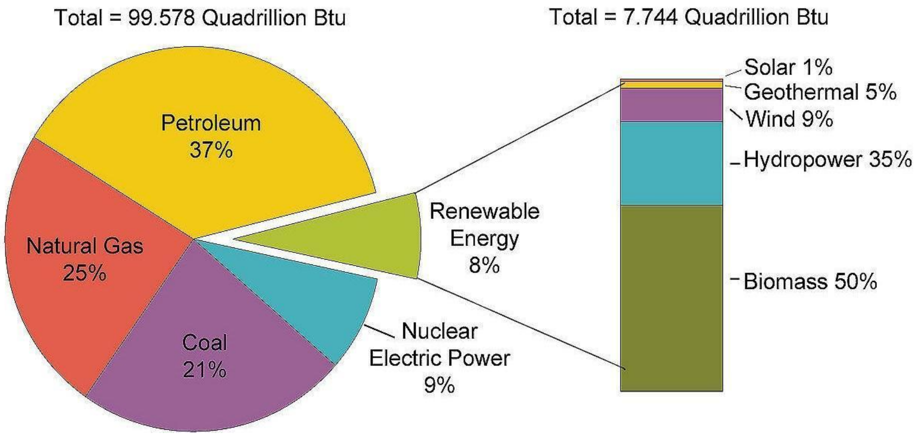
There are some graphs to comment:

Figure 4. Development of renewable energy in Germany, 2006



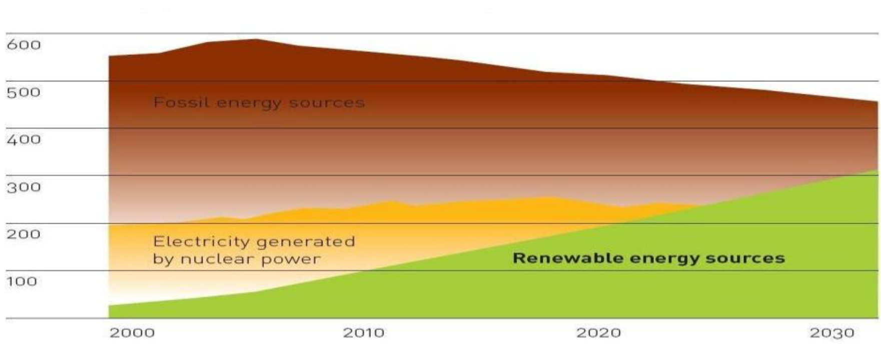
There was a significant increase in the share of renewable energy sources such as hydropower, wind energy, geothermal energy, biomass and solar energy – from 4.7 % in 2005 to 5.7 % in 2006.

Figure 5. The role of Renewable Energy in the Nation's Energy Supply, 2009



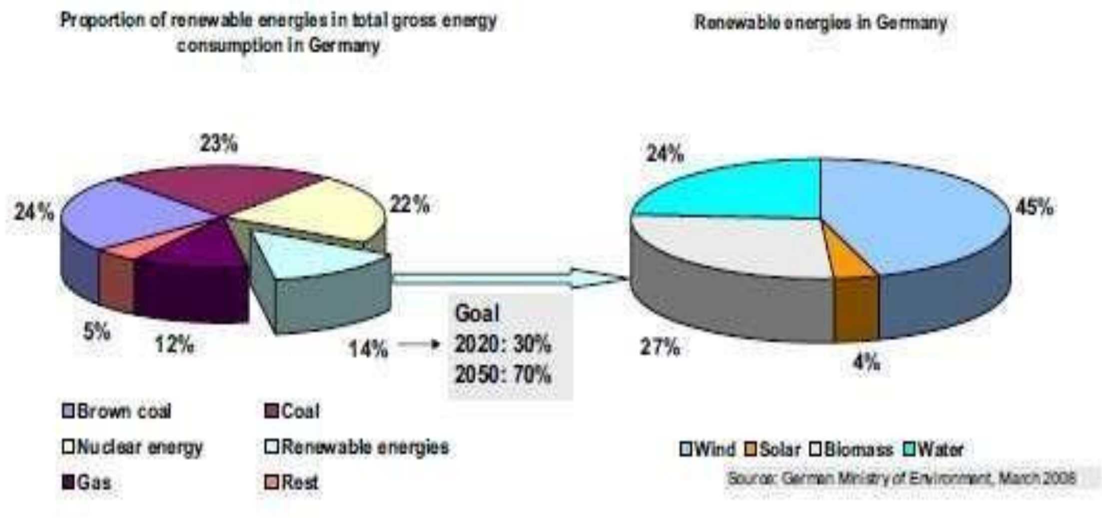
The graph shows the proportion of the energy produced in the overall energy balance of the country. Renewable energy sources (RES) in 2009 amounted to 8% of these; solar is 1%, geothermal is 5%, wind is 9%, hydro is 35%, Bioenergy is 50%. From 2006 to 2009 share increased by 2,3%.

Figure 6. Electricity production in Germany in billions kilowatt-hours, 2012.



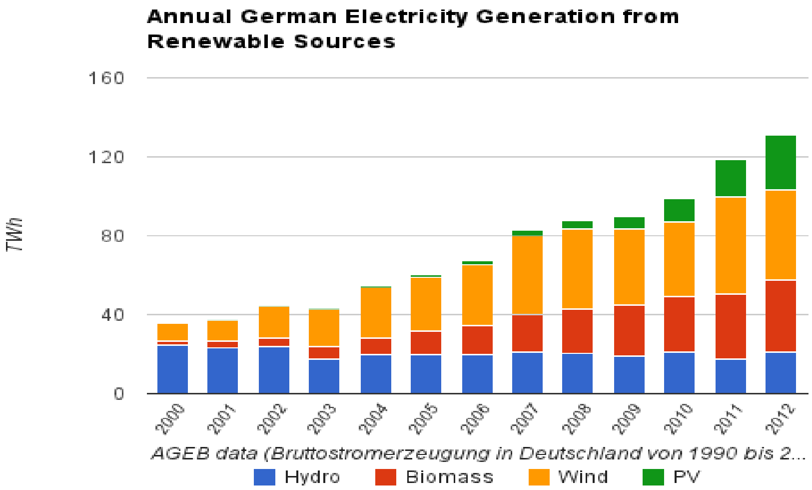
This graph confirms the increase in the volume of energy produced through renewable energy: in 2000 development of renewable energy was about 30 billion kilowatt hours, it was 5.7% in 2010 100 billion kilowatt hours, and it is 18%. Forecast 2020 200 billion kilowatt hours and it is about 37% with bringing in 2030 to 65%.

Figure 7. Proportion of renewable energies in total gross energy consumption in Germany, 2013.



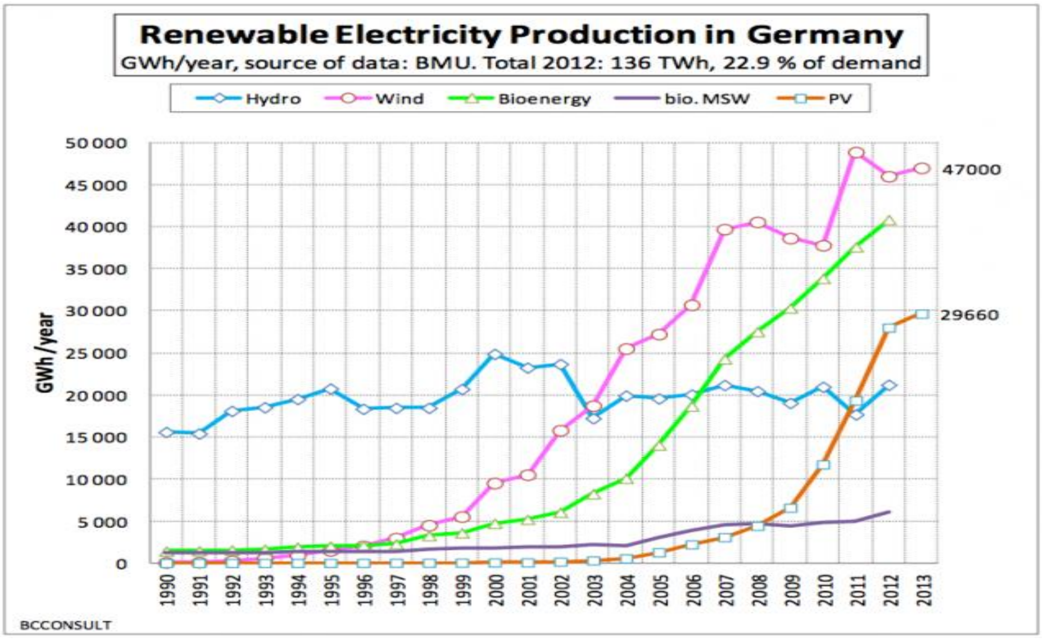
This graph shows the proportions of renewable energy development and objectives for the period until 2050 to bringing renewable energy to 70%, in 2020 will 30%.

Figure 8. Annual German Electricity Generation, 2012.



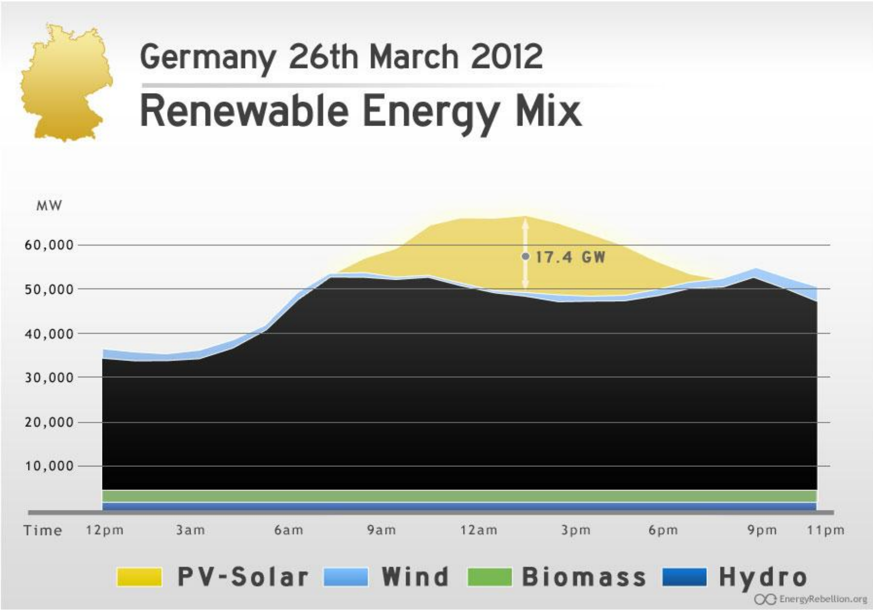
The graph shows the annual energy generation from 2000 to 2012, hydropower production remained at the same level even fell, bio increased from almost 0 to 30 Twh, wind from 10 to 45 Twh and sunny with 0 to 20 Twh.

Figure 9. Renewable Electricity Production in Germany, 2013.



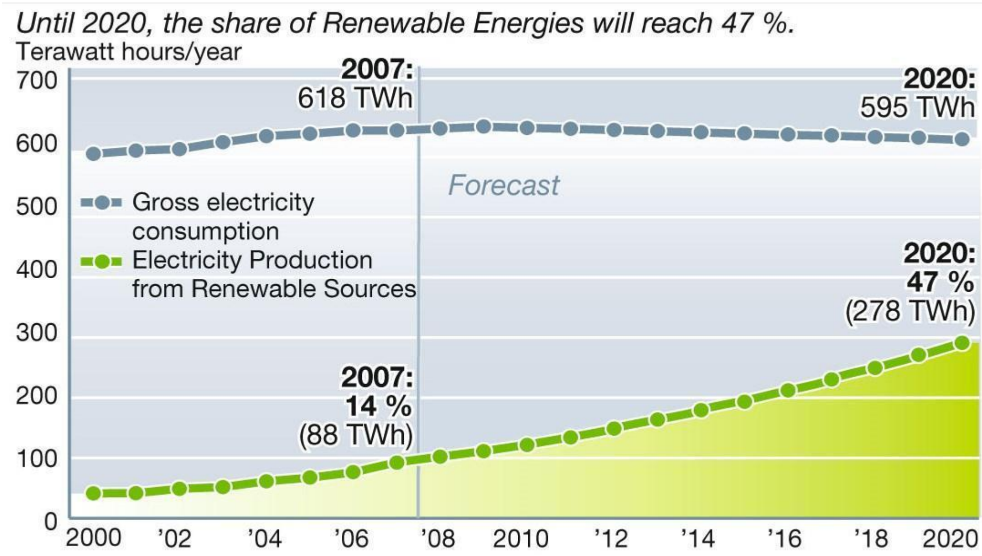
Hydro energy remains approximately at the same level, bio and wind energy grew faster pace, since 2006 production of solar energy has dramatically increased. The energy produced from the total Energy consumption produced from alternative sources in 2013 accounted for 1/3 of the wind energy, and about 1/3 of bioenergy.

Figure 10. Solar revolution in Germany.



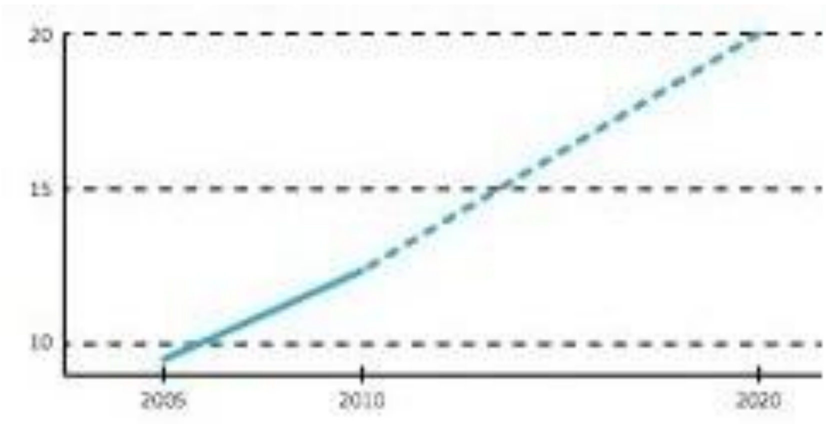
There is impressive statistics illustrating the renewable energy revolution in Germany. On March 26, in 2012 year, Germany had a peak electric power production of 17 GW, compared to 47 GW conventional power generation.

Figure 11. Share of Renewable Energies in Germany's Electricity Consumption until 2020, 2009.



Very optimistic growth forecast of RES to 47% in 2020, while at the same time we can see that Gross electricity consumption virtually unchanged.

Figure 12. Total graph of share of renewable energy in gross final energy consumption



Graph shows the figures for the 27 EU countries in 2005 to 2010, as well as the targets for 2020 agreed as part of the Europe 2020 strategy, shows increase the share of renewable energy to 20%.

4.1.5. The forecast of alternative energy development in Germany

WIND POWER

Most wind turbines of Germany are located in coastal area. We have already discussed their installed capacity, it is planned to increase it to 45 GW by 2020. It is an impressive figure, it would amount to one fourth of the total installed capacity. As new wind farms will not be built, it is supposed to enhance capacity by updating of existing facilities (Alternative energy sources, 2014).

SOLAR POWER

Installed capacity of all solar power stations in 2011 was 24.8 GW. Photovoltaic is one of the biggest expanding sectors because of specific tariff-setting. It is expected that installed capacity of photovoltaic stations will meet 39.5 GW by 2020 (Alternative energy sources, 2014).

BIOPOWER

Biopower also plays an important role in development of alternative energy sources in Germany. Hard (wooden, agricultural), liquid (biodiesel, bioethanol) and gaseous (landfill gas) sources are used as raw materials. By 2020, increase of the aggregate capacity of such power stations is projected at the level of 9.3 GW (Alternative energy sources, 2014).

HYDROPOWER

The share of hydropower is not more than 2%, however, the target is to enhance capacity to 6.5 GW (Alternative energy sources, 2014).

GEOTHERMAL POWER

Geothermal energy is a promising renewable source of energy for the growing demand of heat and electricity worldwide. As a base load energy source with a modest environmental footprint it is able to mitigate climate change and improve energy secu- rity (Goldstein et al., 2011).

Today, the country is actively conducting geological investigations and searching for the land suitable for construction of geothermal stations. It is supposed that capacity of such stations will meet 600 MW by 2020 (Alternative energy sources, 2014).

Speaking about the numbers, one should keep in mind that these are just forecasts that not always work well due to various reasons (Fradkin, 2003).

4.1.6. Tariff - setting

The system of feed-in tariffs has been functioning for a long time in the country. Under this tariff, the grid has to buy electrical power from renewable energy producers. As to persons, the premium system is arranged in such a way that a consumer purchases and installs the RES system at his own cost. However, for every kWh of produced power a person will receive a premium during 20 years. The premium may amount to 30 cents, and it also depends on time, as those who installed RES several years ago, will receive more compared to those who are just going to install it (Alternative energy sources, 2014).

Table 2. Solar tariffs of March, 2014

	Up to 10 kW	Up to 40 kW
Compensation of a part of total income	100%	90%
Cost, €-Cent/kW (of 01.03.2014)	13.41	12.72

4.1.7. Renewable energy issues in Germany

Raising of electricity tariffs for end users. Renewable energy producers sell it to the grid operator at an overestimated rate. The latter, in its turn, sells excess of power at the spot market, imposing costs on the customer. (Alternative energy sources, 2014).

Traditional power stations have to cut generation of electric power when RES output increases and vice versa. This leads to considerable growth of power stations costs of production. Thus, they also bear losses. (Alternative energy sources, 2014).

RES producers found themselves in a challenging situation. So, German manufacturers of solar panels had to cut production because of cheap Chinese analogues that flooded the market. To preserve production, the Government had to interfere (Alternative energy sources, 2014).

4.1.8. The 2020 climate and energy package

The climate and energy package is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020.
These targets, known as the "20-20-20" targets, set three key objectives for 2020: a 20% reduction in EU greenhouse gas emissions from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20%, 20% improvement in the EU's energy efficiency (European Commission, 2012).

Germany’s renewable energy (RE) policy reflects existing legal and political realities German policy must be seen in a national (and European) context: aggressive RE development as part of essentially eliminating emissions by 2050 is part of German and EU law. There is high popular support for phasing out nuclear power Reducing emissions (Weiss, 2014).

5. CONCLUSION

This thesis presents the materials on alternative forms of energy in Germany. The advantages and disadvantages of the main types of alternative energy: wind, solar, bio, geothermal.

Characteristics of the pace of development as compared to traditional energy, and for certain types of alternative energy.

The prospects for the advanced development of energy from renewable sources. If in 2005 their share was less than 10%, in 2010 around 13%, it is assumed to increase 20% in 2020, and after 2030 the share of alternative energy in the overall energy balance will exceed 50% by 2050, bringing to 75%.

Alternative sources of greatest acceleration receive solar energy, the growth of which is 6 times higher in 2013 compared to 2008, but the most common would be wind and bio energy – 2/3 of the production of alternative energy sources.

Germany is one of the leading countries on the replacement of energy based on mineral raw materials, for energy from renewable sources. This will not only reduce dependence on imported fossil fuels for energy, but also the preservation of raw materials for processing in the chemical industry to produce a useful product, as well as significantly improve the environmental situation.

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7. LIST OF VISUALS

7.1 List of tables

7.2 List of figures