MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ENVIRONMENTAL SCIENCE

APPROVED TO DEFENCE
Head of the Graduate Department
_____ Tamara DUDAR
«_____» _____ 2023

BACHELOR THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 "ECOLOGY",
EDUCATIONAL AND PROFESSIONAL PROGRAM:
"ECOLOGY AND ENVIRONMENT PROTECTION"

Theme: «Prospects for the development of renewable energy in post-war Ukraine»

Done by: student of EK-402 Ba group, Yelyzaveta I. Honcharenko
(student, group, surname, name, patronymic)

Supervisor: cand. of Phys. and Math., associate professor Valentyna A. Groza
(academic degree, academic rank, surname, name, patronymic)

Standards Inspector: _____ Andrian A. IAVNIUK
(signature) (S.N.P)

KYIV 2023

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____ Тамара ДУДАР
«_____» _____ 2023 р.

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»
ОПП «ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Перспективи розвитку відновлювальної енергетики в Україні у післявоєнний час»

Виконавець: студентка групи ЕК-402Б, Гончаренко Єлизавета Ігорівнаа
(студент, група, прізвище, ім'я, по батькові)

Керівник: канд.фіз.-мат. наук, доцент кафедри екології Гроза Валентина Анатоліївна
(науковий ступінь, вчене звання, прізвище, ім'я, по батькові)

Нормоконтролер: _____ Андріан ЯВНЮК
(підпис) (П.І.Б.)

КИЇВ 2023

NATIONAL AVIATION UNIVERSITY

Faculty of Environmental Safety, Engineering and Technologies

Department of Environmental Science

Specialty, Educational and Professional Program: specialty 101 "Ecology", Educational and Professional Program: "Ecology and Environment Protection"

(code, name)

APPROVED
Head of the Department
_____ Tamara DUDAR
«____» _____ 2023

BACHELOR THESIS ASSIGNMENT

Yelyzaveta I. Honcharenko

1. Theme: «Prospects for the development of renewable energy in post-war Ukraine» approved by the Rector on April 19, 2023, № 529/ст.

2. Duration of work: from 29.05.2023 to 20.06.2023.

3. Output work (project): Energy strategy of Ukraine for the period until 2035, materials of world experience in the use of alternative energy sources, scientific and scientific and technical materials on modern technologies of using solar, wind energy, and bioenergy.

4. Content of explanatory note: (list of issues): 1. Traditional and alternative energy sources. 2. Development of renewable energy in the world 3. Development of renewable energy in Ukraine.

5. The list of mandatory graphic (illustrated materials): tables, figures, graphs.

6. Schedule of thesis fulfillment

№ з/п	Task	Term	Advisor's signature
1	Justification of the goal, object and subject of research	29.05.2023 – 03.06.2023	
2	Review of literary sources	01.06.2023 – 09.06.2023	
3	Collection and analysis of materials	01.06.2023 – 10.06.2023	
4	Writing chapters I of the thesis	02.06.2023 – 05.06.2023	
5	Writing chapters II of the thesis	05.06.2023 – 12.06.2023	
6	Writing chapters III of the thesis	09.06.2023 – 12.06.2023	
7	Issuance of an explanatory note	13.04.2023 – 19.06.2023	
8	Defense of the thesis	20.06.2023	

7. Date of task issue: «19» April 2023

Diploma (project) advisor: _____ Valentyna GROZA
(advisor's signature) (S.N.P.)

Task is taken to perform: _____ Yelyzaveta HONCHARENKO

(graduate's signature) (S.N.P.)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет екологічної безпеки, інженерії та технологій

Кафедра екології

Спеціальність, освітньо-професійна програма: спеціальність 101 «Екологія», ОПП «Екологія та охорона навколишнього середовища»

(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
_____Тамара ДУДАР
«____» _____ 2023 р.

ЗАВДАННЯ
на виконання кваліфікаційної роботи
Гончаренко Єлизавети Ігорівни

1. Тема роботи «Перспективи розвитку відновлювальної енергетики в Україні у післявоєнний час» затверджена наказом ректора від «19» квітня 2023 р. № 529/ст.

2. Термін виконання роботи: з 29.05.2023 р. по 20.06.2023р.

3. Вихідні дані роботи: Енергетична стратегія України на період до 2035 року, матеріали світового досвіду використання альтернативних джерел енергії, наукові та науково-технічні матеріали щодо сучасних технологій використання енергії сонця, вітру, біоенергетики.

4. Зміст пояснювальної записки: 1. Традиційні та альтернативні джерела енергії. 2. Розвиток відновлюваної енергетики у світі 3. Розвиток відновлюваної енергетики в Україні.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки, діаграми.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Обґрунтування мети, об’єкта та предмета дослідження	29.05.2023 – 03.06.2023	
2	Огляд літературниз джерел	01.06.2023 – 09.06.2023	
3	Збір та аналіз матеріалів	01.06.2023 – 10.06.2023	
4	Написання І розділу кваліфікаційної роботи	02.06.2023 – 05.06.2023	
5	Написання ІІ розділу кваліфікаційної роботи	05.06.2023 – 12.06.2023	
6	Написання ІІІ розділу кваліфікаційної роботи	09.06.2023 – 12.06.2023	
7	Видання пояснювальної записки	13.04.2023 – 19.06.2023	
8	Захист кваліфікаційної роботи	20.06.2023	

7. Дата видачі завдання: «19» квітня 2023 р.

Керівник кваліфікаційної роботи: _____ Валентина ГРОЗА
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____ Гончаренко Єлизавета
(підпис випускника) (П.І.Б.)

ABSTRACT

Explanatory note to the thesis "Prospects for the development of renewable energy in post-war Ukraine": 56pages, 9 figures, 2 tables, 23 literary sources.

Object of research: renewable energy and prospects of its development in Ukraine and the world as a whole.

Aim of work: to analyze traditional and alternative energy sources. Assess the development of renewable energy in Ukraine and the world in recent years. To consider the prospects for the development of RES in Ukraine in the post-war period.

Mehods of research: data processing and composition. Analysis of prospects for renewable energy development in Ukraine after the war. Analysis of the energy strategy of Ukraine for the period until 2035. The dynamics of the development of renewable energy in the countries of the world. Identifying the effects of the war on RES.

Traditional sources of energy and the main directions of alternative energy are analyzed. Dynamics and competitiveness of renewable energy development in Europe, Asia and America are studied. State of renewable energy sources in Ukraine in the pre-war period is investigated. On the basis of the energy strategy of Ukraine for the period until 2035 prospects for the development of renewable energy in post-war Ukraine are analised.

List of keywords: RENEWABLE ENERGY, TRADITIONAL AND ALTERNATIVE SOURCES OF ENERGY, SOLAR ENERGY, WIND ENERGY, HYDRO ENERGY, BIOMASS ENERGY.

CONTENT

LIST OF CONDITIONAL DESIGNATIONS

RES - renewable energy sources;

WPS – wind power station;

Bio PP - bioenergy plant;

Biogas PP - biogas power plants;

SPP – solar power plant;

Home SPP – home solar power plant;

HPS – hydroelectric power station;

Small HPS – small hydroelectric power station;

EPIA - European Photovoltaic Association;

IEA – International Energy Agency.

INTRODUCTION

Relevance of work: Renewable energy sources (RES) are energy sources that can be renewed in a short period of time and are not exhausted as a result of their use. These energy sources are usually clean and environmentally friendly, which is why they have become increasingly popular around the world as an alternative to coal, oil and gas energy sources. Renewable energy sources include such sources of energy as solar, wind, hydro, geothermal and biomass. The energy produced by these sources can be used for electricity supply, heating and other consumer needs.

Renewable energy is an important and promising energy sector industry of the world. Today, all civilized countries are developing their economies based on the use of renewable energy sources, which are gradually replacing old power plants using fossil fuels, which have ability to deplete and pollute the atmosphere.

In December 2015, as part of the climate summit in a new global agreement was adopted in Paris by 192 countries the climate agreement that replaced the Kyoto Protocol and the purpose of which was to restrain the processes of the global warming Participating countries have agreed to prevent the average temperature from rising by more than 2 degrees. The primary task of the countries of the world is precisely the development of renewable energy, because it exists ecologically clean inexhaustible source of energy.

In general, the issue of transition to renewable energy sources is relevant in the world for several reasons:

1) the growth of the world's population and the increase in its energy needs lead to an increase in the use of hydrocarbons (oil, gas and coal) for energy production. This causes environmental pollution and global climate change, which has serious consequences for human health and the environment as a whole;

2) the use of hydrocarbons is unstable and dependent on the political situation in the countries that export these resources. It is also dependent on oil and gas prices, which fluctuate on world markets;

3) renewable energy sources such as solar, wind, hydropower, biomass and

geothermal energy can provide sustainable and uninterrupted energy needs of the population and industry.

The war in Ukraine has many consequences, including an energy crisis and dependence on hydrocarbon imports. Therefore, the issue of transition to renewable energy sources is also very important and relevant for Ukraine. The war in Ukraine led to a decrease in coal and gas production, as well as to the destruction of the energy infrastructure in Donbas. This led to an energy crisis and dependence on hydrocarbon imports from abroad.

The development of renewable energy sources can help reduce dependence on hydrocarbon imports, which often come from countries that do not support Ukraine in its struggle with Russia. Thus, the transition to renewable energy sources can ensure the independence and stability of Ukraine's energy system.

Spread of renewable energy sources can help reduce emissions of pollutants and help preserve the environment in the face of war and climate change. In addition, it can help reduce energy costs and provide affordable energy for people and businesses.

Therefore, the transition to renewable energy sources is important for post-war Ukraine and the world as a whole, as it can help ensure an independent and sustainable energy system, reduce dependence on hydrocarbon imports, and reduce emissions.

Aim of work: to analyze traditional and alternative energy sources. Assess the development of renewable energy in Ukraine and the world in recent years. To consider the prospects for the development of RES in Ukraine in the post-war period.

Tasks of the work:

- consider traditional and alternative energy sources;
- identify and analyze the impact of the use of alternative energy sources on the environment;
- consider the dynamics of development and competitiveness of renewable energy in the countries of the world;
- to analyze the energy strategy of Ukraine for the period until 2035;
- to reveal and analyze the state of RES in Ukraine in the pre-war period;

- to consider the prospects and plans for the development of renewable energy in post-war Ukraine.

Object of research: processes of functioning and development of alternative energy in Ukraine and the countries of the world

Subject of research: prospects of developing alternative energy in Ukraine after the war.

Methods of research: data processing and composition. Analysis of prospects for renewable energy development in Ukraine after the war. Analysis of the energy strategy of Ukraine for the period until 2035. The dynamics of the development of renewable energy in the countries of the world. Identifying the effects of the war on RES.

Personal contribution of the graduate: recommendations and plans were developed regarding the prospects for the development of renewable energy in Ukraine after the war.

Approbation of results: the results of the thesis were published in an article written within the framework of the project of the Razumkov Center with the Hans Seidel Foundation "Decarbonization of the Energy Industry of Ukraine".

Publications: it is indicated in how many articles in scientific journals, anthologies research results are published in scientific papers, conference materials, etc.

CHAPTER 1

TRADITIONAL AND ALTERNATIVE ENERGY SOURCES

Traditional energy sources are energy sources that have been used since ancient times and are considered the main sources of energy. These energy sources include oil, coal, gas, nuclear energy produced at nuclear power plants, etc. However, the use of traditional energy sources is associated with significant negative consequences, such as environmental pollution, ecological disasters, emissions of harmful substances into the atmosphere, climate change and other problems.

Alternative energy sources are energy sources that do not use traditional fuel resources and are less harmful to the environment. These energy sources include solar, wind, hydro, geothermal energy, biomass and others. The use of alternative energy sources helps reduce the negative impact on the environment, reduce greenhouse gas emissions, improve air and water quality, and reduce dependence on energy imports.

In the world, there is a growing interest in alternative energy sources because they are efficient and have become more affordable in terms of cost, which allows replacing traditional energy sources with more environmentally safe and sustainable sources.

Advantages of renewable energy sources:

Zero emissions - the absence or significant reduction of emissions of pollutants compared to burning fossil fuels, is one of the most important advantages of clean energy.

Unlimited resources - unlike fossil fuels, renewable sources are constantly renewed. The rivers are constantly flowing, the wind blows and the sun shines every day. In this way, we can avoid a situation similar to the current one in the future, when fossil fuels start to run out and we look for alternative sources of energy.

Saving money - although the creation of new wind or solar power plants is quite expensive, in the long run the costs pay off. Plus, you don't have to pay for fuel to power them, unlike coal and oil, which have to be mined and then transported to power plants.

1.1 Analysis of traditional energy sources

Traditional energy sources such as oil, coal and natural gas are an integral part of modern life. The use of traditional sources of energy became a key factor in the industrial revolution and the economic development of countries. However, the use of traditional energy sources has also led to many environmental problems and dependence on energy imports.

Oil: One of the largest traditional sources of energy is oil. Petroleum is used in many industries, including transportation, power, and industry. According to the International Energy Agency (IEA), global oil consumption in 2020 was 91.5 million barrels per day. In addition, oil is the main source of energy for many countries, including the United States, China, India, and the European Union.

A few main aspects of oil as an energy source:

Fuel production: Petroleum is used to produce a variety of fuels, including gasoline, diesel, jet fuel, and heating fuel. This makes it possible to meet the needs of transport, industry and household consumption.

High energy density: Oil has a high energy density, which means that a large amount of energy can be obtained from a small amount of oil. This makes oil an efficient source of energy.

Global Use: Oil is the world's energy source and is produced and consumed in many countries around the world. Countries that have significant oil reserves use them as the main source of income and for the development of their economy.

Environmental issues: Oil spills can pollute water bodies, and emissions of greenhouse gases, particularly carbon dioxide, contribute to global warming and climate change. In addition, the exploration, production and transportation of oil can cause serious environmental disasters that can have a negative impact on the environment and human health.

Energy Security: Dependence on oil creates an energy security problem as some countries become dependent on oil imports, which can create risks to their economies and geopolitical instability.

Coal: Another important traditional source of energy is coal. Coal is used to generate electricity, as well as in industry and transportation. According to the IEA, global coal consumption in 2020 was 7.4 billion tons. However, the use of coal has several negative environmental consequences. Coal-fired power plants are a major source of air pollution, releasing sulfur dioxide, nitrogen oxides and particulate matter into the air. These pollutants can cause breathing problems, heart disease and other health problems. In addition, coal mining can lead to soil erosion, water pollution and destruction of natural habitats.

The main types of coal used are hard coal, lignite and anthracite. Here are some facts about coal as an energy source:

High energy density: Coal has a high energy density, meaning that a large amount of energy can be obtained from a small amount of coal. This makes it an efficient source of energy.

Wide range of applications: Coal is used to generate electricity in coal-fired power plants, as well as for heating in domestic and industrial installations. It remains an important source of energy for many countries.

Availability and low cost: Coal is a widespread resource available in many regions of the world. The production and consumption of coal is economically advantageous compared to other sources of energy.

Technological improvements: To reduce the negative impact on the environment, carbon capture and storage (CCS) technologies are being implemented, which allow to reduce greenhouse gas emissions by capturing and storing carbon dioxide underground.

Natural Gas: Natural gas is used for heating, cooking and electricity generation. According to the IEA, the world consumption of natural gas in 2020 was 3.9 trillion cubic meters. Although natural gas is often touted as a cleaner alternative to coal and oil, its production and use still has a negative impact on the environment. Natural gas is primarily composed of methane, a potent greenhouse gas that is released during extraction, production, and transportation. In addition, pipelines and storage facilities can leak methane, further contributing to global warming.

Main aspects of natural gas:

Clean fuel: Natural gas is considered one of the cleanest types of fuel among hydrocarbon resources. When burned, it emits less carbon dioxide, harmful substances and solid particles compared to coal and oil. This contributes to reducing the environmental impact on air and human health.

Energy efficiency: Natural gas has a high energy capacity, meaning that a significant amount of energy can be obtained from a small amount of gas. This makes it an efficient source of energy from an economic point of view.

Infrastructure: Existing gas transportation infrastructure makes natural gas available for transportation and supply to various regions. This makes it possible to efficiently use the resource and ensure energy security.

Geopolitical weight: Natural gas can have great geopolitical weight, as countries with rich natural gas reserves can have a significant influence on the global energy market. Dependence on natural gas imports can also create geopolitical risks for countries that consume it.

Sustainability Perspectives: Advances in gas technologies such as liquefied natural gas (LNG) and gas hydrate are opening up new opportunities for the exploitation and use of natural gas.

Nuclear power: Nuclear power plants produce electricity by splitting uranium atoms in a process called nuclear fission. Nuclear power has several advantages, including the ability to produce large amounts of electricity without producing greenhouse gases. However, nuclear energy has a number of disadvantages. Nuclear waste is highly radioactive and can remain dangerous for thousands of years. In addition, nuclear power plants are vulnerable to accidents, as demonstrated by the Chernobyl and Fukushima disasters.

A few main aspects of nuclear power as an energy source:

Nuclear reaction: Nuclear energy is based on nuclear reactions, in particular on the fission of atomic nuclei or the fusion of nuclei, which is accompanied by large energy radiations. These reactions take place in the reactors of nuclear power plants.

High Energy Power: Atomic energy has extremely high energy power. Small amounts of nuclear fuel can provide significant amounts of electricity. This makes nuclear

power a very efficient source of energy.

Low greenhouse gas emissions: Nuclear power has low emissions of greenhouse gases, such as carbon dioxide, compared to burning coal or oil. This makes it attractive from the point of view of combating climate change and reducing the impact on the environment.

Energy security: Nuclear power can provide energy security for countries that have limited natural resources of their own. It does not depend on the import of coal or oil, which allows to reduce the risks of geopolitical conflicts and variations in fuel prices.

Nuclear waste management: Nuclear power generation creates radioactive waste that requires safe storage and disposal. Solving the problem of nuclear waste management is an important aspect of the development of nuclear energy.

1.2 The main directions of alternative energy

Alternative energy is a branch of energy that focuses on the use of energy sources other than traditional fuels such as oil, coal, and natural gas. The main goal of alternative energy is to ensure a sustainable, ecologically clean and independent energy future.

Solar energy: Solar energy is one of the most common sources of alternative energy. It uses solar radiation to generate electricity using solar panels or solar thermal systems. It is a safe, waste-free and non-polluting form of energy that reduces dependence on traditional fuel sources.

Fig. 1.1. A flexible solar cell for providing mobile communication

Here are some main aspects of solar energy:

Solar Panels: Solar panels consist of photovoltaic (solar) cells (fig. 1.1) that are capable of absorbing photons of sunlight and generating an electric current. These cells are usually made of crystalline silicon or other semiconductor materials. Solar panels can be installed on the roofs of buildings, on special structures or on solar farms, where they collect solar energy.

Renewable energy: Solar energy is a renewable form of energy because solar radiation is a limitless and inexhaustible source. Every day, the Earth receives a huge amount of solar energy, and harnessing this potential can ensure a sustainable and clean energy future.

Ecological purity: Solar energy does not emit greenhouse gases and other harmful emissions, which helps reduce environmental impact and pollution. Using solar energy helps reduce dependence on fossil fuels such as oil and coal and helps conserve natural resources.

Decentralized energy production: Solar panels can be installed on homes, businesses or even in remote rural areas where there is no access to a centralized electricity grid. This makes it possible to provide electricity to remote and hard-to-reach places, reduce energy losses due to transmission, and also provide energy independence to users. In the (fig. 1.2.) we can see an airplane that works on solar batteries.

Fig. 1.2. Airplane on solar batteries

Energy efficiency: Solar energy promotes energy efficiency because solar panels directly convert solar radiation into electrical energy. Thanks to the constant development of solar energy technologies, the efficiency of solar panels is increasing, which allows you to get more energy from a smaller number of solar cells. In the (fig. 1.3.) we can see a complex of solar power plants.

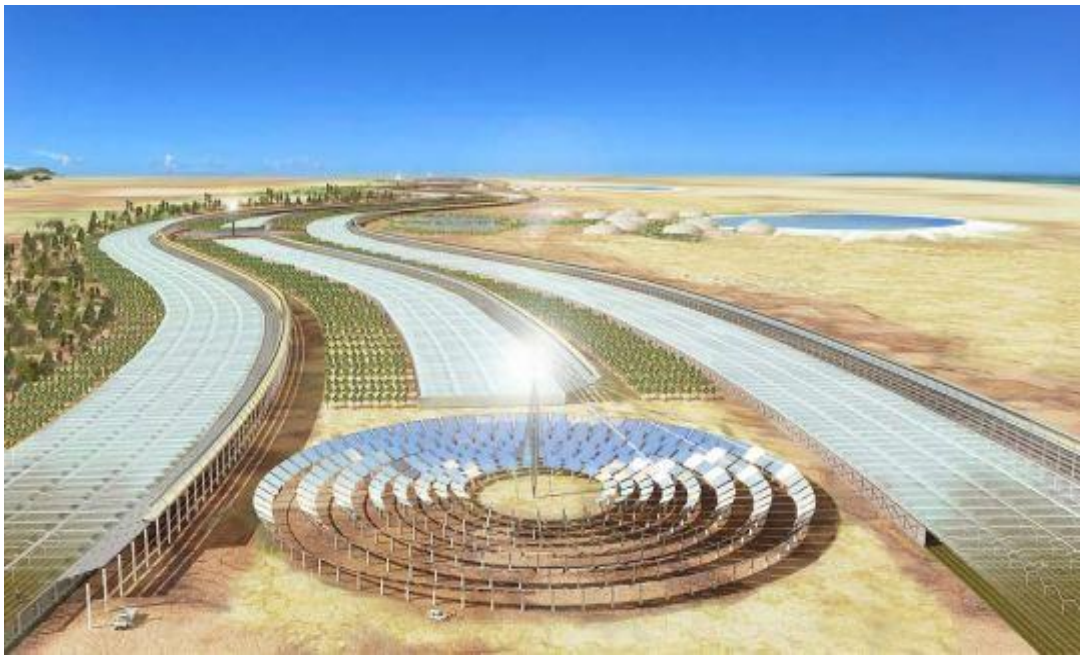

Fig. 1.3. Project of a complex of solar power plants

Economic potential: Solar energy has significant economic potential, especially with the reduction in the cost of solar panels and the support of government programs. The use of solar energy can contribute to the creation of new jobs in the field of manufacturing, installation and maintenance of solar systems.

Wind energy: Wind energy is another important area of alternative energy and uses the power of the wind to generate electricity. It is based on the use of wind generators, also known as wind turbines, which convert the kinetic energy of the wind into electrical energy. Here are some key aspects of wind energy:

Wind Turbines: Wind turbines consist of large rotors with blades that are located on tall towers. When the wind blows, the blades of the wind turbine begin to move, driving the generator, which creates electrical energy. Wind generators can be installed separately or

form wind farms, where several wind generators are combined in one area.

Renewable energy: Wind energy is a renewable form of energy because wind is a free and limitless source of energy. The use of wind energy helps reduce dependence on fossil fuels and contributes to the creation of a sustainable and clean energy future.

Environmental cleanliness: Wind energy is an environmentally clean form of energy, as it does not emit greenhouse gases and other harmful emissions during operation. Using wind energy helps reduce carbon emissions, which helps fight climate change and improves air quality.

Energy independence: Wind energy provides the possibility of local energy production, especially in regions with high wind energy potential. This allows providing electrical energy to remote areas and promotes energy independence.

Economic potential: Wind energy has significant economic potential as it creates new jobs in the field of manufacturing, installation and maintenance of wind turbines. It can also contribute to the development of local economies by attracting investment and generating income for communities.

Challenges and obstacles: Wind energy also faces certain challenges, such as dependence on wind conditions, the need for large areas to install wind farms, and potential impacts on birds and other wildlife. It is important to conduct research and planning before implementing wind energy projects to reduce negative impacts.

Hydropower: Hydropower uses the energy of moving water to produce electricity. Large hydroelectric plants use waterfalls and reservoirs, while small hydroelectric plants can be installed on rivers and streams. It is a stable and environmentally friendly source of energy.

Here are some of the main aspects of hydropower:

Catchment systems: Hydropower uses catchment systems such as rivers, streams and reservoirs to collect water. Large hydroelectric power plants have special downspouts and spillways that control the movement of water and ensure optimal use of its potential.

Hydro Turbines: Water is used to drive hydro turbines, which convert the kinetic energy of the water into mechanical energy. Hydro turbines are connected to generators that produce electrical energy.

Types of Hydropower: Hydropower includes different types of systems, including large hydro, small hydro, and tidal systems. Large hydroelectric plants have a large capacity and use large reservoirs. Small hydropower plants are smaller in size and can be installed on rivers and streams. Tidal systems use the ebb and flow of seawater to generate electricity.

Sustainability of energy source: Water is a free and limitless source of energy as it is renewable through natural processes such as precipitation. This makes hydropower a stable source of electricity, as it does not depend on fluctuations in the natural environment, as can happen with solar or wind power.

Sustainability of distribution: Hydroelectric power plants can provide electricity to large areas because the electricity can be transmitted through electrical grids. This promotes energy independence and can provide electricity to remote regions.

Environmental impact: Hydropower can have a positive or negative impact on the environment. Large hydroelectric plants can affect natural ecosystems and fish migration. Therefore, it is important to assess the impact on the environment and take measures to minimize the negative impact.

Bioenergy: Biomass uses organic material such as wood, agricultural waste and biofuels to produce energy. It can be used for the production of electricity, heat and fuel. Biomass is considered a renewable energy source because plants can be planted to replace the used material.

Here are some key aspects of bioenergy:

Biomass: Bioenergy uses plant biomass such as wood, agricultural residues, perennial grasses and energy crops as a fuel source. These materials can be converted into biofuel, biogas or used directly to generate heat and electricity.

Biofuels: Biofuels include biodiesel, ethanol, and bioethanol, which can be produced from plant biomass or agricultural waste. They can be used as an alternative to traditional hydrocarbon fuels such as oil and coal in transportation and other industries.

Biogas: Biogas is obtained from natural biological processes of decomposition of organic matter, such as composting, anaerobic digestion and biological fermentation. It consists mainly of methane and carbon dioxide and can be used to produce heat and

electricity or as fuel for vehicles.

Sustainability and Renewability: Bioenergy is a sustainable source of energy because the plants and organic materials used to produce bioenergy can be regenerated through natural processes. It can also facilitate the use of agricultural waste and wastewater, reducing their negative impact on the environment.

Reduction of greenhouse gas emissions: The use of bioenergy can contribute to the reduction of greenhouse gas emissions, such as carbon dioxide, compared to traditional hydrocarbon fuels. Bioenergy produces fewer harmful emissions and can contribute to a cleaner and more environmentally sustainable energy system.

Impacts on land and water resources: Biomass harvesting and bioenergy production can have impacts on land resources, water supplies and biodiversity. Effective planning and management of bioenergy production is essential to ensure sustainability and minimize negative environmental impact.

1.3 The impact of the use of alternative energy sources on the environment

The use of alternative energy sources has a significant impact on the environment. Although the use of alternative energy sources has many advantages for the environment, it can also have some negative consequences.

Problems related to the use of solar energy:

1. Manufacturing Solar Panels: Manufacturing solar panels requires the use of a variety of materials, including rare metals and semiconductors. Extraction of these materials can lead to water and land pollution, as well as require large amounts of energy and water resources.

2. Disposal of solar panels: The panels have a limited useful life, after which they need to be disposed of. Uncontrolled disposal can lead to environmental pollution with toxic substances such as cadmium, which is found in some types of solar panels.

3. Use of land resources: Large areas of land are required to install solar farms. This can lead to the loss of natural ecosystems, a decrease in biodiversity and soil pollution due to the use of chemical fertilizers.

4. Energy used for production: The production of solar panels requires energy that can be obtained from traditional sources such as coal or gas. If this energy is not renewable, the production of solar panels can introduce greenhouse gas emissions and other negative environmental impacts into the system.

5. Efficiency in areas with insufficient solar radiation: The use of solar energy is not efficient in areas with limited solar radiation. In such places, the efficiency of solar panels can be low, which reduces their practical value and requires compensation with other energy sources.

Problems related to the use of wind energy:

1. Effects on birds and wildlife: Wind turbines can have effects on birds and wildlife. Birds can collide with turbine blades and be injured or killed. Some wind farms may be located on bird migration routes, disrupting their migration and affecting their populations.

2. Noise pollution: Wind turbines can create noise, especially at high wind speeds. This can create discomfort for people who live near wind farms. Long-term exposure to noise can have negative effects on people's health, including sleep problems and psychological disorders.

3. Use of land resources: Large-scale wind farms require large areas of land. It can affect land resources, occupy agricultural land and natural ecosystems. The displacement of natural habitats can have a negative impact on biodiversity and ecological balance.

4. Impact on the landscape and tourism: Wind turbines can change the landscape and affect the aesthetic appeal of natural areas. This could have a negative impact on the tourism potential of some regions, particularly in places where natural beauty and open spaces are important attractions.

5. Manufacturing and recycling of materials: The manufacturing of wind turbines requires the use of a variety of materials, including structural steel, fiberglass, and rare metals. The use and disposal of these materials can have a negative impact on the environment if proper control and recycling measures are not implemented.

Problems related to the use of hydropower:

1. Flooding of lands and loss of ecosystems: During the construction of hydroelectric power stations, reservoirs are formed, which can lead to the flooding of large areas of land. This can lead to the loss of residential areas, agricultural land and natural ecosystems, including forests and water bodies. Changes in water levels can also affect local flora and fauna, reduce biodiversity and cause the extinction of some species.

2. Impact on river ecosystems: Construction of dams and reservoirs for hydroelectric power plants can disrupt the natural balance of river ecosystems. Changes in water flow can affect river flora and fauna, including fish and other aquatic life. Reduced water flow below the dam can also lead to reduced oxygen in rivers and create dangerous conditions for aquatic ecosystems.

3. Effects on fish and migration: Hydroelectric power plants can interfere with fish migration, including natural reproduction and movement to isolated river areas. Dams and reservoirs create obstacles in rivers, which can lead to a decrease in fish populations and disruption of the natural ecological cycle.

4. Methane emissions: Reservoirs created during the construction of hydroelectric power plants can release methane, which is a powerful greenhouse gas. The decomposition of organic material in flooded areas of the reservoir releases methane, which leads to an increase in the greenhouse effect and climate change.

5. Social impacts: The construction of hydroelectric power plants can have social impacts, including changes in land use, displacement of local residents, and changes in the way of life and culture of communities. Such changes can be destabilizing and cause conflicts in local communities.

Problems related to the use of bioenergy:

1. Land use changes: Large areas of land may be required to grow biomass used for bioenergy production. This can lead to a change in land use, occupying agricultural land, forests or other natural ecosystems. The occupation of natural lands can affect biodiversity and reduce the natural value of those areas.

2. Competition with food production: Increasing the cultivation of biomass for bioenergy can create competition with food production. In particular, the use of land and

water resources for growing energy crops can reduce the availability of land and resources for growing food crops. This can have a negative impact on access to food and cause food security issues.

3. Use of chemicals: Bioenergy production may involve the use of chemicals, such as fertilizers or pesticides, to support the growth of biomass. Uncontrolled or misused use of these chemicals can have negative effects on soil, water resources and biodiversity.

4. Energy efficiency: Production and processing of biomass for bioenergy can be an energy-intensive process. For example, the use of fuel and energy to transport, harvest and process biomass can reduce the overall energy efficiency of bioenergy.

5. Greenhouse Gas Emissions: Some forms of bioenergy, particularly biomass burning, can release greenhouse gases such as carbon dioxide and methane. If proper cleanup and emission reduction technologies are not applied, this can lead to an increase in the greenhouse effect and climate change.

1.4 Conclusions to Chapter 1

In summary, traditional energy sources have played a crucial role in the development of modern society, but their negative impact on the environment cannot be ignored.

Coal has a large energy capacity and wide application, but its use is accompanied by significant environmental problems.

Oil is also of great importance as a source of energy, but its use is associated with a number of environmental, energy and geopolitical problems. The development of sustainable and ecologically clean energy is an important task for the future of the energy sector.

Nuclear energy has its advantages and disadvantages. Solving problems related to nuclear waste management, safety and risks remains an important task for the further development of this energy source.

Therefore, it is important to explore alternative energy sources such as renewable energy sources that can reduce our dependence on traditional energy sources and help

mitigate the negative environmental impact of energy production.

The use of alternative energy sources has the potential to positively impact the environment, reduce dependence on depleting resources, and promote sustainable development. However, it is important to consider each energy source with an overall assessment of its environmental impact, including construction, production and disposal, to ensure minimum negative impacts and maximum environmental benefits.

CHAPTER 2

DEVELOPMENT OF RENEWABLE ENERGY IN THE WORLD

The development of renewable energy in the world in recent decades is an important trend. Society is increasingly aware of the need to replace traditional sources of energy with more sustainable and environmentally friendly sources. In many countries of the world, there is a significant increase in the installed capacity of renewable energy sources, in particular solar and wind (fig. 2.1). This is due to the growth of technological capabilities, a decrease in the cost of equipment and favorable regulatory policies.

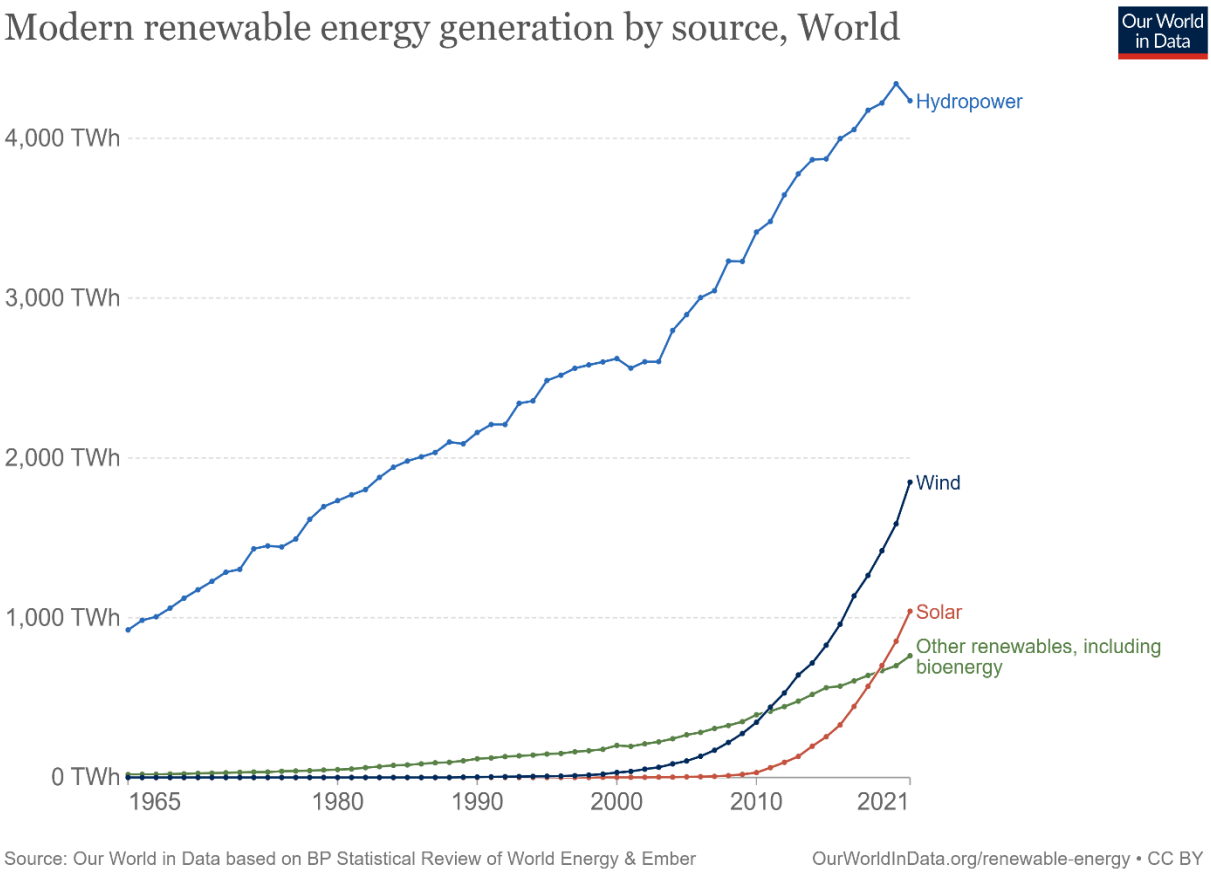

Fig. 2.1 Modern renewable energy generation by sources

According to the calculations of the International Energy Agency (IEA), in 2022, a record increase in the share of RES is planned in the world - up to 320 GW of new capacities.

The governments of most countries increasingly understand the growing role of RES in ensuring energy security.

Russia's attack on Ukraine led to an unprecedented global energy crisis. To protect consumers from rising energy prices, many countries are trying to reduce dependence on Russian energy resources by implementing a policy of accelerated transition to carbon-free technologies.The transition to RES provides great potential for reducing prices and dependence on fossil fuels in the short and long term.

The war in Ukraine added reasons for an accelerated green transition to reduce dependence on Russian energy imports. Investments in RES development are now a strategic point for many countries, especially in the EU. Many EU countries have announced plans to develop RES, in particular wind and solar plants, which have the greatest potential to reduce the dependence of the EU energy sector on Russia by 2023. As an example, Poland increased the budget for financing geothermal technologies to PLN 480 million.

The EU is already a world leader in offshore wind energy. Today, this is 16 GW of installed offshore wind power capacity. The new EU target is to reach 60 GW by 2030 and 300 GW by 2050.

Many countries are implementing stimulating legislation, financial incentives and state support for the development of renewable energy. This may include priority tariffs, feed-in tariff systems, tax incentives, subsidies and other measures aimed at stimulating investment in this sector.

Renewable energy receives significant support from technological progress. New developments and innovations contribute to reducing the cost of installation and operation of renewable energy sources, improving their efficiency and reliability. For example, solar panels are becoming more efficient, wind turbines are getting more powerful, and energy storage technologies are developing.

Many countries have joined international agreements and commitments aimed at

reducing greenhouse gas emissions and increasing the use of renewable energy. For example, the Paris Agreement obliges countries to reduce their emissions and promote the transition to sustainable energy. The development of renewable energy is also accompanied by economic benefits. Creating new jobs, developing local energy markets, reducing dependence on energy imports and reducing energy costs for countries are important arguments in favor of renewable energy.

The development of renewable energy in the world has great potential for reducing dependence on exhaustible energy sources and reducing greenhouse gas emissions. However, it is important to address the challenges associated with the integration of renewable energy into the energy system, ensuring the sustainability of energy supply and the balanced development of the energy mix.

2.1. The dynamics of the development of renewable energy in the countries of Europe, Asia and America

The dynamics of the development of renewable energy in the countries of Europe, Asia and America show significant progress in the use of these energy sources and the impact on the global energy system. Each region has its own characteristics and specific factors affecting the development of renewable energy. In the following (fig. 2.2, fig. 2.3, fig. 2.4), we can see the rapid development of renewable energy.

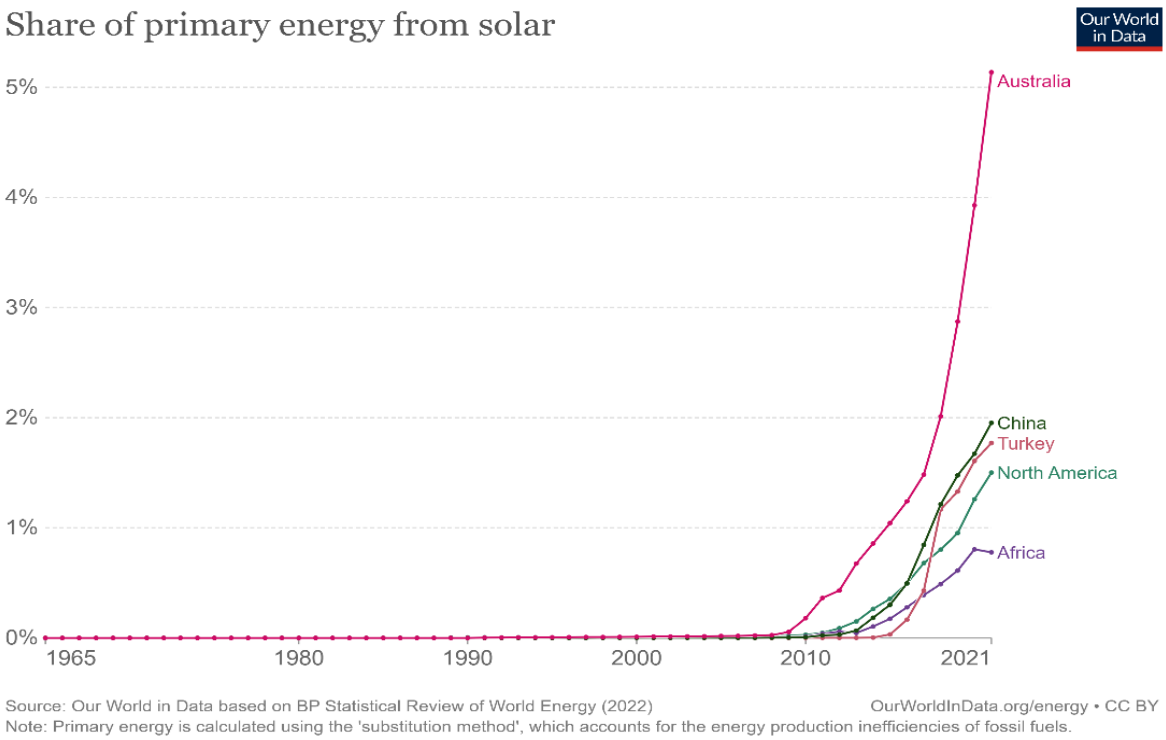

Fig. 2.2 Share of primary energy from solar

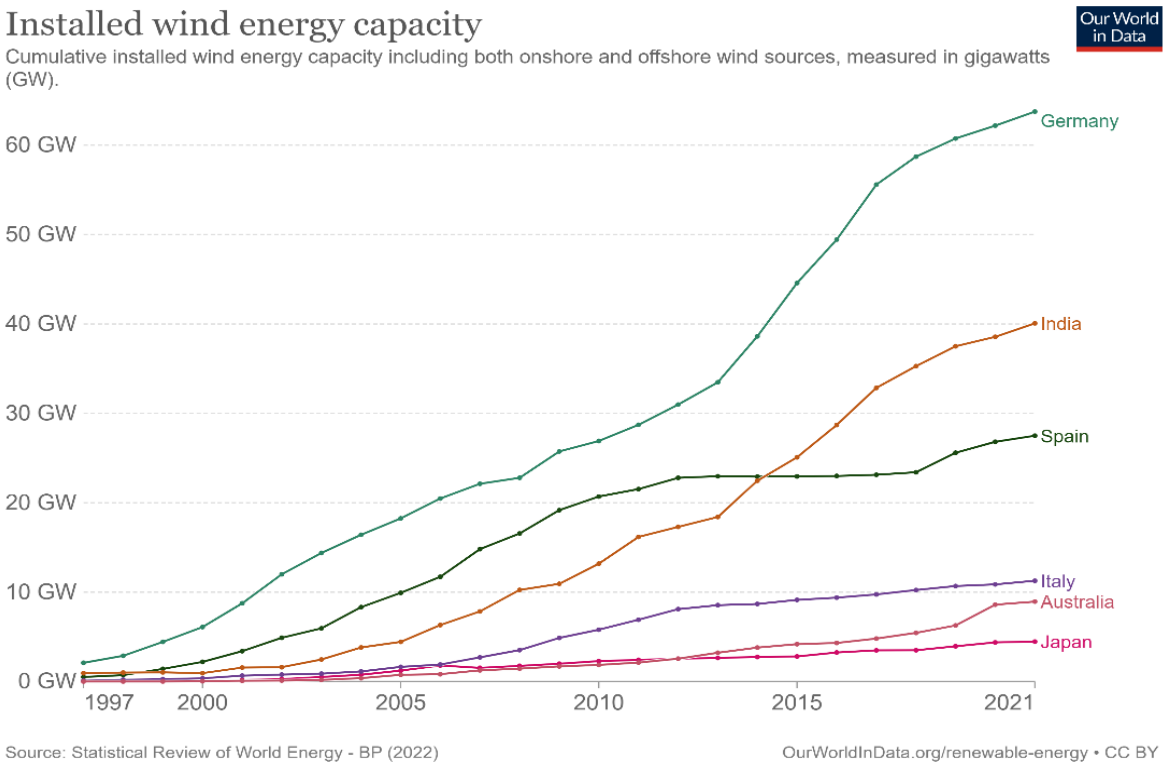

Fig. 2.3 Wind energy capacity

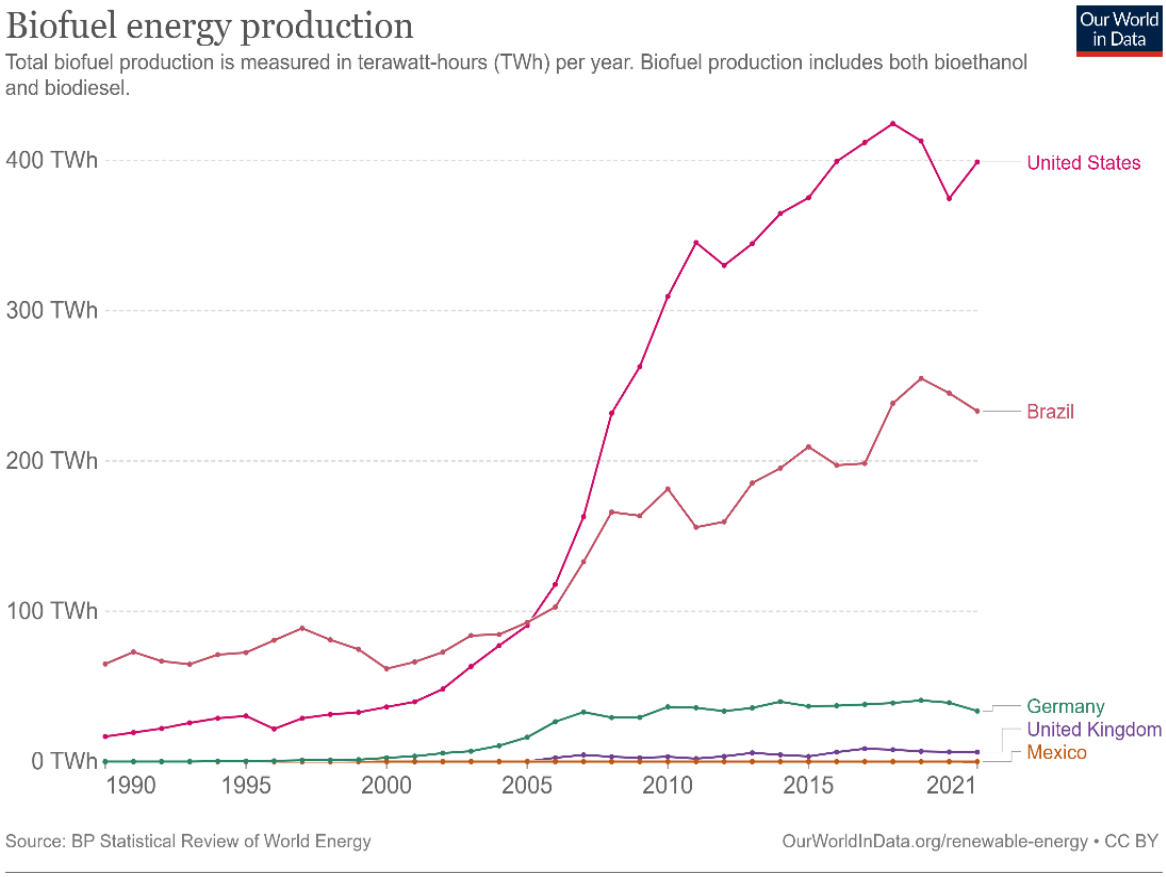

Fig. 2.4 Biofuel energy production

Europe

The dynamics of renewable energy development in European countries is impressive. Many European Union (EU) countries have decided to reduce their dependence on traditional energy sources and are actively investing in renewable energy sources.

Increasing installed capacity: European countries are investing heavily in renewable energy sources such as wind, solar, hydro and biomass. There has been a significant increase in the installed capacity of renewable energy systems across Europe. Many countries set records for the amount of electricity generated from renewable sources.

Expansion of wind power: Wind power has been the main focus of renewable energy development in Europe. Offshore wind farms have grown significantly, especially in countries such as the UK, Germany, Denmark and the Netherlands. Technological

progress and favorable government policies have contributed to the spread of wind energy.

The rise of solar energy: Solar energy has also seen significant growth in European countries. Falling costs of solar panels, increased efficiency and government incentives have fueled the installation of solar photovoltaic (PV) systems. Countries such as Germany, Spain, Italy and the Netherlands have seen significant increases in solar capacity.

Use of biomass and bioenergy: Biomass and bioenergy are used for both electricity and heat production in Europe. Biomass includes organic materials such as wood pellets, agricultural waste, and biofuels. Many European countries use biomass as a renewable energy source either in special power plants or by co-firing with coal.

Policy support and targets: European countries have introduced various policies and targets to promote the development of renewable energy. The European Union has set binding targets for its member states to increase the share of renewable energy in their energy balance. This has led to the introduction of feed-in tariffs, renewable energy subsidies, tax breaks and other support mechanisms to encourage investment in renewable energy projects.

Interconnection and cross-border cooperation: European countries are increasingly focusing on interconnection and cross-border cooperation to facilitate the integration of renewable energy into their energy systems. This includes the development of cross-border transmission lines, joint projects and the sharing of renewable energy sources to improve grid stability and reliability.

Energy storage and grid flexibility: With the increasing penetration of renewable energy sources, the importance of energy storage and grid flexibility is becoming more prominent. European countries are investing in energy storage technologies such as batteries and pumped storage to balance the intermittent nature of renewables and ensure a stable supply of electricity.

Asia

The dynamics of renewable energy development in Asian countries is also

impressive. This region shows significant interest in the use of renewable energy sources, especially in the context of reducing dependence on traditional hydrocarbon fuels and reducing the impact on the environment.

China - is a leader in renewable energy: China is a world leader in the use of renewable energy sources. It has the largest installed capacity of wind and solar power plants in the world. China is also actively developing hydropower and the use of biomass.

India - Expansion of solar and wind energy: India is one of the leading countries in the use of solar energy. The country has significant wind energy potential and has installed a large number of wind turbines. India is also actively developing hydropower and the use of biomass.

Japan - development of solar and wind energy: Japan, although it has limited resources for renewable energy, is actively investing in solar and wind energy. After the nuclear accident in Fukushima in 2011, Japan paid more attention to the development of renewable energy sources.

South Korea - Expanding Wind and Offshore Energy: South Korea is actively investing in wind energy and developing offshore wind farms. The country is also focusing on the development of solar energy and the use of biomass.

Eastern Europe and Central Asia - development of wind and solar energy: Countries in Eastern Europe and Central Asia, such as Ukraine, Kazakhstan and Romania, are seeing significant development of wind and solar energy. They use their natural resources to ensure sustainable energy production.

Funding and investment promotion: Asian governments are actively engaging the private sector and investors in the development of renewable energy. They provide financial support, tax breaks and other incentives to attract investment in restoration projects.

International cooperation: Asian countries actively cooperate with international organizations and other countries for the joint development of renewable energy. This includes the exchange of technology, the transfer of know-how, joint research and the implementation of joint projects.

America

The dynamics of the development of renewable energy in American countries has shown significant progress in recent years.

United States: The United States has seen significant growth in renewable energy capacity, particularly wind and solar. Several states have set ambitious renewable energy targets and enacted supportive policies to promote clean energy. The country has also made significant investments in research and development of renewable technologies.

The role of alternative energy sources in the US economy deserves special attention. In particular, they account for about 10% of total energy consumption and 15% of electricity production. While hydropower is the largest source of renewable energy in the US, geothermal energy only accounts for about 0.5% of total electricity. Consumption of biofuels and other alternative energy sources more than doubled between 2000 and 2015, mainly due to state and federal incentives28.

Canada: Canada is actively expanding its renewable energy sector, with a particular focus on hydroelectricity. The country has enormous hydropower potential, and many provinces have developed large-scale hydropower plants. In addition, Canada is making progress in wind, solar and bioenergy.

Brazil: Brazil is a leader in renewable energy, primarily due to the widespread use of bioenergy. The country has a well-established biofuel industry, in particular the production of ethanol from sugar cane. Brazil has also invested in wind power and has significant potential for solar energy.

Mexico: Mexico has shown significant progress in the development of renewable energy sources, particularly wind and solar energy. The government introduced reforms to promote clean energy, including auctions for renewable energy projects. Mexico aims to increase the share of renewable energy sources in the structure of electricity generation and reduce dependence on fossil fuels.

Chile: Chile has made significant progress in renewable energy, particularly solar. The country has abundant solar resources and solar power plants are rapidly being deployed. Chile has also made progress in wind power and is seeking to diversify its

energy mix by increasing the share of renewable energy.

Costa Rica: Costa Rica has made significant progress in achieving high levels of renewable energy production. The country pays significant attention to hydropower and aims to become carbon neutral by 2021. Costa Rica is also exploring geothermal energy and has made progress in wind and solar energy.

2.2. Competitiveness of renewable energy

The competitiveness of renewable energy is constantly increasing worldwide as it becomes a more viable and attractive option for meeting energy needs.

Advances in renewable energy technologies such as solar photovoltaic (PV), wind turbines, and energy storage systems have greatly increased their efficiency and lowered costs. Continuous innovation and research in these technologies has led to increased energy production and better productivity, making renewable energy more competitive compared to traditional fossil fuel-based sources.

One of the main drivers of the competitiveness of renewable energy is the significant reduction of costs over many years. Economies of scale achieved through large-scale deployment, combined with technological advances, have resulted in significant reductions in the costs of renewable energy systems. For example, the cost of solar PV modules has dropped dramatically, making solar energy increasingly competitive with conventional electricity sources in many regions.

Policy support and market incentives. Governments around the world have introduced supportive policies and market incentives to promote the use of renewable energy. These include feed-in tariffs, tax incentives, renewable portfolio standards and green procurement programs. Such policies provide long-term visibility, reduce investment risks and create a favorable market environment for renewable energy technologies, thus increasing their competitiveness.

Energy diversification and security: renewable energy sources offer a diversified energy balance, reducing dependence on fossil fuels and increasing energy security. As concerns about energy security and fossil fuel price volatility grow, countries are

recognizing the value of renewable energy to reduce import dependency and increase energy self-sufficiency. This aspect further contributes to the competitiveness of renewable energy.

Renewable energy sources produce significantly fewer greenhouse gas emissions and air pollutants compared to conventional fossil fuels. Recognition of the environmental and health impacts of burning fossil fuels has led to increased support for renewable energy as a cleaner, more sustainable alternative. The social and economic benefits associated with reduced pollution and improved public health contribute to the overall competitiveness of renewable energy.

Job creation and economic growth: The renewable energy sector has become a major source of job creation and economic growth in many countries. The deployment of renewable energy projects such as wind and solar power plants requires a skilled workforce for production, installation, operation and maintenance. This sector has the potential to create local jobs, stimulate economic activity and promote sustainable development, further increasing its competitiveness.

Technological learning and innovation: The continuous growth of installations using renewable energy sources has led to a successful cycle of technological learning and innovation. As more renewable energy projects are rolled out, the industry gains experience and knowledge, leading to further technology improvements, efficiencies and cost reductions. This continuous innovation cycle increases the competitiveness of renewable energy through continuous progress in the sector.

2.3 Conclusions to Chapter 2

The development of renewable energy in the world has great potential for reducing dependence on exhaustible energy sources and reducing greenhouse gas emissions. However, it is important to address the challenges associated with the integration of renewable energy into the energy system, ensuring the sustainability of energy supply and the balanced development of the energy mix.

The dynamics of the development of renewable energy in European countries was

determined by a combination of favorable policies, technological progress, cost reductions and increasing public awareness of the need to transition to cleaner and more sustainable energy sources. This has led to significant progress in decarbonising the energy sector and reducing greenhouse gas emissions across Europe.

The development of renewable energy in Asian countries is accelerating due to the growing awareness of climate change, reduced dependence on energy imports and increased energy security. Countries use their natural resources, invest in new technologies and create favorable conditions for the development of renewable energy in order to create a sustainable and environmentally friendly energy system.

It is important to note that the dynamics of renewable energy development may vary across the Americas due to factors such as natural resources, political frameworks, and economic conditions. However, in general, there is growing recognition and commitment to the transition to cleaner and more sustainable energy sources in the region.

Despite the growing competitiveness of renewable energy, challenges remain. These include the intermittency and variability of certain renewable sources such as wind and solar, which require efficient energy storage and grid integration solutions. In addition, the availability of suitable land, transmission infrastructure and regulatory framework can affect the competitiveness of renewable energy in certain regions.

In summary, the competitiveness of renewable energy has improved significantly over the years due to technological advances, cost reductions, policy support, environmental benefits, job creation and technological learning. As the world moves towards a low-carbon and sustainable energy future, the competitiveness of renewable energy will continue to grow, making it a more attractive and viable alternative to meet global energy demand.

CHAPTER 3

DEVELOPMENT OF RENEWABLE ENERGY IN UKRAINE

The development of renewable energy in Ukraine is one of the priorities in the field of the country's energy policy. Ukraine has significant potential for the use of various types of renewable energy sources, such as solar, wind, biomass and hydropower.

3.1. Analysis of the energy strategy of Ukraine for the period until 2035

The level of development of the energy industry has a decisive influence on the state of the economy in the country, the solution of social problems and the standard of living of a person.

The goal of the welfare state, which Ukraine is according to the Constitution, should be comprehensive provision of citizens' well-being. One of the most important components of well-being in civilized countries is providing citizens with heat and electricity.

The goals and priorities of the Energy Strategy of Ukraine for the period until 2035 "SAFETY, ENERGY EFFICIENCY, COMPETITIVENESS", approved by the order of the Cabinet of Ministers of Ukraine dated August 18, 2017 No. 605-r, are:

- creation of conditions for the development of a conscious and energy-efficient society;
- orientation towards energy independence, reliability and stability of the energy-supply complex;
- development of markets;
- ensuring conditions for the investment attractiveness of the energy industry of Ukraine;
- integration of the United Energy System of Ukraine into the European energy

system with a consistent increase in electricity exports;

• development of a modern management system.

The implementation of the specified goals will create conditions for the intensive development of the economy and the improvement of the standard of living of the country's population.

According to the Energy Strategy, the structure of the total primary supply of energy (which is calculated as the sum of production (extraction), import, export, international bunkering of ships and changes in energy reserves in the country) has the form (tab. 3.1):

Table 3.1

The structure of the primary energy supply of Ukraine, %

Names of sources	**2015**	**2020**	**2025 (forecast)**	**2030 (forecast)**	**2035 (forecast)**
Coal	30,4	22	16,1	14,3	12,5
Natural gas	28,9	29,3	31	30,8	30,2
Oil products	11,6	11,5	9,2	8,2	7,3
Atomic energy	25,5	29,3	32,2	29,7	25,0
Biomass, biofuel and waste	2,3	4,9	6,9	8,8	11,5
Solar and wind energy	0,1	1,2	2,4	5,5	10,4
HPP	0,5	1,2	1,1	1,1	1,0
Thermal energy	0,6	0,6	1,1	1,6	2,1
In total	100	100	100	100	100
Including fossil resources	96	92	88	83	75
Including relative resources	4	8	12	17	25

The implementation of the Energy Strategy should ensure the transformation of Ukraine into an influential and active participant in international relations in the field of energy, in particular through participation in international and interstate entities and energy projects.

3.2. The state of RES in Ukraine in the pre-war period

In 2019, Ukraine entered the TOP-10 countries in the world in terms of renewable energy development rates, and in 2020 — in the TOP-5 European countries in terms of solar energy development rates. In the same 2019, in the Climatescope rating by Bloomberg New Energy Finance (Bloomberg NEF), Ukraine took an honorable 8th place (up from 63rd) among 104 countries of the world in terms of the country's investment attractiveness, specifically in the issue of the development of low-carbon energy sources and the construction of "green » economy. In 2021, Ukraine was in 48th place in terms of the total investment potential of the state among 136 countries in the world in the BloombergNEF rating.

In general, since 2019, investments in new renewable energy projects in Ukraine have been consistently higher than in fossil fuel projects. In the last 10 years alone, leading international and Ukrainian RES investors have attracted more than USD 12 billion of foreign direct investment into the economy of Ukraine, and the share of foreign investors in the installed RES capacity as of the end of 2021 has reached more than 35%, which characterizes the Ukrainian RES sector as quite competitive and open.

In 2021, the share of electricity generated from RES reached 8.1% or 12.8TWh, of which 56% — due to solar radiation, 33% — wind energy, almost 8% — due to the burning of biomass and biogas, and 3% accounted for small hydropower.

In 2021, all RES power plants produced 12,804 million kWh of clean electricity, which was 1,941.9 million kWh or 17.8% higher than last year's figures:

• WPPs of Ukraine produced 3,866 million kWh or 614.4 million kWh more than in 2020, which is 2.97% of total electricity production;

• SPPs produced 7,670 million kWh or 4.8%, which is 1,065.4 million kWh more than the amount of electricity produced in the same period of 2020;

• mHP generation increased by 56.1 million kWh, reaching 276 million kWh or 0.17% of the total balance;

• Ukrainian bioelectric power plants generated 992 million kWh or 0.6%, which is 206 million kWh more than the production level of the previous year.

At the same time, it should be noted that 2021 has become a defining year for the national RES sector, because on May 11, 2021, the daily production of electricity from RES for the first time in the history of Ukraine exceeded the level of generation by thermal power plants — 79 million kWh versus 77 million kWh.

Thanks to the successfully implemented projects in the field of renewable energy in Ukraine, annual emissions of CO2 into the atmosphere as of 2021 have been reduced by more than 10.3 million tons, which is equivalent to emissions from more than 2.2 million cars. For example, thanks to the generation of electricity by industrial wind power plants alone, 1.8 million tons of coal, 1,171.4 thousand m3 of natural gas were saved in 2021, and approximately 3.1 million tons of CO2 emissions were reduced.

We can see the dynamics of the capacities of RES facilities in recent years in the (tab. 3.2 and fig. 3.1)

Table 3.2

Capacities of RES facilities, MW

	2018	**2019**	**2020**	**2021**
Boigas PP	40,8	96,4	103,1	124,1
Bio PP	98,4	103,2	106,3	120,9
smal lHPS	63,4	87	108,7	151,8
WPS	533	1170	1314,1	1672,9
home WPS	157	533	779	1205,15
WPS	1388	4836,5	6075,7	6381,1

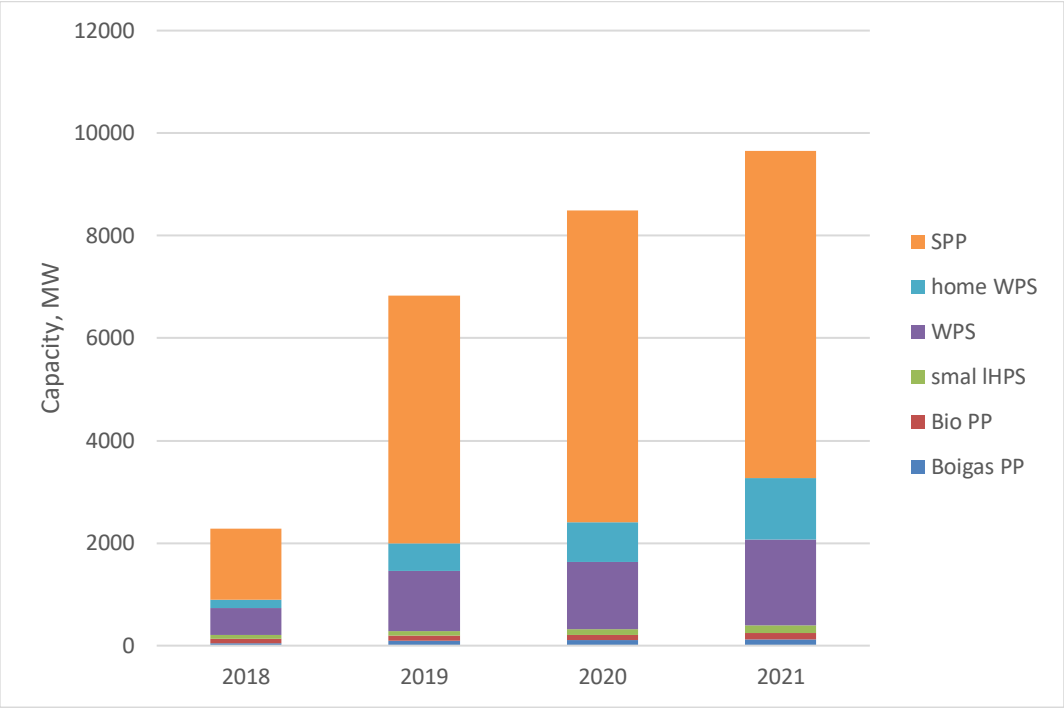

Fig. 3.1. Dynamics of capacities of RES facilities, MW

The state of wind energy

The state of wind energy in Ukraine before the war was in a state of active development. Over the past few years, Ukraine has turned its attention to wind energy as one of the priority sources of renewable energy.

According to data for 2021, more than 800 megawatts of wind power was installed in Ukraine. The country has developed a favorable legal framework to attract investments in wind energy, including a system of "green" tariffs, auctions and other support mechanisms. According to the target indicators, Ukraine planned to reach the installed capacity of wind energy at the level of 2.5 gigawatts by 2020.

Several large wind farms were built in different regions of Ukraine, such as Mykolayivska, Zaporizhzhya and other regions. For example, in 2019, the largest wind power plant in Ukraine was launched in the village of Balabyne in the Mykolaiv region with a capacity of 200 megawatts (fig. 3.2).

Fig. 3.2. Wind energy facilities in Ukraine until 2022

1. Wind turbine Bonus, Ryiv region
2. WPS Staryi Sambir 1, Lviv region
3. WPS Staryi Sambir 2, Lviv region
4. Zborivska WPS, Ternopil region
5. WPS Boienergoprodukt, Ternopil region
6. WPS Shevchenkove-1 (first turn), Ivano-Frankivsk region
7. WPS Ovid Wind, Odesa region
8. Dnistrovska WPS, Odesa region
9. WPS Yuzhne Energy, Odesa region
10. Wind park Ochakivskyi, Mykolaiv region
11. Wind park Blahodatnyi, Mykolaiv region
12. Wind park Prychornomorskyi, Mykolaiv region
13. Wind park Pivdennyi, Mykolaiv region
14. Wind park Shchaslyvyi, Mykolaiv region
15. Wind park Shvydkyi, Mykolaiv region
16. WPS “Ltd Singa Energy”, Mykolaiv region
17. Novorosijska WPS, Kherson region
18. WPS Stavky, Kherson region
19. WPS Berehova, Kherson region
20. Novotroitska WPS, Kherson region
21. Overianivska WPS, Kherson region
22. Myrnenska WPS, Kherson region
23. Syvaska WPS (2006), Kherson region
24. Syvaska WPS (2019), Kherson region
25. Botiievska WPS, Zaporizhzhia region
26. WPS Prymorska 1, Zaporizhzhia region
27. WPS Prymorska 2, Zaporizhzhia region
28. Orlivska WPS, Zaporizhzhia region
29. Zaporizhska WPS, Zaporizhzhia region
30. Kramatorska WPS, Doneeіл купшщт
31. WPS Vitroenergoprom, Donetsk region
32. Wind park Novoazovskyi, Donetsk region
33. Wind park Krasnodonskyi, Luhansk region
34. Wind park Lutuhinskyi, Luhansk region

It is also worth noting that Ukraine has great potential for the further development of wind energy. According to estimates, there is a powerful wind potential along the coast of the Black and Azov seas, as well as in some regions of the Carpathians and other mountain ranges.

The Government of Ukraine has set ambitious goals in the field of wind energy. According to the wind energy development strategy by 2030, the country plans to achieve 11% of the total amount of electricity from renewable sources, including wind energy. Various mechanisms have been introduced to support the development of wind energy, such as special tariffs for renewable energy, auctions and guarantee purchase of electricity.

Ukraine is also attracting foreign investors to wind energy projects. Thanks to the favorable investment climate and government support, many international companies are investing in the construction and operation of wind power plants in Ukraine. This contributes to the development of the industry and the increase of the country's total wind capacity.

However, it is important to consider that the development of wind energy may face various challenges. For example, one of the biggest challenges is the lack of sufficient electricity transmission infrastructure, which may limit the further development of the sector.

In general, the state of wind energy in Ukraine in the pre-war period was characterized by active development and a favorable investment climate. The country uses its natural potential for wind power generation and attracts foreign investment for new projects. However, challenges related to the infrastructure and regulatory environment need to be addressed for the further development of the sector.

The state of solar energy

The state of solar energy in Ukraine before the war period was in a state of active development. Ukraine has significant potential for the use of solar energy, as the country is located in a temperate climate zone with a high amount of solar radiation. Solar energy is considered one of the most affordable and environmentally friendly sources of renewable energy.

At the beginning of 2021, about 1.5 gigawatts of solar power was installed in Ukraine. In recent years, several large projects in the field of solar energy have been implemented, which contributed to the increase of the total solar capacity in the country. For example, in 2019, the largest solar power plant in Ukraine with a capacity of 200 megawatts was commissioned. Such projects help reduce the use of hydrocarbons and reduce greenhouse gas emissions.

The Government of Ukraine has set ambitious goals in the field of solar energy. According to the strategy for the development of solar energy by 2030, the country plans to achieve 11% of the total amount of electricity from renewable sources, including solar energy. To support the development of solar energy, various mechanisms have been introduced, such as special tariffs for renewable energy, auctions and guarantee purchase of electricity.

One of the successful mechanisms for supporting solar energy in Ukraine is the green tariff. The green tariff is a state-guaranteed price at which electricity produced using solar energy is purchased. This mechanism contributes to the attractiveness of investments in solar power plants, provides stable income to producers and reduces financial risks.

Ukraine is also attracting foreign investors to solar energy projects. Thanks to the favorable investment climate and government support, many international companies are investing in the construction and operation of solar power plants in Ukraine. This contributes to the development of the industry and the increase of the total solar capacity of the country.

Ukraine is also directing efforts to stimulate the installation of solar panels on the roofs of residential buildings and commercial facilities. This helps not only to increase the total amount of solar energy in the country, but also to involve the population in the active production of electricity and reduce their dependence on traditional energy sources.

However, it is important to consider that the development of solar energy may face various challenges. For example, one of the main challenges is the unstable regulatory situation and insufficient financing for the development of the infrastructure of solar power plants. The government of Ukraine should continue to improve the regulatory environment and ensure sufficient funding for the development of solar energy.

In general, the state of solar energy in Ukraine in the pre-war period was characterized by active development and a favorable investment climate. The country uses its solar energy potential to ensure a sustainable and environmentally friendly electricity supply. However, for the further development of the industry, it is necessary to solve the challenges related to the regulatory environment and infrastructure financing.

3.3. Plans for the development of renewable energy in post-war Ukraine

The large-scale war launched by Russia on the territory of Ukraine in February 2022 left the RES sector in a state of waiting and uncertainty, which deepened not only due to active hostilities, damage and occupation of energy facilities, but also due to the artificial creation by individual state structures of additional problems and challenges in the market.

From the very first hours after the invasion, Russian troops have been massively shelling not only Ukrainian cities and towns, but also trying to destroy critical energy infrastructure facilities: high-voltage networks, transformer substations, control centers, as well as directly power plants, including renewable energy facilities . In general, after nuclear power facilities and power lines, renewable energy power plants became the second priority of destruction for the Russian invaders.

The war unleashed in Ukraine by the Russian aggressor deepened the financial crisis in the country's energy sector. The lack of sufficient funds to continue operations has become an urgent problem that all sectors of the Ukrainian energy system are currently facing. However, this had a particularly painful effect on the renewable energy sector. The national sector of renewable energy faced the question of survival within the state. First of all, this can be explained by the fact that in the first days of the war, the state's efforts were directed to ensuring the stable operation of the base load generation and the reliable operation of the Ukrainian power system in isolated mode, which was disconnected from the networks of Russia and Belarus on February 24, 2022 year Accordingly, solving some problematic issues of renewable energy did not become one of the priority tasks.

Along with this, it is already necessary to think about the restoration of the energy sector of our country, solving the issues of reforming the energy sector, taking into account

the consequences of military actions.

Post-war Ukraine sets ambitious plans for the development of renewable energy. This is reflected in various strategic documents and programs aimed at increasing electricity production using renewable sources.

One of the key documents that defines the strategy for the development of renewable energy is the State Program for the Development of Renewable Energy until 2035. This program includes a wide range of measures and objectives for the government and the energy sector.

One of the priority areas of development is solar energy. The plans call for a significant increase in the country's solar capacity by building new solar power plants and encouraging the installation of solar panels on the roofs of private homes and commercial properties. The government provides favorable conditions for investment in solar energy and develops support mechanisms, such as the introduction of green tariffs and financing programs.

Regarding wind energy, plans include increasing the country's wind capacity by building new wind farms. The government is actively working to create the necessary regulatory and financial conditions for the attractiveness of investments in wind energy. In particular, support mechanisms are being developed, such as auctions for obtaining priority conditions for the construction of wind power plants.

Hydropower is also included in the renewable energy development plans. Modernization and reconstruction of existing hydroelectric power stations, as well as construction of new small hydroelectric power stations on rivers and reservoirs are planned. This will allow to increase the production of electricity using hydropower and effectively use the potential of the country's water resources.

The development of biomass energy is another important direction. Ukraine has significant biomass resources such as agricultural waste, wood and other organic materials. Plans include increasing the use of biomass for electricity and heat generation by building new biomass power plants and upgrading existing ones.

Since 2013, a powerful Bioenergy Association (UABIO) has been operating in Ukraine, which unites business and experts for the development of bioenergy in our

country. Members of this UABIO are scientific and pedagogical workers of our faculty who are specialists in chemical technologies of alternative energy resources.

In particular, according to UABIO calculations, the domestic biomethane industry can potentially provide up to 20% of the needs of the European Union. The development of the direction involves the attraction of investments in the agricultural sector; creation of new jobs; increase in tax revenues; as well as the growth of export foreign exchange earnings.

The biomethane industry is considered quite promising, taking into account the following considerations:

• Biomethane obtained from agricultural waste is ready for injection into the gas network.

• Export (physical and virtual) can be carried out through the existing extensive gas transportation system.

• Now it is profitable to produce biometn only for export.

• There is a huge demand for it in EU countries.

• It is the cheapest possible renewable energy source.

The government also actively cooperates with international organizations and partners, in particular with the European Union, to obtain financial support and technological expertise in the development of renewable energy.

In the general perspective, in order to solve possible future problems related to the development of the modern carbon-free energy sector of Ukraine, taking into account RES, it is necessary to:

• To approve a single fundamental strategic document that defines the direction of development of energy and, in particular, RES in Ukraine.

• To approve a plan of measures for implementation for 5-10 years, which must be implemented by both the state and market participants.

• Oblige all state bodies and state enterprises involved in energy to include measures from the plan in their development programs and establish administrative responsibility for non-implementation.

In the short term, for the stable functioning of the RES sector, it is necessary to:

1. Ensure the immutability of legislation regarding the system of support for RES producers and the gradual repayment of debts, as well as comply with the existing guarantees provided to investors at the legislative level;

2. Make changes to the Order of the Ministry of Energy "On settlements with producers under the "green" tariff" dated June 15, 2022. No. 206, in order to bring the level of payments to RES producers to an economically justified level for the possibility of servicing all operating costs;

3. To reduce the volume of RES system restrictions on the part of NEC "Ukrenergo".

4. To ensure settlements with SE "Guaranteed Buyer" for imbalances on the part of NEC "Ukrenergo" and to stabilize the payments of OSP for the service of increasing the share of RES.

5. At the legislative level, it is necessary to extend the term of validity of the technical conditions of wind energy projects proposed by the Ministry of Energy of Ukraine, the construction of which was interrupted by the war, as well as the term for their completion for the purposes of obtaining a "green" tariff, for at least 2 years.

6. Establish a cash register method of calculating and paying VAT for the load reduction service.

7. Open the opportunity to export electricity for renewable energy producers, create a transparent and non-discriminatory mechanism for forming tariffs and distributing throughput capacities, simplify the procedure for organizing transit based on the principle of free access to transit capacities.

8. In order to stimulate the sale of electricity by RES producers on foreign markets, the export PSO requires the exclusion of RES producers from the list of exporters to whom such PSO applies.

9. As soon as possible, it is necessary to adopt at the legislative level a mechanism for issuing and circulating guarantees of origin of electric energy from RES and subsequently to create a national register of guarantees of origin for electric energy produced from RES.

In the long-term post-war perspective, the large-scale development of RES and the

creation of a new model of the energy sector of Ukraine will be possible on the condition that:

1. Adoption of clear National strategies for the development of RES, production of renewable hydrogen and development of offshore wind energy;

2. Setting ambitious goals for the development of RES, which will correspond to the current energy policy of the EU, namely to achieve at least a 50% share of RES in the electricity balance of Ukraine by 2030 (taking into account large-capacity hydropower plants) and achieving a carbon-free economy by 2050;

3. Conducting international communication campaigns to encourage international strategic and financial investors to enter the RES market of Ukraine;

4. Implementation of new market mechanisms for stimulating RES development, including "green" auctions, corporate PPAs, contracts for difference, etc.;

5. Increasing the use of biomass in electricity and heat generation;

6. Ensuring the development of the renewable hydrogen market, namely:

• Provide guarantees of origin of hydrogen, revise the carbon tax and increase it;

• Ensure the implementation of national hydrogen projects;

• Build a reliable infrastructure for the production, consumption and export of renewable hydrogen;

• Stimulate scientific organizations for research in the field of hydrogen technologies;

7. Study of the potential and development of the appropriate legislative framework for the construction of hybrid power plants with RES;

8. Promotion of the development of local energy initiatives, in particular, energy cooperatives, small and medium-sized enterprises in the energy sector, generation and supply of electricity taking into account regional characteristics, development of distributed generation;

9. Stimulation of national production of equipment and components for RES facilities, including wind turbines.

10. Application of best practices in environmental protection;

11. Development of legislation regarding the introduction of a trading scheme for

greenhouse gas emission quotas and other market and non-market instruments for reducing greenhouse gas emissions;

12. Increasing the share of installed automated electric energy accounting systems;

13. Ensuring the reliable functioning of the energy infrastructure, carrying out the necessary modernization measures, reducing breakdowns and accidents.

3.4 Conclusions to Chapter 3

With the transition to RES, energy as such will cease to be an instrument of political or military influence of one country on another. Almost all the wars that took place in the world until today were related to energy and the struggle for energy resources: oil, gas, coal, etc. Ukraine, in particular, is a country that, for 31 years of independence, is trying to survive under constant energy blackmail and pressure from the Russian Federation. Instead, using renewable energy sources, countries will not have to fight for them, because they are local energy resources available to all.

After all, renewable energy sources guarantee the safety and health of society. Neither Ukrainian nor European society knows how many bombs and projectiles hit the territory of wind stations or wind turbines, because it is safe for their lives and health. Wind energy makes society independent not only in the matter of electricity, but also in the matter of decarbonization of other carbon-intensive sectors of the economy, including the transport sector. Hydrogen produced at the expense of the wind and the sun is a real fuel for all types of transport and a tool for the independence of countries from the import of relevant petroleum products.

The plans for the development of renewable energy in post-war Ukraine are ambitious and aimed at increasing the use of renewable energy sources to ensure a sustainable and environmentally friendly energy complex. The development of solar, wind, hydro and biomass energy plays an important role in diversifying the country's energy mix and reducing dependence on energy imports. It is important to continue working on creating favorable conditions for investments in renewable energy, modernization and reconstruction of existing facilities, support for research and innovation, as well as

development of the necessary infrastructure for the effective use of renewable energy sources. Under today's conditions, the Government of Ukraine faces a single task — to preserve those national and international investors in renewable energy sources who have already invested in Ukraine's economy and to provide conditions for their further business activities in the post-war period.

CONCLUSIONS

Established: renewable energy sources are more efficient, ecologically clean and economically profitable than traditional energy sources; the transition to renewable energy sources is important for post-war Ukraine and the world as a whole, as it can help ensure an independent and sustainable energy system; impact of the use of alternative energy sources on the environment; the development of renewable energy in the world in recent decades is an important trend.

Defined: the impact of the use of renewable energy sources on the environment; main directions of renewable energy development; the level of development of renewable energy in the countries of the world; the level of competitiveness of renewable energy; level of development Development of renewable energy in Ukraine.

It is predicted: the energy strategy of Ukraine for the period up to 2035; prospects for the development of renewable energy in Ukraine after the war; recommendations and plans for the development of RES in post-war Ukraine.

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