MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
KYIV NATIONAL ECONOMIC UNIVERSITY
NAMED AFTER VADYM HETMAN

Faculty of International Economics and Management
Department of International Economics

BACHELOR DEGREE **«INTERNATIONAL ECONOMICS»**
FIELD OF KNOWLEDGE **05 Social and behavioral sciences**
SPECIALTY **051 «Economy»**

Form of education full-time

BACHELOR THESIS

Title «Energy policy of the state in the context of economic security (on the example of a particular country) »

By **Tsvyntarna Yuliia**
(Student's name, surname) (Signature)

Academic Supervisor PhD, Professor
(Scientific degree, academic status)

Liudmyla Tsymbal
(Signature) (Name, Surname)

Bachelor Thesis has been approved for defense at Attestation Examination Commission (EC)

Head of the Department of International Economics Doctor of Science, Professor
______________________**Y. Stoliarchuk**
(Signature)

KYIV 2024

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AGREED
Head of the project group (guarantor) of the educational-professional program
________________ Y.Stoliarchuk
(Signature)
________________ 2024

APPROVED
Head of the Department
________________ Y.Stoliarchuk
(Signature)
________________ 2024

INDIVIDUAL TASK
higher education applicant Tsvyntarna Yuliia
Name, Surname
full-time form of education

Bachelor Thesis

Title**: « Energy policy of the state in the context of economic security (on the example of a particular country) »**

The title of the Bachelor's thesis has been approved by the Rector's Order «07» 12. 2023 №2231-ст

Plan of Bachelor Thesis and the terms of its submission to the Academic Supervisor

Chapter 1. Theoretical foundations of the energy policy

Chapter 2. Peculiarities of the development of modern energy policy

Object of research:	Energy policy of Ukraine
Subject of research:	Investigation of energy policy with the objective of assisting the state in attaining a state of relative security and mitigating potential threats.
The purpose of the Thesis:	To consider the concept of energy policy and its role in providing economic security, investigate the structural dynamics in the energy sector, and give recommendations for Ukraine about the ways to mitigate the current challenges, taking France as an example of developed energy security with similar energy mix in Europe.

Specific tasks applicant has to accomplish to meet the objective:

In Chapter 1: Conduct a literature review on the topic of energy policy, its role and theoretical concepts; explore the implementation of energy policy in the structure of economic security; investigate the modern global challenges of the world energy sector and methods of its regulation.

In Chapter 2: Collect statistical data on the structural dynamics of the global energy sector in the last years; analyze the energy policy of the European Union; investigate the development of energy security in the case of France; view the energy policy of Ukraine and propose directions for its improvement.

The task has been set
by the Academic Supervisor _______________ **Liudmyla Tsymbal**
(Signature) *(Name, Surname)*
“11” 01.2024

The task has been given to
Applicant ________________ **Yuliia Tsvyntarna**
(Signature) *(Name, Surname)*
“11” 01.2024

ABSTRACT

The bachelor`s thesis contains 70 pages, 5 tables, 16 figures and a list of references from 134 titles.

The *object* of the research is the energy policy of Ukraine.

The *subject* of the research is the investigation of energy policy with the objective of assisting the state in attaining a state of relative security and mitigating potential threats.

The purpose of the study. The purpose of the thesis is to consider the concept of energy policy and its role in providing economic security, investigate the structural dynamics in the energy sector, and give recommendations for Ukraine about the ways to mitigate the current challenges, taking France as an example of developed energy security with similar energy mix in Europe.

To achieve the goal, the following research tasks are to be solved:

- to investigate the essence and the role of energy policy;
- to determine the role of the energy policy in the structure of economic security;
- to consider the global challenges of the world energy sector and methods of its regulation;
- to view the structural dynamics of global energy sector;
- to analyze the energy policy of the European Union;
- to access the process of energy security development on the example of France;
- to consider Ukraine`s energy policy and formulate directions for its improvement.

The *theoretical, methodological and practical significance* of the results obtained is to study the peculiarities of the European Union`s energy policy in the context of economic security, as well as a separate investigation of France as the closest country with a similar energy mix to formulate directions for improving Ukraine`s energy policy in view of current challenges.

The year of defense: 2024.

Keywords: energy policy, energy security, economic security, renewable energy, fossil fuels, energy sector, energy market regulation

Academic supervisor's review
on the bachelor thesis
by the applicant of Kyiv National Economic University
named after Vadym Hetman
bachelor degree program "International economics"

Tsvyntarna Yuliia
Title **Energy policy of the state in the context of economic security (on the example of a particular country)**

1. Relevance of the research topic is related to the importance of energy policy for the country's economic independence, its weight in maintaining macroeconomic stability. This issue is especially relevant during the war and energy crisis in Ukraine.
2. Positive aspects of the thesis: the paper analyzes the energy policy of the European Union, its structure, conjuncture and development dynamics. The structure of the energy sector of France is determined and the possibilities of its development are characterized, taking into account the proximity of the structure of the energy sector to the Ukrainian one.
3. The author's independent ideas and conclusions, scientific novelty. the author identified the main areas of improvement of Ukraine's energy policy. Based on the analysis of the structure and dynamics of development, opportunities for Ukrainian regeneration in the energy sector and ways of post-war restructuring are determined.
4. Practicality of the conclusions and recommendations. conclusions and recommendations can be used in the formation of a strategy for the development of the energy sector of Ukraine.
5. Negative aspects of the paper: the work could be improved by calculating the efficiency of implementation of the proposed measures, taking into account possible losses in the energy sector.
6. Total result of the master Thesis and its approval for defense at Attestation Examination Commission: The work is performed at a high theoretical level, in accordance with the requirements for qualifying bachelor theses and can be admitted to the defense before the examination board with a total score of 46 points.

Academic Supervisor Doctor of economic sciences, professor

_______________ Liudmyla Tsymbal
(Signature)
"___"_____________ 20____

CONTENTS

INTRODUCTION

Relevance of the topic. There are numerous factors influencing the economy, and energy is one of them. A state`s energy policy is crucial for economic security, as it directly influences the stability, affordability, and reliability of energy supplies. A stable and affordable energy policy helps businesses maintain operations and manage costs effectively, preventing disruptions that could affect entire industries. Addressing supply dependence by diversifying sources and investing in domestic production reduces vulnerability to external factors, enhancing a state`s resilience and economic stability. Access to reliable energy is essential for economic growth, and policies that promote innovation and efficiency can attract businesses and investors, leading to technological advancements and economic development. The energy sector is a significant source of employment, and policies focused on renewable energy can create new opportunities in emerging sectors. Addressing climate change within energy policy is essential, as it mitigates risks and positions the state as a leader in sustainable practices. The importance of energy policy is only gaining momentum now, given external factors, such as the geopolitical situation, and internal factors, such as available capacity.

Purpose. The purpose of the thesis is to consider the concept of energy policy and its role in providing economic security, investigate the structural dynamics in the energy sector, and give recommendations for Ukraine about the ways to mitigate the current challenges, taking France as an example of developed energy security with similar energy mix in Europe.

To achieve the goal, the following research tasks are to be solved:

- to investigate the essence and the role of energy policy;
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- to analyze the energy policy of the European Union;

- to access the process of energy security development on the example of France;
- to consider Ukraine`s energy policy and formulate directions for its improvement.

The *object* of the research is energy policy of Ukraine.

The *subject* of the research is investigation of energy policy with the objective of assisting the state in attaining a state of relative security and mitigating potential threats.

To achieve the objectives, the *methods of research* include analysis of scientific literature, including reports, publications, news, official regulation documents and textbooks, statistical data analysis, comparative analysis.

The *theoretical, methodological and practical significance* of the results obtained is to study the peculiarities of the European Union`s energy policy in the context of economic security, as well as a separate investigation of France as the closest country with a similar energy mix to formulate directions for improving Ukraine`s energy policy in view of current challenges.

CHAPTER 1. THEORETICAL FOUNDATIONS OF THE ENERGY POLICY

1.1. The essence and the role of energy policy

The framework for managing and safeguarding a country`s energy resources is known as its energy policy. However, it is on a very general basis. Undoubtedly, it is essential for energy security and sustainable development in a period of rising energy consumption, environmental awareness, and technology breakthroughs. It includes a number of goals, namely encouraging the use of renewable energy sources, preventing climate change, and guaranteeing dependable and reasonably priced energy access. Knowing energy policy facilitates a country`s ability to balance a wide range of interests and priorities while navigating difficult possibilities and challenges. The shift to cleaner, more sustainable energy systems is accelerated by proactive energy governance, which also improves resilience and stimulates energy innovation. Addressing energy-related concerns and building a more resilient and fair future require a broad understanding of energy policy.

The essence of the term "energy policy" is wide. There are several definitions are mentioned from different perspectives (table 1.1).

Table 1.1 – Perspectives utilized in the definition of the term energy policy

Plane of definition	Explanation
Security and Resilience Perspective	Energy policy refers to "measures aiming to ensure that energy supply and use contribute to the achievement of goals related to energy security, economic growth, and sustainable development." [1]
Governmental Perspective	Government initiatives, plans, and laws together referred to as energy policy are designed to guarantee that affordable, adequate energy is available for both national security and economic growth [2].
Economic Perspective	Energy policy consists of "a set of laws, regulations, incentives, and institutional structures that affect the production, distribution, and consumption of energy." [3]
Environmental Perspective	Energy policy can be defined as "the strategy and actions intended to ensure that energy supply and use meet the social, economic, and environmental goals of society, while minimizing negative impacts." [4]

Source: based on [1; 2; 3; 4]

Generally, energy policy pertains to the governmental or organizational choices, strategies, and initiatives directed towards securing sufficient energy supply, optimizing distribution efficiency, and fostering sustainable utilization of energy resources. The specific objectives of energy policy can vary across countries or organizations, but commonly encompass endeavours to enhance energy security, diminish reliance on oil imports, advocate for renewable energy sources, mitigate greenhouse gas emissions, and guarantee accessible and dependable energy for consumers.

In this case, it is obvious that subjects are government, industry, consumers, regulators and civil society [5]. The government sets the regulatory framework, defines objectives, and allocates resources for the energy sector. Energy companies and stakeholders in the energy industry are directly involved in energy production, distribution, and investment decisions. Individuals, businesses, and communities use energy and are engaged in this chain. Independent regulatory bodies or agencies oversee the energy sector and enforce compliance with energy policies and regulations. Non-governmental organizations, advocacy groups, and community organizations can influence energy policy through public engagement, raising awareness, and advocating for sustainable energy practices.

On the other hand, energy resources, energy infrastructure, energy efficiency, energy security and environmental impact play the role of objects [5]. Energy resources include various energy sources such as fossil fuels, renewable energy, nuclear energy, etc. and the policy aims to regulate the exploration, extraction, and utilization of these resources. Energy infrastructure refers to the physical structures and facilities involved in the generation, transmission, and distribution of energy. Policies focus on developing and maintaining efficient infrastructure to ensure reliable energy supply. Besides, policies target improving the efficiency of energy use in various sectors to reduce waste and enhance sustainability. Energy security is a key objective of energy policy to mitigate risks associated with supply disruptions. And remembering about environmental consequences, energy policies aim to promote cleaner technologies and reduce emissions.

Thus, the attributes of energy policy are legislation, international treaties, incentives to investment, guidelines for energy conservation, taxation, and other public policy techniques.

Proceeding from it, the goals that energy policy instruments are intended to achieve are known as energy policy objectives. There are several objectives [6] for the policy, such as:

- energy security;
- the affordability and accessibility of energy resources for low-income populations;
- conservation of energy resources;
- research into energy supply technologies;
- economic efficiency in the energy supply;
- efficiency in energy use;
- diversity in the sources of energy supply;
- coherence between energy policy objectives and other policy objectives, particularly environmental policy objectives.

As can be seen, energy efficiency is one of the crucial elements in terms of defining the degree of successfulness of energy policy [7]. It is a complex phenomenon that has an impact on society, the environment, and the economy of a nation. Fundamentally, it promotes economic growth by saving companies money, increasing productivity, and enhancing their ability to compete internationally. In addition, it plays a key role in promoting sustainability, reducing greenhouse gas emissions, and thwarting climate change.

National energy efficiency programs are also essential for guaranteeing energy security, lowering reliance on imported resources, and bolstering supply chain resilience. Through portfolio diversification and consumption optimization, countries can improve their independence and stability. Energy efficiency reduces waste and lessens the environmental effect of energy production and extraction, which together promote resource conservation. This careful management promotes sustainability by preserving important resources for next generations.

Furthermore, through enhancing air quality and reducing the health risks linked to pollution, energy efficiency initiatives provide noticeable benefits for public health. Countries may encourage innovation, support sustainable practices, and speed up the shift to a low-carbon economy by enacting legislative frameworks and governmental action. International agreements on climate action and broad sustainability goals are in line with national energy efficiency initiatives, which have a worldwide impact. Countries can ensure that the earth has a more sustainable future by exhibiting leadership in environmental management [7].

Additionally, many different energy policies are developed and put into effect by nations worldwide, mostly in response to their own national interests [8]. Some nations might be interested in decarbonization, system dependability, resource diversification, potential for technological exports, affordability, or availability to power, for instance. In other words, a country's energy policy is determined by its concerns and interests.

One more necessary consideration will be about policy fundamentals [9], which also influence the policy objectives. One of such is “Energy Trilemma” (fig. 1.1).

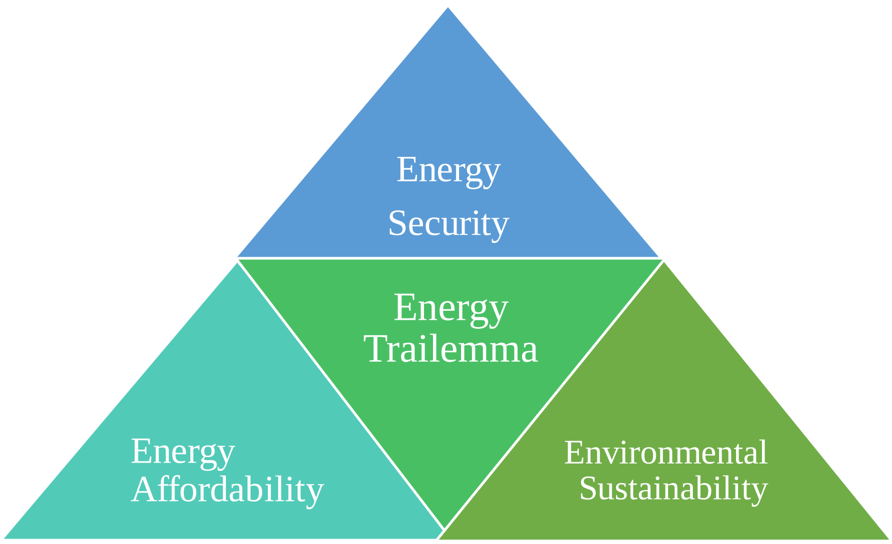

Figure 1.1 – The “Energy Trilemma”
Source: based on [9]

Energy security means that consumers will always have access to energy (heat, for example, or electricity) in spite of different obstacles. These hazards include both short-term ones, like blackouts, and longer-term ones, like interruptions brought on by geopolitical wars that impact the oil markets. The cost of energy, taking into account both average cost and volatility, is referred to as affordability. It places a strong emphasis on making sure that energy is affordable and available to customers, which will advance social and economic justice. “Energy equity”, which includes both affordable and accessible energy, is relevant in some situations, particularly in developing nations. Beyond just financial concerns, sustainability requires factors that have an impact on the environment, such as carbon dioxide emissions and pollution of the air, land, and water. The significance of using energy resources in a way that reduces environmental damage, fosters long-term ecological health, and slows down climate change is highlighted by this feature. As a result, the optimal energy policy entails policy utility, which equals to the sum of the abovementioned elements. However, the trilemma alone can lead to “Utilitarian” solutions that are not acceptable in democracies, which is proved by another research [10].

Energy trilemma – energy security, affordability, and environmental sustainability – as well as related policies, have an impact on energy systems. This connection shapes geopolitics and promotes sustainable economic development on a global scale by affecting the competitiveness and prosperity of nations. In light of this, this study employs the Markov-switching panel vector autoregressive model to close the knowledge gap by investigating the ways in which large energy users' energy trilemma is impacted by complexity-based policies, such as sharing the economy and economic complexity, and resource-portfolio-decision policies, such as switching to a “non-carbon-based fuel portfolio” and energy prices. The results showed that achieving energy security through energy-related policy is more difficult than for the others. Therefore, for major energy consumers, the opportunity costs of the measures related to energy security are substantial. It is seen as one of the disadvantages of meeting the energy needs for both ongoing and upcoming operations that enhance nations' capacity to react to interruptions. In addition, the proposed policies result in the formation of an overall a-cyclical pattern of energy trilemma dimensions, which lowers risks and increases the resilience of the panel's energy systems. As a result, when shocks occur in energy systems, a dynamic interaction between energy policies is proposed for the balanced growth of the energy trilemma.

The content and mechanism of energy policy implementation should take into account such nuances. As previously was pointed out, the realization of energy policy [11] involves a series of mechanisms and processes aimed at implementing strategies and goals set by governments or relevant authorities in the energy sector. Key mechanisms include policy formulation, legislation and regulation, resource allocation, monitoring and evaluation, stakeholder engagement, international cooperation, and technology deployment. Policy formulation involves developing goals and strategies, while legislation and regulation provide a legal framework. Resource allocation involves funding and incentives, monitoring tracks progress, stakeholder engagement ensures inclusivity, international cooperation fosters collaboration, and technology deployment drives innovation. By effectively utilizing these mechanisms, policymakers can work towards achieving sustainable and secure energy futures.

Governments is one of the actors, who have connection to the realization mechanisms. They implement energy policies to influence both the supply and demand for energy [12]. These measures include the ways in which governments address disruptions in the energy supply as well as their initiatives to affect economic growth and energy consumption. Hence, choices about the production and use of energy are shaped by policies [3]. Different kinds of policy instruments, like building energy regulations, tax credits, and air quality requirements, are used by institutions ranging from local governments to international trade organizations - this is just a case to affect energy-related behaviours. However, there are also tendency to decentralization in energy governance [13]. The process consists of splitting decision-making power and duties among diverse governmental tiers, encompassing both local and regional levels. Through active policy development, customized solution development, flexibility and innovation promotion, community engagement, increased resilience and efficiency, and multi-level governance, local governments and communities can take charge of energy policy. The example of technologies, applied to it, is blockchain ones. It seeks to decentralize energy networks, securing transactions and potentially making electricity more accessible [14].

Decentralization presents both advantages and disadvantages. The former includes capacity building and maintaining consistency across governance levels, while the latter is associated with benefits such as local empowerment and innovation. To accomplish sustainable and efficient energy policy, a harmonious blend of local autonomy and central assistance, capacity building, and coordination are necessary to strike the correct balance between centralization and decentralization.

To summarise, an energy policy is a collection of choices, plans, and actions meant to ensure a supply of energy, maximize the effectiveness of its distribution, and encourage the sustainable use of energy. Government, business, consumers, regulators, and civil society are all involved. Energy security, cost-effectiveness, accessibility, preservation, economic efficiency, energy utilization, diversity, and coherence among policy objectives are among the goals of energy policy. The main elements of energy policy include infrastructure, security, efficiency, environmental effect, and energy resources. Governments establish the rules, but decisions about the production, delivery, and investment of energy are made by industry, consumers, and regulatory agencies. Through public involvement and advocacy, non-governmental organizations, advocacy groups, and community organizations can have an impact on energy policy. One of the fundamentals, impacting energy systems are the energy trilemma, which includes affordability, environmental sustainability, and energy security. The findings indicate that major energy consumers have greater difficulty establishing energy security through energy-related policies, which results in significant opportunity costs. The following subtleties should be taken into account while implementing policies: developing policies, passing laws, allocating resources, keeping an eye on things, involving stakeholders, working with other countries, and utilizing technology.

1.2. The energy policy in the structure of economic security

In essence, economic security is a complex multifactorial category that characterizes the ability of the national economy to expand self-reproduction in order to meet the needs of its own population and the state at a certain level, to counteract the destabilizing effects of factors that threaten the normal development of the country, and to ensure the competitiveness of the national economy in the global economic system [15]. Key components of economic security (fig. 1.2) of the state are financial, external economic, macroeconomic, investment and innovation, information, scientific and technological, and energy security [16; 17].

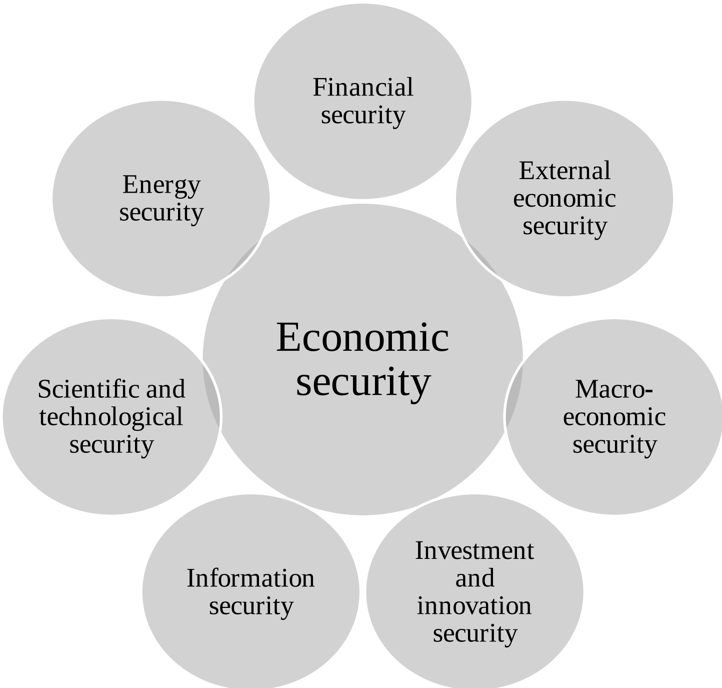

Figure 1.2 – The components of economic security
Source: based on [16; 17]

Financial security refers to the situation of the financial system, wherein effective financial growth is guaranteed and crisis development is prohibited [18]. In order to be considered financially secure, a country must have a stable national currency exchange rate, establish an effective banking system, guarantee the stability of its budget, and stay away from financial crises and manipulations. A state's capacity to maintain its economic viability and foster economic growth is largely dependent on its financial stability [19]. A state's foreign policy must include external economic security in order to maintain its foreign economic ties, reduce its dependence on foreign markets, and increase domestic competitiveness in global markets. It offers defence against unfair competition and discrimination from overseas and guarantees stability and dependability in the increasingly interconnected global economy. Control over cash flows, trade, foreign investments, the creation of economic sanctions, and systems for managing international economic relations are important elements [20]. Economic security is closely linked to macroeconomic security, which focuses on a state's ability to prevent inflation, GDP contraction, unemployment, balance budgetary expenses, and increase revenue. It includes maintaining price stability, controlling monetary policy, managing exchange rates, implementing balanced fiscal and budgetary policies, reducing unemployment, and raising incomes. It also includes reducing external economy risks like import reliance, external demand shifts, and global market rivalry [21; 22].

In order to ensure economic growth and foster new ventures, investment and innovation security are essential for societal progress. Encouraging international investment, defending investor rights, fostering national innovation potential, and fostering a good investment climate are all part of it. Importantly, in order to foster innovative businesses and high-tech industries, the state must effectively regulate and promote entrepreneurial activity. Facilitating innovative infrastructure and competitiveness requires these actions [23]. For a state to be strong, information security is essential because it shields its data from dangers like theft, unauthorized access, and cyberattacks. Protecting disinformation, private information, and state and business secrets are all part of it. Creating an infrastructure for communication and information and guaranteeing accessibility for all facets of society are also part of it. The creation of this kind of infrastructure is necessary to protect the economy and national security from potential threats [24]. One more component to point out, a state's economic security is greatly influenced by its scientific and technological security, which focuses on the advancement of research and technology, their use in production, and the protection of intellectual property. It is particularly crucial for nations competing in global markets and high-tech businesses. The state supports the advancement of science, establishes the framework for commercialization, encourages creative businesses and start-ups, and safeguards intellectual property [25]. And eventually energy security, which means the ability of a nation or region to ensure the uninterrupted availability of energy sources at affordable prices. While energy access has always been important, energy security goes beyond simply having energy available. It focuses on the reliability and stability of that access. Different countries and researchers may define energy security based on their specific needs and contexts. This can lead to a variety of definitions and approaches. Energy security considers the vulnerability of energy systems to various threats like price fluctuations, supply disruptions, or political instability [26].

As was mentioned previously, one of the important goals of energy policy is energy security, which is the part of economic security respectively. Energy is the foundation of the economy and a critical component of both economic expansion and the fight against poverty. The role of energy in economic growth is a topic of significant importance. Energy is considered a crucial input for production and a necessary requirement for economic and social development. It is also seen as potentially a limiting factor to economic growth. The relationship between energy resources, energy policy, and economic development is heavily influenced by the type of political governance in place. The mainstream theory of economic growth, which explains the economy as a closed system where output is produced by inputs of labour and capital, initially paid little attention to the role of energy. However, recent studies have incorporated energy as an explicit factor of production, linking growth performance to profit incentives and the rate of growth of real energy prices. This implies that continuously rising real energy prices will tend to slow down economic growth [27].

As one more thing to mention, energy scarcity also imposes substantial and varied limitations on economic progress. First, a lack of energy poses a serious barrier to economic expansion by reducing the potential growth of economies that depend on an adequate supply of energy. Furthermore, ecologists limit the possibility for capital and resource substitution as well as technical advancement by claiming that these mechanisms provide only partial respite from resource scarcity. Additionally, as technological developments frequently depend on higher energy consumption, energy scarcity has a considerable impact on productivity and economic dynamics. Biophysical economic models emphasize that energy is a vital component of production and the engine of economic growth. Energy is the primary source of value production and directs the actions of capital and labour, highlighting the significant impact that energy scarcity may have on economic systems [28]. That is why the constant flow of energy in abundance is equal to fuel for the bloodstream of the country`s livelihood.

Energy sources which are utilized to generate energy and support economic growth, can be different. There are non-renewable, renewable and secondary energy sources [29]. The sources of non-renewable energy are those that will deplete or cannot be regenerated within our lifetimes, or even in a very long period. It includes natural gas, petroleum, coal, oil, and uranium. In contrast to this, power produced from naturally replenishing resources is known as renewable energy, and comprises hydropower, solar, wind, geothermal and biofuels [30; 31]. The last category of secondary energy sources means all energy derived from changing original energy, especially thermally generated electricity [32], and hydrogen, which is a clean-burning fuel that only emits water vapor as a by-product when mixed with oxygen in a fuel cell to produce heat and power [29].

The energy sector is undergoing a transformation driven by innovation [14]. Shifting to renewable energy not only aids in environmental preservation by minimizing harmful emissions but also taps into constant sources like the sun, wind, and geothermal reserves. Advancements in solar power technology, with more efficient photovoltaic cells, and the evolution of wind energy through larger turbines, are improving energy conversion rates even in low-wind conditions. IoT-connected renewable sources allow remote monitoring, optimizing energy production and distribution. However, a lack of cost-effective energy storage solutions impedes stable pricing. As for more traditional source usage, the central architecture of electric power systems faces challenges which the Internet of Energy (IoE) addresses by offering greater efficiency. Smart meters enable real-time energy usage monitoring, while IoT-based predictive maintenance prevents downtime in power plants and grids. The storage of energy is also not the last topic in the agenda. Lithium-ion batteries and flow batteries offer promising storage solutions, alongside kinetic energy storage systems like flywheels for grid stabilization. The ways to produce the energy, such as Distributed Energy Resources (DERs), are revolutionizing the energy landscape by empowering consumers to generate electricity or heat locally and contribute surplus power to the grid. Technologies like solar panels, small-scale wind turbines, and battery storage systems enable efficient energy generation, storage, and distribution, reducing costs and enhancing utilization efficiency.

Another part of trends, Demand Side Management (DSM) strategies, including smart grid technologies and energy-efficient appliances, further optimize energy systems by balancing supply and demand, thus promoting sustainability. Quantum computing, Vehicle-to-Grid (V2G) and Power-to-X (PtX) are responsible for power optimization. The first one is advancing energy solutions by optimizing infrastructure development, electricity generation planning, and material discovery for renewables. V2G technology transforms electric vehicles into grid assets, enhancing stability and efficiency. And the last one, PtX technologies offer promising avenues for reducing emissions and improving energy efficiency through innovative conversion processes. These advancements collectively drive towards a more sustainable and diversified energy future, fostering resilience and environmental stewardship [14]. Summarizing, the resources can be converted into energy in many ways that is beneficial for the bunch of purposes, such as heating, manufacturing, transportation, and the production of electricity, among many other facets of contemporary life. Energy sources are seen as essential components of production from an economic standpoint, and changes in their cost and availability can have a big influence on the expansion and prosperity of the economy.

And, after all, the global energy market is influenced by diverse energy sources. It has undergone significant transformations globally, with various countries implementing reforms to transition from traditional monopoly structures to competitive markets. These reforms aim to enhance efficiency, promote competition, and improve service quality for consumers. One key aspect of energy markets is the establishment of electricity capacity markets to ensure product adequacy and reliable energy supply [33]. While some argue against the necessity of capacity markets in open markets, others believe they play a crucial role in ensuring adequate production capacity, mitigating market power issues, and ultimately benefiting consumers. In today's energy market, market participants offer energy supply suggestions and prices for each hour of the next day, allowing for the coordination of production and demand forecasting. This process helps in meeting projected demand efficiently and managing volatile prices in real-time.

Despite the challenges posed by transitioning from traditional to restructured energy market systems, careful planning and adherence to market principles are essential for overcoming obstacles and advancing market goals [33]. In conclusion, the energy market is undergoing a profound transformation towards greater competitiveness and consumer empowerment, driven by innovation and sustainability goals. Smart technologies, renewable energy sources, and efficient market mechanisms are reshaping the global energy landscape, aiming to maximize social welfare while reducing environmental impact. The rise of novel energy markets, exemplified by ramp markets emphasizing clean and affordable sources like solar and wind power, underscores the industry's commitment to sustainable practices and investment in cutting-edge technologies. This evolution heralds a future where energy markets are more responsive, resilient, and aligned with the needs of both consumers and the planet, marking a significant step towards a more sustainable energy future. When considering the dynamics of the energy market as a whole, the importance of energy security becomes clear because it not only promotes stability and diversification within these markets but also manages possible conflicts, like the use of renewable energy sources, thereby directing the course towards a more sustainable and secure energy future. Secure and reliable energy supplies foster stable energy markets. Price fluctuations and supply disruptions caused by geopolitical issues or resource scarcity can be mitigated [26]. This stability encourages investment and long-term planning within the market. Besides, a focus on energy security can lead to diversification of energy sources and suppliers. Countries reliant on a single source or fuel type become vulnerable to price hikes or supply interruptions. This encourages exploration of renewables, domestic production, and trade with multiple partners [26]. While energy security often pushes for increased use of domestic resources, a recent study suggests it might discourage some countries from adopting renewables if they already have secure traditional fuel supplies [34]. However, the focus on energy security can also be a driver for innovation in clean energy technologies, leading to a more secure and sustainable future. Thus, a prerequisite to attaining sustained economic development is guaranteeing energy security.

Following written above, energy security covers a wide range of factors, including the constant availability of energy in different forms, at reasonable costs, and in appropriate amounts [35]. It indicates a lower degree of susceptibility to abrupt or protracted disruptions in imports. It also refers to the availability of resources, both domestic and foreign, at fair rates to supply the ever-rising demand for energy. Energy security is significantly impacted by issues related to the environment, deregulation and liberalization, and the growing power of market forces. These forces have affected the historically important role of government and brought new dimensions to energy security. So, as the bottom line, there are several evidence of the relationships between economic and energy security:

- unstable energy prices due to supply disruptions or geopolitical tensions can disrupt businesses and hinder economic growth; energy security, with its focus on reliable and affordable energy sources, fosters a stable economic environment conducive to investment and long-term planning [36];
- dependence on volatile energy imports exposes an economy to external shocks; energy security that emphasizes diversification and domestic production reduces this vulnerability, leading to more resilient economic performance [35];
- reliable and affordable energy is crucial for powering industries and manufacturing processes; energy insecurity can lead to production slowdowns, impacting export competitiveness and overall economic output [37];
- energy security achieved through promoting renewable energy sources can attract investments in clean technologies; this fosters innovation and creates new economic opportunities in the green energy sector [38].

So, energy security is a key objective of energy policy because it is the backbone of the economy and a critical component of economic growth and poverty reduction. Energy shortages can limit economic progress by reducing growth potential, limiting capital and resource substitution, and affecting productivity and economic dynamics. The diversification of the energy fuels pushes the sector to continuous improvements. Numerous innovations in the energy sector are aimed at improving the efficiency of resource use in the areas of distribution and optimization. Thus, economic and energy security are interconnected, with unstable energy prices hindering growth and promoting stable economic environments. Energy security, focusing on reliable and affordable energy sources, reduces vulnerability to external shocks and promotes resilience. Dependence on volatile energy imports exposes an economy to external shocks, while renewable energy sources attract investments in clean technologies, fostering innovation and creating new economic opportunities in the green energy sector.

1.3. Modern global challenges of the world energy sector and methods of regulation

The global energy sector has seen significant changes in the last few years, bringing in new ideas and patterns that are changing the course of fuel and energy development all over the world. These changes are not only impacting national plans and programs, but they are also changing the fundamental principles of global energy governance. Numerous issues that have emerged since the start of the XXI century have come to define the present trends in the growth of the world energy market.

Among the main challenges in the global energy market at the beginning of XXI century are:

- depletion of the non-renewable resources;
- increased dependence on energy imports;
- soaring and unpredictable prices for oil, natural gas and coal;
- political instability in the resource-rich regions;
- failure in the maintenance of security from nuclear energy utilization;
- lack of investments in the development of new resources and building infrastructure for efficient circulation of existing ones;
- continuous capturing of climate changes in upper lines in global risks charts – both long-term and short-term.

The extraction of fossil fuels and other limited energy sources results in the depletion of non-renewable resources. The problem is that these resources used to look limitless. The depletion of non-renewable resources is primarily driven by three main factors – overconsumption, extraction method issue, and lack of alternatives [39]. Over the past few decades, as economies, populations, and energy needs have all grown significantly, so too has our reliance on energy sources. Furthermore, oil, gas, and other non-renewable resources have received the majority of our attention [40]. Over the past 200 years, many different resources have emerged (fig. 1.3).

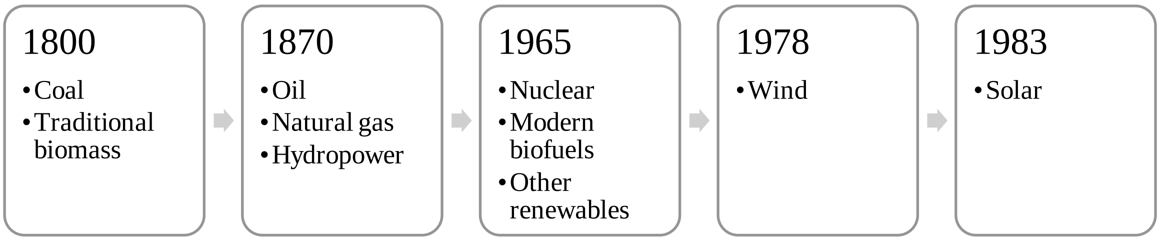

Figure 1.3 – The timeline of new energy source emergence in global consumption for the period from 1800 till 2022
Sources: based on [41]

As this shift was made not so quickly, the consumption of more recent resources are still in the process of implementation in active usage, comparing with already known, which are actively used and applied by a great number of systems (fig. 1.4).

Until the mid-19th century, traditional biomass – the burning of solid fuels such as wood, crop waste, or charcoal – was the dominant source of energy used across the world. With the Industrial Revolution came the staggering rise of coal. By the turn of the 20th century, around half of the world’s energy came from coal; and half still came from biomass. The globe began to use a wider variety of sources during the 1900s. Petroleum, gas, and then hydropower. The inclusion of nuclear energy did not occur until the 1960s. Solar and wind power, which are frequently referred to as “modern renewables”, were added considerably later, in the 1980s.This 200-year history of global energy use highlights how slowly energy shifts have historically occurred. It has taken several decades, if not a century, for one energy source to overtake others. While historically accurate, there are indications that this is beginning to change. Recent energy changes have occasionally occurred swiftly.

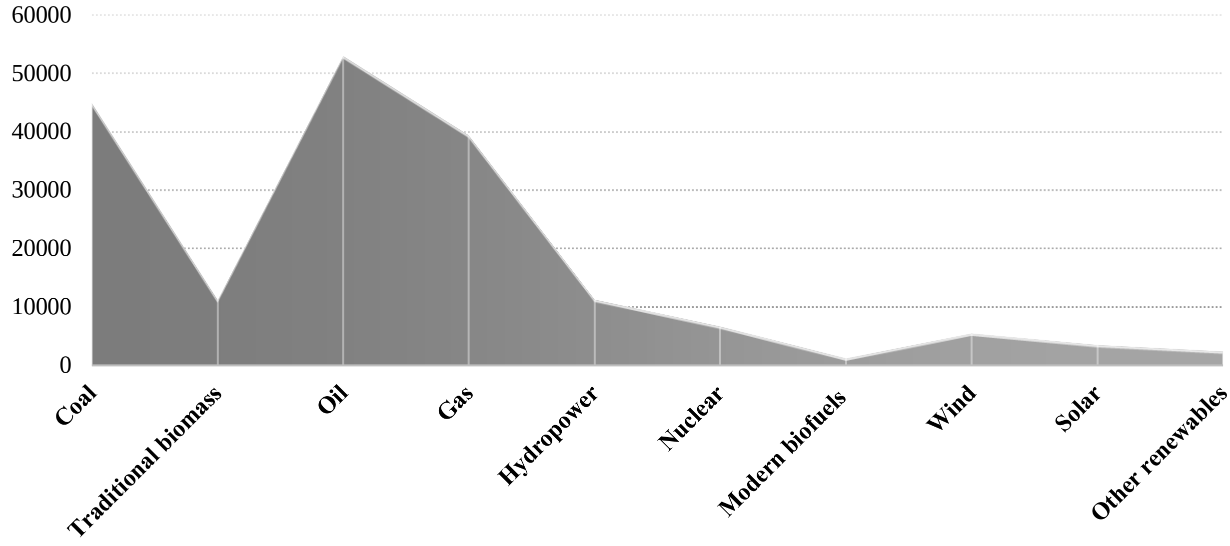

Figure 1.4 – The consumption of different energy sources as of 2022, in TWh (terawatt-hours)
Source: based on [41]

Moving forward in factors of resources depletion, many extraction techniques, such as mountaintop removal mining and fracking, are not only environmentally destructive but also economically costly. These methods exacerbate resource depletion and leave long-term environmental scars. And, renewable energy sources like wind and solar power are increasing, but still their reliance on non-renewable resources will persist until more advanced technologies are adopted. Consequently, there are major negative effects on the economy, society, and environment when non-renewable resources are depleted. In terms of the economy, the depletion of non-renewable resources can result in shortages and price hikes. Socially, it might result in lost jobs and unstable economies in areas where resources are scarce. It may have negative environmental effects like as pollution, habitat destruction, and climate change. In order to achieve sustainable growth, the depletion of non-renewable resources is a difficult issue that needs to be carefully managed [39].

As mentioned above, renewable sources are not on the level, when it can fully cover troubles or inefficiencies, or costs caused by non-renewable, the issue of energy import dependence is in force. Security of the energy supply and energy independence are two of the most important components of economic development. In order to attain appropriate levels of energy security, nations had to deal with a number of short-term challenges, including those pertaining to dependency rates, energy prices and volatility, scarcity of energy sources, and environmental protection; long-term challenges included the political stability of supplier nations, investments, and policies to support domestic renewable energy sources. As a result, due to the sensitive recent geopolitical and military issues, energy reliance has drawn more attention in the past year [42]. Thus, there already three challenges are connected – dependence on energy imports, fluctuations of prices and political instability in resources-rich countries. The recent increase in the price of energy commodities has boosted and will continue to increase energy affordability. Additionally, a further increase in commodity trading prices for energy items (mostly gas) is anticipated as a result of the recent energy crisis, which was brought on by the war in Ukraine and the subsequent implementation of international sanctions against Russia. The impact of energy poverty on households will be exacerbated by these price hikes, which will be reflected, among other things, in retail pricing [42].

For instance, in the EU, imports from Russia account for almost a half of the natural gas needs before the war [43]. As a result, increasing gas prices in the EU hubs directly and immediately affect wholesale electricity rates, which are based on the gas-fired power plants' short-term marginal costs. More vulnerable people will be affected by the gas price hike, particularly in the wake of the COVID-19-related economic downturn, but households who were not previously at risk will probably also be significantly impacted. Furthermore, the anticipated decrease in gas supplies is rearranging the generation basket, raising the prospect that several European nations would soon restart coal-fired power facilities in order to supply families' and companies' electricity needs. Naturally, this will affect how quickly European nations switch to cleaner energy. According to recent studies, increasing the generation of renewable energy can dramatically lower energy poverty in European nations. By increasing energy efficiency, renewable energy both directly reduces and significantly inhibits global energy poverty[42].

The conflict in Ukraine has caused a significant impact on energy prices and market stability, particularly in the euro area [44]. With concerns over potential disruptions to energy supplies and stricter sanctions on Russian energy, prices have been volatile. Euro area energy markets, which heavily relied on Russian supplies before the conflict, have been especially affected. Following Russia's invasion of Ukraine, oil, coal, and gas prices surged, with gas prices leading to increased wholesale electricity prices in the euro area [44]. Despite some moderation, prices remain elevated, with oil and coal prices still significantly higher than pre-invasion levels, while gas prices have slightly decreased. Recent increases in oil prices are attributed to the EU's decision to embargo most Russian oil imports and increased global demand due to China's COVID-19 restrictions easing. Wholesale electricity prices have also risen and remained volatile, influenced by policy measures responding to price hikes. Overall, the war in Ukraine has caused significant disruptions and uncertainties in euro area energy markets, impacting both commodity and consumer prices.

Shifting the attention to nuclear energy utilization, it still cannot be called like a safe way for energy generation. With the advent of commercial nuclear power plants as an alternative to fossil fuels in the 1950s, the focus of global industrialization has switched towards renewable energy sources like solar and wind power [45]. Nuclear power projects saw a surge in funding as a result of the energy crisis of the 1970s; the majority of reactors were constructed between 1970 and 1985. At the moment, 439 nuclear power plants are in service in 32 nations, and 55 more reactors are being built. This means that nuclear energy supplies 10% of the world's energy needs. 13 nations, led by the US, China, and France, produced at least 25% of their electricity through nuclear power in 2020 [45]. What are advantages and disadvantages? Among the positive sides of it – clean and emission-free, fast decarbonization, environmentally sustainable, safer than fossil fuels, high reliable and efficient fuel usage [45]. Nuclear power plants don't produce greenhouse gases during electricity generation. As an example of reduced carbon emissions serves France [46]. According to the European Commission, nuclear power is recognized as a green energy source. Nuclear waste poses less risk to public health compared to air pollution from fossil fuels. Additionally, nuclear plants boast the highest capacity factor among energy sources, requiring less maintenance and offering consistent power output. And lastly, up to 90% of used nuclear fuel can be reprocessed and reused in reactors [47].

However, the utilization of nuclear energy has its drawbacks. The first concern is nuclear weapon proliferation. The history of atomic bombs and current conflicts raise concerns that nuclear technology could be misused. The last year has seen fraught relations among the world's great powers, who are engaged in nuclear modernization programs and the nuclear arms control regime continues to collapse. Concerns remain about Russia's possible use of nuclear weapons in the conflict against Ukraine [48]. In February 2023, Russian President Vladimir Putin announced his decision to suspend the New Strategic Arms Reduction Treaty (New START), which will decrease confidence in Russia's nuclear forces over time. In March 2023, Putin announced the deployment of tactical nuclear weapons in Belarus, but it remains unclear if any weapons have been moved. Russia retains around 2,000 tactical nuclear weapons for regional conflicts. In October 2023, Russia's Duma voted to withdraw Moscow's ratification of the Comprehensive Nuclear Test Ban Treaty, leading to increased activity at nuclear test sites in Russia and China. The US and China are on the verge of a major nuclear arms race, with debates about whether the US nuclear arsenal may need to increase over the next decade to counter China's expansion. The 2024 US presidential election raises the issue of the immense nuclear power vested in US presidents [48]. The next problem lays in radioactive waste disposal. Highly radioactive waste, lasting thousands of years, poses a long-term storage and safety challenge. Over 90,000 metric tons of radioactive waste, including over a quarter million metric tons in the US, is stored near nuclear power plants and weapons production facilities [49]. This waste poses serious risks to human health and the environment, and is aging. Researchers are studying the degradation of materials like steel and glass for long-term nuclear waste storage containers to protect people and the environment from waste leakages. Accident risk is one more issue to consider. Accidents like Fukushima can cause widespread environmental damage, displacement, and economic loss. The 2011 Fukushima nuclear disaster led to the release of radioactive material into the atmosphere, dispersed locally, regionally, and globally due to weather [50]. The north-west of the plant received high levels of contamination, particularly in the prefecture of Fukushima. Radioactive iodine, tellurium, and caesium were particularly relevant for environmental and human contamination. Iodine, with a half-life of up to eight days, disappeared from the environment after three months, while caesium, with a half-life of around 30 years, remains in the environment for a long time. Foodstuffs were contaminated by radioactive material deposited on leaves or agricultural produce, and water was also contaminated. Contaminated water was pumped out of the reactor, cleaned, and stored in tanks on the site. Lastly, building nuclear plants is expensive and time-consuming, hindering rapid carbon reduction efforts. The factors which make contribution to high costs are cost inputs for plant construction, rising labor costs, constant changes in regulation, quality assurance and control requirements [51]. The capital expenses of nuclear power include site preparation, engineering, manufacture, construction, commissioning, and finance. Nuclear power is an expensive energy source. The annual cost of repaying the initial investment is significantly more than the annual running costs, and these costs are higher than those of energy sources like coal and natural gas. It is challenging for nuclear power plants to compete with alternative energy sources in the US, especially natural gas, due to their high construction costs. Generally speaking, the US has a greater discount rate for nuclear construction projects than many other nations, particularly those where the government partially subsidizes the nuclear industry – about 12.5% [52]. The global economic feasibility of nuclear power is largely determined by this difference in discount rates. Government-subsidized capital expenses contribute to the explanation of why the nuclear power industry in China and Russia is more vibrant than in the US. China is predicted to produce roughly three times as much electricity from nuclear sources by 2026 – about 100 gigawatts [52].

Following the topic about expenses, the lack of investments in the development of new resources and building infrastructure for efficient circulation of existing ones also make an issue. The global energy transition is rapidly expanding, but the infrastructure required for renewable energy deployment is lagging. Insufficient grid capacity to integrate renewable energy with demand centers is threatening progress and stifling future investment. The lack of grid capacity has significant implications for international climate and energy goals, as countries need to add or refurbish over 80 million kilometers of grid infrastructure by 2040 to fulfill their national climate commitments [53]. Investment in electricity networks is a challenge for advanced, emerging, and developing economies

(EMDEs). In mature markets, electric vehicles, heating, and cooling systems, previously powered by fossil fuels, take greater market shares and require access to already stretched systems. At least 1,500 gigawatts of wind and solar PV (power voltaic) projects [54] in advanced stages are backlogged and waiting in grid connection queues in markets like the US and Europe. In developing economies, outages caused by ailing or outdated grids are a constant concern affecting critical systems. However, investment in grids has been declining in EMDEs, where grid upgrades and expansion could yield significant financial, environmental, and social returns. Meeting national climate pledges would require a five-times increase in grid investments [53].

The last but not the least point in the challenges is concerning climate changes. The Human activities, such as fossil fuel burning, deforestation, land use changes, industrial processes, and unsustainable agriculture, emit greenhouse gases, leading to the degradation of Earth's climate. This phenomenon, commonly referred to as Climate Change or Global Warming, is predominantly driven by human actions, including the combustion of fossil fuels, deforestation, and industrial processes [55]. Notably, the energy sector stands out as the largest contributor to greenhouse gas emissions, significantly impacting climate change [56]. Climate change can therefore affect infrastructure, cause disruptions to energy networks, and endanger public safety. The Global Risks Report 2024 outlines potential risks in the next decade due to rapid technological advancements, economic uncertainty, global warming, and conflict, suggesting that even minor disruptions could threaten resilience [57].

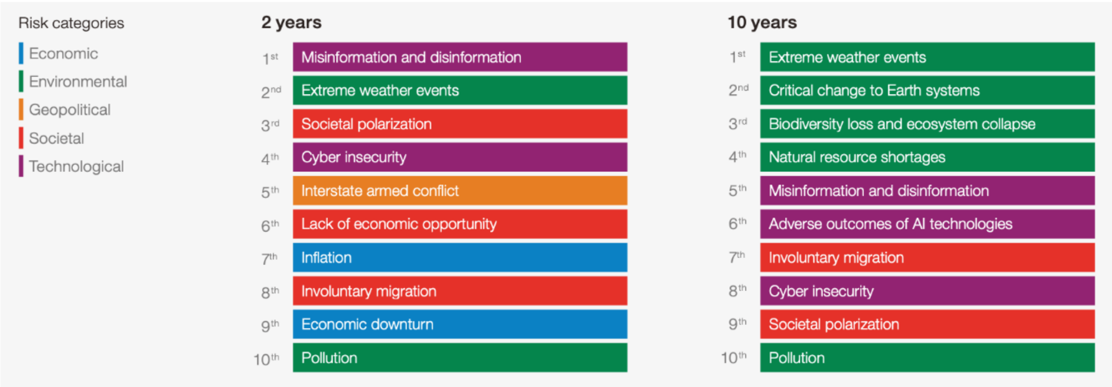

Figure 1.5 – Global risks ranked by severity over the short and long term
Source: based on [57]

And, taking into account global risks ranked by severity (fig. 1.5), environmental risk category takes 2 out of 10 places in short-term period, and 5 out of 10 places in the long-term one. Thus, it can be concluded that climate issue is still among most of the challenges, introduced in open sources and cannot be missed.

As challenges require constant attention and the seeking of resolving methods, it is necessary to find out the process of energy market management. It can be conducted by both – government and external actors, introduced by international organizations. As for the methods of regulation at the state level, there are several different approaches to their classification. Forms and methods of commodity market regulation are classified by forms of influence and means of influence [58]. The forms include direct and indirect, and the means include legal, administrative, economic and propaganda. In its turn, the mechanism of state regulation in the field of renewable energy development offers a division by methods - direct and indirect, and means - economic, financial, legal and institutional, and instruments - price regulation and tax regulation and incentives [59]. For the energy market regulation, something united are to be build (fig. 1.6).

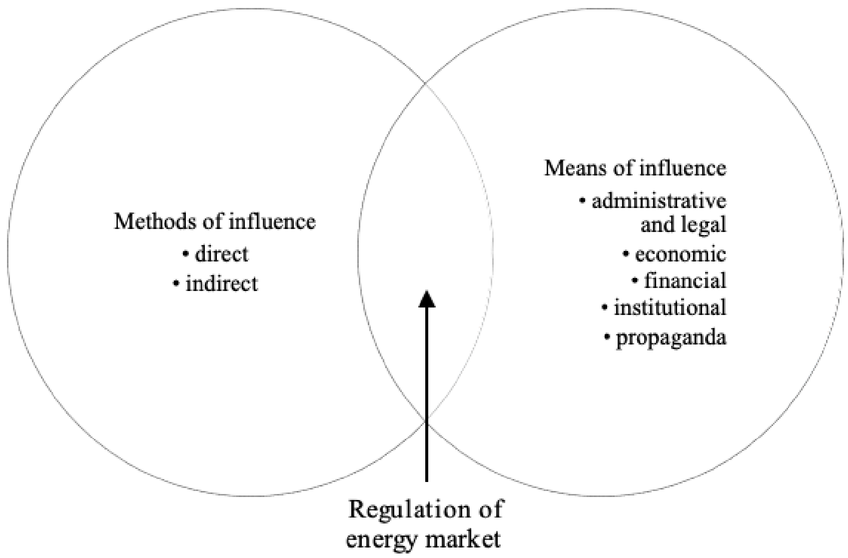

Figure 1.6 – Organization of energy market regulation on governmental level
Source: systematized by the author

Direct methods directly affect how market participants operate. Administrative and legal tools that control the operations of businesses and other economic instruments of direct influence are used to exert this kind of direct influence. These latter seek to control the economy's growth pace and structure, as well as the amount of output and non-production consumption, the scope of the public sector's operations, and other factors. All things considered, the primary tools of direct state control are as follows: laws, state budget expenditures, quotas, standards, licenses, sanctions, centralized pricing, government orders, macroeconomic plans, and targeted comprehensive programs. As for indirect methods, they work to control market participants' behavior without directly influencing it. And the examples of this category are instruments of fiscal, budgetary, monetary, investment, depreciation, innovation and other economic policies. In administrative and legal means of influence mainly regulations and other legal acts are used. While economic means include taxes, subsidies and price policy, financial ones encompass investments, research and development funding and green bonds. Institutional category cover formation of research and production integrated systems, energy data collection and dissemination, consumer education and conclusion of the contracts and agreements. Lastly, propaganda in context of energy market regulation refers to the utilization of informational campaign to influence on the behavior of subjects of the market. In other words, these means aim to establish and preserve specific convictions, moral stances, spiritual ideals, and mental attitudes regarding state actions. Thus, the government has a range of instruments to regulate the energy market. However, as problems are continuously replenish the discussion agenda of many international organization, it is crucial to find out who and how regulate the actions called to solve or mitigate them.

The global structure of international energy regulators can be classified by energy sources, by region, and by mission (fig. 1.7).

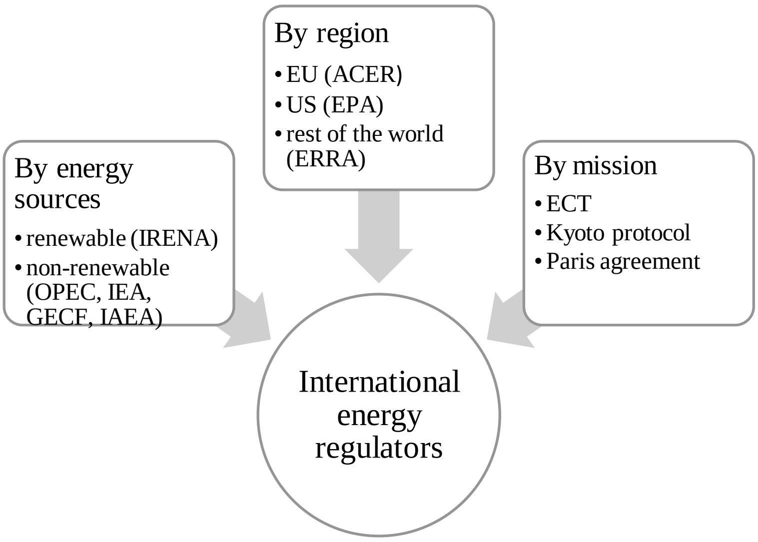

Figure 1.7 – Classification of international regulators in energy sphere
Source: systematized by the author

In the renewable energy issues, International Renewable Energy Agency (IRENA) was created in 2009 to promote the widespread use of renewable energy sources and their sustainable application. It is achieved by encouraging collaboration between nations engaged in renewable energy, increasing the investigation of renewable energy technologies, and encouraging the global adoption of laws pertaining to renewable energy. About 160 nations are full members of IRENA, while 24 more states are in various phases of the accession process. As one of the founding members, the EU takes part in all of IRENA`s work program`s activities [60].

On the other hand, introducing non-renewable sources, go immediately four organizations – The Organization of the Petroleum Exporting Countries (OPEC) and International Energy Agency (IEA) for oil, Gas Exporting Countries Forum (GECF) for gas, and International Atomic Energy Agency (IAEA) for nuclear energy. The Organization of the Petroleum Exporting Countries (OPEC) is a permanent, intergovernmental organization founded in 1960. OPEC currently has 13 member countries that work together to coordinate and unify petroleum policies. Their core objectives include securing fair and stable oil prices for member countries, ensuring a steady supply of oil to consumers around the world, and providing a fair return on investment for those in the oil industry [61; 62]. Lately, The International Energy Agency (IEA) is an intergovernmental organization established in 1970s, as a response to oil crisis in 1973. Although the promotion of renewable energy sources has been a major part of its purpose in recent years, its stated mandate remains to ensure the stability of the global oil supply. As of 2022, the IEA has 31 member nations [63]. Shifting to gas, Gas Exporting Countries Forum (GECF) is international intergovernmental organization which was established in 2001, and turned into a fully- fledged organization in 2008. The Forum, having 12 participants, is regarded as a worldwide forum for research, conversation, and debate on developments in the gas market. It is involved in the long-term outlook and study of the gas market, data sharing mechanisms, creation of partnerships with all global gas industry stakeholders, and monitoring of market trends [64]. And finally, International Atomic Energy Agency (IAEA), founded in 1957, works to advance the safe, secure, and peaceful application of nuclear technologies and is the global hub for nuclear cooperation [65].

In “by region” division, the greatest place is taken by EU Agency for the Cooperation of Energy Regulators (ACER) and US Environmental Protection Agency (EPA). The Third Energy Package Act of 2011 created ACER as a separate organization in March 2011 with the goal of promoting the completion and integration of the European Internal Energy Market for natural gas and electricity. Among the decentralized agencies of the EU is ACER. Agencies, as opposed to EU institutions, are established as independent legal bodies with the purpose of carrying out certain technical and scientific duties that support the implementation of policies and decision-making by EU institutions and Member States. By combining technical and specialized knowledge, EU Agencies also facilitate collaboration between the EU and national governments. ACER makes ensuring that national energy markets are integrated and that laws are implemented in Member States in accordance with the goals and regulatory frameworks of EU energy policy [66]. US Environmental Protection Agency (EPA) was founded in 1970. The EPA`s goal is to safeguard both the environment and public health. The EPA protects Americans' access to clean air, land, and water by enforcing federal laws, lowering environmental hazards based on scientific data, and incorporating environmental stewardship into American policy. All members of society are guaranteed access to correct information, contaminated areas and toxic sites are cleaned up, and the safety of chemicals sold in the market is reviewed. It also takes into account things like energy, transportation, industry, agriculture, human health, natural resources, and global trade [67; 68]. And, as something more general, there is the Energy Regulators Regional Association (ERRA), inter-institutional non-profit organization inaugurated in 2000 and with the financial help of US Agency for International Development (USAID), established and institutionalized between 1999 and 2008. The goals of ERRA`s creation are to strengthen energy regulation, encourage the growth of reliable energy regulatory organizations, and eventually support the integration of the energy markets indirectly [69].

Besides from this, it is necessary to mention three important documents, regulating the energy sector by mission. The first one is the Energy Charter Treaty (ECT). It is the first economic pact that brings together all of the former Soviet republics, the nations of Central and Eastern Europe that had a centrally planned economy, the European communities and all of their member states, as well as Australia, Japan, Norway, Turkey, and Switzerland. The European Energy Charter calls for the establishment and enhancement of a legal framework for cooperation in energy problems, and this is its primary duty. Being the first multilateral agreement to offer such a general rule, the ECT also covers trade and investment protection, applies transit rules to energy networks, and provides binding international dispute settlement [70]. The second one – the Kyoto protocol. As part of the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol of 1997 is the only legally enforceable accord in the world aimed at reducing greenhouse gas emissions. However, Kyoto only addresses roughly 18% of global emissions because many significant emitters are not included by it [71]. And, eventually, Paris agreement, adopted in 2015 during UN Climate Change Conference. By the end of this century, it seeks to keep the rise in the average world temperature below 2°C over pre-industrial levels and to 1.5°C. Greenhouse gas emissions must peak before 2025 and drop by 43% by 2030 in order to accomplish this. The deal, which unites countries to fight and prepare for the effects of climate change, represents a turning point in the multilateral approach to address climate change [72].

As a result, it can be concluded, that there are a lot challenges to fight with. The dependance on fossil fuels and non-renewable energy sources are marked by the early emergence. And as all systems were linked to it, it is hard to make a quick shift to renewable sources and cross out a half of the problems in the list. Some external factors, influencing the sources utilization include geopolitical instability in main suppliers to the destinations, having a great portion of fossil fuels consumption. Not the least is the issue of climate, which everyone has been struggling for the decades. To combat challenges, which cause difficulties every day to a greater or lesser extent, except government, there are a great number of international organizations and agreements. Government is more indoor regulator, attempting to balance the energy policy, using direct and indirect methods. Outside the country, the environment is full of organization of narrow and broad focus which impact a scope of nations, giving a task and deadline. They usually are guided by documents that serve to legitimize the adopted amendments and affect the efficiency.

CHAPTER 2. THE PECULIARITIES OF THE DEVELOPMENT OF MODERN ENERGY POLICY

2.1. The structural dynamics of global energy sector

The energy sector is key to the global economy, as it provides essential energy for industry, transportation, utilities and domestic use, driving economic development and growth. It also influences international relations, security policies, and environmental strategies. That is why it is important to understand exactly how much and what kind of resource is used, as this affects not only the state of the country's economy, but also the development or emergence of new challenges that impede the smooth functioning of the internal and external environments. Having previously considered the periodization of the emergence of a particular resource, it becomes clear that the nature of the origin and the volume of resource use is uneven. By 2000 all the resources were in active use and it became possible to view the changes between shares of non-renewable and renewable energy sources (fig. 2.1). During 2000-2020 non-renewable resources took the overwhelming majority, however it is important to mention that in twenty-year period, the utilization of renewable resources managed to rise by 6% and accounted for 13%. Among the first group, oil, coal and gas made up on average 86% of total. Traditional biomass volumes seemed to freeze at 11 thousand TWh after 2015, which signalize about the stop in consumption. As for nuclear energy, it fluctuated with negative trend, falling by 620 TWh till 2020. Considering the other group, hydropower was a clear leader at the beginning of the period, taking almost 98% of total. With time the situation changed – the share of hydropower began to fall, taking only a half, while wind and solar increased in 59 and 1100 times and accounted for 26% and 16% respectively. Other renewables and modern biofuels also rose, made up 8% collectively.

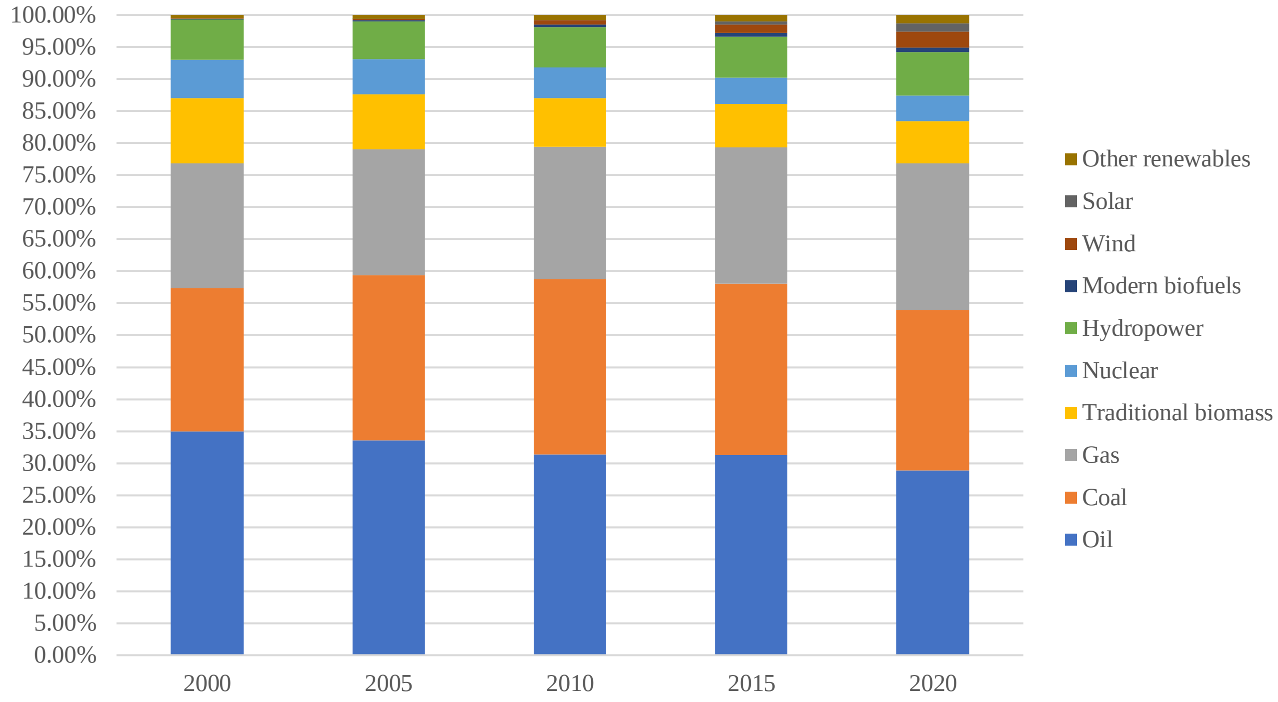

Figure 2.1 – The structural consumption dynamics of non-renewable and renewable resources between 2000 and 2020, in TWh (terawatt-hours)
Source: based on [73]

Thus, it can be concluded that among non-renewable resources, most consumed turned out to be oil, coal and gas, while hydropower, wind and solar accounted for greater portion in renewables. Apart from this, it is important to keep an eye on nuclear energy because it is not only a resource, but also a threat if used for other purposes.

Considering the world tendency in energy consumption in 2020, oil stayed the dominant resource with 31% in energy mix. Coal is the second largest fuel in 2020, making up 27%. Not far from it went gas (25%). Hydro-electricity accounted for almost 7%, and renewables in line with nuclear had 10% of total. By region consumption is characterized by the leadership of particular regions (fig. 2.2). According to the BP [74], the greatest portions of oil is used in American region (more than 40%), due to the USA which accounted for 32,5 EJ (Exajoules). Besides, this region is characterized by increased concentration of hydro-electricity, especially Brazil (3,5 EJ), Canada (2,4 EJ). Gas is dominant fuel in CIS and Middle East, taking a half, where Iran and Saudi Arabia made up 8,4 EJ and 4 EJ respectively. Coal is mostly consumed by Asia Pacific (near a half), particularly in China (3,25 EJ). Nuclear energy, in a row with renewables are in active utilization in Europe (10% and 12% respectively). The greatest share of nuclear energy is consumed by France (3,1 EJ), while renewables are dominant in Germany (2,2 EJ) and the UK (1,2 EJ).

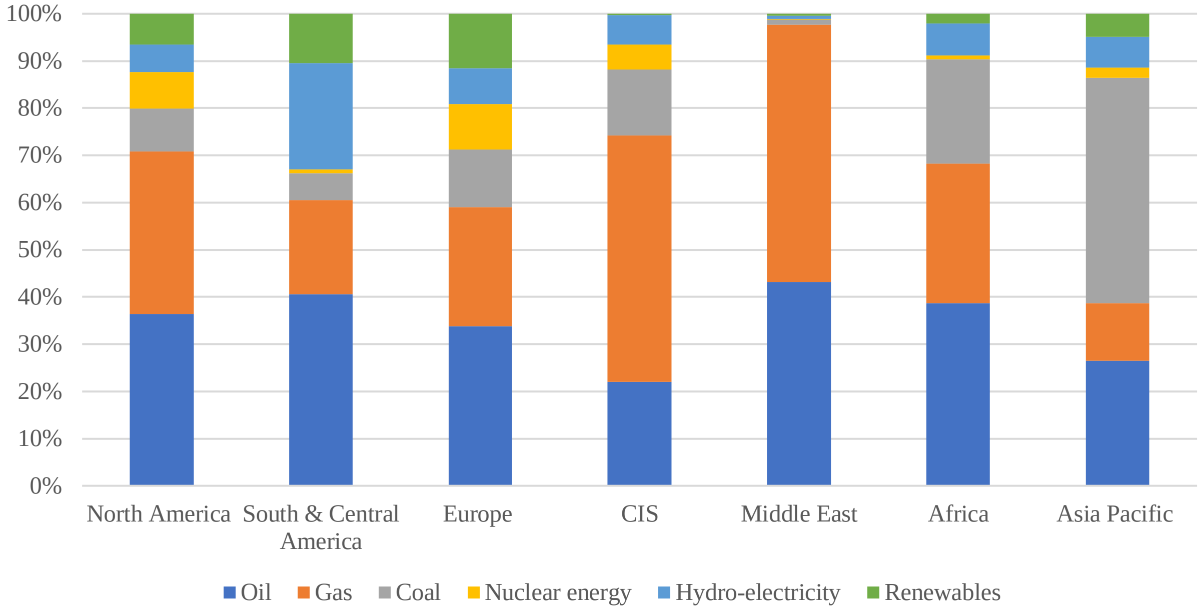

Figure 2.2 – The regional consumption pattern in 2020
Source: based on [74]

In the result, America region is dominant by oil and hydro-electricity, CIS and Middle East – by gas, Asia Pacific – by coal and Europe – by nuclear energy and renewables. Some reasons for the domination of non-renewable resources are the advantages which they bring [75]. Non-renewable energy sources like coal and oil pack a bigger punch, delivering more energy compared to some renewable options like solar or wind. In addition, they`re a goldmine for profits, with opportunities in mining coal, selling oil, or building natural gas pipelines. Convenience is another perk. These resources can be easily used at home or anywhere else. They`re budget-friendly for consumers, often available at a very cost-effective price. For some, there`s no substitute for tradition. Familiar and reliable, these resources are the tried-and-true choice for many. Accessibility is another advantage, as non-renewable energy sources are found worldwide, making them readily available even in remote locations. Most importantly, they`re a job creator, because from extraction and transport to refining, these resources fuel employment opportunities across various sectors. And finally, any non-renewable resources can be easily stored for later use.

However still, they have some negative aspects 76[]. One of the major disadvantages of non-renewable energy is that it is time-consuming. Coal mining, oil exploration, drilling, rig construction, pipe extraction, and natural gas transportation are all labor-intensive operations. Furthermore, non-renewable energy sources are steadily disappearing from the planet because they take billions of years to develop [77]. Using non-renewable resources indiscriminately without considering our future generations could be seen as selfish. Furthermore, because non-renewable energy sources like fossil fuels release pollutants like carbon monoxide into the atmosphere, they can be hazardous and cause respiratory issues in people [78]. Consequently, there are a large number of diseases, injuries, and even deaths. The environment also experiences harmful influence. Sources like coal, oil, and natural gas release a large amount of carbon dioxide when burnt (fig. 2.3). The best evidence of fight with this negative factor was shown by America region, accounting for more than 1 thousand million tones reduction. Europe held the second place, decreasing emissions by more than 600 million tones. CIS and Africa regions managed to lower it by around 1% both. Middle East even increased the number, but in comparison with Asia Pacific, the percentage was five times smaller. All these changes are due to the shares of non-renewable and renewable sources, as America region and Europe prevail in the second category significantly.

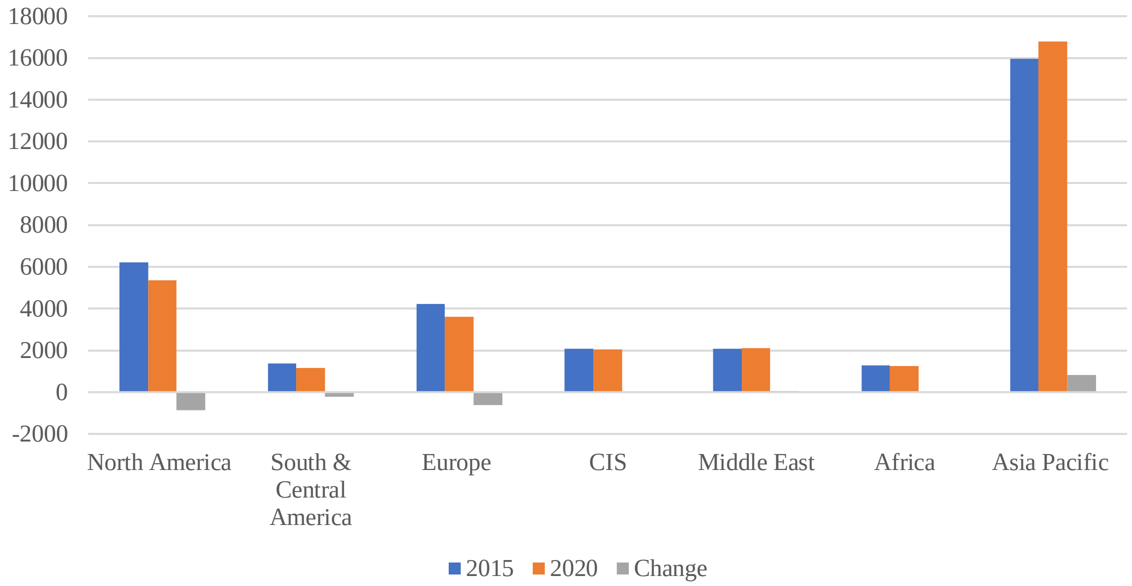

Figure 2.3 – The dynamics and changes in carbon dioxide emissions by regions between 2015 and 2020, million tones
Source: based on [74]

The result of carbon dioxide increased emissions is rapidly destroying the ozone layer [79]. Oxides like sulfur oxide and others released while burning fossil fuels convert the rain into acid rain, which is harmful to wildlife as well as human beings. The haze that envelops buildings is released by numerous non-renewable sources. People who are complaining about this issue are typically found in modern cities. Buildings and other properties may eventually appear gloomy and unclean due to black fog [80]. Moreover, transporting non-renewable sources can be risky [81] as huge cargo ships and oil tankers may crash and spill their contents in the sea or elsewhere. This can be deadly for sea animals and human beings who come in contact with it.

Afterall, the increase of renewable sources share in two times is potentially caused by the disadvantages of non-renewable and sustainable planning. Undoubtedly, there are some drawbacks of renewable resources, such as high initial costs for set-up, production volatility, location and landmass requirements or supply chain limitations [82]. Although switching to renewable energy might result in long-term cost savings, setup and component expenses can be substantial initially. For example, depending on their energy requirements, small businesses may have to pay up to 100 thousand USD for commercial solar installations [83]. Rebates, tax credits, and incentives, however, can aid in lowering these costs. Because renewable electricity generation is susceptible to certain weather conditions, such calm, foggy, and drought-prone days, it presents issues in terms of maintaining continuous energy production. Renewable energy generation is location-specific, requiring more space than conventional power plants. Traditional geothermal, hydropower, wind, and solar farms require proximity to hot water sources, water movement, open regions, and sunlight, according to ICF Climate Center research [84]. And barriers in the supply chain are impeding the implementation of renewable energy projects. Project developers face three major hurdles, according to a McKinsey report [85], including limited supplier variety for crucial components, limited access to expertise and machinery, and limited availability of raw materials and rare earth metals amid an anticipated shortage.

But, in line with this, it has numerous benefits, such as limitless availability, energy production without carbon emissions, a more hygienic and well-being setting and energy independence and self-reliance [82]. The fact that renewable energy sources like the sun, wind, and water never run out is one of its key advantages. Another point is that decarbonization is the aim of the clean energy transition. The production of energy from renewable sources produces little to no carbon emissions when powering homes, cars, and companies. It is much better than the fact that in 2022 carbon dioxide emissions reached 37 billion tones [86]. In the wake of such changes, businesses develop their decarbonization plans based on practicality, opportunities, and business sense. They adopt critical tactics like increasing operational effectiveness, pursuing electrification, transitioning to low-carbon energy sources, cutting emissions from both the upstream and downstream, and putting in place procedures to manage leftover emissions [87]. Also, fossil fuel mining can lead to water pollution and harm to animal habitats, while burning fossil fuels like coal generates airborne pollutants like sulfur dioxide and nitrogen oxide. Reducing these pollutants and lowering dangers to the environment and public health can be achieved by switching to renewable energy from fossil fuels. Lastly, through the creation of new domestic energy production options, renewable energy strengthens energy security by lowering dependency on energy imported from outside. Thus, European countries have attempted to decrease their imports of Russian gas and oil following Russia`s invasion of Ukraine. In 2023, the European Union`s electricity mix grew to include a record 44% renewable energy output [88], while imports from Russia decreased. This development contributed to the creation of a more resilient and stable power grid.

Major powers and regional blocs are navigating the energy transition and its impact on geopolitics in several ways [89]. Firstly, protectionist elements and subsidies play a significant role. Some major powers, such as the US [90] and the EU [91], have implemented protectionist measures in their energy policies, influencing the direction of clean energy mineral supply chains. Additionally, subsidies in wealthy nations can affect global renewable energy supply chains, potentially redirecting them towards larger markets rather than supporting a universal transition. Furthermore, regional and multipolar leadership is crucial to ensure that developing nations are not left behind in the energy transition. Developing countries are expected to drive energy demand growth in the coming decades, emphasizing the need for cooperation and coordination among nations [92]. Moreover, the energy transition raises fundamental issues in foreign policy and international security. Existing national security arrangements, such as ties between the US and fossil fuel exporters like Saudi Arabia, may need to be reevaluated as the transition progresses [93]. As a result, new power brokers and regional cooperation mechanisms may emerge to address these shifts. Apart from this, geopolitical tensions, such as those involving Russia in Central Asia and the dynamics in East Asia and the Pacific, require careful consideration during the energy transition. Understanding how state relations shift during this period is essential for developing coherent frameworks for climate and foreign policy objectives. While competition between major powers like the US and China is prevalent, there is also a growing recognition of the need for cooperation in the energy transition. Building frameworks for regional cooperation, especially among developing countries, can lead to new practices of reciprocation, interdependence, and noninterference. Lastly, price volatility in fossil fuels and geopolitical fragmentation can hinder the energy transition. Therefore, coordination between consumers and producers, along with interventions from international financial institutions, is necessary to mitigate economic damage and facilitate a smoother transition.

The most significant events in terms of influence on global energy sector are the war in Ukraine and the US and China tensions. Vulnerabilities in conventional energy supply networks, especially for natural gas and oil, have been brought to light by the conflict in Ukraine. Concerns over possible interruptions to the trade of petroleum products, including diesel, resulting from Ukrainian drone assaults on Russian oil refineries have been brought up by the International Energy Agency (IEA). Russian attacks on Ukraine's gas and electricity infrastructure resulted in a 10% increase in gas prices throughout Europe. Ukraine has effectively targeted 14 large refineries and 2 smaller plants in Russia since the year`s beginning, greatly affecting operations [94]. As payback, Russia has launched massive strikes on Ukraine's power plants and, for the first time since its invasion more than two years ago, has used drones and missiles to target vital gas infrastructure. President Putin said that the recent damage of the biggest power plant in the Kyiv region was a reaction to actions by the Ukrainian government [95]. US Defense Secretary Lloyd Austin has urged Ukraine to prioritize military objectives in light of these developments in order to lessen the wider impact on international markets [96]. Nonetheless, given that Congress has been slow to provide Ukraine with almost $60 billion in aid [97] – aid that is vital to their defense – Ukraine has underlined the importance of these steps.

As a result, diversification is now necessary, as is a reduction in reliance on politically delicate areas. Uncertainty in energy markets, such as that which exists between the US and China, has an impact on the energy transition. China and the US have implemented industrial policies to quicken the switch to renewable energy [98], which has an effect on the dynamics of commodities prices and global energy security. These conflicts highlight the necessity of international cooperation in tackling shared issues like climate change, energy security, and sustainable development. Investment in supply chains and clean energy technology can also be stimulated by geopolitical conflicts [99]. To facilitate a more seamless transition to a more secure and sustainable energy future, policy alignment is essential.

Thus, geopolitical threats such as war threats and terror threats have a significant negative impact on energy transition efforts [100]. They have a greater dampening effect on energy transition compared to geopolitical acts. This is because during periods of uncertainty caused by these threats, countries may be less inclined to invest in clean energy technologies and innovation, leading to a shift towards more traditional and fossil fuel-based energy sources. Next, war threats and terror threats can lead to large-scale conflicts and disruptions, diverting funds from long-term development projects, including those related to renewable energy production, transmission, and consumption. This diversion of resources can impede the progress of new energy transition projects. Besides, geopolitical threats increase the cost of private sector investment, which in turn negatively affects clean energy consumption. During times of geopolitical turmoil, people may allocate less spending towards clean energy due to rising living costs, impacting investment in renewable energy projects. And, the development of markets for renewable energy can be hampered by geopolitical threats, which can result in changes in energy costs, interruptions in energy supply chains, and a drop in investment. The energy shift process may be hampered by the volatility of the world energy market.

Under the current circumstances, the access to energy services is a key prerequisite for socio-economic development, which is essential for improving the quality of life. Energy affects access to jobs, food, water, housing, healthcare, education and communication. It is important to ensure adequate energy supply, especially in developing countries, as well as in industrialized and transition countries. Energy supplies must be safe and reliable, given the dependence on imports, vulnerability of systems, and exhaustibility of resources. For sustainable development, energy must be affordable, socially acceptable, and create opportunities for local employment and industry. The development of energy systems should be consistent with the principles of sustainability without jeopardizing the quality of life of current and future generations, and should include the efficient use of resources and the development of alternative energy sources. Environmentally friendly short-term solutions should not interfere with long-term sustainable development [101].

In this way, with the transition to renewable energy sources, many countries around the world have been trying to get rid of their dependence on fossil fuels and nuclear power. While the vast majority are experiencing great difficulties, as their economies have been running on non-renewable resources for a long time and a quick transition is not possible, Europe is an example of an effective transition to renewable resources. This is also reflected in the record-breaking differences in the reduction of carbon dioxide emissions. This process has also been accelerated and revitalized by geopolitical tensions. Russia`s full-scale invasion of Ukraine was a major shock to the global energy sector. In view of this, the European Union's energy policy needs to be studied in more detail, as the pressure of internal and external factors brings about major changes.

2.2. Analysis of the European Union energy policy

Seeing from the previous analysis, Europe is the most suitable country for effective decarbonization and successful management of sustainable development. Since emissions from the energy industry have increased by more than 50% over the last 25 years, it is imperative that global warming be kept to 1,5°C. Decarbonizing energy systems is now more important than ever due to the crisis in Ukraine and the world's food, energy, and economic issues. In order to attain carbon neutrality by the middle of the century, the International Energy Agency forecasts that investment in clean energy must triple by 2030, reaching over $4 trillion annually. In particular, sectors like heavy industries, aviation, and shipping that lack low-carbon alternatives to fossil fuels require increased investments in energy efficiency, renewable energy, power networks, and innovative technology in order to meet these targets. In the last ten years, the European Investment Bank (EIB) Group has committed about 106 billion euro to sustainable energy projects across the globe including the EU [102]. With these expenditures, Europe is better able to handle the fallout from Russia's abrupt cut off of gas supply. For projects in energy efficiency, renewable energy, power, and storage within the EU, the EIB granted more than 17 billion euro in 2022, boosting economic resilience. The development arm of the EIB Group, EIB Global, further provided approximately 2 billion euro in funding for renewable energy projects outside of Europe in 2022.

In the net of EU energy sector regulation, there are four basic policies – the Green Deal, REPowerEU and Renewable Energy Directive and Energy Strategy 2050 [103]. The European Green Deal, introduced by the European Commission in 2019, aims to achieve carbon neutrality by 2050. The European Climate Law, which established an interim target of lowering net emissions by 55% by 2030 relative to 1990 levels, formally established this aim in 2021. In 2021, the Commission unveiled the 'fit for 55' package, which included changes to several important energy-related laws, including the gas and hydrogen package, the Energy Taxation Directive, the Renewable Energy Directive (RED), the Energy Efficiency Directive (EED), and the Energy Performance of Buildings Directive (EPBD). The Social Climate Fund (SCF) Regulation was also put forth. The

RED, EED, and SCF were enacted by 2023, and more legislative changes were still being worked on. Going to the second policy, the objective of the REPowerEU plan was to accelerate the shift to clean energy and phase out fossil fuels, with a particular focus on reducing the EU`s dependency on Russian energy. Energy efficiency, diversifying energy imports, and boosting the use of renewable energy sources were prioritized in the plan. It contained two major legislative proposals: one to amend the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED), and the Renewable Energy Directive (RED) in order to accelerate permits for renewable projects, set higher targets for efficiency and renewable energy, and encourage solar installations on buildings; the other to amend the Recovery and Resilience Facility (RRF) Regulation in order to incorporate REPowerEU objectives into national recovery plans. In addition, REPowerEU put forth plans for hydrogen acceleration, biomethane, solar energy, energy conservation, external energy involvement, and an EU energy platform for shared purchasing of gas, LNG, and hydrogen.

Proceeding from it, the EU`s energy transition depends on renewable energy. The EU`s energy consumption from renewables climbed from 21,8% in 2021 to 22,5% in 2022 [104]. This is tracked for transportation, heating and cooling, and electricity. A target of 42,5% renewable energy consumption in the EU by 2030 was set by the Renewable Energy Directive (RED) [105], which was updated in 2023 and renamed as RED III. Each member state makes a national contribution to the EU average. There are sector-specific targets in RED III as well. Countries can opt for a 29% share of renewable energy or a reduction of 14,5% in GHG intensity when it comes to transportation by 2030 [106]. With particular targets for renewable hydrogen (42% by 2030 and 60% by 2035), the industry must grow its contribution of renewables by 1,6% annually [107]. A binding aim for heating and cooling is to raise the share of renewable energy by 0,8% year until 2026, and then by 1,1% until 2030 [107]. Additional goals originate from other European Union projects. Aiming for approximately 320 GW (Gigawatt) of new solar photovoltaic capacity by 2025 and nearly 600 GW by 2030, the 2022 solar energy strategy is backed by initiatives like the EU Solar PV Industry Alliance and the European Solar Rooftops initiative [108]. By 2023, the European wind power package seeks to address licensing, auction mechanisms, skills, fundin, and supply chains in order to deliver around 111 GW of offshore renewable capacity. Lastly, by reaching net-zero greenhouse gas emissions, the EU`s 2050 long-term policy is to establish Europe as the world's first climate-neutral continent. This objective is the cornerstone of the European Green Deal and is mandated by the European Climate Law. Making the shift to climate neutrality presents an opportunity to ensure that no one is left behind and to create a brighter future. All facets of society and the economy, including power, industry, transportation, buildings, agriculture, and forestry, will be involved in achieving this goal. With an emphasis on industrial policy, finance, and research, the EU intends to take the lead through investments in technical solutions, citizen empowerment, and measures enabling a peaceful and equitable transition. The EU submitted its long-term plan to the United Nations Framework Convention on Climate Change (UNFCCC) in March 2020, in line with its commitment to global climate action under the Paris Agreement [109].

Considering financial issue, in its budget for 2021-2027 and through the Next Generation EU instrument, the EU has set a spending target of 30% for climate action, which, assuming the loan component of the Recovery and Resilience Facility (RRF) is fully utilized, would come to almost 600 billion euro [110]. Implemented through national recovery and resilience plans (NRRPs) with a target of 37% for climate investment, the RRF is a part of the NGEU [111]. The plans prioritize the transportation of CO2 and low-carbon gases, power transmission, green energy infrastructure, energy efficiency, and renewable energy. NRRPs have been updated with a REPowerEU chapter as part of the REPowerEU program. The InvestEU Fund, STEP, Modernization Fund, Innovation Fund, Cohesion Policy, Just Transition Fund, Social Climate Fund, Connecting Europe Facility, LIFE Clean Energy Transition sub-program, EU Renewable Energy Financing Mechanism, Horizon Europe, EIB, EGF, and Technical Support Instrument are just a few of the specific instruments that the EU uses to significantly finance the energy transition. Sustainable infrastructure is funded by the InvestEU Fund, while clean technology is supported by 7,5 billion euro from STEP [112]. In areas that rely heavily on carbon emissions, the Modernization Fund promotes energy efficiency, renewable energy, and a just transition. Innovative innovations in energy-intensive industries are financed by the

Innovation Fund. Energy transition is supported by the Cohesion Policy through a number of programs.

The EU continues to improve the energy transition and important energy and environmental measures were adopted in the last two plenary sessions of the European Parliament under this mandate [113]. The goal of the Heavy-Duty Vehicle (HDV) Regulation is to reduce carbon emissions from HDVs by 90% by the year 2040. Oil and gas companies are required under the Methane Reduction Regulation to take certain steps in order to identify, record, and address methane leaks. In addition to expediting the switch to hydrogen, the Gas and Hydrogen Package lays the groundwork for a potential hydrogen network. A registry for certified carbon dioxide removals is established under the Carbon Certification Framework. Long-term contracts for renewable energy are the main means by which the Electricity Market Reform Regulation seeks to safeguard consumers and maintain price stability. In order to better safeguard the environment and public health, wastewater management regulations are updated by the Urban Wastewater Treatment Directive. Additionally, the EU has adopted several regulations to achieve its climate goals, including the Trans-European Transport Network (TEN-T) Regulation, the Energy Charter Treaty withdrawal, the Ecodesign Regulation for product sustainability and energy efficiency, the Ambient Air Quality Directive for 12 pollutants, and the Net-Zero Industry Act (NZIA) to enhance Europe's manufacturing capacity for net-zero technologies. The Clean Transition Dialogues result from the European Commission, which emphasizes a more robust industrial strategy and regulatory framework for renewable energy, is another noteworthy step. The photovoltaic sector and the use of renewable energy are supported by a recently established European Charter for Solar Energy. Transnational carbon storage and transportation are made possible by international agreements between five countries in Northern Europe. Provisional standards were devised to evaluate the necessary use of hazardous substances.

The first push was climate issue, however now, the reason for all the mentioned actions is the current situation with lack of reserves and energy sources export. The Europe was always in export mode in reserves question (fig. 2.4). According to the 2020 data, the share of oil and natural gas didn`t exceed 2% of the world total. A little better situation with coal didn`t save because this reserves were in less active utilization. The leaders in oil are Middle East, where Saudi Arabia took the greatest part of 17,2% and CIS, where Russia managed to hold 6,2% of CIS total. As for gas, Iran in Middle East group accounted for 13%, while Russia took record fifth part of all world reserves.

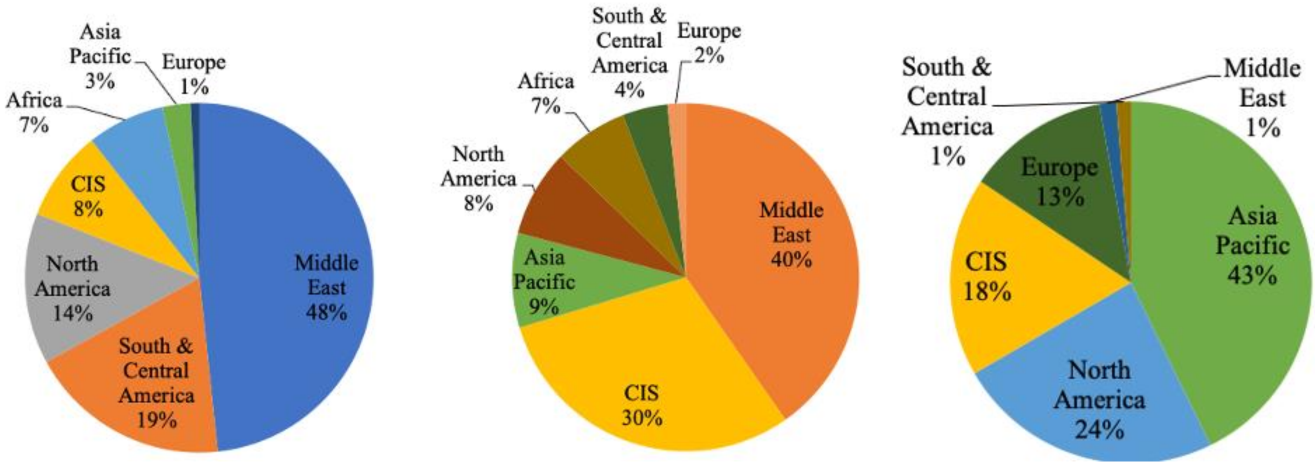

Figure 2.4 – Distribution of proved oil, gas and coal reserves in 2020
Source: based on [114]

And, as Russia was one of the main exporters of non-renewable resources to the EU, the consequences of war pushed EU to put sanctions on goods which cannot be imported from there. The list included crude oil (from December 2022) and refined petroleum products (from February 2023), with limited exceptions, coal and other solid fossil fuels and some other products of industry [115]. So, the EU continuously works on active integration of renewable resources to warrant the absence of significant reserves of fossil fuels, nuclear power continues to remain in the structure of energy sources and, according to Commissioner Thierry Breton [116], it should be included in the EU`s 2050 carbon neutrality targets. All of these actions further the EU`s commitment to energy transition, industrial sustainability, and climate goals. Analyzing the nuclear energy consumption in Europe (fig. 2.5), the overall volume decreased by 23% during 2010-2020 and accounted for 7,45 EJ (Exajoules). The greatest portion of more than 40% is held by

France. Then goes Ukraine and Germany (9% and 7,6% respectively).

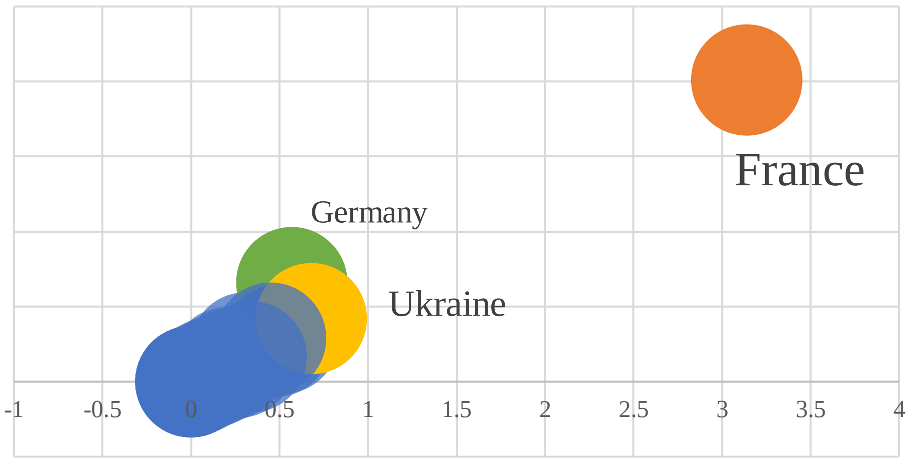

Figure 2.5 – The consumption of nuclear energy in Europe in 2020
Source: based on [114]

The reasons for nuclear energy utilization are carbon-free energy, more safety in comparison with fossil fuels, and greater effectiveness that renewable sources [117;118]. The benefits of nuclear energy over fossil fuels are demonstrated by France's accomplishment in lowering emissions. One of the cleanest energy sources is nuclear power, which emits just water vapor into the environment and no other pollutants or radioactive materials. In its categorization scheme, the European Commission classified nuclear energy as a green energy source [119]. Besides, from the standpoint of public health, nuclear energy is deemed safer than fossil fuels since radioactive waste poses fewer risks than harmful substances derived from fossil fuels. One in five deaths globally are attributed to fossil fuels [120], but nuclear power has only resulted in three incidents in the past 70 years: the Fukushima disaster of 2011 and the Three Mile Island accident of 1979; the only incident to directly cause any deaths was the Chornobyl accident in Ukraine. Lastly, compared to other renewable energy sources, nuclear energy has benefits like less maintenance needs, longer operating lifetimes, and increased power output. According to the US Office of Nuclear Energy, nuclear power is three times more reliable than wind and solar electricity, producing over 93% of its maximum power year-round [121]. However, apart from it, nuclear energy can cause numerous problems, such as nuclear weapon proliferation, poisonous chemicals of radioactive nuclear waste, and costly in finance and time [118]. The debate around the Hiroshima and Nagasaki bombings, as well as the conflict between Russia and Ukraine, led to the opposition to nuclear energy on the grounds that it could lead to the proliferation of weapons. The 1970 Treaty on the Non-Proliferation of Nuclear Weapons [122] sought to safeguard nuclear energy for peaceful purposes and stop the proliferation of nuclear weapons. Opponents counter that there is a substantial possibility of nuclear weapons technologies ending up in the wrong hands, especially in nations with high levels of instability and corruption, and that nuclear energy is intricately linked to these technologies. The movement`s principal worry is that nuclear weapons could end up in the wrong hands. Next, although radioactive waste from nuclear energy is safe, it contains hazardous materials including uranium pellets and plutonium [123]. Reluctant parties are afraid of mishaps, but they also understand that they might go very wrong, as seen by the Fukushima tragedy in 2011, which resulted in fatalities, massive cleanup expenses, and displaced people. Finally, building nuclear power requires billions of dollars and takes longer than building infrastructure for other renewable energy sources. It is competitive since it is reasonably inexpensive to operate. However, as countries cannot afford to rely on new nuclear facilities to satisfy their emission reduction targets, the protracted development process provides a significant barrier to achieving net-zero emissions.

Given the intricate nature and significant consequences associated with nuclear energy, it becomes crucial to explore more comprehensive approaches to ensure energy security. In this light, France emerges as a compelling case study, being a nation that has traditionally depended on nuclear power to meet its energy requirements. The French experience offers profound lessons on the intricate interplay between the advantages and drawbacks inherent in nuclear energy. By delving into the nuances of France's reliance on nuclear power, a deeper understanding can be gained regarding the complex dynamics that underpin the utilization of this energy source. France`s journey with nuclear energy serves as a valuable resource for policymakers and stakeholders worldwide to navigate the complexities and trade-offs involved in harnessing nuclear power for sustainable energy development.

2.3. The development of energy security: the case of France

The second-largest nuclear fleet in the world, France's electrical mix is remarkably low in carbon. With the 2019 Energy and Climate Act, France, a pioneer in laying out a comprehensive energy transition, established a net zero emissions target for 2050 and plans to cut its greenhouse gas emissions by 55% by the year 2030. Implementing the long-term aim is a multiannual plan for energy investments and a national low-carbon strategy with 5-year carbon budgets. Describing total energy supply of France as of 2022, the greatest portion of 37% goes to nuclear energy, the second place is taken by oil (31%), and followed by gas (16%) close the top-3 positions in rating. Other 17% is composed by biofuel and waste, coal, wind, solar etc. and hydro. Production almost solely is occupied by nuclear energy (74%), which is mostly used for electricity production. Renewable resources hold a bit less than 25%. Hydro and wind are also actively used for electricity production, prevailing natural gas and oil (fig. 2.6).

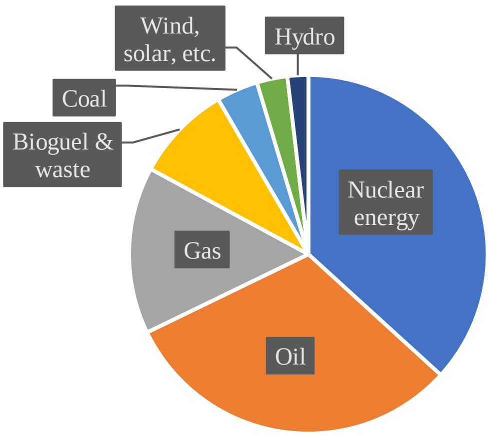

Figure 2.6 – The composition of energy mix for France in 2022
Source: based on [124]

As can be seen, such a rating is not so typical for Europe and because of this France becomes an object for further investigations in energy security and energy policy. So, the most interesting resource in energy policy of the country are nuclear energy, oil and gas.

According to International Energy Agency (IEA), approximately 70% of France`s low-carbon electricity supply now comes from nuclear energy, which is the mainstay of the country`s energy transformation (table 2.1). France is the second-largest nuclear electricity producer in the world, after the United States, with 63 GW (Gigawatt) of reactors. Greater benefits from electrification are also made possible by this low emissions intensity, especially in areas like heavy industry, transportation, and housing. According to the International Energy Agency`s net zero by 2050 strategy, nuclear energy is essential for reaching net zero carbon emissions by that year. By 2035, the French government wants to reduce the percentage of nuclear power to 50%, with the remaining 50% coming from renewable sources. Twelve reactors, including the two that are already closed at Fessenheim, must be shut down for EDF (Électricité de France) to accomplish this. The development of France's offshore wind farms and their connectivity, assessments of energy costs and affordability, and the evolution of power commerce with neighboring nations are all critical to the country's progress toward achieving this aim. However, because of the ongoing PPE (Personal protective equipment) and socio-economic assessment of the long-term electricity and energy mix, the role of nuclear power beyond 2035 is still unclear. The report is now being finalized by the French Nuclear Safety Authority (RTE) for publication. France needs to either develop new reactors or maintain its current reactors in order to continue contributing to nuclear energy. In order to continue operating its nuclear reactors for longer than 40 years, EDF is renovating its fleet, putting each reactor through a safety evaluation and maintenance schedule.

Building on the EPR design, which is currently in operation in China and is being built in France, Finland, and the United Kingdom, EDF suggests constructing six additional EPR2 reactors. Following the Flamanville EPR`s (Extended producer responsibility) commissioning in 2023 – that is, following the 2022 French presidential elections – a decision is anticipated. The primary obstacle to nuclear in France continues to be funding EDF`s long-term operations plans and/or new construction, which may call for modifications to the country`s regulatory structure. The European wholesale prices dropped below 42 euro per MWh (Megawatt-hour) , which limited the ARENH`s (Regulated Access to Incumbent Nuclear Electricity) ability to increase competition and generate income for EDF to support its long-term operations program. It would be necessary for new nuclear power facilities to have their own pricing structures, including asset-based regulations or contracts for differences with fixed strike prices. A complicated interaction of national initiatives, European regulations on state aid, sustainable finance, and negotiated agreements will determine investment in the French nuclear energy sector. In order to direct public and private financial flows during the energy transition to low-carbon technologies, the EU has created a new taxonomy for sustainable financing. With Orano manufacturing uranium and nuclear fuel and Framatome, which is three-quarters owned by EDF, being a prominent player in the industry, France's nuclear business has experienced a significant transformation. For nuclear energy-related research, the Alternative Energies and Atomic Energy Commission is principally in charge. France prioritizes decommissioning and nuclear waste management due to its sizable and aging nuclear fleet. The government needs to finish putting in place a long-term nuclear waste storage option and openly disclose the expenses associated with the Cigéo underground storage site.

Table 2.1 – Characteristics of nuclear energy in France

Component	Description
Energy transition and climate goals	Nuclear power is a key part of France`s plan to achieve net zero emissions by 2050. It provides low-carbon electricity for electrification in hard-to-decarbonize sectors.
Government target and challenges	Reduce nuclear share to 50% by 2035, with renewables making up the difference. Balancing emissions reduction, security of supply, affordability, and public perception.
Renovation of equipment	EDF's 49,4 billion euro program (“Grand Carénage”) extends the lifespan of existing reactors beyond 40 years. EDF proposes building six new EPR2 reactors, a decision expected in 2023.
Utilization of waste	France is a global leader in implementing a definite solution for the long-term storage of its nuclear wastes. Cigéo is a deep geological repository for high-level wastes from the treatment of spent nuclear fuel and intermediate-level long-lived radioactive wastes.
Financing and investment	Financing long-term operation and new builds is a major challenge. The ARENH mechanism and future pricing arrangements are being reviewed. The new EU sustainable finance taxonomy may impact investment.

Source: based on [125]

Analyzing gas resources utilization of France (table 2.2), with 11,4 million users, natural gas consumption in France in 2019 accounted for 20% of total energy consumption. The nation is dependent on a wide range of imports, with Nigeria, the Netherlands, Norway, and Russia providing the majority of the gas supply. LNG will supply half of France`s imports in 2020, indicating its growing importance in the country`s supply chain. In 2019, France sent 7 billion cubic meters of natural gas to Spain, Italy, and Switzerland. In addition, as of 2018, the French government has merged the remaining two market zones into a single gas-trading zone, TRF, capping a rigorous process of market integration. As a result, supply security and market liquidity have both improved. Since the start of the regulated tariff reform in 2014, alternative suppliers have more than doubled the number of residential customers they serve, and their market share of non-residential customers has increased by more than 50%. According to the IEA, France has among of the highest gas costs. Besides, to encourage the low-carbon energy transition and the security of the gas supply, the government has been assisting domestic producers of biogas and biomethane. In 2019, domestic production accounted for about 0,3% of the world`s total gas supply. In 2030, the PPE aims to consume 7% of biogas as gas, and 10% if the costs anticipated in the baseline trajectory continue to drop. By 2030, biogas output is expected to rise dramatically to 3,1 billion cubic meters annually, necessitating further investments and legislative measures. Reverse flows on low-pressure pipelines and network meshing are two examples of grid adaptation that will be required. In order to assist build 6,5 GW of hydrogen production capacity by 2030, France unveiled an ambitious national hydrogen strategy in 2020, with the goal of investing 7,2 billion euro over the following few years. Nevertheless, there is currently no tangible plan of action from the government to achieve these goals, and France might lose out on the opportunity to join a pan-European hydrogen network. In particular, France`s highly decarbonized power offers significant potential for electrolysis-based hydrogen production; thus the country needs to move swiftly to catch up with its European counterparts. With the non-household sector using 75% of gas in 2019, targeted policy actions are insufficient to enable the 25% reduction in gas consumption by 2030. Reaching the goal will depend on the decisions made about the future mix of electricity, especially when it comes to investigating new gas-fired power facilities in conjunction with carbon collection, utilization, and storage. Concerns over stranded assets can be allayed by developing an energy system strategy that optimizes the relative advantages of each energy vector and carrier.

Table 2.2 – Characteristics of gas utilization in France

Component	Description
Demand and Supply	The final energy demand made up 20% in 2019, with LGN accounting for 45% of imports in 2020. The origins for imports were Norway, Russia, the Netherlands, and Nigeria. The destinations for exports included Italy, Spain, and Switzerland in 2019.
Government Plans	The French government has integrated two market zones into a single gas-trading zone (TRF), improving liquidity and supply security. Supporting indigenous biogas production promotes low-carbon energy transition, with a target of 7% biogas in 2030.
Transition and Investments	France`s ambitious hydrogen strategy, aiming for 7,2 billion investments by 2030, lacks a concrete action plan, potentially missing opportunities to participate in a pan-European hydrogen network.
Consumption Targets	The 25% gas consumption reduction target by 2030 is hindered by insufficient policy measures, requiring future electricity mix choices and energy system strategies to address stranded assets.

Source: based on [125]

Proceeding in oil resources (table 2.3), France`s total oil demand in 2019 was in 11% less than ten years ago, and made up 44% of France`s Total Fuel Consumption (TFC), with 56% of that amount going toward domestic transportation. Compared to 2015, the use of gasoline has climbed by 18,8%, while that of diesel has declined by 5,8%. This ratio needs to alter rapidly, as the government plans to have 15 million electric and hybrid vehicles on the road by 2035. The supply security of French crude and refined products is guaranteed by the country`s different supply chains. While some refined items are imported by pipeline, road, or river, the majority of crude and refined products are imported through ports. France has a large amount of storage space – 46 million cubic meters – and has mandated that fuel distributors incorporate biofuels. Since 2015, the mandatory blending standards for gasoline and diesel oil have been progressively raised. In 2023, the targets were set at 1,2% and 0,4%, respectively, and by 2028, they were expected to rise to 2,8% and 3,8%, respectively. In response to growing demand, France`s well-established biofuels manufacturing sector is anticipated to expand production capacity during the next ten years. Nevertheless, obtaining adequate amounts of completed biofuels and sustainable feedstock will present difficulties. Oil operators will have financial difficulties in implementing these targets, which could result in asset consolidation, a decline in investment, and possible effects on supply security. The government of France intends to cut oil usage from 2012 levels by 19% by 2023 and 34% by 2028. These regulations, which are centered on the transportation industry, prioritize rail and modal shifts in urban transportation while also supporting electric and hybrid cars and provide incentives for the construction of charging stations. Additionally, by outlawing new oil installations in the residential and tertiary sectors and replacing all oil boilers by 2028, France hopes to gradually phase out oil use in the heating industry.

Table 2.3 – Characteristics of oil consumption in France

Component	Description
Demand and Supply	France`s oil demand decreased 11% in 2019, accounting for 44% of Total Fuel Consumption. With a government plan to have 15 million electric and hybrid vehicles by 2035, this ratio needs to change. France`s diverse supply chains ensure supply security, and mandatory blending of biofuels is set for fuel distributors.
Transition and challenges	France`s biofuels manufacturing sector is set to boost production over the next decade, but challenges in sourcing and sustainable feedstock may pose economic and supply security risks.
Consumption targets	France`s government plans to decrease oil consumption by 34% till 2028, focusing on transport, electric and hybrid vehicles, charging stations, biofuel blending, urban transport shifts, and phase-out of oil in heating.

Source: based on [125]

Apart for the basic assessment of three most used resources, IEA gives recommendations for France [125]. The French government ought to reassess the legal mandate limiting the use of nuclear energy in power generation to 50% until 2035, taking into account the deployment of renewable energy sources, affordability, and the urgency of addressing climate change. In order to reach net zero by 2050, they should decide how nuclear energy will be used after 2035 based on continuing research and socioeconomic analysis. Additionally, long-term, stable funding is essential for nuclear energy production, and includes supporting the renovation and safety enhancement of current reactors as well as the construction of new reactors starting in 2023. In order to prepare for the energy transition, nuclear energy research must be strengthened. Taking gas resource, the French government ought to coordinate its objectives for reducing its consumption with practical policy actions, like combining biogas and hydrogen, enacting energy-saving regulations, offering financial incentives, and advancing the electrification of industrial processes. Also, it should create a plan for the integration of the energy systems to facilitate the economical and efficient decarbonization of the gas industry and establish legislative frameworks that will support the growth of biogas and biomethane production and permit the grid to absorb up to 10% of biogas by 2030. Lastly, government should extend the hydrogen plan while consulting with relevant parties, taking infrastructure advancements, production, and demand into account. The evaluation of the supply security situation will be sound in case of France. Considering the situation with oil, to assess the effects of initiatives intended to lower the demand for petroleum products and rationalize infrastructure for domestic supply, the French government should work with market participants and stakeholders. To satisfy the needs of biofuel production and distribution, they should also look into options for asset repurposing. Along with ensuring the availability of sustainable feedstock, the government should evaluate options for supplying the country`s biofuel needs. A minimum stock level should be set to guarantee sufficient stock availability in the event of market disruptions, and the capacity and resilience of the transportation and storage infrastructure in the Paris region should be evaluated.

In the result, France relies heavily on three main energy sources: nuclear energy, natural gas, and oil, each with its distinct characteristics. Nuclear energy is the backbone of France`s energy system, providing a significant portion of its electricity with minimal carbon emissions. Natural gas plays a crucial role in meeting both residential and industrial energy needs, despite the country`s negligible domestic production and reliance on a diverse portfolio of imports. Oil, while decreasing in demand, remains vital for transportation and industry, with a significant share of consumption and extensive infrastructure to support its import and distribution. Given this context, it is insightful to compare France`s energy strategy with that of Ukraine, which is the second-largest consumer of nuclear energy. Ukraine`s current situation, marked by war and frequent blackouts, presents unique challenges and opportunities. This comparison can offer valuable insights into enhancing energy security, reliability, and sustainability under adverse conditions.

2.4. The overview of Ukrainian energy policy and directions for its improvement

After the analysis of France resource development, it becomes obvious that in Europe there is one more country, distinguishing in its energy mix composition. Ukraine is among the countries with reserves of various primary energy resources, including crude oil, natural gas, and coal [126]. France and Ukraine share notable similarities in their energy mix, setting them apart from many other European countries. Both countries have diverse energy portfolios that include nuclear power, fossil fuels, and renewable energy sources. However, their reliance on different forms of energy and the strategies they employ to achieve energy security distinguish them from the broader European context.

Looking closer at the energy mix of Ukraine, it is mainly composed by non-renewable sources (93%), and less than tenth part is taken by renewable resources, such as biofuels (5%), and hydro with wind, solar and others (2%). The overwhelming part is divided by gas, oil and nuclear energy, averaged a quarter per each, and oil, accounting for 17% (fig. 2.7). Production is occupied by nuclear, holding 41%, and by natural gas on 28%. In electricity generation mix nuclear energy also has the greatest portion of more than 50%, and coal managed to take the second big share of almost 25%.

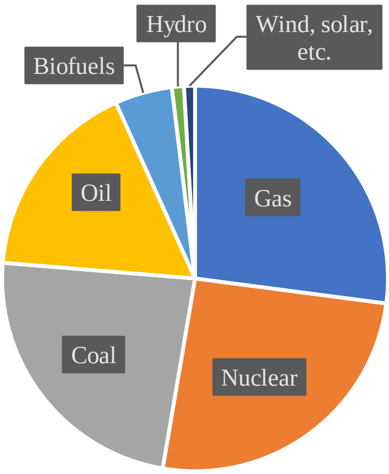

Figure 2.7 – The components of energy mix in Ukraine in 2021
Source: based on [127]

Thus, it can be concluded that the generating capabilities and production is surely taken by nuclear energy. The decision for the development of nuclear energy was made because of such factors as high efficiency of nuclear power plant (NPP), low costs nuclear of electricity generation, and the availability of uranium inside the country. The oil and gas industry in Ukraine began in the mid-19th century at the Boryslav field. Despite initial growth, production decreased in the early 1990s and has remained at 20-21 bcm (billion cubic meters) per year since the early 2000s. Ukraine has attempted to attract international investors through production sharing agreements, but these have been unsuccessful. The government's goal to increase gas production was set in 2016, but the COVID-19 pandemic and global economic crisis impacted the industry [128]. Due to its low efficiency and environmental contamination, coal`s importance in the world has shrunk. The greenhouse effect is caused by the reaction of coal`s carbon content with oxygen. Despite this, coal could be a major contributor to meeting the world's future energy resource demands due to its vast reserves. Many industries, such as those that produce plastics, coke, power, and iron ore agglomeration, depend on coal. In addition, metallurgy, municipal and residential sectors, and thermal power plants use it. Because it burns for a long time, is inexpensive, and works with modern boilers, coal mining is a common fuel in Ukraine for both residential and commercial use. There are seventeen different kinds of coal in the nation, such as anthracite, brown, gas, long-flame, and coke. Particle size is used to disperse coal into several categories, including plate, fist, fist-nut,

nut, seed, and stove. For coal mines and quarries, however, hazards such intricate geological formations, unstable coal seams, and degradation of qualitative features as a result of unfavorable changes in mining-geological circumstances and automation call for technological advancement and cutting-edge machinery [129].

The Ukrainian renewable energy sector is grappling with feed-in tariff arrears, a result of partial payments over the past few years. The “green” tariff payment comes from the National Energy Company Ukrenergo`s funds and the revenues of the Guaranteed Buyer, which is responsible for centralizing the procurement of electricity from renewable sources. As of 2024, the transmission tariff is set at UAH 528,57/MWh, excluding VAT, with support for alternative energy sources at UAH 191,36/MWh [130]. The debt under the “green” tariff is estimated to be no less than 30 billion UAH. As of 30 November 2023, NEC Ukrenergo`s debt to the Guaranteed Buyer for “green” tariff payments amounted to 32,57 billion UAH. The arrears are primarily attributed to overregulation of the market and the mix of market mechanisms with temporary restrictions. State-owned producers finance the assignment of special obligations, such as increasing the share of electricity generation from renewable energy sources, acting as a supplier of last resort, providing services to support generating capacities, and improving combined heat and power generation efficiency. Shifting from negative aspects, Ukraine`s renewable energy sector has seen positive changes, with settlements by Guaranteed Buyers exceeding 91% in November 2023 and reaching 98,6% in December. The Guaranteed Buyer paid part of its debts for October, reaching 77,2%. Various methods are being developed to pay off green generation, including an increase in the electricity transmission tariff, the creation of a carbon dioxide trading market, and the introduction of feed-in-premium. The Ukrainian Climate Office aims to help decarbonize economic sectors, build adaptation governance, and implement the Paris Agreement provisions.

As any other country, Ukraine has some policies, regulating the development of energy sector. In line with Ukraine`s Energy Community commitments, the National Renewable Energy Action Plan (NREAP) was approved in 2014 [131]. Its ambitious objectives call for investing between 60 billion UAH and 70 billion UAH to increase the nation`s wind energy capacity to 2,28 GW by 2020. The installed capacity of biomass electricity generation is expected to increase 40 times, while solar energy will increase from 450 MW to 2300 MW and small hydro capacity will be increased from 120 MW to 150 MW. However, energy security of Ukraine is critically challenged by extensive damage to its energy infrastructure, prompting significant investments and international collaboration to enhance resilience and capacity even ten years ago. The extended gas price discussions with Russia, military action in eastern Ukraine, and the collapse of governmental power in Crimea all presented difficulties for Ukraine`s energy security in 2014. To mitigate the dangers of supply disruptions and shortages, the nation urgently needs effective energy policies. Significant harm has been done to coal mining and other energy-intensive businesses as a result of the drastic reduction in coal production in the Donbass region. The cessation of train operations and the devastation of roads and bridges caused a halt to the supply of coal from the Donbass region to central Ukraine and thermal power plants. Ukraine is continuing the reduction its gas import dependency and diversifying its supply sources through emergency measures, increasing domestic gas production, and expanding reverse-flow import capacities from European markets. However, the timeline of challenges can make the final and precited results look different. Ukraine joined the European Energy Community in 2011 and made an effort to put European energy policies into practice prior to the invasion in 2014. But progress was hampered by oligarchs` and vested interests` opposition. To keep political power, real reforms like market pricing for households were mostly ignored. Energy resources in occupied territories were lost as a result of the conflict, which had an impact on Ukraine`s coal self-sufficiency and increased its reliance on energy imports. Russia made matters worse by tampering with gas supplies and prices, which could have put Naftogaz in danger of going bankrupt. Another policy was adopted in 2015. In line with the Energy Community Treaty, Ukraine also approved a National Energy Efficiency Action Plan (NEEAP) with the goal of achieving 9% energy savings by 2020 [132]. Nonetheless, the government`s loss of control over Crimea and a portion of the Donbass region, coupled with two significant recessions in 2009 and 2013 - 2014, cut overall final consumption by 29,6% in 2015 – above the level set for 2020. The NAP stipulates that, provided all plans through 2019 and 2020 have been carried out, a new NEEAP and an updated NREAP must be created. Both are intended to be effective until 2030. From 2014 to 2017, Ukraine implemented important energy laws to increase energy security and bring the country into compliance with European norms, despite societal reluctance and concerns of an impending energy crisis. In August 2017, the Ukrainian government enacted the Energy Strategy of Ukraine (ESU), which attempts to break the link between economic growth and energy use [131]. Over the next 20 years, the GDP is expected to grow by 2,3 times while the total primary energy supply (TPES) is expected to expand by 7%. As a result, the TPES structure will change significantly and the energy intensity will decrease, with the share of renewable energy rising from 4% in 2015 to 25% in 2035. By 2035, the ESU will have established an emissions trading system and ensured adherence to pledges made to reduce emissions. Although coal will still be used to generate power, by 2035 its efficiency will have increased to 36,8%. A big conflict was expected by late 2021, with particular attention paid to possible risks to hydropower and nuclear installations. A lot of Ukrainian energy infrastructure was badly damaged during the full-scale invasion in 2022, and previously planned results were destroyed again.

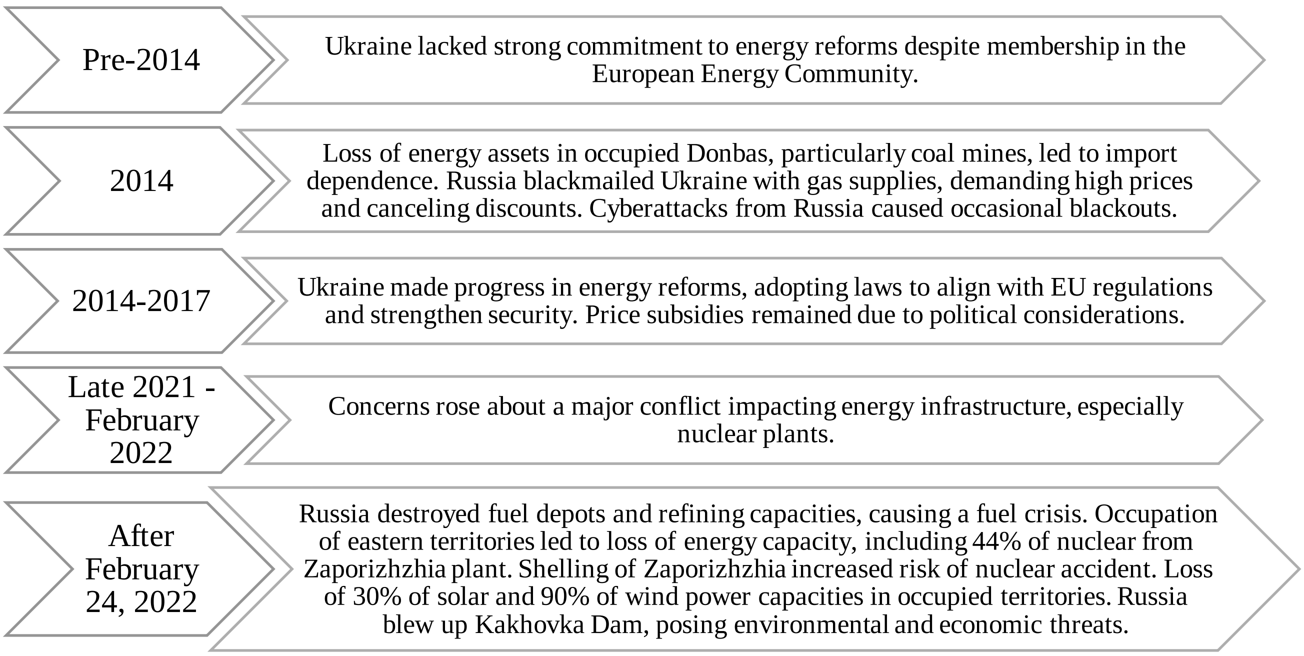

Figure 2.7 – Dates of negative impacts on the energy security of Ukraine
Source: based on [132]

According to International Energy Charter [133], the damages are made to nuclear energy, thermal energy, combined heat and power plants, large hydropower, and even renewable energy sources. More than half of Ukraine`s electricity is produced using nuclear energy, making it a vital power source. With a combined installed capacity of almost 14 thousand MW, the nation is home to four nuclear power stations (NPPs). Zaporizka NPP (ZNPP), the largest nuclear power station in Europe and the sixth largest worldwide, has been under Russian military occupation since the beginning of March 2022. Of Ukraine`s total installed nuclear power capacity, the plant's installed power capacity accounts for 43%. ZNPP produced almost 25% of the energy used in Ukraine prior to the Russian invasion. Due to strikes on Khmelnytska and Rivnenska NPP`s transmission system infrastructure as well as shelling of Pivdennoukrainska NPP, operations at ZNPP have been ceased since September 2022. State-Original Energoatom, the operator of all Ukrainian nuclear power plants, determined the estimated value of destroyed and damaged assets based on a preliminary examination of the losses inflicted on the ZNPP by Russian military forces. Following the plant's release, the precise number of losses and damages will be ascertained. Next, with 12 thermal power plants (TPPs) and a total installed generating capacity of 21.5 GW in 2022, coal was the main fuel used by these plants. TPPs produced 23,8% of the power in 2021. Two TPPs with 3,3 GW of capacity have been located in the occupied Donbas territory since 2014. Following February 24, 2022, three TPPs with a 7,7 GW capacity were taken over by Russian military forces. Presently, 44% of Ukraine's thermal power capacity are occupied; prior to February 24, all TPPs were destroyed or damaged. Switching to another point, the combined heat and power plants (CHPs) had an installed generating capacity of 6,1 GW in 2022, using in its work natural gas. They produced 5.5% of the electricity in 2021. Nonetheless, 8% of CHPs` capacity is occupied, and Russian assaults have destroyed or damaged 45% of them. Natural gas is the main fuel used by the majority of CHPs.

Taking the next issue, with installed electricity capabilities of 4,7 GW and 1,5 GW, respectively, Ukraine had three pumped storage projects (PSPs) and ten big hydropower plants (HPPs) in 2022. As auxiliary services to balance intermittent renewable energy (RES) capacities and satisfy peak demand, these plants are essential to the Ukrainian power system. PSPs and HPPs contributed 0,8% and 5,8%, respectively, to the production of energy in 2021. All facilities, however, were either attacked or destroyed; the Russian army-occupied Kakhovska HPP sustained damage. The primary operator, Ukrhydroenergo, filed a claim for damages over 0,5 billion USD at the European Court of Human Rights. The last part of sources loss analysis includes renewables. With 874 GW of potential for solar, onshore, and offshore wind, Ukraine has the most technical renewable energy potential in Southeast Europe. The nation's renewable energy industry has been expanding quickly; by 2021, it will account for 8,2% of electricity produced, up from 1,8% in 2018. At now, Ukraine has 9,5 GW of installed renewable energy capacity, of which 25% are occupied by users. In Ukraine between 2019 and 2021, the photovoltaic (PV) industry has the fastest growth rate with 7,6 GW installed. The RES facilities were gradually placed into service following the liberation of the briefly occupied regions by Russia; however, the amount of green power generated didn`t surpass 15% of their installed capacity due to damages. Eighty percent of Ukraine`s wind power capacity is located in occupied territory. Wind power plants are mostly found in the southern areas of the country, close to the coasts of the Black and Azov seas. Despite having an installed capacity of 273,9 MW, bioenergy power facilities only have 5,7 MW in use. In 2021, Ukraine`s small hydropower plants (SHPPs) had an installed capacity of 120 MW.

The consequences of war effected storage, transmission system, distribution networks, and demand and supply. The Zaporizka TPP built the first pilot energy storage facility in 2021, with plans for 212 MW. However, the only facility is currently under occupation, and all planned projects have been temporarily suspended. The distribution network, which included 200 thousand transformer substations, was run by 32 operators during the conflict. However, 8 thousand transformers, have been broken or disconnected. A fall of 30-35% in electricity demand was observed in Ukraine in 2021 as a result of mass displacement and industrial shutdowns. In 2022 it was seen a 25% decrease in total electrical generation compared to pre-war projections. Approximately 5 million customers lacked energy as of January 24, 2023, as a result of hostilities or capacity-limiting schedules. Although restoration work is ongoing, fresh attacks frequently impede its progress.

Nevertheless, the global and Ukrainian energy sectors adapt to both internal and external pressures in a dynamic environment. Ukraine has concentrated on increasing energy efficiency, expanding renewable energy sources, lowering reliance on imported energy resources, particularly gas, and diversifying its generating sources in recent years. However, Russia's attempts to exert pressure on the Ukrainian government by destroying its energy infrastructure were considered as a crucial instrument in accomplishing its objectives, which has presented Ukraine with significant issues as a result of the conflict. In 2022-2023, energy infrastructure was damaged and the energy supply became unstable due to military aggression.

According to the World Bank, due to war actions, Ukraine`s energy infrastructure has sustained substantial damage, resulting in losses of 11 billion USD. There are power outages all throughout the nation as a result of the damage to more than 50% of the infrastructure. The World Bank is contributing 200 million USD in grant finance for repairs as part of the government`s efforts to restore the energy grid alongside other international partners. The majority of power plants are back up in the grid, although production is still being limited by damage to the transmission substations. In 2023-2024, Ukraine will prioritize electrical grid restoration, which would meet 11% of the nation`s overall recovery needs. According to the United Nations Development Program (UNDP), protracted attacks will make Ukraine`s energy industry extremely vulnerable in 2023. Losses result from the system's emergency mode operation with constrained safety margins. 45% of vital high-voltage transformers in areas under government control have been destroyed or seriously damaged by drone or missile strikes since the beginning of the conflict. Many foreign and national institutions also express predictions about the state of affairs in energy sector in Ukraine and on global level (table 2.4).

Table 2.4 – Forecasts of different institutions about the future of global and Ukrainian energy sector

Institution	Forecasts
The World Bank	Ukraine`s economy would expand by 3,5% in 2023 and 4% in 2024 as a result of improved harvests, donor support, government expenditure increases, and adjustments to export routes via the nation`s western borders.
The United Nations Organization (UNO)	Since 2022, the capacity to generate energy has reduced by 50%; of the 37 GW deployed, 19 GW have been damaged, occupied, or destroyed. A considerable loss in maneuverability, including 67% of thermal generation capacity, further complicates this.
International Energy Agency (IEA)	Global power demand is expected to rise by 3,3% in 2024. This represents a recovery from earlier declines brought on by the current energy crisis and economic downturn. Improved prospects for the world economy are associated with this recovery. By 2024, renewable energy sources are predicted to overtake one-third of the world`s energy supply. Over the following two years, a decrease in fossil fuels is anticipated.
US Energy Information Administration (EIA)	The residential usage will account for the majority of the projected 2% rise in power use in 2024. Production of renewable energy is anticipated to increase, with solar energy playing a major role. It is anticipated that the use of fossil fuels will diminish, as natural gas output is projected to drop from 42% in 2023 to 41% in 2024. As a result of the US energy sector`s declining demand, coal production is also predicted to decrease, from 16% in 2023 to 15% in 2024.
International Renewable Energy Agency (IRENA)	Expediting energy transitions towards climate security has the potential to boost the world economy by 2,4% in the upcoming ten years. By 2050, the 1.5°C Plan hopes to generate up to 122 million employments in the energy sector, with over one-third of those jobs coming from renewable sources. Businesses, especially in the private sector, view the shift as a huge opportunity that will bring about changes in financing and draw in more long-term funding for renewable energy projects.
NPC Ukrenergo	A 2 GW winter energy system shortage is anticipated. But increasing import costs from nearby countries force Ukraine to turn to emergency aid. Volodymyr Kudrytskyi, the chairman, projects 15 billion USD investment to increase the flexibility and capacity of the energy system. This will involve additional thermal power and biofuel plants, as well as the expansion of wind farms, solar power plants, thermal power plants, energy storage systems, and pumped-storage hydroelectric power plants.
Ministry of Energy of Ukraine	Ukraine plans to focus on key energy sector areas in 2024, including nuclear industry development, decentralization of electricity generation, and strengthening energy infrastructure protection. The Ministry of Energy plans to collaborate with the US, UK, Canada, and the US to displace Russia from global nuclear fuel markets. Significant progress has been made in 2023, including the development of a new nuclear fuel for VVER-440 reactors and decentralization of energy generation. The ministry also aims to ensure safety and repair of energy infrastructure.

Source: based on [134]

The conclusions of global energy tendencies include renewable energy growth, decrease in fossil fuel usage, increased power demand, and investments in energy infrastructure. Ukrainian energy sector is predicted to face capacity challenges and further recovery, investment and infrastructure development with the help of partners, nuclear industry improvement and ensuring energy infrastructure security.

On the ground of all conducted analysis, the recommendations for Ukraine can be formulated. Change the leadership in the industry by appointing new leaders in the Ministry of Energy who have the necessary experience and competence to implement large-scale reforms, and ensure transparency and accountability in decision-making on energy recovery and development. Setting priorities for construction and restoration can be done by conducting a thorough damage analysis and assessing the viability of restoring generation facilities, focusing on the construction of new generation facilities that meet updated needs and challenges. Giving priority to controlled shunting generation (gas, PSPPs, biofuel power plants) can provide ensuring of balance in the grid. The government should also consider the possibility of gradually phasing out coal-fired power plants, taking into account environmental aspects and logistical difficulties with coal mining. Distributed and secure generation includes locating new generation facilities closer to new consumption centers in the center and west of Ukraine. The principle of microgrids can be introduced to increase the autonomy and resilience of regional power systems. Generation facilities are to be protected from enemy attacks with air defense systems and other methods. Attracting investments involves creating a favorable investment climate to attract private funds for the construction of new generation facilities. Public-private partnerships are to be considered for the implementation of large-scale projects. State budget funds and international assistance should be used to finance priority projects. Developing renewable energy sources without compromising stability covers the support of the development of renewable energy sources (RES) through market mechanisms and incentives while maintaining the stability of the energy system. The integration of RES with energy storage systems and the development of flexible grid elements should encouraged. Inefficient feed-in tariff schemes that create imbalances in the market are to be abandoned. Modernizing hydro-accumulative power stations, the most economical and potent energy storage option, is a part of the development of energy storage systems. For short-term storage, the introduction of battery-based energy storage systems is encouraged. Owners of RES are encouraged to integrate energy storage systems through the introduction of mechanisms. In order to increase the number and capacity of interconnectors, actively extending collaboration with the EU is necessary for integration with the European energy system. The Ukrainian grid is balanced by means of the European power system's capabilities. A strategy is created and put into action to synchronize the Ukrainian power grid with ENTSO-E. Lastly, establishing an open, competitive energy market free from monopolies and unfair competition is a key component of market regulation and consumer protection. There is assurance of precise regulation and control over market participants' actions. The rights of consumers to have reasonably priced, high-quality power are upheld (fig. 2.8).

Figure 2.8 – Measures for renovation of Ukrainian energy sector
Source: systemized by the author

Despite the significant damage caused to the Ukrainian energy system by the Russian occupiers, Ukraine has every chance to fully restore and modernize it. The primary task is to ensure reliable protection of existing power generation and transmission facilities by air defence systems. This will minimize the risk of repeated attacks and allow us to focus on restoring and modernizing the energy infrastructure. The restoration of

Ukraine's energy sector should be based on the following principles: distribution and resilience, energy efficiency, renewable energy sources, integration with the European energy system, and environmental protection: Implementing environmentally friendly technologies and minimizing the negative impact of energy on the environment. The implementation of these principles will not only restore Ukraine`s energy sector, but also make it more sustainable, safe and environmentally friendly. It is important to note that energy recovery will require significant investments. These funds should come from the state budget, international funds, and the private sector. Ukraine has already demonstrated its ability to mobilize resources and join forces to overcome difficult challenges.

Ukraine`s energy sector has experienced many shocks in recent years. As the dependence on fossil fuels remains high, the geopolitical situation in the supplying countries has a significant impact on Ukraine. A transition to green energy is in the near future, although since it only accounts for one tenth of the energy mix, this transition will not be quick. Nuclear energy continues to be the leading sector in terms of production and consumption, driven by a number of factors, mainly efficiency and availability of resources. However, concerns about the threat of a hostile neighbour are gaining momentum in global discussions. Currently, due to significant disruptions in the supply and generation chains, Ukraine is forced to use blackouts to stabilize the energy system. One of the reasons is the concentration of significant capacities within a single generation station, so it is worth considering decentralization. Other components that need to be changed are management due to poor efficiency, equipment refurbishment and a winning strategy for further construction of new plants, and the financial issue of attracting foreign investment, as in the near future, the largest share of the country's income will be used to support the military sector of the economy. In addition, the harmonization of the EU and Ukraine in the regulatory sphere, in particular taking into account the example of France, will help to partially overcome difficulties in the short term, building the basis for further long-term development.

CONCLUSION

Energy policy is a set of decisions, plans, and actions aimed at securing energy supplies, maximizing the efficiency of energy distribution, and promoting sustainable use. It involves government, business, consumers, regulators, and civil society in achieving energy security, economic efficiency, affordability, conservation, cost-effectiveness, energy use, diversity, and coherence among policy objectives. The main elements of energy policy include infrastructure, security, efficiency, environmental impact and energy resources.

Energy security is a key objective of energy policy because it is the backbone of the economy and a critical component of economic growth and poverty reduction. Energy shortages can limit economic progress by reducing growth potential, limiting capital and resource substitution, and affecting productivity and economic dynamics. Diversification of energy fuels pushes the sector towards continuous improvement, while innovations in the energy sector aim to increase resource efficiency in distribution and optimization.

Economic and energy security are interconnected, as volatile energy prices impede growth and contribute to a stable economic environment. Energy security focused on reliable and affordable energy sources reduces vulnerability to external shocks and promotes resilience. Dependence on volatile energy imports exposes the economy to external shocks, while renewable energy sources attract investment in clean technologies, fostering innovation and creating new economic opportunities in the green energy sector.

There are many challenges that need to be addressed, such as dependence on fossil fuels and non-renewable energy sources. Europe is an example of an effective transition to renewable resources with record differences in carbon dioxide emissions. Geopolitical tensions have also accelerated this process, as Russia's invasion of Ukraine has been a major shock to the global energy sector.

France relies heavily on three main sources of energy: nuclear, natural gas and oil, each with its own distinctive characteristics. Nuclear power is the backbone of France`s energy system, providing a significant portion of electricity with minimal carbon emissions. Natural gas plays a crucial role in meeting the energy needs of both residential and industrial enterprises, while oil remains vital for transportation and industry. Comparing France`s energy strategy with that of Ukraine, which is the second largest consumer of nuclear energy, provides valuable insights into improving energy security, reliability, and resilience in adverse conditions. The analysis of France and Ukraine`s resource development highlights their unique energy mix compositions within Europe. Both countries utilize a diverse range of energy sources, including nuclear power, fossil fuels, and renewables. However, their strategies for energy security differ, with Ukraine heavily reliant on non-renewable sources, particularly nuclear energy, which dominates its production and electricity generation.

The renewable energy sector in Ukraine struggles with financial issues, such as feed-in tariff arrears, but has seen some positive changes in settlements. Significant investments and international collaboration are needed to enhance the sector's resilience, especially given the extensive damage to energy infrastructure from ongoing conflict.

Ukraine`s energy policies, like the National Renewable Energy Action Plan (NREAP) and National Energy Efficiency Action Plan (NEEAP), aim to increase renewable energy capacity and improve energy efficiency. However, geopolitical conflicts and economic crises have disrupted these plans, leading to increased reliance on energy imports and significant losses in energy self-sufficiency.

The war has severely impacted Ukraine`s energy infrastructure, including nuclear power plants, thermal power plants, and renewable energy facilities. Damages have led to power outages and substantial financial losses. Restoration efforts are ongoing, with international support focusing on rebuilding the electrical grid. Despite the challenges, Ukraine aims to adapt by increasing energy efficiency, expanding renewable sources, and diversifying energy generation. Recommendations for the future include appointing experienced leaders, prioritizing controlled generation, phasing out coal plants, and attracting investments for new generation facilities. Emphasizing renewable energy development, integrating energy storage systems, and strengthening collaboration with the EU are also crucial for Ukraine`s energy sector recovery and resilience.

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