Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Bachelor Thesis

Potential for the Renewable Energy Development in Europe

Sobolewski Ilya

Declaration

I declare that I have worked on my bachelor thesis titled "Potential of Renewable Energy Development in Europe" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person

In Prague on 15/3/2022

Acknowledgement. I would like to thank the supervisors of my thesis – Prof. Ing. Karel Tomšík, Ph. D for advices and support during my work of this thesis.

Potential for the Renewable Energy Development in Europe

Abstract

The subject of this bachelor thesis is the analysis of renewable energy source in European economy, analysis of renewable energy by sectors: (wind energy hydropower, geothermal energy, solar energy). Explained the history of the development of these resources, their principle of operation, the structure of the formation of renewable sources, the policy of adopting laws, investment policy.

In second part considered the renewable energy sectors and analyzed the leading countries in the production of green energy. Comparison of two different countries in energy production ways to evaluate differences between renewable and non-renewable energy sources.

Keywords: Renewable Energy, Energy Analysis, Policy, Investments, Economics, Wind, Solar, Hydro, Geothermal.

Table of content

List of pictures

List of tables

Abbreviatures:

RED – renewable energy directive

RES – renewable energy source

AI – artificial intelligence

1 Introduction

Human has used the energy of nature since ancient times. It was the most affordable extraction. First, wood, which was the most accessible for mining, then coal. Along with advances oil and gas appeared, and it was the led to a huge leap in the development of energy and progress in general. Humanity has become completely dependent on these resources, and along with this dependence new global problems have appeared. One of them is the depletion of natural resources. For human needs, a huge amount of oil and gas are used every minute. Emissions from them pollute the environment, which can lead to adverse global consequences. Europe depends largely on the import of natural resources: oil and gas, so renewable energy sources can play a huge role in the economy. But as before, the structure of the global energy economy today produces 4 out of 5 kilowatts of energy in the same way that primitive people used to. They burned fuel, but today the process of production became much more difficult. So, today in Europe, renewable energy accounts for almost 22% of total energy production. Production technologies are being improved, production materials are falling in price, and this gives a new impetus to the development, supply, and achievement of a new targets. Therefore, this topic is so important today. And this should be focus on it!

2 Objectives and Methodology

The main goal of my thesis is to determine the potential of renewable energy sources in the countries of the European Union. To understand what decisions and actions the countries have achieved today's result. Explain how renewable energy sources can be superior to traditional ones, their level of development, and their potential for further growth. Analyze the leading countries in producing a particular type of green energy and identify possible problems for countries that depend on high-carbon energy resources production.

The methodology is based on the study of various literature, scientific publications, and articles on renewable energy. The diploma thesis is divided in to two parts: theoretical and practical. In theoretical part could be found description, explanation types of renewable energy like sun, water, wind, geothermal and their history of development and utilization in economic development. It is also an analysis of renewable energy policy, development support and investment attractiveness. Assesses the renewable energy sector and monitors the development of legislation and policies in relation to them.

The second part reveals the full picture of the development of renewable energy sources. I explain because of what resources the development of renewable energy began. Over the course of development, which renewable energy sources have received more attention. I also show examples of countries that have achieved the highest energy production from certain types of renewable energy sources and explain why they succeeded on that. I compare 2 countries with different priorities in energy production and draw a conclusion about the problems of countries dependent on the production of exclusively fossil resources.

I chose this topic because I understood that with the development of civilization, a human opens new ways to solve energy problems that we cannot ignore. The bureaucratic understanding of the solution of energy dependence, in my opinion, is outdated. Now there is an opportunity to bypass drilling, processing, transportation and use the energy of nature that surrounds us. The European Union is an excellent example of the development and implementation of new energy technologies in the economies of countries.

3 Theoretical Review

3.1 Wind as a renewable energy source

The wind is a stream of air moving near the earth's surface. Humans have been using wind energy for more than 5 thousand years for movement by sea, selling, trading goods. Western Europe has been the most developed region in the use of wind. Denmark created the first wind generator. Then, there were discussions about the optimal number of blades and their aerodynamic properties. However, with the end of the industrial revolution, generator creation became possible to generate electricity from the air. By the beginning of the 20th century, Wind engines established production. In the 20s of the 20th centuries, the first projects of wind turbines produced electricity appeared. The first copy was placed in Berlin on the tower. Height 15 m, blade diameter 20 m .[1]

Wind power principles of working

Today's wind turbines can convert vast amounts of wind energy into energy. If the wind turns the edges, we get power from an attached generator. All these thanks to the blades. Due to the aerodynamic structure, when the air flows around the blade, a lifting force drives them. Modern generators are powerful; the wind tower can turn in the direction of the wind and change the vector of the blades to achieve the maximum efficiency level. However, what is this level? The wind's kinetic energy is converted into the mechanical rotation of the blades. The wind turbine will take 100% of the kinetic energy if the wind speed behind the turbine becomes zero. According to the laws of physics, this is impossible, so wind farms have an efficiency limit: of 59.3%

Types of industrial applications.

Wind turbines can be divided into three groups according to the amount of energy generated

- Small (up to 40 kW)

- Medium (from 40 to 500 kW)

-Large (from 500 kW and above)

The amount of energy depends on the density of the air, the area covered by the blades.

There are two main types of modern wind turbines.

- Wind turbines with a horizontal axis of rotation, having two or three blades mounted on top of the tower. This type is the most common and widely available.

- Wind turbines with a vertical axis of rotation have long curved arcuate. Such generators can generate energy from the wind blowing from any direction, and for this, it is not necessary to change the position of the rotor.

Modern wind turbines can be used both in industrial production and in agriculture.

Advantages

Wind generators generate clean energy without hydrocarbon interference. The wind is a resource that will always be there if the sun shines. Point is free and unlimited. Wind farms can be installed in areas not intended for agriculture (Rocky Mountains coastal areas and water).

Disadvantages

The main disadvantage of wind farms is their high investment costs. For the environment, the noise generated, and the rotation of the blades may adversely affect birds or animals. Also, the force of the wind cannot be continuous.

3.2 Water as a renewable energy source

Water covers most of our planet, and the flow of kinetic energy in its rivers and beds never stops. Watermills solved many human problems. We made paper, forged iron, sawed logs, and brewed beer. For example, there was one water mill for every 250 inhabitants in England and France.

Humans have been using wind energy for more than 5 thousand years. In 1834, a French engineer created a water turbine. And with the beginning of the invention generator, it only remained to wait who would be the first to guess to attach the generator to the watermill. From that moment began the era of obtaining electricity from water.

Since the 1930s, there has been a sharp increase in hydroelectric power stations worldwide. The first dam in Europe, Oderich, was built in Germany at the end of the 19th century. Length 151 m, maximum height 22 m, thickness 16 m at the crest, and 44 m at the foot. [2]

Hydropower principles of working

The basic principle of converting kinetic energy into mechanical energy is due to water flow. Water falls on the turbine and spins it from a certain height, and the connected generator begins to create electricity from the turbine's mechanical energy.

With the falling dam, a similar method works, only for the common barrier, the process of blocking the water and raising it to a certain level for sufficient energy production works. The lifting storage pumps water at the moment of cheap energy into reservoirs located at a height and discharges this water to the turbines at the highest peak electricity cost.

Types of industrial applications

Hydroelectric dams are the most common form of generating energy from water. For their use, the riverbed is blocking to create pressure. Criteria are essential for dam: a strong water flows for to level evaporation.

This type of energy is entirely dependent on natural conditions. Where there are no rivers, there will be no dam. Therefore, the use for such dam is found in fact. The dam construction requires many building materials, so they are trying to be built next to closely located quarries to extract high-quality sand, stone, and other building materials. According to the type of power generated, dam is divided into three types:

- Small (up to 5 MW) from 3 meters difference in water levels.

- Medium (5–25 MW) from 25 meters water level difference.

- Powerful (more than 25 MW) from 60 meters water level difference.

In pump storage, everything depends on the cost of electricity for pumping water to the height. However, there is an exciting collaboration between wind turbines and pump storage. Wind energy can provide enough electricity to pump water to the level when demand for electricity increases, use this reserve.

Advantages

The advantage of hydroelectric power plants is their renewability and the absence of toxic emissions into the atmosphere. A very long operation (more than 100 years) is possible. They

created artificial reservoirs that contribute to fish reproduction and convenient irrigation of the area. The cost of electricity is also cheap.

Disadvantages

Dams emit water vapor, which is the second (after CO2) greenhouse gas in terms of its impact on global warming. During construction and further use, it is necessary to swamp the land. Dam also affects animals and plants' natural habitat and contributes to the blocking of rivers for fish spawning.

3.3 Sun as a renewable energy source

The sun is the primary source of energy on earth. It warms the world forms the climate on our planet. Under the rays of the sun, one quadrillion plants grow. Thanks to the sun, we have coal, oil, gas, which we are now burning. However, why do we need these intermediaries to extract energy directly?

To satisfy energy needs, we need 10 billion tons of fuel. But if the energy of photons received by our planet translates into fuel equivalent, then this amount will be 100 trillion tons for the year.

For the first time, Scotsman James Clerk Maxwell succeeded in presenting the idea of the connection between the sun and electricity. Rumor has it that they used mirrors to heat objects in ancient Egypt. Practical application has been demonstrated by Alexander Grigoryevich Stoletov in 1888, showing the nature of the effect of light on electricity. The incredible thing is that the electron was discovered only in 1897. In 1905, Albert Einstein theoretically substantiated the occurrence of the photoelectric effect.

In 1954, scientists at Bell Labs created a silicon photovoltaic cell, thereby laying the foundation for silicon cells. Then the percentage of efficiency was 6%. The rapid development of solar energy has occurred over the past 10-15 years. The industry has been developing for a long time, technologies and materials have improved, the oil crisis has forced people to invest in solar panels. The world is still tedious 30 years before reaching 1GW of solar energy. Nevertheless, companies improved and perfected the production approach, and in 1986 an efficiency result of 15% was achieved. [3]

Solar power panels principles of working

Solar panels convert the sun's energy into electricity by concentration energy in one place to boil water and convert stream power to electricity.

For the photoelectric panels the silicon wafer is the heart of the panel. The energy carried by the sun's rays ejects electrons from the flint. Photoelectric device with the advent of silicon semiconductors, efficiency has grown exponentially. From 10 percent to 30 percent of energy is only converted into electricity; this is the efficiency limit.

Types of industrial applications

Solar panels are a fantastic source of energy. With the improvement of technology, the panels become taking any shape size. There are many photovoltaic farms on an industrial scale capable of providing electricity to 250,000 homes. However, as a rule, industrial production often uses collectors that heat water and create steam to rotate turbines.

For photoelectric use of solar panels on the roofs of buildings and in empty areas is the best and most environmentally friendly way to provide the necessary electricity or to heat water.

Solar panels have many uses in addition to industrial production in the network:

- Aircraft, cars, ships can receive an additional energy source.

-Various household devices can receive enough energy for their work.

-Infrastructure capable of receiving enough energy during the day to provide light at night.

Advantages

Solar energy is a renewable, affordable energy source with a low cost. The technology is favorable to developing and producing new materials with improved characteristics. They can be installed on any surface. The panels are noiseless and do not need high maintenance costs. Solar panels can generate energy anywhere. This is especially true for regions with no central power supply network.

Disadvantages

The main disadvantage of solar panels is the high cost of materials and a low-efficiency ratio of 30%. Also, a large area occupied by the system is needed to meet significant energy needs. Of course, photovoltaic panels depend on weather conditions or pollution.

3.4 Earth as a renewable energy source

Earth is our home. A limitless energy supply is under our feet while we extract energy on or near the surface. In my opinion, geothermal energy is the most underestimated renewable energy. At a depth of 1 kilometer, the temperature will be 30 degrees, and every 100 meters, it will increase by 2.5 degrees. In the following trend at 10 kilometers, the temperature should be 250-300 degrees. However, drilling is not always necessary; the Earth itself gives us a chance to harness this type of energy through breaches in the Earth's crust, cracks, volcanoes, etc. Humans have been using energy since ancient times. At first, the heat of sources was used for heating or heating and hygienic procedures.

The first district heating system using geothermal energy was launched in the 14th century in France. The history of geothermal energy began in 1904 when in Italy, electricity was obtained from geothermal steam due to an experiment. A few years later, the first geothermal power plant was launched. [4]

Geothermal power principles of working

The oldest and most common way to generate electricity is to rotate the generator turbine with a powerful stream of water vapor from boiled water. This type of electricity generation is comparable to coal-fired energy production. Only in thermal power plants is coal burned, which must be mined transported, and in a geothermal station, the heat of the Earth allows turning water into steam. There is also a way to extract steam and already hot water coming from underground. Alternatively, a way to find a steam source for subsequent processing into electricity.

Types of industrial applications

As a rule, geothermal energy depends on natural conditions. Where there are sources, faults, it is possible to create an infrastructure to produce energy or heating. However, not everywhere are there such conditions.

Therefore, as a rule, well is created, water sinks to depth, it is converting into steam, which already goes up to the electricity generators. This approach can be applied wherever there is a source of water.

Advantages

The main advantage of such a source is its inexhaustibility. The annual heat flux of the Earth to the surface is about 400,000 TW per year, which is 17 times more than all the planet's power plants generate during the same period. At the same time, heat is generated stably and continuously. The compactness of the structure is very relevant in hard-to-reach regions since construction is mainly carried out in-depth. The environmental friendliness of the station also plays an important role.

Disadvantages

The disadvantages include, first, the high cost, much money is spent on exploration. The station also has relatively low power, even when drilling many wells, the steam flow will still be small, and the generated electricity will be enough only for tiny settlements.

3.5 EU renewable energy development

As we can see, renewable energy sources have long been used by humans. At first, they did not generate electricity; their rapid development in the energy sector began with creating a generator. European countries have made a significant contribution to the development of these resources. However, at first, all energy sources were insignificant and did not have any energy advantage. Only at the beginning of the development of hydropower and the construction of dams by all countries to generate electricity , made us think about the development and improvement of renewable energy sources. From 1930 to 1970, in Europe, almost every country began to build hydroelectric power plants, and this type was the primary renewable source at that time. By the beginning of 1970, very low amount of energy generated from renewable resources, and then the European Union tried to take the first steps. Measures to promote and build an energy economy based on renewable resources.

3.6 Introduction in EU renewable policy

European Union policy towards renewable energy developed over decades since 1990s, due to the relevance of the issue and the establishment of international norms and standards in the field of green energy. The development has evolved from industry efforts to develop RES to creating the most substantial and complete RES support and development program.

The history of attempts begins with strenuous attempts to centralize green energy management for the EC and attempts by individual member countries to develop flexible policies and structures for national development and the use of RES in the regions.

Policy development

After the two oil crises European Union called for the support and development of new technologies in the new source of energy, as a solution to the problem of dependence on hydrocarbon sources to increase the efficiency and energy security of the regions. The focus was supporting and developing new technology research, soft regulation, and potential demonstration. Until 1990, some of the most extensive support and development for green energy came from some EU member states such as Germany, Denmark, Netherlands. They adjusted the policy of developing alternative energy sources to the national idea of meeting energy needs in specific sectors of the economy. However, already in the early 1990s, due to climate change, the focus of the European Union shifted towards fighting this problem and not hydrocarbon dependence. Programs began to be created for the research and technological advantage of various areas of alternative energy sources. [5]

In 2000, the commission released a program on climate change. The program has been created for Promoting RES.

The main topics considered: The problems for solution have been understanding for each country types of renewable energy suitable for the region, and creation of open system for trading European certificates for energy production and The creation of various institutions to not allow non-competitiveness of individual countries that did not have a significant contribution to the development in industry before. [5]

In parallel with the adoption and development of programs, EC has grown and observed the dynamics and pace of development. There was scientific work to improve productivity, reduce production costs, improve quality, and create new materials. With new scientific

evidence was published. Through the period of development the big question to solving was a developing of cross-border cables ,grids , interconnections for successful energy trading/transporting .

Directives of 2008-2009 were vital for developing the green energy industry in the European Union and achieving targets for 20 percent of RES final energy consumption by 2020 . All this led to a more structured and dynamic development. Enormously helped countries that had experience in the development and nationalization of certain types of renewable energy their understanding of adopting policy for bringing healthy investment field and could share the main stages in forming an effective transition of the energy economy to alternative sources. [5]

Result of Politics

The European approach to legislative decision-making to support RES has been innovative and ambitious. The legislative part has played a crucial role in building a successful energy economy, but also the understanding of the prospects for the development of a new electricity market, the ambitions of the first countries to support these sectors. The RES directive was the driving force for the first ten years.

In the early 2000s, RES was not included in the mandatory nature of performance. However, with global fuel crises and climate change, the directives were binding on countries by the beginning of the second decade of the 2000s.The rejection of mandatory national goals aims to rationalize countries' interests for their benefit. Nevertheless, with the advent of RED 2, countries already understood and realized that they would be required to fulfill these conditions.

By 2020, fewer than 20 countries have met the EU's targets. With the economic crisis, the RES sector developed even more slowly and also now due to pandemic situation. The next goal is to reduce greenhouse gas emissions by 55% by 2030. [5]

In 2020, we can see the result achieving in % of share renewable energy sources between EU countries.

Table 1 share of renewable energy sources in 2020

Sweden	60.1
Finland	43.8
Latvia	42.1
Austria	36.5
Portugal	34.0
Denmark	31.6
Croatia	31.0
Estonia	30.2
Lithuania	26.8
Slovenia	25.0
Romania	24.5
Bulgaria	23.3
Greece	21.7
Spain	21.2
Italy	20.4
Germany	19.3
France	19.1
Slovakia	17.3
Czech Republic	17.3
Cyprus	16.9
Ireland	16.2
Poland	16.1
Netherlands	14.0
Hungary	13.9
Belgium	13.0
Luxembourg	11.7
Malta	10.7
Norway	77.4
Iceland	83.7

Source: Renewable energy statistics - Statistics Explained (europa.eu)

Seventeen countries have more than 20% of generated electricity from renewable energy sources. Of which 2 is over 40%, one is over 60, and 2 is over 70. All these steps and measures were not in vain, and politics shows how the right approach of the union state can bring such result for 20 years. In EU we have average 22.1%.

3.7 Investment needs to reach policy in Energy sector

Estimates of annual investment in electricity production range from 54 to 80 billion euros. About 75-80% of this money is spent on renewable energy sources.

Renewable energy investment divided by fields:

-Investing in developing RES

-Investing in Grids it is: transmission, distribution, interconnectors

-Investing in Storage

The impact of the energy transition on accessibility is significant. The total cost of electricity supply systems in 2030 will be 30% higher than in 2010 because the share of costs in household expenses will increase from 7.5% in 2010 to 9.3% in 2030. [6]

Investments in improved energy efficiency result in lower energy operating costs. Also we have additional investments from the hydrocarbon transportation sector, as RES is gradually replacing it. [6]

Healthy investment field

Currently, investments in RES are subject to favorable legislative provisions from the European Union. The presence of specific measures and supports.

Investments in conventional power generation are driven by negative perceptions of economic and market conditions. Also, inadequate regulatory framework, low rate of return, the political. Most RES installations have a guaranteed, predictable support income. Ordinary (traditional) types of energy production depend on international prices in the energy market.

The leading type of investors in the European energy sector

1) Public financial institutions/institutional investors. Public institutions or authorized institutions that correct the lack of market funding. It is a crucial player in the investment arena to support governments mobilizing small investments in the low-carb industry. The size and amount of investment vary; for example, in 2010 in Germany, 37 billion euros were invested in low-carbon projects. Belgium had 6.4 billion euros in 2013. [6]

2) Venture capital and private equity. This is money from private equity funds developing RES technologies. For the most part, these funds are focused on the development of technologies for improving the principle of operation, etc. These are highly qualified investments. The average annual check is 0.5 billion euros. [6]

3) Angel investment. In Europe, this type of investment is complemented by government support, grants, subsidies for the research and development of new technologies and research. The total annual budget is 25 billion euros from 2009–2013. [6]

4) Private companies The most important source of finance comes from local companies and households. The nine largest European companies have invested $11.9 billion in renewable

energy. Individual households are also actively investing. For example, in Germany in 2010, households invested 14.4 billion euros, 38% of the total investment in the low carbon sector. [6]

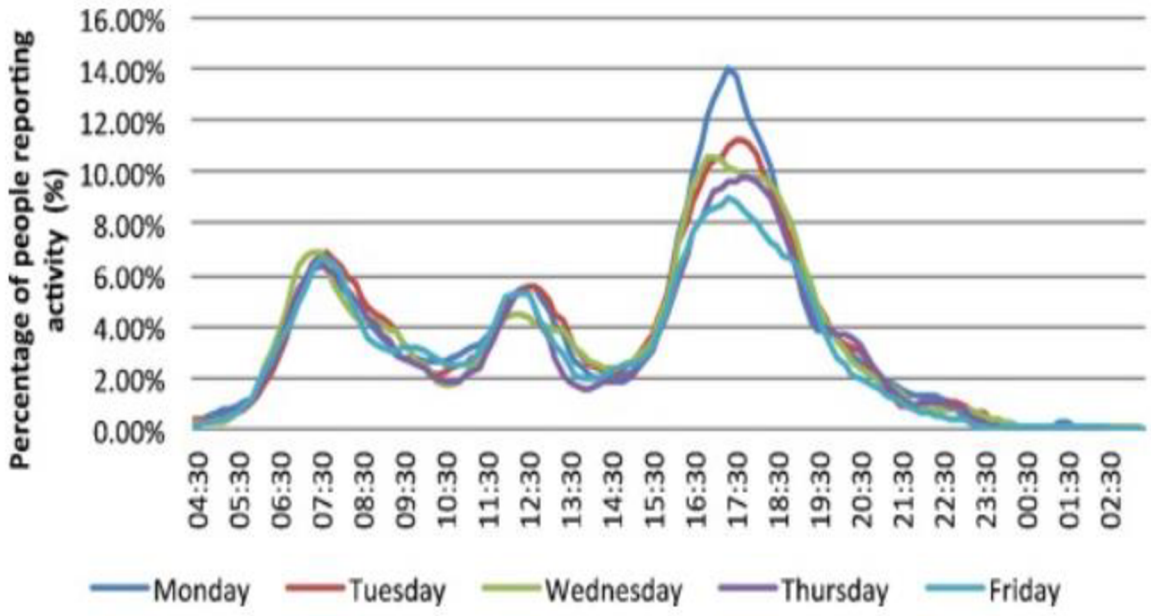
Problems of investment in cross-border

The main factor in the complexity of investments is different national rules licensing procedures between countries. The participation of different investors and states from different sides creates many problems in identifying the most interested parties, the difficulty of coordinating issues from all sides, and a common position on the plan's implementation.

Investment needs in storage

Batteries play a crucial role in decarbonizing energy in the energy sector due to reserve capacities, which allow to accumulate and supply electricity from intermittent RES.The need for investments in storage energy is associated with an increase in the intermittency of electricity supply from wind and solar sources and an increase in peak demand.

Figure 1 Electricity consumption hours



Source : https://www.sciencedirect.com/science/article/pii/S2214629616302985

As we can see, peaks in demand are not uniform, and renewable energy at peaks in demand may not meet all needs, so energy storage is significant today. EC's storage capacity was 51GW in 2010. Moreover, every year the increase increased by 1-2GW per year. [6]

3.8 Grids development

With new capacity installing from renewable energy in different regions, European network of transmission system for electricity included a long development plan. With higher capacity installed it of renewable energy we will be able to provide energy in different regions with higher quality and lower price [6]. To fulfill this long development plan, we need:

Grids development: Creation of new grids to integrate new installed capacities into the network

Grids efficiency: To reduce system cost and accelerate renewables interconnections

System flexibility: During the increasing of installed capacity in the future we need to carry on future network increase

Renewable based electricity: Creation of a system for the distribution of electricity to new sectors of the economy that will be replaced by provision from renewable energy. [7]

3.9 New technology integrations

Artificial intelligence implementation

Due to the rapid development in all renewable energy sectors, we receive technologies that significantly improve many economic aspects. And one of the most breakthrough technologies is implementation artificial intelligence. There is the areas where AI can improve such process:

- Weather forecast can help predict and prevent critical conditions
- Decision making process for solution ecological problems through earth monitoring data process
- AI can help to develop more sustainable business models for factories that have an impact on the environment through the production, delivery process
- AI applications can predict the customer behavior for better market understanding process

Already now AI play a crucial role in sectors like agriculture, manufacturing, construction, waste management, water and electricity supply, trade and retail, transport. So over time, artificial intelligence will be more and more deeply embedded in all technological, production, operational, managerial processes, which will significantly help improve the renewable energy sector. [8]

Hydrogen production from RES

There are two ways to produce energy at the moment. This is the production of electricity through renewable resources or production in plants burning fossil fuels. At the moment, the main fuel is gas and oil, coal , lignite . In turn, there is also a 3rd fuel option - hydrogen. The big challenge for Europe's full transition to fully renewable energy is to ensure that production, construction and transport capacity is lacking from renewable energy sources or from storage systems. The way out in this situation is the conversion of hydrogen at the expense of RES capacities. Today, 95% of the world's hydrogen production comes from burning fossil fuels. But in recent years, investment in technologies for the production of hydrogen from renewable energy sources through the electrolysis of water has been increasing.[14] Now, 2 electrolysis technologies are common:

Table 2 economic characteristics of electrolysis

	kWh of electricity /kg of H_2	Lifetime	Total system cost EUR/kW
Alkiline (ALK)	51	80 000 h	750
Proton Exchange Membrane (PEM)	65	40 000 h	1 200

Source: https://www.irena.org/publications/2018/Sep/Hydrogen-from-renewable-power

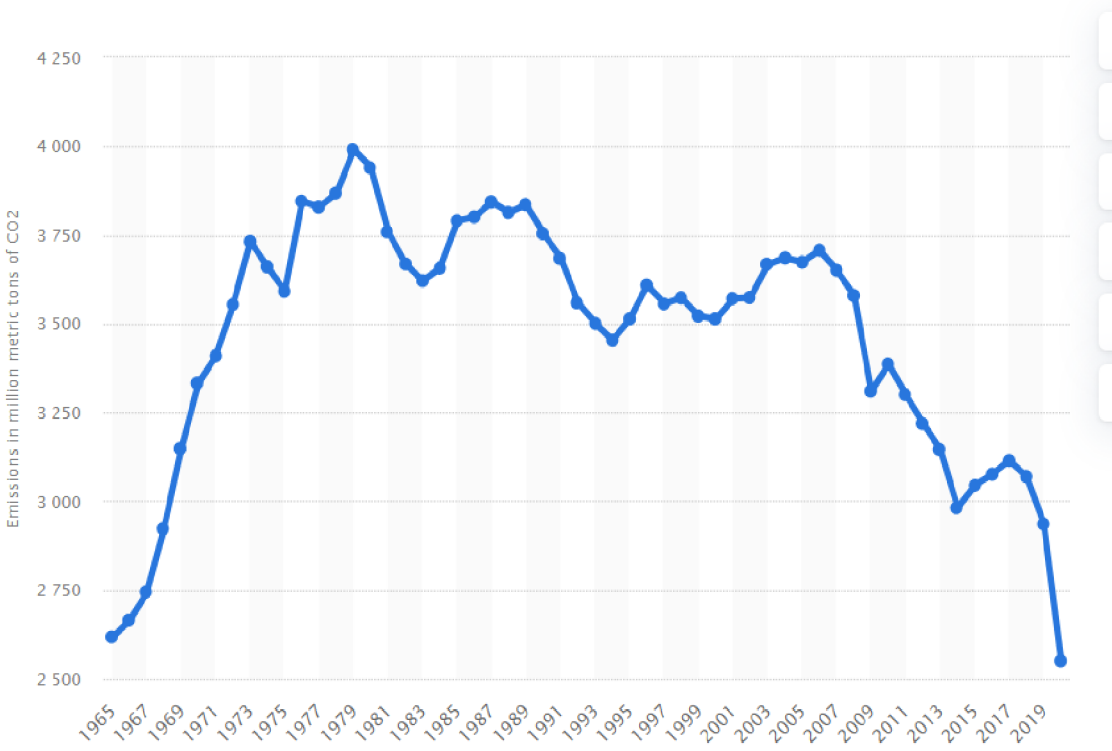
Alkiline (ALK) and proton exchange membrane (PEM). Despite the fact that PEM has a shorter life and higher cost, this type of electrolysis works at high pressure, which plays a significant role in production and compactness.

There are 2 ways to integrate electrolysis for hydrogen production. The first is the installation of electrolysis on separate offshore wind turbines, electrolysis pushes hydrogen out of the water by supplying electricity. This approach is economically increasing the benefit of the recoilless operation of wind farms produced as a resource for energy production.The second principle of hydrogen production is the construction of a manufactory for the production of hydrogen from electrolysis on an industrial scale. In Denmark, it is already planned to build such a plant, the energy of which will be received from offshore wind with a capacity of 1 GW, capable of producing 90 tons of hydrogen per year. Subsequently, hydrogen will be spent on providing transport and industrial sectors. [15]

If we want to create a hydrocarbon-neutral economy without hydrogen, it will be impossible to replace key sectors of the economy, and now we see active development of the production of this energy resource using RES.

3.11 Carbon dioxide emissions in the European Union

Figure 2 CO2 emissions in EU



Source: https://www.statista.com/statistics/450017/co2-emissions-europe-eurasia/

We can observe a negative correlation between the growth in the use of renewable sources and a decrease in greenhouse gas emissions by almost two times, considering the development and greater electricity consumption.

3.12 Introduction in practical part

Now we can understand how renewable energy sources work and are used. What is their difference from traditional types of energy production, because of it, the European Union has embarked on the path of developing alternative energy. The policy of promoting and developing new technologies and installed capacities has enabled the European Union to set goals and achieve them. The creation of investment attractiveness contributed to the involvement of different groups of the population in the development. And all this to get rid of hydrocarbon dependence and ensure the preservation of the climate in the future.

Let's track the dynamics of the involvement of renewable energy sources in the economies of countries, and using the example of certain countries, it will help us explain how replacing hydrocarbons with renewable energy is possible in nowadays.

4 Economic analyses of the current state of renewable energy sources in Europe

With the development of technology and the increase in the general availability of renewable resources, European countries have adapted to development trends. Thus, we can observe the development of renewable energy in countries for 14 years.

4.1 Renewable energy share position from EU energy consumption

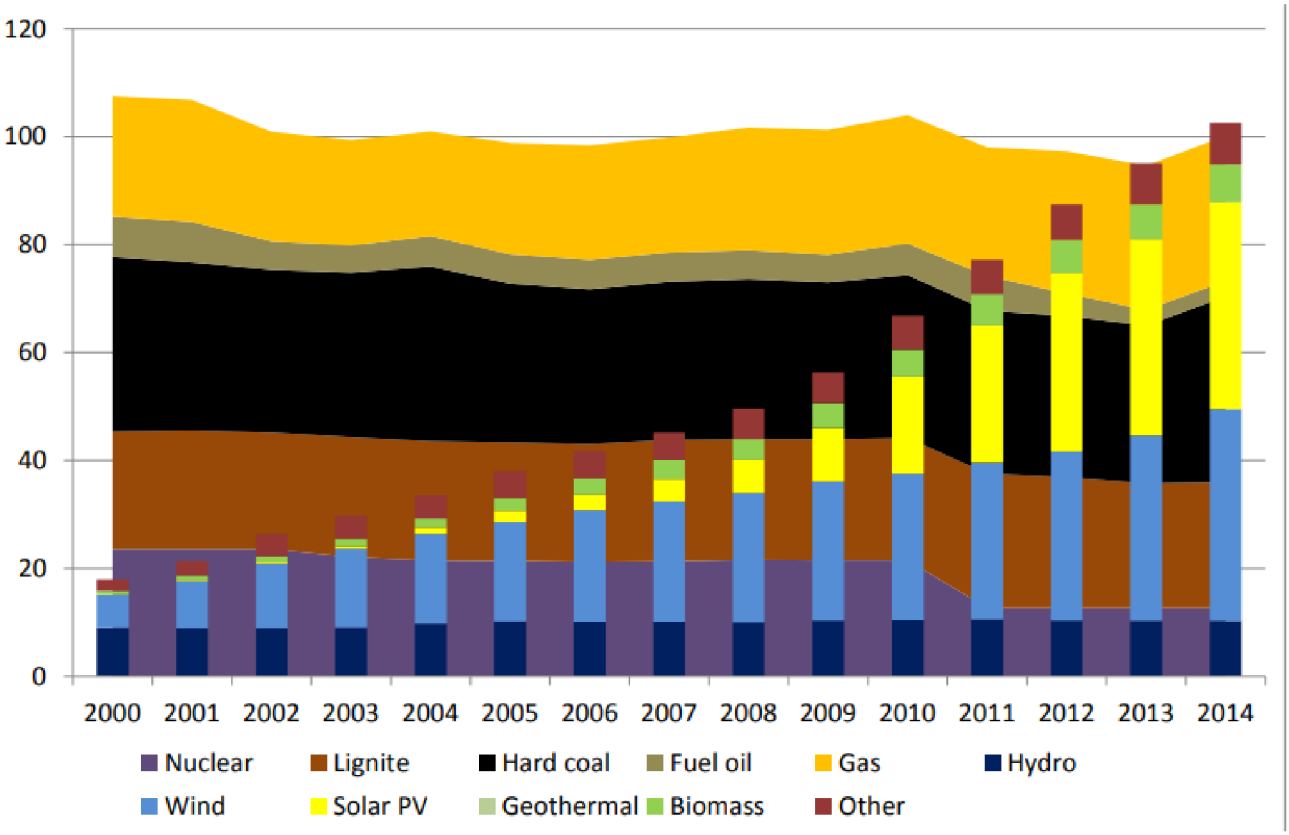
Table 3 Share of energy from renewable sources 2004-2018

	2004	2015	2016	2017	2018
EU	8.5	16.7	17	17.5	18
Belgium	1.9	8	8.7	9.1	9.4
Bulgaria	9.2	18.3	18.8	18.7	20.5
Czech Republic	6.8	15.1	14.9	14.8	15.1
Denmark	14.8	30.9	32.2	35	36
Germany	6.2	14.9	14.9	15.5	16.5
Estonia	18.4	28.2	28.7	29.1	30
Ireland	2.4	9.1	9.3	10.6	11.1
Greece	7.2	15.5	15.4	17.0	18.8
Spain	8.3	16.2	17.4	17.6	17.4
France	9.5	15	15.4	17	18
Croatia	23.4	29	28.3	27.3	28
Italy	6.3	17.5	17.4	18.3	17.8
Cyprus	3.1	9.9	9.9	10.5	13.9
Latvia	32.8	37.5	37.1	39	40.3
Lithuania	17.2	25.8	25.6	26.0	24.4
Luxembourg	0.9	5	5.4	6.5	9.1
Hungary	4.4	14.5	14.3	13.5	12.5
Malta	0.1	5.0	6.2	7.3	8
Netherlands	2	5.7	5.8	6.5	7.4
Austria	22.6	33.5	33.4	33	33.4
Poland	6.9	11.7	11.3	11.1	11
Portugal	19.2	30.5	30.9	30.6	30.3
Romania	16.8	24.8	25.5	24.5	23.9
Slovenia	16.1	21.9	25	24.5	23.9
Slovakia	6.4	12.9	12	11.5	11.9
Finland	29.9	39.9	39	40.9	41.2
Sweden	38.7	53.5	53.4	54.2	54.6
UK	0.9	8.3	9.0	9.7	11.0
Norway	58.5	69.1	70.2	71.60	72.8
Montenegro		43	41	39.7	38.8
North Macedonia	15.7	19.5	18.8	19.6	18.1
Albania	29.6	34.4	35.5	34.5	34.9
Serbia	12.7	22	12	20.3	20.3

Source: Eurostat *292cf2e5-8870-4525-7ad7-188864ba0c29 (europa.eu)*

Over 14 years, the average share of renewable energy in Europe has increased by 2.1 times from 8.5% in 2004 to 18% in 2018. Among countries, we can observe that in 2004 the share of renewable energy exceeding 15% in countries with population under 11 million people due to the early adaptation of countries' water resources to create hydropower capacity. Most successful examples such as 58% share in Norway or 22.6% in Austria. But also, development of wind energy has allowed some countries to achieve 14% of the share of renewable resources in total electricity like Denmark. On the example of the installed capacity in the energy source in Germany, we can understand how quickly the possibilities of wind and solar energy have developed.

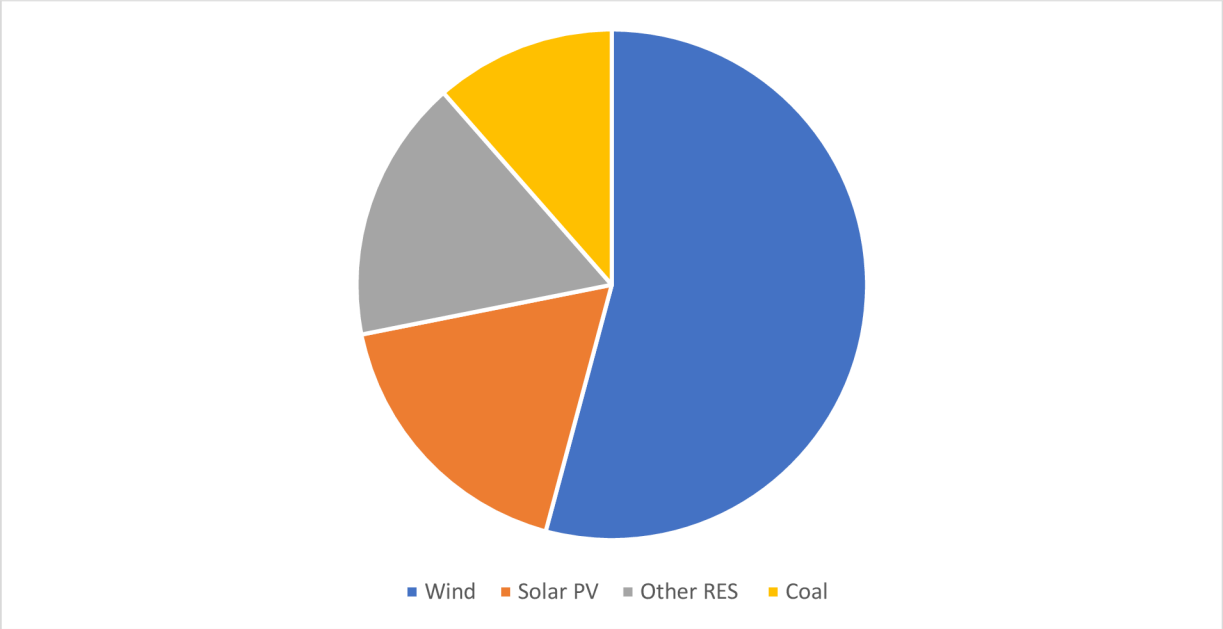
Figure 3 Installed capacity of energy sources (GW)



Source: [European Energy Industry Investments (europa.eu)]

Wind power doubled from 2000 to 2004 and has continued to grow rapidly. Solar energy began to find its application around 2004, subsequently catching up with wind energy in the example of Germany. But most countries of the European Union did not consider the energy of the sun as the main one. Only by 2007 Spain begin active development and then Italy. On the chart below, we can see how in 2015 the emphasis was placed on investment in electricity production in EU.

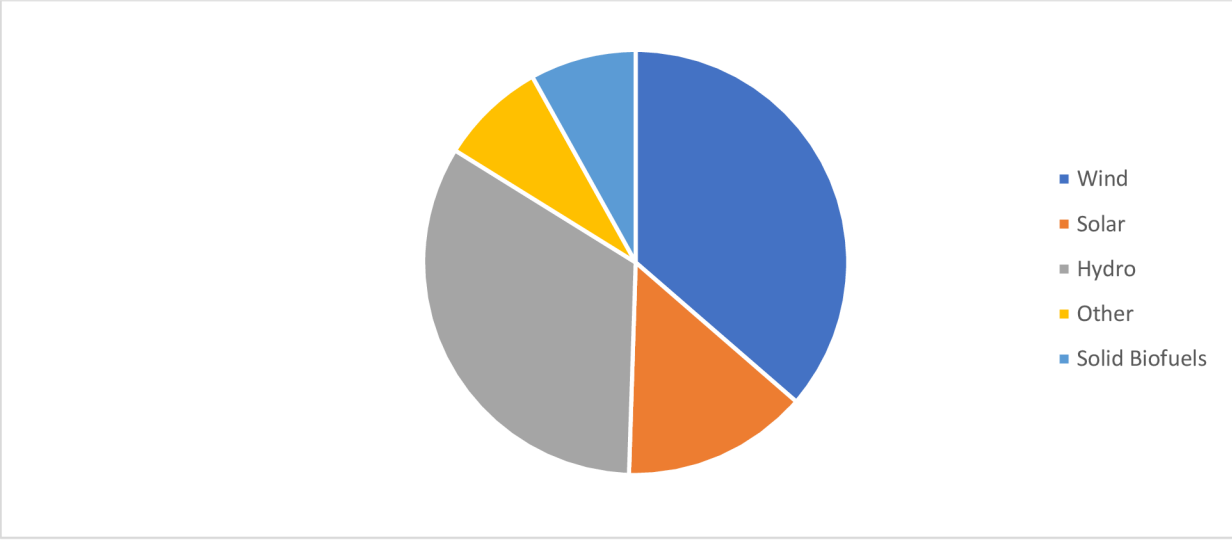
Figure 4 Investments spent for power generation in 2015



Source: European Energy Industry Investments (europa.eu)

Trend and emphasis on the development of renewable resources where wind energy sector has been accepted as the main and widely available type of for power generation, which estimated for 54% of investments. Solar energy 18%. Already at that time it was clear that wind energy could be the solution to achieve the transition goals to RES. In addition to the initial installed hydropower capacity in many countries wind towers began to be actively integrate. And by 2020 we can see:

Figure 5 Share of renewable source generating electricity in the EU 2020



Source: Renewable energy on the rise: 37% of EU's electricity - Products Eurostat News - Eurostat (europa.eu)

That figure 6 showing us 36% of renewable source generating electricity produced by wind energy, where hydropower is behind for 2%. The share of solar energy in production is 14%. It became

clear that the economy and market conditions consider wind energy as the main way for adopting renewable energy in different economies of countries.

Let's look at the main countries in the production of renewable energy sources and analyze their impact on the overall picture in the European Union.

4.2 Evaluation of solar energy in Europe

Today in Europe a lot of countries suitable for economic and natural conditions for the development of solar energy. For 2021, the total installed capacity in EU was 164 GW, 19% higher from a year earlier, adding 25.3 GW of new photovoltaic panels. [9]

Table 4 Top solar energy producers by countries

Country	Average total energy produce GW	Solar energy produces GW	New capacities for 2021 GW	% From total solar EU production
Germany	418	59.9	5.3	32%
Italy	118	22	0.8	13,3%
Spain	252	17.9	3,8	10,86%
France	136	13.2	2,5	8%
Netherlands	35	10	3.3	6%
Total	819	116.1	13.2	70.1%

Source: National data

We can observe that the 5 countries produce 70% of the total amount of solar energy production in Europe. This shows us that the development of the sector is narrowly focused on certain countries due to the development of active investment, policy in this sector over the past 15 years, but nevertheless, half of the newly installed capacities are not in the leading countries, which indicates the active development of a number of new countries in the solar energy sector. Also, we can see that top producers' countries is not the sunniest countries in Europe. This development depends on economic conditionals, production potential, investment field and policy.

Germany is a leader of solar energy producers in Europe.

- Number of solar panels installed: 1.8 million
- Total installed capacity: 59.9 GW by 2021
- 32 % of total solar energy production in Europe.
- 14,3% % of Gross electricity production in country.

Germany is a pioneer in the development of renewable energy sources. The country's production capacity allows increasing the installation of new capacities and strong government support and household understanding of the prospects for alternative energy sources, allows this sector to be supported by investments.

Germany produces 3.5 billion euros worth of solar and wind power plants every year, and only 10% is exported. Also, Germany has successfully developed the production of storage facilities for electricity, which helps to successfully continue the development of green energy. [9]

4.3 Evaluation of wind energy in Europe

In Europe, wind power is currently the most common form of renewable energy. By 2021 have been installed 236 GW, of which 207 are onshore and 28 offshore. The installation of new capacities in 2021 amounted to 17 GW, which is 18% more than a year earlier. [10]

Table 5 Top wind energy producers by countries

Country	Average total energy produce GW	Wind energy produce 2021 GW	New capacities for 2021 GW	% From total solar EU production
Germany	418	63	1.9	26.7%
Spain	252	28	0.7	11.86%
United Kingdom	110	27	2,6	11.44%
France	136	19	1.1	8.05%
Italy	118	11	0.2	4.66%
Total	894	143	5,2	63%

Source: National data

Wind energy is a more balanced renewable source in Europe. The largest producing countries account for 63% of the total wind energy production in Europe. Also, 62% of new installed capacity was not in the top 5 producing countries. This indicates the development of the industry in many other countries. In 15 European countries, wind power accounts for 10 percent of electricity demand. We have successful examples of countries like Denmark with 49% share of energy consumption from wind. In Irland 40 %.

Germany, the largest wind energy market in Europe.

Wind power in Germany - ranks third in the world in terms of installed capacity, after China and the United States.

- Number of turbines installed: 29,608 thousands.
- Total installed capacity: 63 GW by 2020
- 26.7% of total solar energy production in Europe.
- 15.7 %of Gross electricity production in country.

Germany has historically shown the first interest in wind energy. The first serious prototype of a wind farm was installed in Berlin. Government subsidies, priority grid access, and affordable tariffs have enabled the government and households to develop wind power. Simplified issuance of licenses for onshore wind energy and the creation of auctions by the state has led to a leading position in Europe. [10]

4.4 Evaluation of hydropower energy in Europe

Hydropower is the most dependent renewable energy source on natural conditions. Hydropower long time was a dominant renewable resource in Europe. Since countries traditionally try to use water resources on their territory. Hydropower installed capacity 230 GW (2020) from that pumped storage installed capacity 50 GW.

Table 6 Top hydropower energy producers by countries

Country	Average total energy produces GW	Water energy installed capacity GW	Pumped GW	% Of total Europe production
Norway	36	33	1,4	14.35%
Turkey	291	28,5		12.39%
France	136	25,6	5,8	11.13%
Italy	118	22,6	7,6	9.83%
Spain	252	20,4	6,1	8.87%
Total	693,8	130.1	20.9	56.5%

Source: National data

Hydropower is distributed more evenly among the countries of Europe. 5 countries produce 56% of the total amount of hydropower energy production in Europe. In 2020, only 3 GW of new installed capacity was welded, which indicates about a limitation in the development of this sector which was clear from the investment trends mentioned above.

Norway, the largest hydropower energy market in Europe. Norway has the largest share of electricity generated from renewable sources in Europe.

- Number of hydropower panels installed: 1 681
- Total installed capacity: 36 GW by 2020
- 14,35 % of total hydropower energy production in Europe.
- 90 % of Gross electricity production in country.
- 65,000 largest lakes

Norway has been engaged in the successful development of hydropower in the country for 100 years. Since the establishment of NVE in 192 . The purpose of this organization is to ensure the development of hydropower, to meet energy needs and transition to environmentally friendly energy production. The country was not rich and the government was forced to attract foreign investment and technology. With the attraction of capital, the development of hydropower began to provide the industrial sector in order to return the money invested to investors. After experiencing successful development in the industrial sector, the government began to convert money from the oil sector into green energy. And by the beginning of the 21st century, the dominant source of energy in the country was the energy of water resources. [11]

4.5 Evaluation of geothermal energy in Europe

In Europe, geothermal energy is the most underdeveloped source of renewable energy in terms of energy production. Around 3.5 GW is used for energy production in Europe. By the end of 2019, 2 million geothermal heats plants had been installed. There are also 130 geothermal electrical plants.

Table 7 Top geothermal energy producers by countries

Country	Average total energy produce GW	Heating, cooling GW	Energy produce GW	% of total Europe energy production
Iceland	9.3	2.1	0.75	22.73%
Turkey	291	1	1.5	45.45%
Italy	136	0.17	0.96	29.09%
Total	436.3	3.27	3.21	97.2%

Source: National data

Geothermal energy directly depends on natural conditions. Not all countries have access to our earth's heat to produce geothermal energy. However, this type of renewable energy production is developed in Europe compared with world. Electricity generation from geothermal energy is created by 3 countries: Turkey, Italy and Iceland, which account for 97% of electricity production from geothermal energy in Europe . But besides this, many European countries are involved in the process of heating and cooling, such as France, Germany, Spain.

Iceland, the largest geothermal heating and cooling producer in Europe.

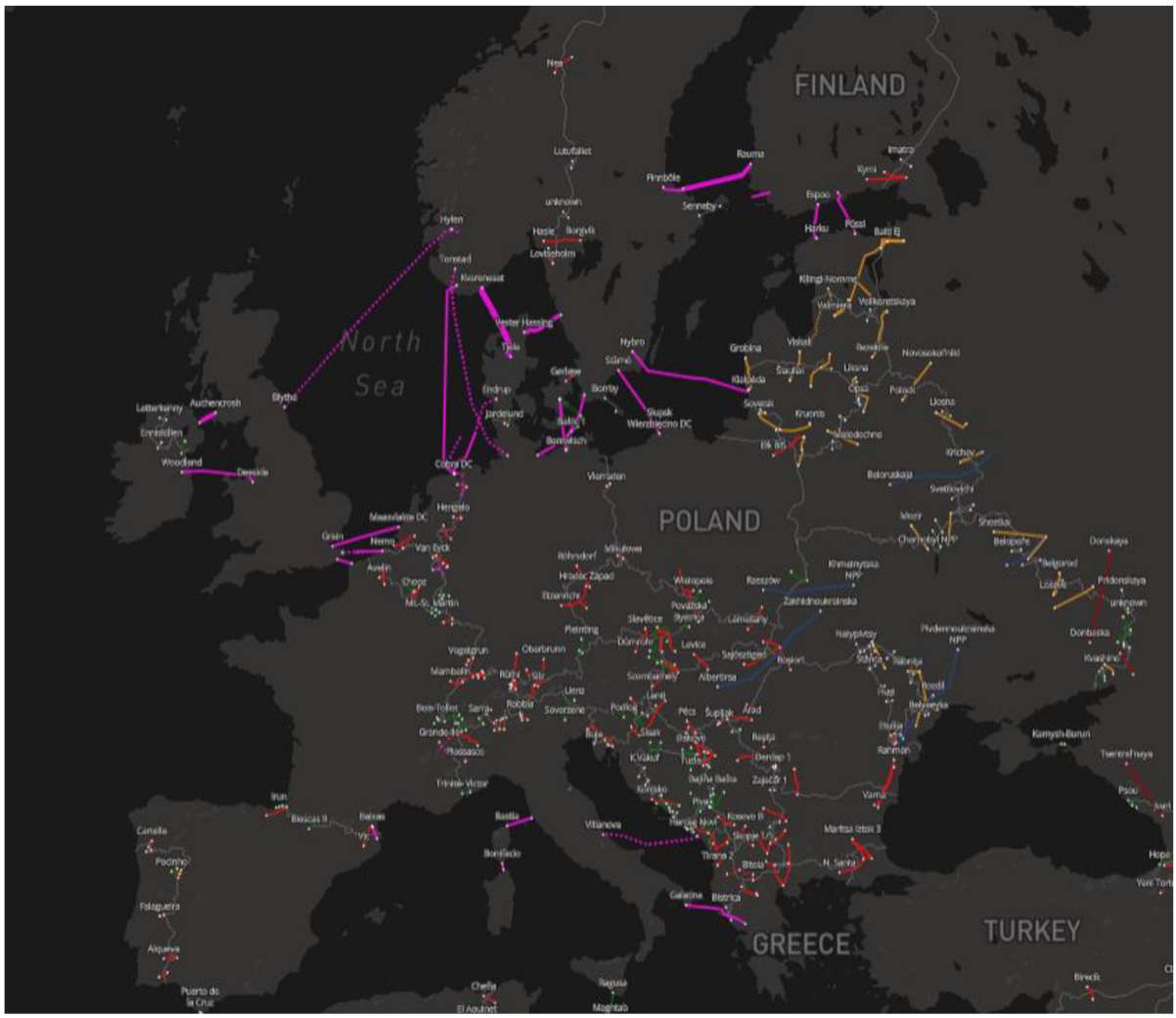
- Number of geothermal installed: over 50
- Total installed capacity: 0,755 GW by 2020
- 8.87% of total geothermal energy production in Europe.
- 25 % of Gross electricity production in country.

Iceland is a pioneer in the use of geothermal resources for home heating. Over the course of the 20th century, the country went from being a poor country producing tor and coal to one of the leading European countries in terms of covering energy needs from renewable resources. So in 2014, 85% of the energy accounted for green energy, of which 66% is geothermal. The successful policy of the country introduced a law on the ownership of land resources belonging to private property, and all public territories belonged to the state. Over the years of development was able to provide heat from geothermal sources to the population, then investments went to the development of hydropower to produce electricity. [12]

4.6 Importance of cross-border renewable energy trading

Europe trade of renewable energy sources between the countries of the union is at a very high level, which allows countries to manage supply and demand. To maintain the level of integration of new capacities created by renewable energy in Europe, large projects are being built everywhere that allow the exchange of electricity between countries by water or mountain routes. For example, a 1000 MW submarine cable connecting Belgium and the UK, also similar cables between England and the Netherlands a 1000 MW, France a 2000 MW. By 2020, 31 projects in the electricity sector have been completed. Below is a map of cross-border connections between Europe countries.

Figure 6 Cross-border renewable energy map



Source: https://www.entsoe.eu/data/map/

Denmark produces a lot of surplus wind energy, and instead of limiting production, the country produces surplus energy and sells it to a neighbor, for example, Norway, which uses this energy to fill its pumped storage accumulating them, and when demand is high, they will sell it.

Such cooperation provides a huge potential for the emergence of energy sources. Where each region benefits from a unique geographic and climatic location for further cooperation with a neighboring country. For example, mountainous regions such as Norway, Sweden invest in pumped storage facilities, buying cheap energy, and filling their reservoirs with water. Subsequently, they can sell this electricity at a better price. Western regions use strong Atlantic winds to generate energy with the help of wind farms and also sell their surplus energy to neighboring countries. It is also not obligatory to transport energy over long distances, this will only lead to power losses during transmission. But such issues can be resolved. For example, Spain may produce a lot of solar electricity, and Denmark does not have enough wind turbine capacity

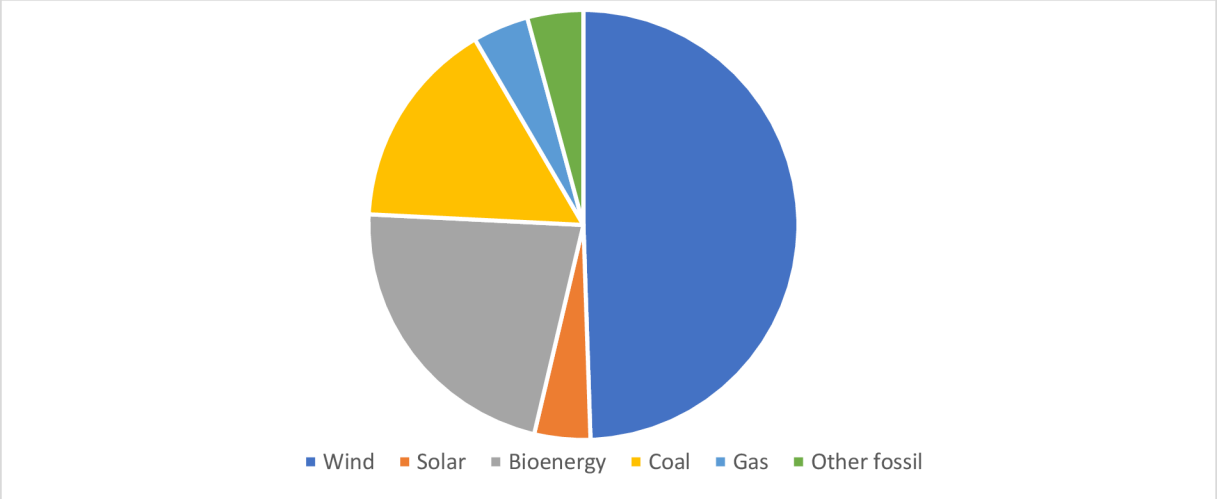
to meet the weight of the demand. Then France comes to the rescue, which buys cheap energy from Spain and then sells its own nuclear energy to Denmark at a better price.

This high level of cooperation is leading Europe to huge cost savings. So, if the successful trend of development of trade between the continues, the union can save consumers from 12 to 40 billion euros annually. Connectors can provide lower electricity prices and stable supply. [13]

4.7 Analysis of countries using renewable/non-renewable energy sources

Evaluation of renewable energy in Denmark

Figure 7 Energy production in Denmark



Source: *Denmark: power production share by source 2021 | Statista*

Denmark is an example of a successful country that is generating surplus energy from wind resources by 2021. This keeps electricity pricing stable and enables renewable energy trading with neighboring countries.

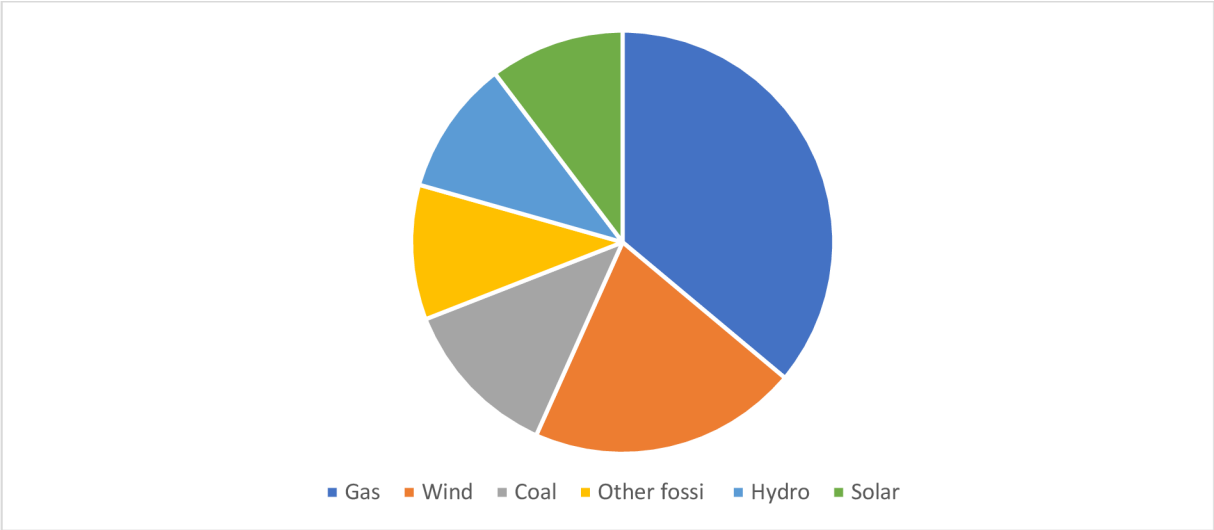
Economics benefits:

- Independence from global fossil fuel prices
- Inexhaustible energy resource of more 70 % of the energy economy
- High energy efficiency
- Creating a more favorable energy environment for production and agriculture.

Disadvantages:

- Energy transmission costs are much higher than other types of electricity
- Huge investment in charging stations

Figure 8 Energy production in Greece



Source: https://www.statista.com/statistics/1235419/greece-distribution-of-electricity-production-by-source/

Greece is a country that has been involved in the production of renewable energy from the very beginning, but with the discovery of a gas field in 2009, the country began to build its economy at the expense of the gas sector. But in last 3 years Greece started to develop wind energyas most of Europe countries that bringing to them 40 percent of electricity production renewables-based.

Economics benefits:

- Fossil energy sources are a traditional source of energy and power plants, vehicles and various industrial enterprises are built on their basis.
- The ability to rapidly develop the economy through the sale of resources.

Disadvantages:

- Final energy source (non-renewable)
- Environmental pollution
- less emphasis on creating new technologies,
- lack of incentives of creating new income source

4.8 Meaning

I have compared energy production in 2 countries, Greece and Denmark. Denmark is a successful example of a country that has developed its energy potential in renewable resources to

an extremely high level with its huge reserves of oil. The country is 43rd in the world in terms of oil potential. But Danish sound policies have decarbonized the energy sector and created long-term prospects. This method of energy production will allow future generations to conserve clean energy. Independence of renewable energy maintains stable electricity prices and ensures the country's security before the change in the course towards world raw materials

Greece, in turn, continues the development and production of natural gas, which may adversely affect the further environmental development of the country. Also, hydrocarbon resources are not endless, and in the long term, when many countries have already switched to renewable energy sources, the country will have to develop these technologies to continue stable economic growth. Competitive risk is equally important.

4.9 Problems of an economy dependent on non-renewable energy sources

Resource curse

The term resource curse was first mentioned in 1993 by Richard Auty. He worked with the resource development model and researched a surprising fact. The rise in oil prices in the 1970s and 1980s led to faster economic development in resource consuming countries, while resource exporters, on the contrary, grew more slowly, despite high prices and the idea that the more you have export resources, the easier you can get out of poverty. The standard of living in countries with criteria for resource wealth should have increased, but in fact it only decreased or did not change.

In the mid-1990s, economists conducted a cross-country study and found a negative correlation between the share of resources in exports and the share of economic growth.

Dutch disease

This term describes the features of the economic development of the Netherlands in the 60s. Dutch disease is a problem that has appeared in the economy of Holland, after the discovery of a large gas field, which supplied most of Europe with gas. Dutch disease is a situation when, due to the development of one of the exporting industries in the economy, currency begins to flow into the country, and this causes growth mainly in non-exporting sectors of the economy, for example, in the service sector. Unexpected wealth leads to the strengthening of the national currency and the uncompetitiveness of the manufacturing industry. As a result, the disease

consumes a significant part of the earnings and with the fall in fossil fuel prices, the subsequent recession in the economy. One factor plays an important role in this effect. Competing countries capture new non-commodity markets and invest in new technologies, and therefore, when commodity prices fall, it is too late to catch up with competitors.

Results

The resource curse is actually a more fundamental problem than the Dutch disease. It lies in the fact that in large resource countries, problems arise with the creation of modern political institutions and economic institutions. Economist Kevink Tsui has shown that the unexpected discovery of 100 million barrels of oil reserves in the country over the next 30 years leads the country to reduce the level of democracy by 20%.

According to World Bank estimates, in developed countries, natural resources account for 2% of national wealth, while in poor countries this figure reaches 26%. In fact, it is not the availability of the resources themselves that is important, but their combination with developed political institutions. The oil business is little dependent on institutional policy, it is perfectly standardized and globalized.

Countries with a strong and competent distribution of funds in the country and in the presence of non-renewable resources should take into account their dependence on world prices, and over time invest the money received from this sector in the development and development of technologies, creating a platform for the people who will be able to support economic growth in the future.

5 Conclusion

Renewable energy sources have a number of advantages over traditional energy sources. Europe has been involved in the development history of every renewable energy source. The right approach to policy building helped to develop a strategy of implementation and create an attractive investment platform for the green sector. At first, the countries were forced to join in RES development to achieve their goals. But now with economic benefits understanding in the long term contributes with the creation of a healthy competitive market which brings competitiveness in pricing. Successful energy relations between the countries made it possible to correctly distribute supply and demand. Europe, in its dynamics, is striving for decarbonization of the economy in order to get rid of dependence on world prices for fossil fuels and ensure climate preservation. But it is not that simple.

Renewable energy sources largely depend on economic and natural conditions. The high cost of installation and the long payback period can be a serious barrier for development. As we understood from my work, today the two main types of renewable energy receiving large investment for development. These are solar and wind energy. 70 percent of solar energy in Europe is producing by five counties, which indicates a narrow focus and certain conditions associated with the development incentive and the level of development, the potential of production capacity. Wind energy is more commonly used be countries and is currently the fasters growing type of energy production. But it is enough to install wind generator or solar panels to getting energy steadily. Not on an industrial scale.

An infrastructure is needed to support all the processes of production, storage, and transmission of energy. In addition to the huge cost of installing renewable energy capacity, investments are required in expensive grids, storage, interconnections. Sometimes RES might produce over demand of energy. This waste could be avoided without energy storage. The country's economy should allow to produce batteries, subject to the development of renewable energy sources, because most producing countries working for their national market. There is also a problem with energy grid within countries. Sometimes, to transfer energy from one part of the country to another, necessary to use network of another country. Investments in interconnections will only increase as green energy develops.

But despite all these difficulties, Europe continues its systematic development in the field of renewable energy. Already by 2030, the goal has been set at 55 percent of reducing greenhouse emission. Throughout the development and involvement of Europe in renewable energy, technologies have improved and improved. Special attention for future development and

achievement of goals should be given to the underestimated potential of geothermal energy, as well as energy recovery from waste, the success of which is demonstrated by some European countries. Also, in order to achieve climate neutral status, great attention will be paid to the production and storage of hydrogen, which will ensure the efficiency of manufacturing. All these aspects must be combined with a highly developed infrastructure covering all sectors of the economy.

Of course, all this is done to reduce greenhouse gas emissions and save the climate. Now, this is the main reason for the development and for this reason new plans and goals are being set. In this way we can observe how renewable energy is being integrated into the economies of countries. The European Union and its members are the best example of demonstrating the possibility of building and implementing plans for the gradual decarbonization of the economy. Now plans and goals have been set, leading to the complete carbon neutral status, which will make a huge contribution to the protection of our environment.

References:

1: Ziet online, Wind power [Online] https://tortillala.livejournal.com/18929.html

2: Hydro energy museum [Online] http://www.hydromuseum.ru/history-of-hydropower/ancient-ages/nachalo-gidroenergetiki/pervye-gidroelektrostantsii

3: US Departure of energy, Energy efficiency and renewable energy [Online] The History of Solar (energy.gov)

4: Geothermal Energy [Online] History of Geothermal Energy Use | Request PDF (researchgate.net)

5: Ingrid Stober and Kurt Bucher University of Freiburg [Online] (PDF) EU Renewable Energy Policy: A Brief Overview of its History and Evolution (researchgate.net)

6: European Parliament: Policy Department [Online] European Energy Industry Investments (europa.eu)

7: Wind Europe [Online] https://windeurope.org/intelligence-platform/product/getting-fit-for-55-and-set-for-2050/

8: European Parliament Artificial Intelligence [Online] The role of Artificial Intelligence in the European Green Deal (europa.eu)

9: Solar Power Europe [Online] SolarPower Europe – Leading the Energy Transition

10: Wind Europe [Online] WindEurope - the voice of the wind energy industry

11: International Association of the Year [Online] Europe (hydropower.org)

12: United Nations [Online] https://www.un.org/ru/chronicle/article/22094

13: Grid Interconnection [Online] chapter2.pdf (un.org)

14: Irena Hydrogen from renewable power [Online]: *https://www.irena.org/publications/2018/Sep/Hydrogen-from-renewable-power*

15: S&P Global commodity index [Online] https://www.spglobal.com/commodity-insights/en/market-insights/latest-news/electric-power/090221-h2-energys-1-gw-danish-green-hydrogen-project-to-supply-trucks-stations-industry

Books:

Renewable Energy in Europe: Markets, Trends and Technologies by European RenewableEnergy Council

Advances in Renewable Energies and Power Technologies by Imene Yahyaoui

Additional internet sources:

The Potentials of Renewable Energy: [Online] The Potentials of Renewable Energy (ren21.net)

IRENA Renewable energy benefits: [Online] Renewable Energy Benefits: Measuring

the Economics(irena.org)

Geothermal EGEC [Online] EGEC - The Voice of Geothermal in Europe

International Hydropower Association [Online] International Hydropower Association