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

Form of education *full-time*

BACHELOR THESIS

Title: Global energy problem as a factor of world economic imbalances

By: Anisiia Tatarintseva ___________
(Student's name, surname) (Signature)

Academic Supervisor Doctor of economic sciences
(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 2023

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AGREED	**APPROVED**
Head of the project group (guarantor) of the educational-professional program	Head of the Department
___________________Y. Stoliarchuk	_____________Y. Stoliarchuk
(Signature)	*(Signature)*
______________ 2023	___________________ 2023

INDIVIDUAL TASK
higher education applicant: Anisiia Tatarintseva
Name, Surname
full-time forms of education

Bachelor Thesis
Title: Global energy problem as a factor of world economic imbalances

The title of the Bachelor's thesis has been approved by the Rector's Order «07» 12. 2022 №535

Bachelor Thesis is based on Eurostat, BP, International Renewable Energy Agency, U.S. Energy Information Administration, International Energy Agency, United Nations, World Bank, European Parliament, European Commissions

Deadline for submitting the final version of Bachelor's Thesis to the Academic Supervisor 20.05.2023

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

Chapter 1. Theoretical aspects of the global energy problem research
Chapter 2. Regional features of the formation and functioning of the energy market

Object of research:	**Global energy problem**
	Characteristics of energy problem
	Energy problem's essence
Subject of research:	**Features of global energy problem**
	Types of energy problem
	Consequences of Ukrainian-russian war on energy problem
The purpose of the Thesis:	**Understanding of the energy problem**
	Analyze the nature of energy problem
	Acquainting with policy towards energy problem

Specific tasks applicant has to accomplish to meet the objective:

In Chapter 1, the tasks involve examining the global energy problem and its impact on economic imbalances. These tasks include identifying key components of the energy problem, analyzing relevant aspects of global energy dynamics, and exploring factors contributing to energy imbalances. Additionally, assessing broader economic implications and aligning the energy challenge with Sustainable Development Goals (SDGs) are necessary. Progress towards achieving the energy-related SDGs is assessed by analyzing existing initiatives, policies, and achievements to identify areas requiring further attention and action.
In Chapter 2, renewable and non-renewable energy sources are examined. Tasks include assessing global availability and utilization of renewables, examining advancements in renewable energy technologies, and analyzing patterns of production, consumption, and distribution of non-renewables, especially fossil fuels. Key energy-consuming countries like the United States, China, Germany, and Norway are studied for insights into energy profiles and consumption patterns. Ukraine's energy dynamics within the European market are also analyzed, focusing on challenges and opportunities in achieving stability and reducing imbalances.

The task has been set by
the Academic Supervisor __________ Liudmyla Tsymbal
(Signature) *(Name, Surname)*
"17" 01. 2023

The task has been given to
Applicant __________ Anisiia Tatarintseva
(Signature) *(Name, Surname)*
"17" 01. 2023

Abstract

The bachelor's thesis consists of 86 pages, 3 tables, 21 figures, a list of 108 references, and appendixes.

"Global energy problem as a factor of world economic imbalances"

The object of research of the qualification bachelor's thesis is the energy problem, its essence and characteristics through the lens of the concept of imbalance.

The subject of the paper is an in-depth study of the types and features of the energy problem with an emphasis on the concept of imbalance and consequences of Ukrainian-russian war on energy problem.

The purpose of the paper is to provide a comprehensive understanding of the energy problem, in particular, focusing on the concept of imbalance. The study aims to analyze and describe the nature and characteristics of the energy problem together with the policy.

In accordance with this purpose, the following tasks are defined:

– Consider the concept of imbalance in the context of the energy problem;
– Evaluate the current state of renewable energy sources;
– Evaluate the current state of non-renewable energy sources;
– Analyze the energy profiles of key energy consuming countries;
– To explore Ukraine's role in the European energy.

The methodological significance of the study lies in the fact that it analyzes the current state of renewable energy sources, non-renewable energy sources, and the energy profile of key energy consuming countries. By addressing key aspects such as energy sources, consumption patterns, and market dynamics, the study provides a valuable knowledge base for promoting energy sustainability, resilience, and addressing global energy challenges.

The year of completion of the qualifying master's thesis is 2023.

The year of defense is 2023.
Keywords: energy problem, imbalance theory, renewable energy sources, non-renewable energy sources, energy profile, energy-consuming countries, energy market, energy policy, Sustainable Development Goals, energy transition

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"

Anisiia Tatarintseva
Title: Global energy problem as a factor of world economic imbalances

1. Relevance of the research topic is related to the restructuring of the energy market, the introduction of sanctions for the energy industry and, accordingly, a change in the general situation
2. Positive aspects of the thesis: the paper examines the key aspects of the development of the global energy market, the place of energy in the structure of global development goals, and the place of Ukraine in the global energy market.
3. The author's independent ideas and conclusions, scientific novelty. In the qualification work, an analytical assessment of renewable and non-renewable energy resources was carried out, which made it possible to assess the impact of energy resources on the economy of countries and determine the prospects for the formation of imbalances.
4. Practicality o the conclusions drawn and the specified recommendations can be used in the formation of the national strategy of economic development, tasks of the development of the energy sector in the post-war period.
5. Negative aspects of the paper: the work would greatly benefit from calculating the potential impact of sanctions on the energy market for individual countries of the world.
6. Total result of the bachelor Thesis and its approval for defense at Attestation Examination Commission: the work meets the requirements for qualifying bachelor theses, is written at a high theoretical and practical level and can be recommended for defense before the examination board with a total score of 48 points.

Academic Supervisor: Dr. of economic science, professor, professor of Department of international economy

____
(Signature) Liudmyla Tsymbal

"07" June 2023

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INTRODUCTION

The global energy landscape is undergoing a rapid transformation, characterized by a growing recognition of the need to address the imbalances inherent in our current energy systems. The nature and characteristics of the energy problem, viewed through the lens of imbalance, have become central to understanding the challenges and opportunities in achieving a sustainable and secure energy future. By analyzing the current state of renewable and non-renewable energy sources, examining the energy profiles of key energy consuming countries, and Ukraine's role in the European energy market, this study seeks to shed light on the complex dynamics that underlie the global energy landscape.

It is difficult to overestimate the importance of understanding the nature and specifics of the energy problem in an imbalanced world. This serves as a basis for developing effective energy policies and strategies that can guide the economy towards a sustainable and resilient energy future. By examining the imbalances that exist in our energy systems, we can gain a deeper understanding of the root causes of our energy challenges. These imbalances can take many forms, such as overreliance on fossil fuels, underinvestment in renewable energy infrastructure, or unequal access to energy resources. Identifying and addressing these imbalances is crucial to achieving a more equitable, secure and sustainable energy landscape. In addition, this study aims to assess the current state of renewable energy sources. Renewable energy technologies, such as solar, wind, hydro, and geothermal energy, have enormous potential to mitigate the environmental impact of our energy systems and reduce our dependence on limited resources. By analyzing recent advances, success stories, and obstacles faced by renewable energy, this paper aims to shed light on the opportunities and challenges associated with the transition to a renewable energy paradigm. At the same time, a careful assessment of non-renewable energy sources is essential to understand the complexity of our energy mix. Despite the urgent need to reduce greenhouse gas emissions and combat climate change, non-renewable energy sources, including fossil fuels and nuclear power, continue to play a significant role in global energy production. This work has a dual purpose. First, it aims to provide a comprehensive understanding of the nature and characteristics of the energy problem by exploring the concept of imbalances in our energy systems. Secondly, it seeks to analyze the current state of renewable and non-renewable energy sources, identify key challenges, and explore the energy profiles of leading energy consuming countries, with a special focus on Ukraine's position in the European energy market. The subject of the study is the energy problem, with a special emphasis on the concept of imbalance. The object of the analysis is the current state of renewable and non-renewable energy sources, energy profiles of key energy consuming countries, and Ukraine's role in the European energy market.

The importance of the study lies in its ability to inform policy makers, energy experts, and stakeholders about the imbalances inherent in our energy systems, as well as the critical factors shaping the global energy landscape. By revealing the nature and characteristics of the energy problem, this study will contribute to the development of sustainable and effective energy policies, promote international cooperation, and inspire transformative action towards a safer, cleaner, and more sustainable energy future.

CHAPTER 1
THEORETICAL ASPECTS OF THE GLOBAL ENERGY PROBLEM RESEARCH

1.1 The essence and characteristics of the energy problem in concept of imbalance

The rapid growth of the human population has led to unprecedented levels of energy demand. Rising living standards, urbanization and economic growth are the main reasons for the growing demand for goods and services. Unfortunately, this phenomenon has a negative impact on non-renewable energy sources, air and water pollution, and the global climate. These problems raise serious social and environmental issues when viewed in combination. Problems related to the production, distribution and consumption of energy are commonly referred to as the "energy question," with a particular focus on fossil fuels. Among the wide range of issues it addresses are energy poverty, climate change, energy security, and environmental degradation. This problem has become a huge global issue requiring immediate action as energy consumption is growing, especially in developing countries.

Rapid population growth has led to unprecedented levels of energy demand. Improving living standards, urbanization and economic growth are the main reasons for the growing demand for goods and services. Unfortunately, this phenomenon has a negative impact on non-renewable energy sources, air and water pollution, and the global climate. These problems raise serious social and environmental issues if considered in their complexity.

It is crucial to recognize the enormous impact of the energy paradigm on society as a whole, both in terms of the economy and the environment. This is reflected in Figure 1.1.

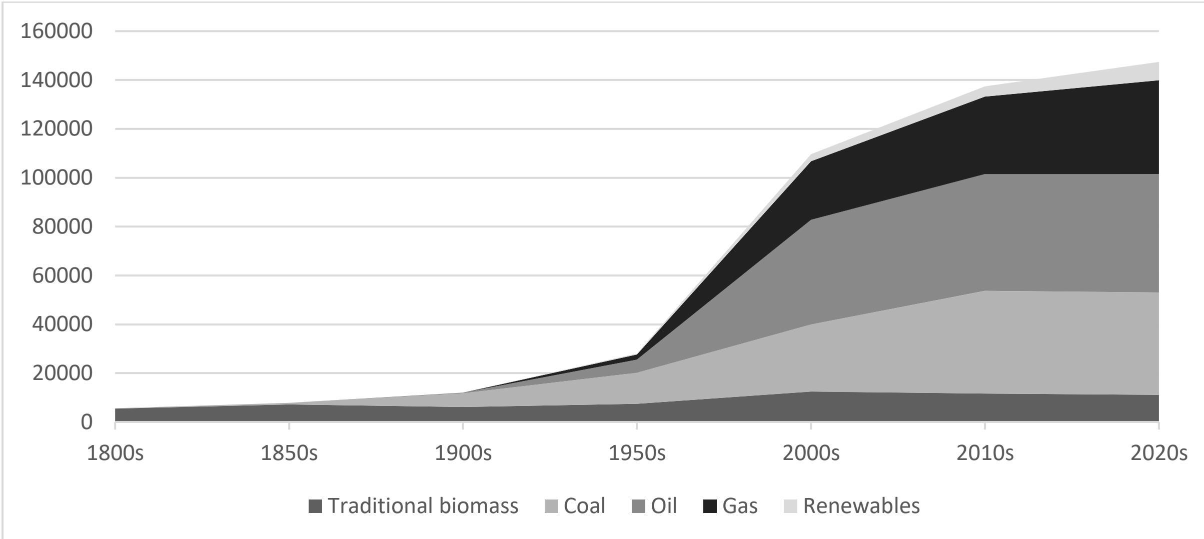

Figure 1.1. A comprehensive overview of the energy paradigm of the world from 1800s to 2020s, terawatt-hour

Source: BP Statistical Review of World Energy

The discovery and utilization of fossil fuels during the Industrial Revolution fundamentally changed energy production and consumption, leading to enormous economic growth and progress in industrialized countries. The unexpected economic expansion and progress, especially in United Kindtom, Europe and USA, was driven by the widespread use of coal and steam power [1, p. 290]. The exploitation of natural resources, particularly coal, oil, and natural gas, which were abundant and relatively easy to extract, fueled this development. However, this dependence on fossil fuels also had negative consequences, such as air pollution, climate change, and the economic and social gap between developed and developing countries. The ecosystem has been severely affected by the burning of coal and other fossil fuels, especially in terms of air and water pollution. This has had a significant negative impact on both the environment and human health.

Over the 20th century, the consumption of fossil fuels significantly rose while the economic and social diffirences between developed and developing countries grew wider. Access to affordable energy was crucial for economic growth and development, particularly in the West, but many developing countries were unable to meet their energy demands. As a result, there was a global asymmetry where wealthy nations had easy access to energy resources but had difficulty supplying reliable and affordable energy. The shift to the use of cheap energy sources such as coal, combined with technological innovation, is believed to have contributed to the impressive growth results achieved during this era, although a number of social and non-energy factors also contributed to the increase in productivity during this time [2]. Energy supplies around the world are under increasing pressure as nations progress to modernization and industrialisation and consume more energy as a result. Additionally, the ongoing dependence on non-renewable energy sources worsens environmental and societal issues like air pollution and climate change. The past ways of energy production and use have permanently changed the global imbalances, particularly the ecological problems and the economic and social injustices.

Global imbalances are a complex and multifaceted phenomenon that affect the distribution of resources, power, and wealth among countries and regions of the world. To understand the different academic interpretations of global imbalances and their impact on global development and prosperity, Table 1.1. provides an overview of five well-known academic definitions.

Table 1.1. – An overview of academic theories of global imbalances.

Year	Author	Theory
1967	Frank A.G. [3]	Dependency theory
1974	Wallerstein I. [4]	World systems theory
2005	Harvey D. [5]	Neoliberalism
1978	Said E. [6]	Postcolonial theory
2000	Mol A.P.J. & Sonnenfeld D.A. [7]	The theory of ecological modernization

Source: Systematization by author

Dependency theory is the first academic interpretation of global imbalances, which explains that global imbalances arise from unequal relations between developed and developing countries. Developed countries extract resources, control markets, and impose unequal trade relations on developing countries, which leads to a cycle of underdevelopment in developing countries, perpetuating their dependence on developed countries for aid and resources [3].

The second academic interpretation is world systems theory, which argues that global imbalances are a product of the capitalist world system. Central regions, usually developed countries, exploit peripheral regions, usually developing countries, for their resources and labor, resulting in social and economic inequality [4].

The third academic interpretation is neoliberalism, which views global imbalances as the result of free market economies and globalization. This interpretation emphasizes the concentration of wealth and power in the hands of a few wealthy individuals and corporations, leading to economic and social inequality, political instability, social unrest and conflict [5].

The fourth scholarly interpretation is the postcolonial theory, which argues that global imbalances are a legacy of colonialism and imperialism that left developing countries with limited access to resources and infrastructure. This interpretation emphasizes the historical context of global imbalances and the impact of colonialism on global development and prosperity [6].

The fifth academic interpretation is the theory of ecological modernization, which views global imbalances as the result of environmental degradation and resource depletion. This interpretation emphasizes the unsustainable use of resources, which causes environmental degradation and climate change. Sustainable development and global cooperation are crucial for solving environmental problems [7].

The energy problem arises from a number of challenging issues that negatively affect the availability, cost, environmental and public health impacts of energy sources. One of the most visible characteristics of the energy problem is the limited availability of traditional energy resources. The exhaustion of fossil fuels, the main source of energy, is a serious concern, as it is estimated that their reserves will last only for a few decades. This makes it necessary to find new sources of energy to meet energy needs. Energy sources are generally classified into two categories: non-renewable and renewable. The types of non-renewable and renewable energies can be seen in Appendix A.

Non-renewable energy sources are finite and cannot be replaced within a human life-time. These energy sources, including fossil fuel such as coal, oil and natural gas, are widely used for electricity production, heating and transportation. They are formed over millions of years as a result of the decomposition of dead organisms and are extracted from underground storage reservoirs through drilling or mining. Nuclear energy, which relies on the nuclear fission to produce heat, is another non-renewable energy source used to generate electricity. Non-renewable energy sources are the main source of energy used worldwide, accounting for around 75% of total energy consumption [8, p. 19]. However, their use has significant disadvantages. Fossil fuels are limited resources that will eventually be drained, and their extraction and consumption contribute to environmental degradation, including air and water pollution and climate change. Nuclear power creates a risk of nuclear accidents and generates hazardous waste that needs to be safely disposed of.

Renewable energy sources come from natural resources that can be renewed within human time, such as solar, wind, hydro, geothermal, and biomass. These energy sources have the potential to meet global energy needs in a sustainable manner, as they produce almost no greenhouse gases and do not exhaust limited resources. Solar energy is used through solar panels that convert sunlight into electricity; wind turbines that convert the kinetic energy of the wind into electricity generate wind energy. The kinetic energy of moving water, which drives turbines, generates hydroelectric energy. Geothermal energy is produced from the heat of the earth's crust and is used for heating and electricity generation. Biomass energy is produced from organic materials, such as wood, crops and waste, and is used for heating and electricity generation.

Renewable energy sources have the potential to replace non-renewable energy sources, reducing the environmental impact of energy production and consumption. However, renewable energy sources have certain differences [9, p. 2]. One of the key differences is their availability and cost of production. Non-renewable energy sources are limited and are becoming increasingly scarce and expensive to produce as existing reserves are drained and new sources become increasingly difficult to access. Renewable energy sources are becoming increasingly competitive in terms of production costs as technological advances and economies of scale make them more efficient and affordable. Another key difference between non-renewable energy sources and renewable energy sources is their environmental impact. Non-renewable energy sources are associated with significant environmental and health impacts, such as air and water pollution and greenhouse gas emissions. Renewable energy sources are associated with less environmental impact because they do not generate greenhouse gases and other emissions. Finally, there are differences in how non-renewable energy sources and renewable energy sources are classified and regulated. Non-renewable energy sources are often subject to regulations and taxes aimed at reducing their environmental impact. Renewable energy sources, on the other hand, are often subject to subsidies and incentives aimed at promoting their deployment and development, such as feed-in tariffs and tax credits. Other differences between renewable and non-renewable sources can be seen in Table 1.1.

Table 1.1. Distinctions between renewable and non-renewable sources.

	Renewable resources	Non-renewable resources
Advantages	– Do not produce greenhouse gases and help to reduce the impact on environment; – Will not be depleted over time – Can reduce the dependence on foreign oil and increase energy security	– Are easily accessible; – Can produce large amounts of energy; – Are currently less expensive than renewable resources; – Can be stored easily;
Disadvantages	– Are expensive to install and have high maintenance cost; – Require large land areas or water resources; – Can have negative impact on wildlife and habitats; – Are noisy and unappealing; – Are affected by weather.	– Produce harmful pollutants; – Are finite and will eventually run out; – Can cause environmental damage through resource extraction and production; – Can be a subject of price fluctuations and increase the energy dependence.

Source: Systematization by author

Thus, the nature, classification, and differences between non-renewable and renewable energy sources have a significant impact on energy production and consumption, as well as on environmental sustainability and economic development. Policies that promote the development and deployment of renewable energy sources can help ensure environmental sustainability, energy security, and economic development. The transition to clean energy is crucial to creating a sustainable and equitable future for all. In addition, the growing dependence of countries on energy imports raises serious concerns about energy security. Energy dependence has significant geopolitical implications, as states seek to secure access to energy resources to support their economic development and protect national security. Countries with energy resources, such as Saudi Arabia and russia, have significant influence on global politics by using their energy resources in diplomatic and trade relations. This has led to tensions between energy-rich countries and energy-importing countries, as the latter seek to reduce their dependence on a few energy-rich countries by diversifying their energy supply sources.

Definitions of energy poverty typically aim to capture the lack of access to modern energy sources needed to provide basic energy services such as lighting, cooking, and heating. Fuel poverty is another commonly used term that generally refers to households that have access to modern energy services that they cannot afford, but there is no universal definition. Lack of access to modern and reliable energy services affects the health, education, and economic opportunities of millions of people around the world.

Energy poverty is primarily brought on by three factors: high energy costs, poor household incomes and inefficient buildings and equipment. It can occasionally be made worse by additional issues with the energy industry, including a lack of suitable energy services in a certain location. This, as well as the deteriorating state of distribution networks in particular, make the issue worse in many developing countries, especially in rural and distant locations [10, p.1]. While heating subsidies and social tariffs help to reduce the worst effects of energy poverty they are not a long-term solution to lift these households out of energy poverty. There are many negative impacts of lack of access to energy for developing countries, including on health, gender inequality, education, poverty and overall economic development. The impact on health is quite severe, as shown in respiratory diseases, especially among women and children due to high levels of indoor air pollution from traditional biomass stoves. Education suffers greatly in developing countries, due to the inability to study in the evening or to access digital learning tools [11, p.22]. In addition, small businesses cannot operate effectively without access to energy. Solutions have been identified as switching to "modern" fuels, investing in grid expansion or, more recently, supporting micro-scale renewable energy sources.

The socio-economic implications of energy production and consumption are significant and can potentially worse social and economic disparities [12, p.29]. One of the most important problems in the energy sector is the unequal distribution of benefits and costs, which creates social and economic inequality in society. Typically, the benefits of energy production go to a small group of individuals or corporations, while the costs are borne by local communities and ecosystems. This situation can lead to increased poverty and socio-economic displacement. More efficient use of energy can help reduce the negative impacts of energy consumption while ensuring the same economic development. National energy efficiency programs can help to reduce energy costs and reduce energy imports, which reduces pressure on the exchange rate and ensures the availability of scarce energy resources.

The impact is particularly significant in emerging economies, where the benefits of energy efficiency are generally greater than in developed countries, as access to energy is often limited in these countries and energy efficient technologies can help in many cases. Having access to energy efficient technologies can help meet energy needs while reducing costs and increasing energy security [13, p.14]. In addition, energy security has become a critical issue with regard to the reliability of energy supply and access to energy resources. Lack of energy security can have significant economic, social and political consequences, especially for developing countries. Therefore, addressing energy security is essential for sustainable and inclusive economic growth [14, p.15]. The concept of energy security has become a key aspect of global politics as countries seek to guarantee a reliable supply of energy at reasonable prices to support their economic growth and national security. One of the reasons for this goal is that energy systems in different countries differ from each other. This has led to the creation of international institutions and agreements aimed at ensuring a stable and reliable energy supply.

Transforming the energy mix and improving energy efficiency can lead to significant reductions in carbon dioxide (CO_2) emissions and strengthen energy security. The growth of greenhouse gas (GHG) emissions from energy consumption remains a major contributor to climate change. Achieving this goal requires that global CO_2 emissions peak by 2025 and reach net zero by 2050 [15, p.130]. Unfortunately, the current rate of CO_2 emissions does not meet the targets set by the Paris Agreement which aims to curb global temperature rise. Various policies and initiatives, such as renewable energy targets, carbon pricing, energy efficiency standards, and renewable energy subsidies, are key to mitigating climate change, reducing energy dependence, and minimizing the impact of energy price volatility. To this end, environmental taxation, including carbon taxes and fossil fuel "exemptions" can facilitate the transition to low-carbon energy sources and raise additional fiscal revenues that can provide sufficient funding to compensate the most vulnerable households and invest in structural resilience. Decarbonization involves a transition from fossil fuels to cleaner and more sustainable energy sources, such as renewables and nuclear power. This transition can help reduce greenhouse gas emissions and mitigate the effects of climate change [16, p.36].

As a result, the energy dilemma has many different facets, including technological, political, economic, and environmental issues. An important framework for understanding the energy crisis and its root causes is the theory of imbalance, which emphasizes the importance of correcting the imbalance between supply and demand, as well as the imbalance between different energy sources. Improving energy efficiency, deploying low-carbon and renewable energy sources, and developing carbon capture and storage technologies are just some of the responses needed to achieve a sustainable energy system. In addition, the geopolitical implications of the energy problem cannot be ignored, especially in the context of increased competition for energy resources and the growing influence of energy-producing countries. Ensuring energy security and diversification of supplies will be crucial to maintaining a stable and prosperous economy and society.

1.2 Global energy problem as an element of the Sustainable Development Goals

In 2015 the United Nations established the Sustainable Development Goals (SDGs), also known as "Transforming our world: The 2030 Agenda for Sustainable Development". The 17 Sustainable Development Goals, which are part of the 2030 Agenda, help countries in the region analyze and develop ways in which they will realize this new, shared vision of sustainable development set out in the Agenda. The SDGs reflect the demands of global stakeholders to balance social, economic and environmental growth [17, p.4]. Through the creation of public policies and budgets, monitoring and evaluation tools, they support each country on its path to sustainable, inclusive and environmentally sound development. The 17 SDGs listed in Appendix B cover topics such as eradicating global poverty and taking immediate action to mitigate climate change by 2030 [18]. In order to meet the current and future demands of stakeholders and contribute to the sustainable development of society as a whole, the SDGs seek to motivate the operationalization and integration of sustainable development in organizations around the world. However, while this global initiative is a reliable source of inspiration, the diverse interpretation of the SDGs requires additional policy work to increase the understanding and scientific resonance of subsequent SDG-like initiatives. One of the most important issues addressed by the SDGs is the global energy problem, which is central to achieving the other goals. The energy issue is crucial for sustainable development, as it affects economic development, social progress and environmental conditions. Energy poverty, energy security, and energy transition are also related to the energy goals of the SDGs.

The key to solving the energy problem is energy governance. Energy governance is the process of managing and regulating the production, distribution, and consumption of energy resources. Effective energy governance is directly relevant to ensuring energy security and access to modern energy services, which is crucial for reducing poverty (SDG 1) and promoting economic growth (SDG 8), especially in developing countries. Another SDG goal that energy governance addresses is environmental sustainability (SDG 13). Energy production and consumption are the main sources of greenhouse gas emissions that contribute to climate change and other environmental problems such as air and water pollution [19, p.22]. The goals most affected by the energy problem are shown in Figure 1.2.

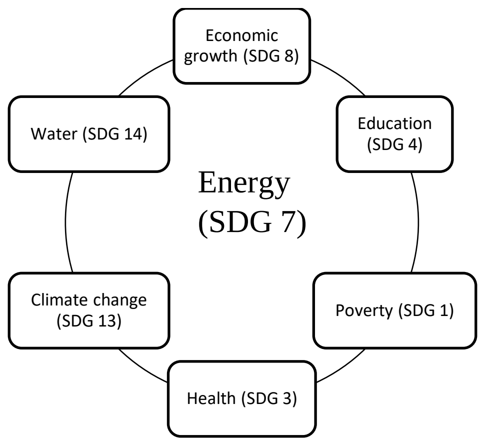

Figure 1.2. The linkage between energy problem and Sustainable Development Goals

Source: Systematization by author

It should also be noted that energy is a key source of economic growth, as many types of production and consumption activities are related to the use of energy as a basic resource. The energy sector fuels the economy, which provides the necessary energy infrastructure. From a physical perspective, energy use drives economic productivity and industrial growth and is central to the functioning of any modern economy. Access to inexpensive, reliable, and sustainable energy is crucial for reducing poverty, enhancing health and educational results and promoting economic progress. A sustainable energy system must also be adopted in order to prevent climate change, protect nature and maintain environmental sustainability. In this sense, the energy transition is a fundamental problem that supports the achievement of each SDG.

The economic growth target (SDG 8) aspires to ensure full and productive employment, decent work for everyone and sustained, inclusive, and sustainable economic growth. Energy use and economic growth have a complicated and interconnected relationship [20, p.437]. Raising living standards, encouraging human development and eliminating poverty and inequality all depend on economic growth. Economic expansion however can also have detrimental effects on the environment, such as rising greenhouse gas emissions, pollution, and the depletion of natural resources. Consequently, encouraging the use of renewable energy sources, increasing energy efficiency, and lowering waste and emissions are all part of fostering sustainable economic growth.

The three main factors influencing energy demand are population expansion, per capita economic activity and technological advancements [21]. Energy demand increases with population growth, especially in developing countries where population growth rates are higher. The amount of economic activity per capita is an important factor in increasing energy consumption, and the demand for energy-intensive goods and services also increases as countries become more industrialized and incomes rise. Education and energy are two of the most important components of sustainable development. Education is the key to unlocking human potential and promoting social and economic development. Access to affordable and reliable energy is crucial to ensure quality education for all students and sustainable energy development. As electricity can offer a wide range of services in the classroom, the shortage of electricity in schools is a regrettable issue. [22, p.4]. It is simpler to introduce information and communications technology (ICTs), such as computers and televisions, into the classroom when there is access to electricity. Principals of electrified schools are able to hire and retain teachers who are better qualified, which leads to higher test scores and graduation rates

In addition, the energy challenge exacerbates poverty and inequality, as those without access to energy are often among the most vulnerable and marginalized [23, p.16]. Students living in remote rural areas may face a lack of access to energy, which can lead to school absence due to lack of transportation to get to school. This may be especially true for girls, which may increase dropout rates. The economic impacts of the energy crisis may limit opportunities for education and training. Lack of resources, technical problems, and theft are additional challenges. By spreading energy knowledge, awareness of the value of sustainable energy can be raised and the transition to sustainable energy systems can be facilitated.

Another element that cannot be ignored in the connection between energy and education is poverty. In order to end the cycle of poverty and build a more fair and equal sustainable future for everybody it is important to address energy poverty and make educational investments. Energy and poverty are interrelated issues facing the world, especially in developing countries [24, p.83]. Energy plays a central role in poverty reduction. The first energy priority for people living in poverty is to meet their domestic energy needs for cooking and heating. The world's poorest and most marginalized communities rely on traditional energy sources such as wood, charcoal, and kerosene. These fuels are often expensive, inefficient and unsafe, leading to indoor air pollution and health problems. Although the Sustainable Development Goals aimed at reducing poverty do not specifically address the role of energy, access to energy services is a crucial element in achieving these goals. However, it is not easy to use new technologies or non-renewable energy in poor areas. The main reason is that policy decisions are not the same for rural and urban areas. A complication for electrification in rural areas is their remoteness and low demand density, which increases the cost of this action several times.

In low-income nations where households use solid fuels, indoor air pollution is a severe health issue [25, p.2]. These fuels produce significant amounts of air pollution, which increases the risk of lung cancer, cardiovascular illness, and respiratory infections. Another major health risk is outdoor air pollution, particularly in urban areas. Lung cancer and other respiratory, cardiovascular, and industrial disorders can all be brought on by burning fossil fuels for energy production. According to the WHO, 7 million premature deaths are thought to occur annually as a result of outdoor and indoor air pollution [26, p.11]. Switching to renewable energy sources is one of the most important measures people can take. The use of energy-efficient technologies and practices is also a vital step. Energy efficient technologies and practices such as heating systems, solar panels can be implemented as a means to achieve this goal. In addition, laws and regulations can reduce the negative health impacts of energy. This could include establishing air quality standards, encouraging non-motorized and public transportation, and phasing out fossil fuel subsidies.

Biodiversity is particularly threatened by climate change, which can lead to rising temperatures, changing precipitation patterns, and more frequent extreme weather events. Climate change has implications for human well-being, including changing disease patterns and increased opportunities for invasive alien species, and affects animal ranges and behavior. The SDGs can only be achieved if the impact of the energy crisis on biodiversity is seriously considered. Firstly, life under water (SDG 14), which calls for the conservation and sustainable use of oceans, seas and marine resources for sustainable development, cannot be achieved without biodiversity. Acid rain and related pollution from fossil fuel combustion continue to damage forests, lakes and soils today. Secondly, the energy challenge also affects the provision of life on land (SDG 15), which aims to protect, restore and promote the sustainable use of terrestrial ecosystems, sustainable forest management, combat desertification, and halt and reverse land degradation and biodiversity loss. Ecosystems provide relatively inexpensive and accessible sources of traditional biomass energy and therefore play a vital role in supporting the poor. If these resources are threatened, as they are in some countries with extreme rates of deforestation, poverty reduction will become an even greater challenge.

The interconnection between energy and water has a significant impact on achieving affordable and clean energy (SDG 7), which aims to guarantee everyone access to affordable, reliable, sustainable and modern energy. Energy is crucial for raising living standards, reducing poverty, and promoting economic growth. Also, the interconnection between energy and water has a significant impact on the achievement of SDG 13, which aims to take urgent action to combat climate change and its impacts. Climate change also affects the availability and sustainability of water resources, as changes in precipitation patterns, droughts and floods affect water availability and quality. The advantages of electricity and water supplies for reducing poverty and advancing the economy are frequently coupled by deteriorating ecosystems with potential negative impacts on the environment and considerable yet intangible costs. Achieving sustainability means first and foremost addressing the co-transformation that economic progress related to the provision of water and energy for fuel and food can have on the environment.

The change in the basic mechanisms governing the evolution of human societies caused by technological, economic and social progress is known as the energy transition. The international community is developing decarbonization plans to continuously reduce greenhouse gas emissions. Due to the influence of regional socio-economic factors, this process is specific to each country. So far, the world has seen three typical energy shifts. The initial shift required a shift from wood as the main energy source to coal. During the second transition, oil took over the role of coal as the main energy source. In the third stage, a global commitment was made to switch from fossil fuels to renewable energy. However, the high cost of renewable energy technologies is one of the main obstacles to the energy revolution. Even if the price of renewable energy has recently fallen sharply, it is still more expensive than the price of fossil fuels. It is believed that today the world is going through the fourth energy transition after three energy transitions in the past. The main goal of this fourth transition is to combat global climate change by decarbonizing energy supply and consumption patterns. For the purpose of lowering carbon emissions, reducing climate change, and achieving SDG 13, which is focused on climate action, an increase in the amount of renewable energy in the energy mix is essential. Second, increasing energy efficiency is crucial. Enhancing energy efficiency can lower energy consumption and carbon emissions making it a key step toward attaining SDG 7 which is focused on supplying affordable and clean energy.

Also attaining SDG 7 depends on increasing access to energy. Presently, 3 billion people rely on conventional biomass for cooking and heating, and more than 900 million people worldwide lack access to electricity [27]. Increasing access to clean and sustainable energy sources is crucial for attaining numerous SDGs, including SDG 1 (no poverty), SDG 3 (good health and well-being), and SDG 8 (promoting economic development). To establish a sustainable energy system, it is necessary to encourage international cooperation and partnerships. International collaboration can make the transfer of technology, money, and expertise easier, increasing the availability of sustainable energy for poor nations. International collaborations can help with the sharing of best practices and experiences, which can result in better programs and policies aiming to create a sustainable energy system.

Thus, the global energy problem is an integral element of the Sustainable Development Goals set by the United Nations. It is not only a fundamental driver of economic growth, but also a critical determinant of social and environmental well-being. The energy problem poses significant challenges to the achievement of the Sustainable Development Goals, including poverty eradication, food security, health, education and climate change. Obviously, achieving the Sustainable Development Goals requires a comprehensive and sustainable solution to the energy problem. This implies adopting a holistic approach to energy planning and management, promoting renewable energy technologies, improving energy efficiency, and expanding access to clean and affordable energy services for all. Countries should work together to create policies and regulations that encourage the development of renewable energy technologies, promote energy efficiency, and reduce dependence on fossil fuels. This transition will require significant investment, research and development, and innovative approaches to meet the unique energy needs of different regions. Governments, the private sector, and civil society must work together to strengthen energy security, increase access to energy, and mitigate the negative environmental impacts of energy production and consumption.

CHAPTER 2.
REGIONAL FEATURES OF THE FORMATION AND FUNCTIONING OF THE ENERGY MARKET

2.1 Current state of renewable energy sources

Today's advances in technology make it possible to use environmentally friendly raw materials, also known as renewable energy sources. These sources of energy, which include solar, wind, hydro, geothermal and biomass, are becoming increasingly available and affordable. For a brief overview of the differences between these types, see Figure 2.1.

Hydro — **15.1% global electricity generation (2022)**
- Dams alter the natural flow of water to increase its elevation and volume. Water flows through dam, generating nechanical energy that spins a turbine connected to an electric generator

Wind — **7.6% global electricity generation (2022)**
- Wind flows over the blades of a wind turbine creating mechanical power by turning blades. The blades are connected to a drive shaft that turns an electric generator to produce energy

Solar — **4.5% global electricity generation (2022)**
- Photovoltaic (PV) cells contain thin semiconductor wafers, forming an electric field. When light hits cells electrons move in response to the electric field. This genersates electricity, transferred through metal conductors on the PV cells

Biomass — **2.4% global electricity generation (2022)**
- Biomass is burned in a boiler to produce steam. Steam rotates the blades of a turbine connected to a generator that produce electricity.

Geothermal — **<1% global electricity generation (2022)**
- Hot water from underground reservois is pumped using pipes or wells. As the water reaches the surface it boils over into steam which rotates a steam turbine. The turbine is connected to a generator that produces electricity

Figure 2.1. Five major types of renewable energy, 2022 [28]

To achieve Sustainable Development Goal (SDG) 7, proposed by the United Nations Development Program (UNDP): Guaranteed access to affordable, reliable, sustainable and modern energy for everyone, financial support and new policies are needed, as well as the willingness of countries to implement new technologies on a large scale globally. The use of renewable energy sources with limited emissions can reduce the number of illnesses and deaths caused by the burning of fossil fuels. On the other hand, the environmental impacts associated with the extraction and processing of large amounts of raw materials needed to produce parts used for renewable technologies can lead to increased greenhouse gas emissions. This will outweigh the savings benefits of switching to renewable energy, and in the worst case scenario, increase poisoning by heavy metals and radioactive elements [29, p.13].

Figure 2.1 shows that the most used energy is hydropower. Hydropower is a renewable energy source where energy is generated from the energy of water moving from higher to lower elevations. It is a proven, predictable and generally cost-competitive technology. It requires a relatively high initial investment, but has a long service life with very low operation and maintenance costs. Hydropower projects are adapted to the specific characteristics of their location, taking into account the river system in which they operate. The wide range of sizes of hydropower plants allows them to meet both large urban energy needs and smaller decentralized rural needs. It is important to note that hydropower plants do not consume the water used to drive the turbines. The water remains available for a variety of other important purposes after electricity generation. Hydropower plants can typically be categorized into three main groups based on their operation and flow type, which are shown in Figure 2.2. These groups include run-of-river (RoR), storage (reservoir), and pumped storage hydropower plants (HPPs), and their size can vary widely based on the hydrology and topography of the watershed they are located in. In addition to these three categories, there is a relatively new technology called in-stream technology, which forms a fourth category.

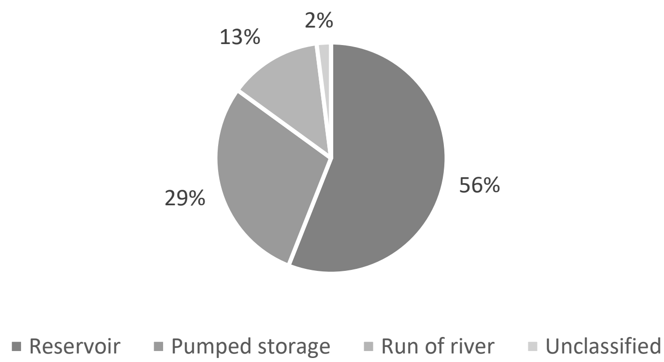

Figure 2.2. Net increase in hydropower capacity by technological segments in the world in 2022, % [30]

A Run-of-river (RoR) hydropower plant primarily relies on the natural flow of a river to generate electricity. The amount of energy generated by the plant depends on the flow of the river, which is largely influenced by precipitation and runoff. The RoR plant has limited control over the flow of the river, and its capacity is determined by the available flow [31]. Reservoir plants frequently include generating stations that are connected to the reservoir through tunnels or pipelines and are situated at the dam toe or further downstream. The design of the hydropower plant and the type of reservoir that can be built is largely dependent on the topography and opportunities presented by the landscape [32, p.11]. Pumped storage plants (PSPs) act as technology for storing energy rather than producing it. During times of low energy demand, water is pumped in this system from a lower reservoir to an upper reservoir. When there is a lot of demand, the water flows against its natural flow to produce energy. PSPs can also integrate renewable energy sources like wind and solar power and help keep the system stable. Pumped storage is the largest grid energy storage option on the market right now. However, the environmental impact of PSPs can be considerable, as the construction of large dams and reservoirs can result in the flooding of natural areas [33, p.599].

The establishment of hydropower infrastructure is closely related to national, regional, and international development strategies. Hydropower can promote poverty reduction and sustainable development in addition to helping to ensure energy security and lessen reliance on fossil fuels. To advance hydropower development, we must address the primary obstacles, which can be categorized into three main groups namely environmental constraints, operational constraints, regulatory constraints [34, p.4] and can be seen in Figure 2.3.

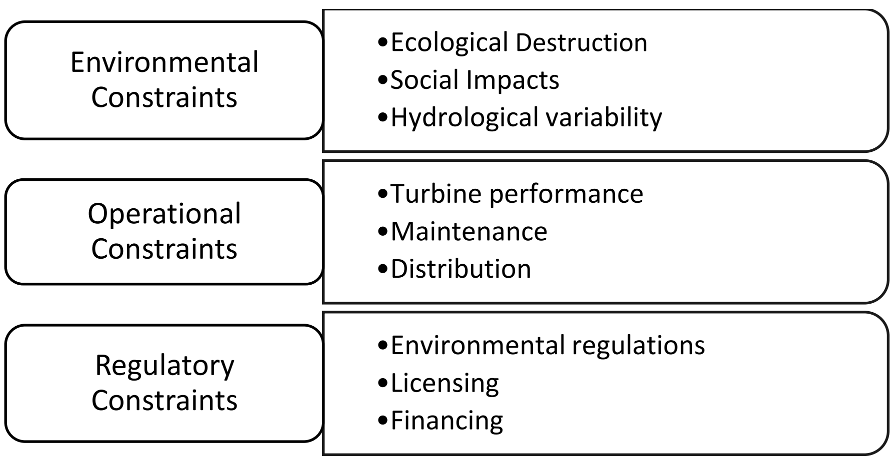

Figure 2.3. Types and subtypes of hydropower system constraints

Source: Systematization by author

Understanding the potential impacts of hydropower construction and operation on the environment and nearby communities is crucial. The physical infrastructure of a hydropower plant can alter the structure of a river's flow, leading to changes in water quality, flow patterns, and aquatic habitats. This process can lead to the flooding of vast areas, which will destroy aquatic habitats, displace local flora and fauna, and change the dynamics of the ecosystem as a whole. Additionally, the benefits of hydropower development might not be equally scattered, leading to existing economic and social gaps getting worse as some areas and groups profit more than others do [35, p.5] The operational constraints for hydropower plants are comparable to those for thermal generators, but they additionally have special water-related constraints. The amount of energy that can be generated, the variety of power levels that can be generated, and the rate of capacity expansion that can be achieved are all limited by these factors. Erosion caused by water passing over parts of the turbine can lead to reduced performance and increased maintenance costs [36, p.4]. The use, production and storage of water at hydropower facilities is regulated by a number of laws and agreements [37, p.2]. Water rights, flood management, and electricity regulation are just a few examples of regulations that may be subject to agreements between various parties, including public and private organizations. The requirement for developers to obtain a license from federal or state regulatory authorities to operate hydropower facilities is another significant regulatory barrier. Government grants, loans, private investment, and project finance are some of the possible financing options.

Hydropower is a desirable source of energy because of its many advantages. It produces the most electricity, accounts for more than 15% of the world's electricity supply, and over the past 20 years, global hydropower capacity has increased by 70%, but its share in total production has remained stable due to the growth of wind, solar, coal and gas power [38, p.7]. Hydropower is a low-emission energy source, as it produces only 4 to 14 g of CO2.eq/kWh per year [39, p.15]. A dam is able to provide steady electricity production for many years after it is built. This means that they can continue to contribute to electricity generation for a long time because dams are built to last. As a result its usage steadily increases throughout years, as it is shown in Figure 2.4.

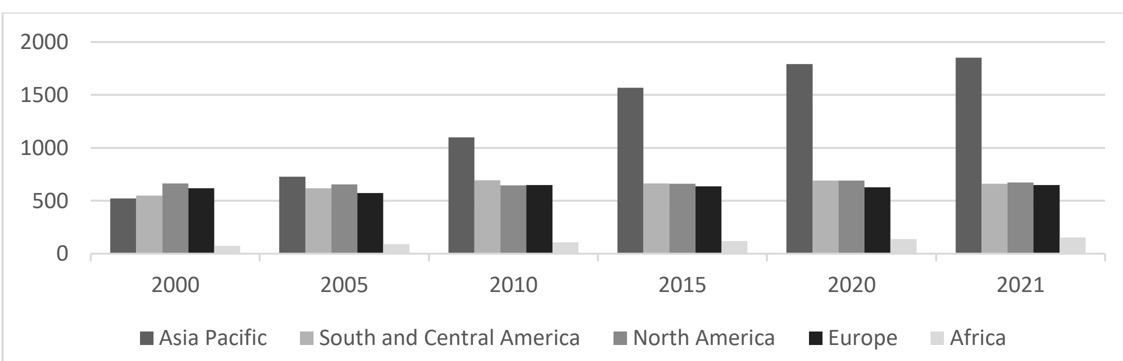

Figure 2.4. Hydropower generation by region from 2000 to 2021, terawatt-hour [40]

To ensure the environmental viability of hydropower projects, an integrated planning strategy is needed that balances environmental factors, including water quality, species diversity, recreation, and physical processes in the ecosystem. The Environmental Measures for New Hydropower is a Department of Energy initiative that aims to provide science-based environmental measures for use by designers, decision makers, policy makers, scientists, and other stakeholders in the evaluation of hydropower projects. The goal of innovation at the moment is to make plants more flexible by changing turbine designs, operating procedures, and digitalization. However, compared to other renewable energy technologies, hydropower projects have longer preparation, construction, and operation periods. This leads to higher investment risks and requires special policy instruments and incentives, as well as a longer-term political perspective and vision.

Wind energy is the second largest producer of renewable energy globally. Numerous ways to generate wind energy have been used for thousands of years. However, it was only in the 1970s that technological advances and government support made commercial wind power production possible [41, p.23]. While there are a variety of wind energy technologies for different applications, the main way wind energy is used to mitigate climate change is to generate electricity through large, grid-connected wind turbines that are installed either on land (so-called "onshore") or in sea or fresh water (so-called "offshore").

Most parts of the world have sufficient technical capacity to support the deployment of significant amounts of wind power. Onshore wind power has particularly large technical potential in North America, Eastern Europe and China, but some regions of Asia and Europe in the OECD have less technical potential for onshore wind power. Research to date suggests that, although the field is still young and requires further research, global climate change may change the geographic distribution of wind energy resources, but these effects are unlikely to have a significant impact on the global potential for wind energy deployment. Modern grid-connected wind turbines have evolved from modest, simple devices to huge, highly complex machines. Figure 2.5 illustrates the stark contrast between the deployment of onshore and offshore wind technologies.

Figure 2.5. Number of annual new wind installations in Europe from 2012 to 2021

Source: WindEurope

Onshore wind turbines are installed on reinforced concrete foundations, which provides stability. In terms of onshore wind farms, China has overtaken Europe to become the largest onshore wind market, accounting for almost a third of the world's installed capacity [42, p.14]. Given the higher initial costs, offshore wind technology is less developed than onshore wind power. Due to the relative lack of maturity of the technology and the inherent logistical challenges associated with maintaining and servicing offshore turbines, there is often a low availability of power plants and higher maintance costs. Nevertheless, the EU and more and more other regions are showing great interest in offshore wind power. With the development of offshore wind power, visual impact, turbulence and noise levels have significantly decreased, allowing for the use of larger turbines and higher turbine rotor speeds.

The expansion of renewable energy capacity is expected to accelerate significantly over the coming years as a result of the combined impact of geopolitical concerns, climate imperatives, and energy security challenges. This acceleration is driven by sustained cost advantages over fossil fuels as countries and regions work to achieve their ambitious energy and climate goals. The COVID-19 crisis and its aftermath (which included significant logistical disruptions and heightened geopolitical tensions) have helped people realize how important it is to have more diversified and resilient supply chains. The numerous challenges associated with wind energy can be categorized into six groups: system design, society, supply chain, technology, infrastructure, and labor. All of these issues have an impact in the near future or will have an impact in the long term, as shown in Appendix C Figure C.1.

Wind power is becoming increasingly important in the global energy mix as more and more people turn to renewable energy sources. Regional differences in wind energy production are largely driven by terrain, climate, and political situations. As shown in Figure 2.6, Asia dominates the global wind energy market with 41% of the installed capacity [43]. Thanks to its share of the global market, Asia Pacific continues to lead the way in wind power development, with impressive growth in China. China, the United States, Brazil, the Netherlands and Germany were the five largest international markets in terms of new installations in 2022.

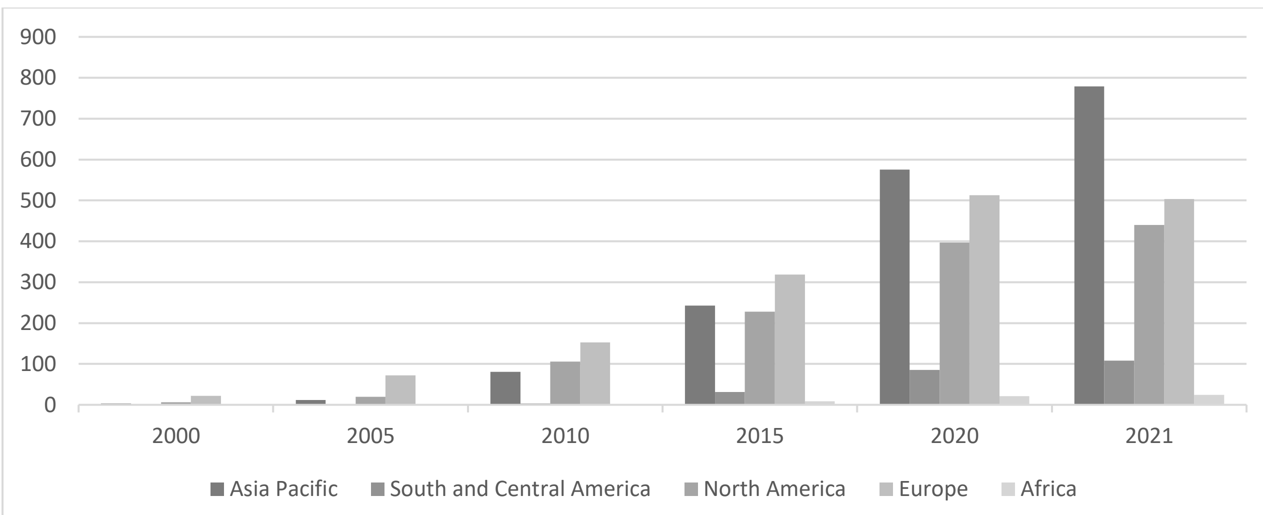

Figure 2.6. Wind energy generation by region from 2000 to 2021, terawatt-hour [44]

In recent years, there has been a significant increase in the use of wind power in Europe due to aggressive climate targets and a favorable governmental environment. Some of the highest wind energy penetration rates are observed in countries such as Germany, Denmark and the UK [45, p.17]. Offshore wind farms are also becoming more common in Europe, with countries such as the Netherlands and the UK setting the bar for large offshore wind projects. Wind power is also expanding significantly in North America: The United States and Canada are among the top ten countries with the largest installed wind power capacity in the world. The world's largest installed wind power capacity is located in the United States. China, with more than a third of the world's installed wind power capacity, is the largest wind energy producer in Asia. With ambitious renewable energy targets driving the industry's expansion, India is emerging as an important player in the wind energy market. As part of their initiatives to reduce their dependence on fossil fuels, Japan and South Korea have also begun investing in wind power projects. Brazil, Mexico, and Chile are the Latin American countries with the largest amount of installed wind power capacity. Wind power is a desirable choice for meeting energy needs in this region due to significant wind resources and growing demand for electricity.

Direct power generation from solar and thermal sources is growing rapidly in the clean energy sector, and new research in nanotechnology is supporting broader development initiatives. Solar power offers clean energy that can be deployed quickly and locally to the source of demand. A solar power system is the conversion of sunlight into electricity, which can be achieved directly through photovoltaic (PV) panels or indirectly through concentrated solar power (CSP). A number of internal and external factors, including environmental, constructional, installational, operational, and maintenanceal factors causes the loss of PV panel efficiency. The environmental elements continue to present a significant obstacle despite recent improvements in PV constructional factors and their installation processes.

CSP is a vital part of the transition to an energy system that is less destructive to the environment and human health and offers greater energy security as a renewable energy technology. In addition, the use of solar energy instead of purchased fuel can significantly reduce the fiscal pressure on countries that depend on fossil fuel imports and improve the balance of payments of these countries. By reducing uncertainty about the future costs of energy production, it can help increase access to finance and reduce the overall system costs of all locally generated energy. Other benefits from CSP can be seen in Appendix C Figure C.2.

Solar energy is the most stable form of energy because of its availability and environmental friendliness. Every year, the demand for photovoltaic solar cells is growing as they improve and generate electricity at affordable prices for both households and commercial use (Figure 2.7). There are four main types of challenges for solar energy, namely: technical challenges, economic challenges, environmental challenges, and energy storage challenges.

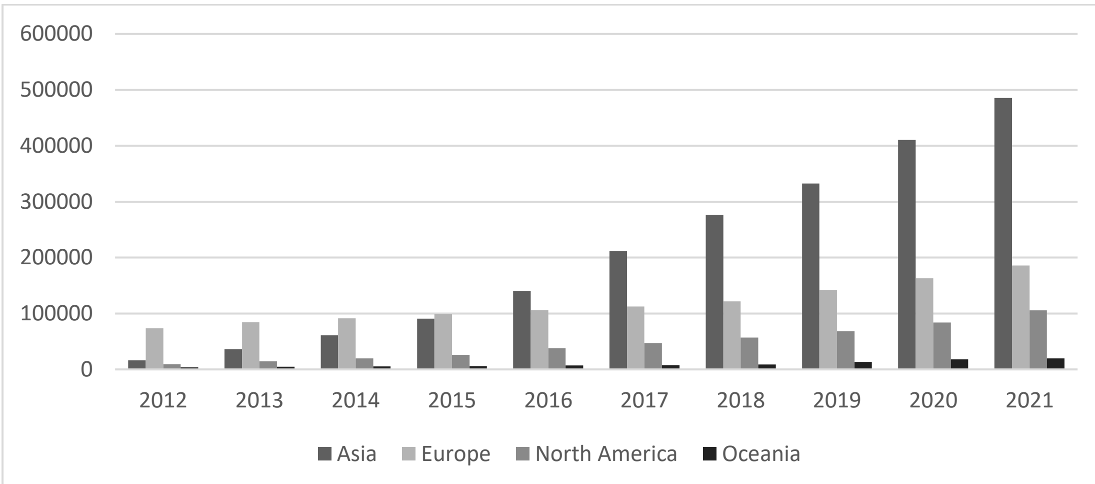

Figure 2.7. Solar energy capacity by region in 2012-2021, megawatt

Source: Systematization by author based on [46]

The intermittent nature of solar energy is one of the biggest technical obstacles [47]. The amount of solar energy produced varies throughout the day and is dependent on the weather. Maintaining a continuous flow of energy can be difficult due to this variability. The grid can become unstable due to fluctuations in power supply, which can lead to blackouts and outages. To solve this problem, technologies are being developed to store excess solar energy generated during peak hours and release it during off-peak hours. The efficiency of solar panels varies depending on the type of material used and the way they are manufactured. Most solar panels convert only 20% of the sun's energy into electricity, so their efficiency is between 15% and 20% [48]. New materials and manufacturing technologies are being researched to improve the efficiency of solar panels. The price of solar energy is a serious financial problem as well. The initial costs of a solar energy system can be high, even if the cost of solar panels has recently decreased. Installation, maintenance, and storage costs can further increase the total cost [49, p.30]. Government incentives, such as tax breaks and rebates, can also reduce the cost of solar energy for both households and businesses. Solar energy is now competitive with fossil fuels due to technological developments. It has become more reliable and cost-effective due to advances in smart grids, energy storage, and solar panel efficiency. In addition, solar energy systems have become more affordable than fossil fuels due to improvements in manufacturing and installation technologies.

Land use is one of the environmental challenges of solar energy. Large-scale solar energy projects require a lot of space to place solar panels, which can have an impact on ecosystems and natural habitats [50, p.20]. In addition, soil erosion and land degradation can result from the development and maintenance of solar energy facilities. Another environmental issue is the disposal of solar panels at the end of their useful life. Despite their long lifespan, solar panels eventually reach the end of their useful life and must be disposed of. Pollutants are not emitted during the operation of solar panels. However, there is a possibility that toxic chemicals contained in the solar modules may be released into the environment in the event of a fire. In the event of an emergency such as a fire, appropriate measures should be taken. The possibility of unintentional leakage of chemicals from the solar modules into the groundwater and soil poses a serious environmental hazard.

Despite all the obstacles, solar energy has pros and cons, as well as great opportunities in the future. Thus, analyzing the strengths and weaknesses, as well as demonstrating the opportunities and obstacles, is important to raise awareness among policy makers, governments, and companies and to redirect the focus of energy investments towards solar energy (Appendix C Table C.1). Another trend affecting the future of solar energy is the integration of solar energy into smart grids. Solar energy can be distributed and utilized more efficiently through smart grids, ensuring that it is used where it is needed mostInvestment in solar energy has increased, as has political support for measures that promote renewable energy. The development of social media has also increased public support for the industry by raising awareness and informing people about the benefits of solar energy.

Biomass production differs significantly from solar energy production, so it is used much less frequently than previous renewable energy sources. The term "biomass" refers to any organic substance that is formed as a result of photosynthesis and is a source of raw materials. All flora and trees growing on land and in water are considered biomass, as are all forestry and agricultural wastes, as well as municipal biological waste (wastewater), municipal solid waste (MSW), animal waste (manure), and some forms of industrial waste. Today, technologies exist that allow us to collect energy, convert it into useful electricity or heat, and do so in an environmentally friendly way. These technologies are expected to drive the development of biomass as one of the leading energy sources. Unlike fossil fuels, biomass is a renewable energy source, and it will only take a short time to replace the energy source that is currently being used [51, p.1]. Biomass feedstocks are organic materials that are used to produce biofuels and bioproducts. They are categorized based on their type, source, and availability.

Lignocellulosic and non-lignocellulosic feedstocks are the two main classifications of biomass. Lignocellulosic feedstocks are the most commonly used, consisting of lignin, cellulose, and hemoglobin. They come from the lignin, cellulose, and hemicellulose found in the cell walls of plants and trees [52]. As they are often considered as by-products of other industries such as forestry and agriculture, they are also relatively inexpensive. Non-lignocellulosic feedstocks include algae and other microorganisms in addition to non-wood plant resources. For biomass energy production, non-lignocellulosic feedstocks are more attractive because they can be processed faster than lignocellulosic feedstocks. They can be processed more efficiently into usable energy sources such as liquid biofuels and require fewer specialized procedures.

The main source of biomass is agriculture. Straw from agricultural crops, including corn, wheat, and rice, is often used as a feedstock for biofuels and other bioproducts. Another important source of feedstock for biomass production is forestry. Logging sites and sawmills are typically places where forest residues such as sawdust, bark, and wood chips can be found. Another possible source of biomass is household and industrial waste. Food waste, sewage sludge, and municipal solid waste are just a few of the types of garbage that can be used to produce biofuels and bioproducts. These materials can be converted into valuable products using a variety of biochemical and thermochemical methods, and are often collected in urban and industrial areas.

The potential of bioenergy systems to produce sustainable energy depends to a large extent on the availability of these feedstocks. A number of variables affect the availability of biomass, including feedstock type, location, and land use [53, p.824]. Land use is one of the main elements affecting the availability of biomass. The production of biomass feedstocks can be limited by the availability of land for forestry and energy crops. The economics of biomass production also affect the supply of biomass as a feedstock. Depending on the location and type of feedstock, the cost of biomass production can vary. Climate change and environmental conditions can also affect the availability of biomass. Finally, laws and regulations can affect the supply of biomass feedstocks. By offering incentives to producers, policies such as feed-in tariffs, bioenergy targets, and criteria for renewable fuels can encourage biomass production.

A reliable and sustainable source of energy, biomass can be used to produce heat, electricity and biofuels. Biofuels made from biomass are liquid or gaseous fuels that are used to run machines or vehicles. Biomass can be continuously grown and harvested, unlike fossil fuels, which are finite and non-renewable, making it a reliable and sustainable source of energy. In some cases, biomass can be used instead of fossil fuels to reduce greenhouse gas emissions and other harmful environmental impacts of traditional fossil fuel use. Biomass energy is used to produce biofuels. It can be produced from a variety of feedstocks, including agricultural crops, forestry waste, and even municipal solid waste.

Depending on the method and feedstock used, biofuels are usually categorized as first-, second-, and third-generation biofuels (Figure 2.8). Food crops such as corn or sugar cane are often used to produce first-generation biofuels. Although these biofuels are widely used, there are concerns about how they may affect environmental and food security. First-generation biofuels can be replaced by second-generation biofuels, which are more environmentally friendly because they are produced from non-food feedstocks such as agricultural waste or specialty energy crops. Although third-generation biofuels, such as those derived from algae, are still in the early stages of development, they have the potential to become a sustainable source of biofuel supply.

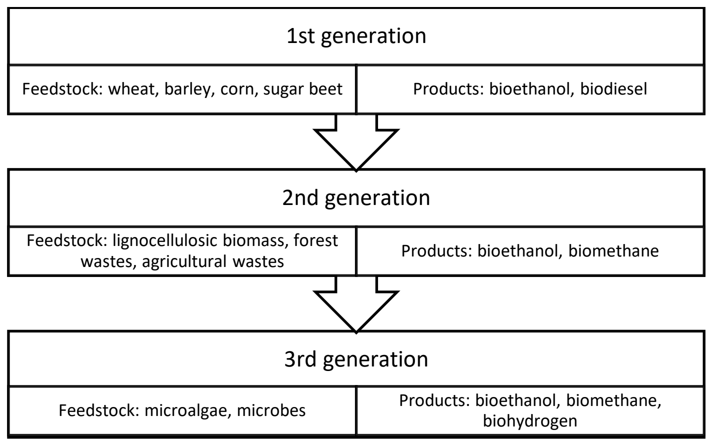

Figure 2.8. Features of biofuels' generations.

Source: Systematization by author based on [54]

In recent years, biofuel production has become an increasingly popular business as the world looks for more environmentally friendly energy sources. Biofuel production has grown significantly in North America, which consists of Canada, the United States, and Mexico. In 2022, the US produced 2.3 billion gallons of biodiesel and 17.4 billion gallons of ethanol [55]. In addition, the United States is a significant producer of advanced biofuels such as renewable diesel and cellulosic ethanol. Government policies that promote the use of renewable energy sources have had a positive impact on the use of biofuels in North America (Figure 2.9). Although biofuel production in North America has increased, the sector still faces a number of obstacles. One of the biggest obstacles is competition with traditional fossil fuels, which are still significantly cheaper and more abundant. The availability and cost of raw materials is another problem, especially in regions where there is a significant demand for food crops. In addition, there are concerns about the environmental impact of biofuel production, especially in terms of land use and deforestation.

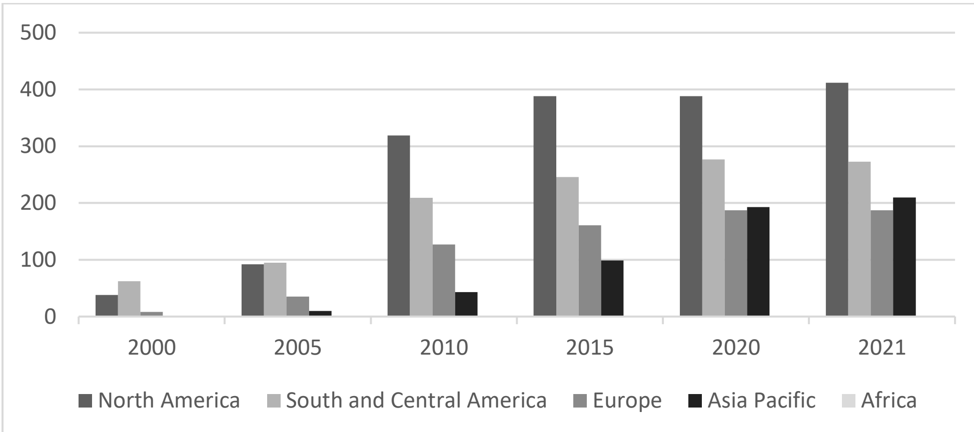

Figure 2.9. Biofuel production by region in 2000-2021, terawatt-hour [56]

Brazil is the largest biofuel producer in South and Central America. Brazil's total ethanol production is expected to reach 31.66 billion liters in 2022, up 6% from 2021 [57, p.5]. Argentina produces both ethanol and biodiesel, making it the second largest biofuel producer in the region. Argentina produces biodiesel from soybean oil and ethanol from corn and sugar cane. With a number of goals and strategies aimed at increasing the use of biofuels, the European Union (EU) is at the forefront of promoting biofuels as a renewable energy source. The use of biofuels is one of the renewable energy sources for which the EU has set targets. Bioethanol and biodiesel are just two of the many biofuels produced in Europe. Europe has invested heavily in second-generation biofuels, which are produced from non-food feedstocks such as straw, wood, and other agricultural and forestry by-products.

The least popular type of renewable energy is geothermal energy. All rocks undergo a long process of radioactive decay, which results in a temperature inside the earth that is higher than on the surface of the sun. Most geothermal reservoirs are hidden deep underground and have no external signs. Volcanoes, fumaroles (vents from which volcanic gases escape), hot springs, and geysers are all examples of places where geothermal energy occasionally breaks through to the surface. The most active geothermal resources tend to be found around major plate boundaries, where many earthquakes and volcanoes occur. The Ring of Fire is where most of the world's geothermal activity occurs [58].As magma approaches the surface, it heats groundwater in porous rocks or water flowing over the surface and through cracks in fractured rock. Water (hydro) and heat (thermal) are the two main components of these hydrothermal resources. Geothermal reservoirs are natural, large-scale areas of hydrothermal resources. Geologists look for geothermal deposits in different ways. The only way to confirm that a geothermal reservoir really exists is to drill a well and measure the temperature very deep below it.

Although geothermal energy has been used directly for centuries, it has only recently received significant attention as a renewable energy source. The high efficiency of geothermal energy for direct use is one of its main advantages. Direct-use geothermal systems also have a very long lifespan; some installations are still in operation after more than 100 years. In both residential and commercial buildings, geothermal heat pumps (GHPs) can be used to provide hot water, heating, and cooling. In these systems, heat is transferred from the ground to the building through underground pipes.

Over the past two decades, the installed capacity of geothermal energy has grown significantly worldwide, which is noteworthy (Figure 2.10).

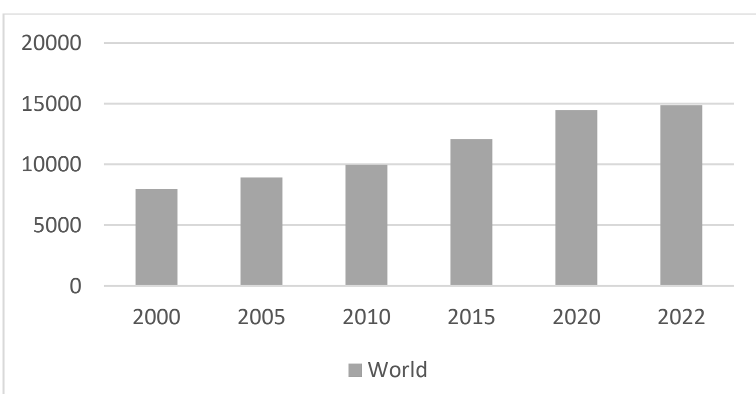

Figure 2.10. Geothermal energy capacity worldwide in 2000-2022, megawatts

Source: Systematization by author based on [59]

For a long time, geothermal energy production was dominated by North America. The exploitation of geothermal resources in California, Nevada and Oregon is responsible for the growth of geothermal energy in the United States. Geothermal energy is playing a crucial role in helping Central American and Caribbean countries meet the region's growing electricity demand. Geothermal energy production has grown significantly in recent years in Europe as well. Germany, Italy and Iceland are examples of countries that are leading the way in geothermal energy development. Asia is another region where geothermal energy production is growing. Countries such as Indonesia, Japan, and the Philippines have significant geothermal resources and have been increasing their geothermal capacity over the years.

Nevetheless that geothermal energy is not used a lot, it is still usefull to know all strengths, weaknesses, opportunities and threats of it (Appendix C Table C.1). High reliability is one of the key advantages of geothermal energy. Unlike wind and solar energy, which are intermittent and dependent on weather conditions, geothermal energy is available 365 days a year, around the clock. The availability of geothermal power plants can reach 95%, which is higher than most other renewable energy sources [60, p.14]. Geothermal energy is a renewable resource that is naturally replenished over time, unlike fossil fuels, which are a finite resource that will eventually be depleted. According to forecasts, geothermal energy on Earth will be available for hundreds of thousands of years. Thus, geothermal energy can offer a long-term answer to the world's energy needs. Geothermal energy is also adaptable. It can be used for many different purposes, including power generation, direct use, heating and cooling.

The fact that geothermal energy is regionally limited is one of its biggest disadvantages [61]. Only regions with active geothermal systems or strong heat flows can produce geothermal energy. Most of these places are located in tectonically active zones, such as the Pacific Ring of Fire. The high initial cost of geothermal energy is another disadvantage. Building a geothermal power plant can be expensive, mainly due to the costs associated with drilling and exploration. The complexity of the technology required to produce geothermal energy also increases the overall cost. As a result, the initial investment required to utilize geothermal energy may deter some investors. The amount of heat that can be extracted from the earth's crust by geothermal plants is limited, unlike solar or wind energy, which can be increased by adding more solar panels or wind turbines.

The creation of new technologies is one of the greatest potentials of geothermal energy. Thanks to improved drilling and exploration methods, geothermal energy can now be extracted efficiently and cheaply from deeper and hotter sources. In addition, advanced geothermal systems and new methods of extracting geothermal energy from hot dry rocks are being developed. Under certain circumstances, geothermal power plants have become an important employer in areas with limited employment opportunities. International cooperation is needed to realize the potential of geothermal energy as a global energy source. Countries with rich geothermal resources can cooperate to share information and skills and promote the use of geothermal energy in underserved regions. International organizations such as the Global Geothermal Alliance (GGA) and the International Renewable Energy Agency (IRENA) promote the use of geothermal energy worldwide. In addition to these opportunities, geothermal energy can contribute to a secure and sustainable energy future in several other ways.

Competition with other renewable energy sources, such as hydropower and wind power, is one of the main challenges for geothermal energy. The development of wind and hydropower technologies has recently accelerated, and their cost is constantly decreasing. As a result, geothermal energy may not be as attractive as other renewable energy sources in some regions. Natural disasters, such as earthquakes, volcanic eruptions and landslides, can also pose a serious risk to the infrastructure supporting geothermal energy, in addition to political unrest. Drilling operations and geothermal power plants are often located in areas vulnerable to natural disasters, which can damage infrastructure and interfere with energy production.

Thus, renewable energy sources are becoming increasingly important in the modern world due to the current energy crisis and the need to reduce carbon dioxide emissions. The adoption of renewable energy sources is expected to continue to grow due to technological advances, increased global awareness of the need for sustainable energy, and favorable government policies. Renewable energy sources have the potential to significantly reduce the world's dependence on non-renewable energy sources, such as fossil fuels, which not only have a negative impact on the environment but are also finite resources. While renewable energy sources come with their own unique set of challenges and limitations, the benefits they offer make them a promising alternative to traditional energy sources. Continued research and development in renewable energy will be crucial to further improve their efficiency and cost-effectiveness, ultimately leading to a more sustainable and resilient energy future.

2.2 Current state of non-renewable energy sources

Natural resources that cannot be renewed at a rate equal to or greater than the rate of their use are called non-renewable. These materials were created from organic substances that were once part of extinct plants and animals that lived millions of years ago. Non-renewable resources are extracted by humans in the form of gas, liquid, or solid, which are then transformed into practical forms for easy consumption. Despite their cheapness, they can be harmful to the environment and are a significant cause of global warming. These resources include fossil fuels such as coal, oil and natural gas, as well as minerals such as metals and ores. Nuclear energy is also a non-renewable energy source (Figure 2.11).

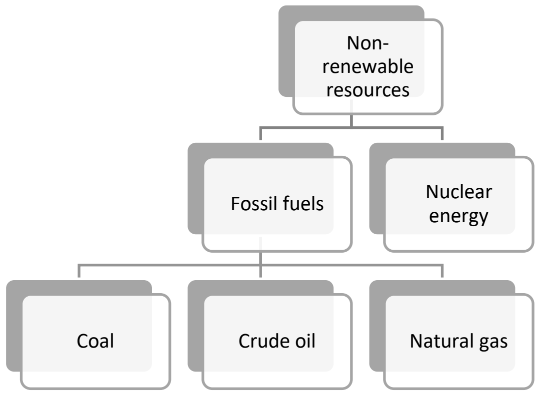

Figure 2.11. Types of non-renewable energy resources.

Source: Systematization by author

Fossil fuels have long been the main source of energy. Coal, oil and natural gas are types of fossil fuels. These fuels were formed from the remains of ancient plants and animals that had been dormant for millions of years deep below the Earth's surface. The use of fossil fuels contributes to the formation of greenhouse gases and is a major factor in anthropogenic climate change. Thus, dependence on them for energy production is unsustainable. For solid fossil fuels, oil, natural gas, and nuclear energy, the trend in primary energy production over the past ten years (2010-2021) has been mostly negative (Figure 2.12). Production of solid fossil fuels, oil and petroleum products, and natural gas decreased the most (-62.4%), followed by a drop of 43.0% and 35.1%, respectively [62]. At the same time, the production of renewable energy sources showed a clear upward trend.

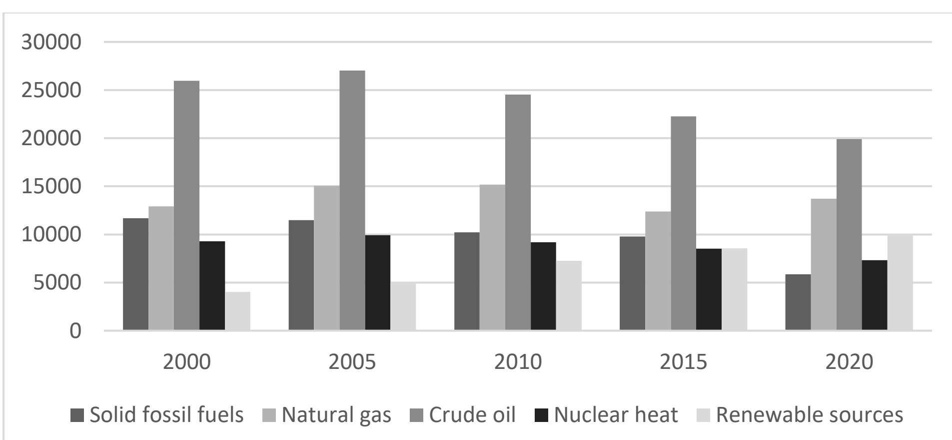

Figure 2.12. Gross available energy in 2000-2020, petajouces

Source: Eurostat

Coal has been one of the primary sources of energy for centuries, and it has played a crucial role in industrial development around the world. The primary use of coal is in electricity generation, and it has been a significant contributor to the growth of the world's economy. Coal is a fossil fuel that is formed from the remains of plants that lived millions of years ago. Coal generates more than 36% of the world's electricity [63]. In 2022, coal markets experienced major upheavals: traditional trade flows were disrupted, prices rose sharply, and coal demand increased by 1.2%, reaching an all-time high and exceeding 8 billion tons for the first time [64]. Coal is found in various forms, including anthracite, bituminous, lignite and peat but onlt first three can be used as fuel.

Coal mining has played a key role in meeting the world's energy needs for thousands of years, but in recent years its negative impact on the environment has become increasingly serious. Environmental legislation has been adopted to reduce the environmental problems associated with coal mining (Figure 2.13).

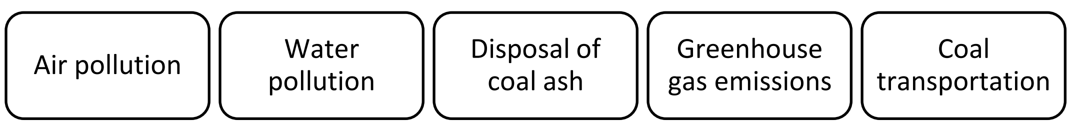

Figure 2.13. Areas of environmental restrictions on coal mining

Source: Systematization by author

Coal mining has played a key role in meeting the world's energy needs for thousands of years, but in recent years its negative impact on the environment has become increasingly serious. Environmental legislation has been adopted to reduce the environmental problems associated with coal mining. Air pollution is one of the biggest concerns, and the Clean Air Act of 1963, revised in 1970, sets national air quality standards and controls pollutant emissions from coal-fired power plants [65]. Coal mining companies are required to use equipment such as low nitrogen oxide burners and scrubbers to reduce emissions. Another important issue related to coal mining is water pollution, which has been regulated by the Clean

Water Act since 1972 [66]. This law requires coal mining companies to obtain permits before discharging pollutants into surface water sources, which can lead to contamination of both surface and groundwater with heavy metals and other pollutants. Regulating the disposal of coal ash is an integral part of environmental issues, as this material, which is generated during the coal combustion process, contains toxic heavy metals and other pollutants. Legislative regulation of greenhouse gas emissions from coal mining is another extremely important environmental issue, as coal-fired power plants emit significant amounts of carbon dioxide, which is one of the main greenhouse gases contributing to climate change. The Clean Air Act regulates greenhouse gas emissions from coal-fired power plants, and the Clean Power Plan, which was put in place by the Environmental Protection Agency in 2015, sets national standards for greenhouse gas emissions from power plants [67]. Labor protection in the coal industry is an important issue, as it is a dangerous job that can lead to injuries and deaths of miners from accidents and harmful substances. In 1977, the Mine Safety and Health Administration was established to ensure the health and safety of miners.

Coal, thanks to its widespread availability and affordability, has become a widely used energy source around the world. Its low cost, abundance and stability are key advantages [68, p.78]. The widespread access to coal and the relative cheapness of its extraction, transportation and processing make it a convenient option for countries seeking to provide their populations with affordable energy. In addition, coal has significant reserves, which guarantees a stable source of energy over a long period of time. Coal also has the advantage of easy transportation and storage, which allows it to be transported over long distances and stored for later use, providing a certain level of flexibility in energy production. Thanks to improved technology and stricter controls, coal-fired power plants have become cleaner and have reduced emissions of pollutants. Every year, the development of carbon capture and storage technologies is becoming more efficient, allowing for the capture and storage of carbon dioxide emissions from coal-fired power plants.

In recent years, there has been a growing recognition of the negative impacts associated with coal as an energy source. One of the major concerns is the environmental damage caused by coal mining. The extraction of coal from underground mines or through mountaintop removal can lead to habitat destruction, soil erosion, and water pollution. Furthermore, the transportation of coal from mines to power plants involves the use of large trucks, trains, and ships, which contribute to air pollution and greenhouse gas emissions. The combustion of coal in power plants is a significant source of carbon dioxide (CO2), a greenhouse gas that contributes to global warming and climate change. Another important consideration is the finite nature of coal reserves. As coal is a non-renewable energy source, its supply is limited and will eventually deplete. As extraction becomes more difficult, the cost of mining coal is likely to increase, making it less economically viable compared to alternative energy sources. More detailed information can be found in Table 2.1.

Table 2.1. Advantages and disadvantages of coal.

Advantages	Disadavantages
– Cheap and widely available; – A stable source of energy; – Reliable source of energy; – Large reserves of coal; – Can be easily transported and stored; – High energy density; – Improvements in technology	– Have a significant environemental damage; – Produce a large amount of green-house gases; – Coal mines lead to accidents; – Can displace local communities; – Is a finite resource; – Coal plants have long construction times

Source: Systematization by author based on [69]

Coal production is distributed across different geographical regions, with some countries producing a disproportionate amount of coal, while others produce no coal at all (Figure 2.14).

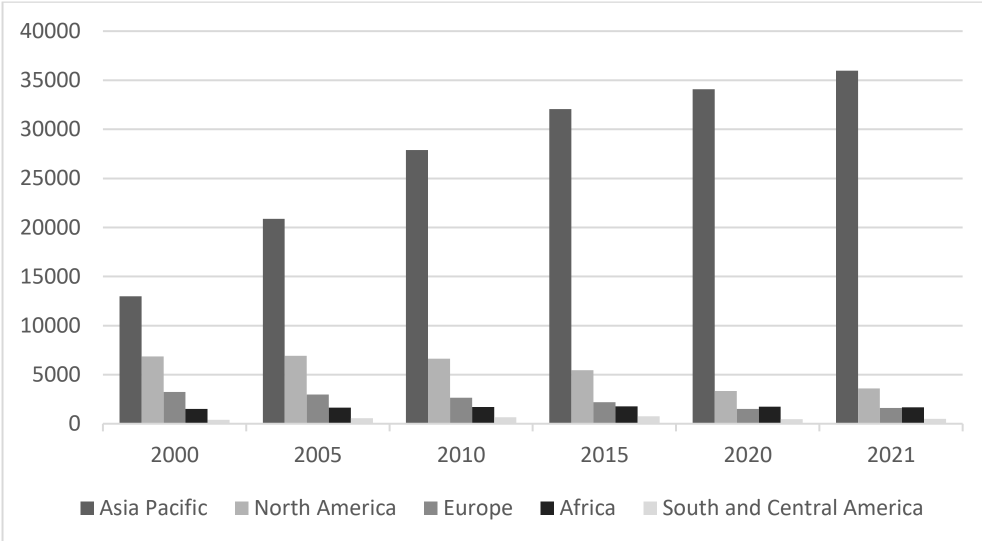

Figure 2.14. Coal production by region in 2000-2021, terawatt-hour [70]

Coal production in the Asia-Pacific region has been growing rapidly over the past few decades, confirming its status as one of the world's leading coal-producing regions [71, p.9]. China, which is the largest coal producer in the world, plays a leading role in the region, being responsible for the majority of total production. In addition, India, Indonesia and Australia are also among the major coal producing countries in the region. Increased demand for energy in the region, driven by rapid economic development in countries such as China and India, has helped to support this growth. Coal reserves have become attractive to investors, both domestic and foreign, leading to the development of new mines and the expansion of existing ones.

The United States and Canada are the main coal producers in North America, which is a major producer overall. Numerous businesses in the region are powered by coal, which is an important energy resource that provides millions of people with affordable and reliable electricity. The Appalachian Mountains, the Illinois Basin, and the Powder River Basin are where most of the coal in the United States is produced [72, p.8]. The growing use of natural gas and renewable energy sources for electricity generation has led to a decline in coal production in the United States over the past decade. Stricter environmental restrictions and the closure of outdated coal-fired power plants also contribute to this process.

Europe produces a significant amount of coal globally, but in recent years, as countries shift to greener energy sources, coal production has declined sharply. Despite this, countries such as Poland, Germany, and the Czech Republic continue to rely heavily on coal as an energy source [73]. However, in order to maintain a healthy ecosystem and environmental sustainability, coal production in Europe is expected to continue to decline in the future. Despite this, coal can still be used in the future energy mix of countries.

Crude oil (also known as petroleum) is a complex, naturally occurring liquid mixture composed primarily of hydrocarbons, but also includes some oxygen, nitrogen, and sulfur chemicals. Crude oil is a fossil fuel made from the remains of marine animals that have lived and died in ancient waters for millions of years. Under the influence of heat and pressure from the layers above it, the organic matter breaks down and turns into crude oil.

Utilizing oil is a much more complicated procedure than using coal. Crude oil, in particular, goes through many stages of processing before it reaches the consumer. This is because different types of crude oil can have extremely different chemical structures, although they have comparable elemental compositions. Depending on the source and geological conditions of formation, the composition of crude oil varies. Impurities of sulfur, nitrogen and metals in crude oil can change its characteristics and make it less suitable for certain purposes. Due to its high energy density, which makes it a reliable and efficient source of energy, crude oil plays a vital role in the energy sector. Compared to other fossil fuels, such as coal and natural gas, it is also relatively cheap to extract and process. The United States, russia, Saudi Arabia, and Iraq are the four largest crude oil producers in the world. The four largest consumers of crude oil are China, India, Japan, and the United States [74, p.2].

Due to the dynamics of supply and demand, geopolitical instability and other factors that can affect global markets, the price of crude oil is quite volatile (Figure 2.15).

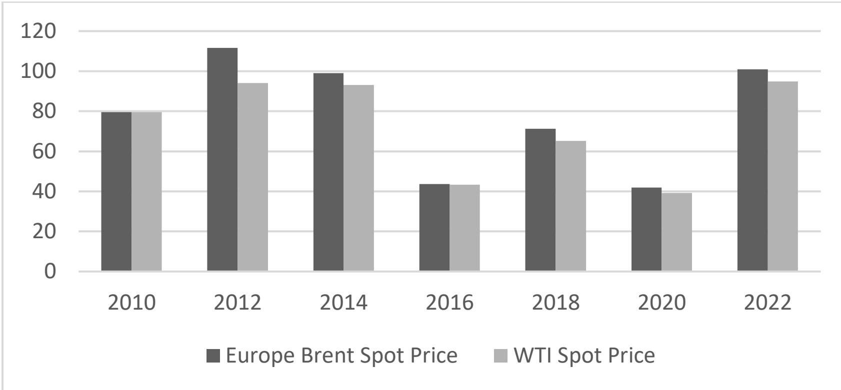

Figure 2.15. The fluctuations of Brent and WTI Spot Prices in 2010-2022, dollars per barrel [75]

Prices often rise when demand for oil outstrips supply and vice versa. Demand for oil is influenced by numerous variables, such as population growth, economic growth and industrial development. On the supply side, the availability of oil is affected by a number of variables, including geological considerations, political unpredictability, and investment in oil exploration and production. The international oil market is extremely complex and has a wide range of participants, including oil producers, dealers, refiners and consumers. Prices often rise when tensions increase in major oil-producing countries, such as the Middle East, as investors fear potential supply disruptions. Likewise, natural disasters such as hurricanes or earthquakes can disrupt oil production and supply, which can cause price movements. Prices often rise when oil demand and the global economy are growing. On the other hand, when the global economy slows down, demand for oil falls, leading to lower prices.

Both energy producers and consumers are very concerned about the future of crude oil production [76]. As global energy needs continue to grow, crude oil production is under pressure. It's not a question of "if" but "when" crude oil production will decline, and this will have a profound impact on both the economy and global politics. Existing oil reserves are being depleted faster than new ones are being discovered, as the world's energy demand is growing. Moreover, less and less money is being invested in crude oil production due to the shift to renewable energy sources and growing environmental concerns. A decrease in crude oil production will lead to a reduction in oil supply, as the oil sector plays a significant role in the global economy. As a result, oil prices will rise, which will have a negative impact on the global economy. In addition, countries whose economies are heavily dependent on oil exports, such as Saudi Arabia and russia, may face serious economic difficulties.

Economically, countries with rich oil reserves often rely on crude oil production and exports to generate significant revenues. Oil export revenues can make a significant contribution to the state budget, financing basic public services and infrastructure development. However, a significant dependence on oil exports can expose countries to risks associated with fluctuations in oil prices on the world market. Oil prices are affected by various factors, including supply and demand dynamics, geopolitical tensions, and global economic conditions. When oil prices decline, countries that are heavily dependent on oil revenues may experience economic downturns, budget deficits and lower living standards. Volatility in oil prices can lead to significant uncertainty in long-term economic planning and impede diversification efforts aimed at developing other sectors of the economy. Moreover, geopolitics related to the production and distribution of crude oil can have a significant impact on global politics. Oil-rich regions often attract attention and are subject to competition from major world powers seeking access to energy resources. The strategic importance of oil can shape alliances, influence foreign policy, and have implications for national security.United States, Saudi Aravia and russia account for almost 45% of global crude oil production [77] (Figure 2.16).

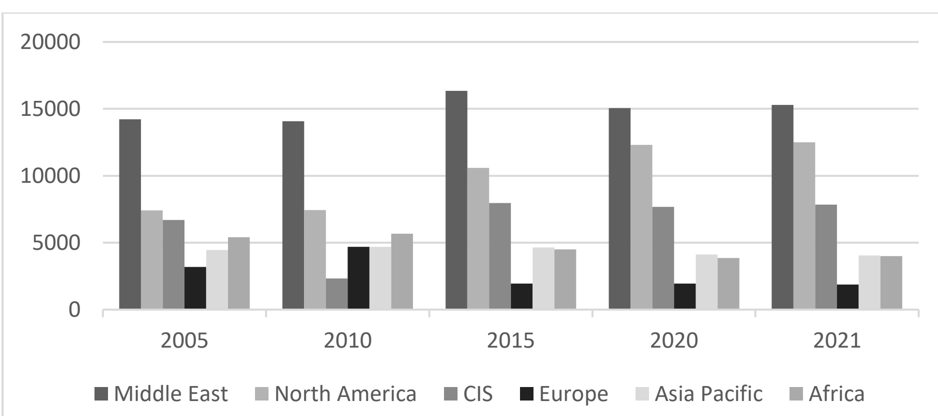

Figure 2.16. Oil production by region in 2000-2021, terawatt-hour [78]

Saudi Arabia, Iran, Iraq, and the United Arab Emirates (UAE) are among the world's largest oil producers, and the Middle East remains an important player in the global oil market today. Many countries in the Middle East are heavily dependent on the oil sector for revenue and jobs, and their governments have made significant investments in infrastructure to support it. However, businesses also face challenges, including falling oil prices, increasing competition from renewable energy sources, and geopolitical concerns. The oil sector in the Middle East is currently facing several challenges, one of which is the fall in oil prices. Low oil prices can have a significant impact on the economies of the Middle East countries, which are heavily dependent on oil exports. In addition, regional geopolitical conflicts may have an impact on the oil sector.

The former Soviet republics form the Commonwealth of Independent States (CIS), a regional grouping. Among Kazakhstan's oil fields located in the Caspian Sea region, the most important are the Tengiz and Kashagan fields in the Caspian Sea region. Azerbaijan's oil production is mainly concentrated in the Caspian Sea and is exported mainly through the Baku-Tbilisi-Ceyhan pipeline. With the exception of Kazakhstan, which has received significant international investment in its oil sector, the oil business in all CIS countries is largely controlled by the state. However, political unrest and corruption are persistent problems in the industry, affecting oil production and foreign investment. The region has also been criticized for greenhouse gas emissions from the oil and gas industry.

The world uses natural gas, a fossil fuel, as a source of energy. Natural gas has become a more important source of energy in recent years due to its low carbon footprint and affordable price compared to other fossil fuels. Natural gas must be compressed and liquefied before it can be transported from production sites to distribution stations. Natural gas is most often transported by pipelines. The efficiency and accessibility of pipelines allows for the transportation of huge volumes of natural gas over long distances. They are prone to leaks and ruptures, require significant upfront costs, and can be difficult to construct in some locations. Natural gas can also be transported by truck. Trucks are more adaptable and can deliver natural gas to places where pipes are not laid, but they are also less efficient and more expensive than pipeline delivery. Liquefied natural gas (LNG) is transported over long distances by ship. It is more expensive to produce and transport LNG than natural gas, but it allows natural gas to be transported over very long distances and to places where there are no pipelines.

Natural gas reserves are found in many countries around the world, but the largest reserves are concentrated in the Middle East, russia, and the United States (Figure 2.17).

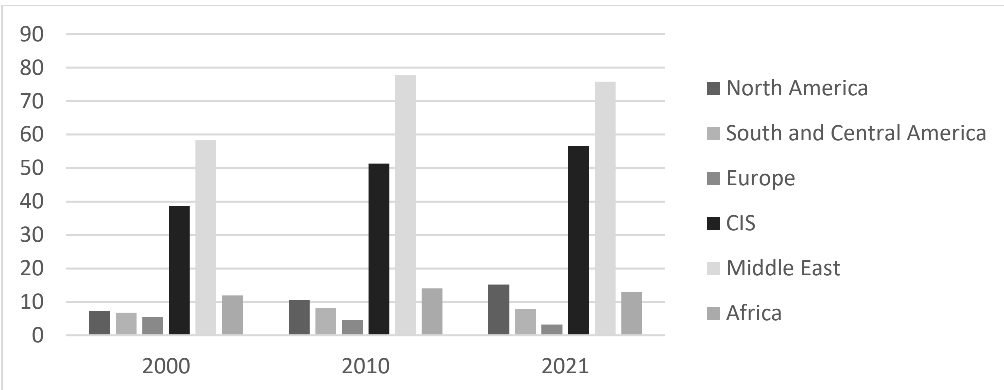

Figure 2.17. Total proved reserves of natural gas in 2000-2021, trillion cubic metres

Source: Systematization by author based on [79]

Total known natural gas reserves in North America increased between 2000 and 2021. Most of these reserves are in the United States, where they have grown very rapidly over the previous 20 years. Canada also has significant proven natural gas reserves, which amounted to 1.6 trillion cubic meters in 2000 [79]. By 2021, this number had grown to 2.4 trillion cubic meters. The increase in natural gas reserves in North America can be attributed to a combination of technological advances in drilling and exploration, as well as the discovery of new natural gas fields. In particular, the development of shale gas has made a significant contribution to the increase in natural gas reserves in the United States.

Europe's natural gas consumption is expected to grow in the future, while domestic production will continue to decline. Depletion is one of the factors contributing to the decline of proven natural gas reserves in Europe. As natural gas is extracted from these fields, it becomes increasingly difficult to access the remaining reserves and more advanced drilling techniques are required, which can be expensive and complex. In addition, much of Europe's natural gas reserves are located offshore or in remote locations, which complicates logistics and makes development difficult and expensive.

Between 2000 and 2010, total proven natural gas reserves in the CIS countries grew. This was due to the discovery of new gas fields and intensification of exploration activities in the region. russia, the largest natural gas producer in the CIS, has made a significant contribution to this growth. In the early 2010s, total proven natural gas reserves in the CIS countries remained relatively stable. In recent years, however, there has been a decline in natural gas reserves in some CIS countries. On the other hand, there have been some positive developments in the region. For example, Turkmenistan, which has the fourth largest natural gas reserves in the world, is increasing gas production and exports. The country is also exploring new gas fields that could further increase its gas reserves in the future. Over the past two decades, the Middle East has remained one of the leading regions in terms of total proven natural gas reserves. The region is home to some of the largest natural gas reserves in the world, including the world's largest non-producing natural gas field, the North Field/South Pars, located in Qatar and Iran. Some countries in the Middle East, such as Saudi Arabia and the United Arab Emirates, have taken initiatives to increase the use of natural gas for power generation and reduce their dependence on oil and coal.

The energy generated by nuclear processes that occur in the nucleus of an atom is known as nuclear energy. The use of nuclear energy has been the subject of controversy and debate for many years, with some claiming it is a clean and reliable source of energy and others pointing to the risks associated with nuclear technology. Compared to traditional fossil fuels, nuclear power has a number of advantages, such as reduced carbon dioxide emissions and the potential to be a stable and reliable source of energy. Nuclear power produces very few greenhouse gas emissions, unlike fossil fuels, which release significant amounts of carbon dioxide and other greenhouse gases. In addition, nuclear power plants can generate electricity around the clock, offering a reliable supply of energy that is not affected by weather conditions or other external variables.

The high energy density of nuclear energy is one of its key advantages. Nuclear fuel contains a significant amount of energy, and when it is converted into electricity, it generates a significant amount of energy. Compared to other energy sources, nuclear energy is also cheaper. The cost of producing energy with nuclear power is quite cheap, even though it can be expensive to build a nuclear power plant. Nuclear fuel is a cheap and efficient way to produce large amounts of energy, making it a good choice for power plants. In addition, because nuclear power plants require less maintenance and do not emit greenhouse gases, their operating costs are lower than fossil fuel power plants.

However, the use of nuclear energy has several disadvantages. The potential for a nuclear disaster is one of the most important. The environment and human health can be severely affected by a nuclear disaster. The problem of radioactive waste is another disadvantage of nuclear power. Radioactive waste from nuclear power plants is created, and it has been hazardous for thousands of years. It is important to remember that nuclear power plants produce relatively less waste compared to other energy sources, such as coal-fired power plants.

Many countries can potentially achieve energy independence through the use of nuclear energy. When a country produces and uses all the energy it needs domestically, it is considered energy independent and less dependent on energy imports from abroad. Nuclear power plants can operate for many years, providing countries with a reliable source of energy security in the long term. Nuclear power plants have a lifespan of up to 60 years or more, making them a reliable source of energy independent of geopolitical or short-term market situations. The country's dependence on a single source is reduced by the availability of uranium, the fuel used in nuclear power plants, which can be obtained from different countries. Several countries play a leading role in nuclear power generation, including the United States, France, China, Japan (Figure 2.18).

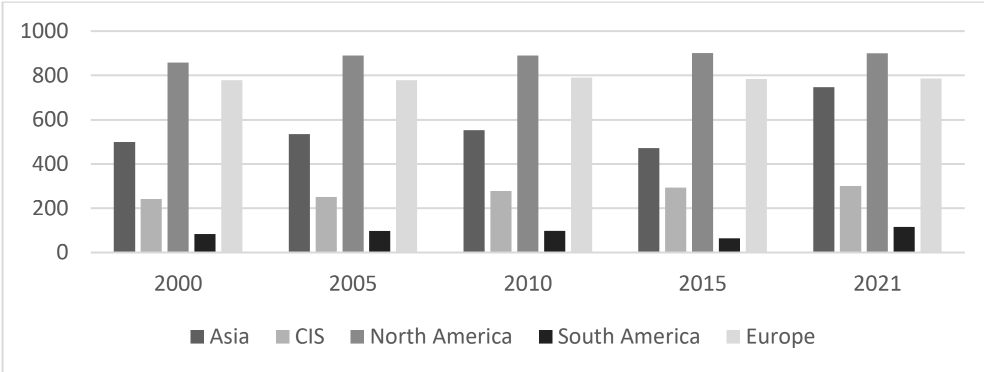

Figure 2.18. Nuclear energy production by region in 2000-2021, terawatt-hour [80]

Since the turn of the century, nuclear power in Asia has made a significant contribution to meeting the region's energy needs. The use of nuclear energy grew steadily between 2000 and 2021 as countries worked to diversify their energy supply and reduce their dependence on fossil fuels. Despite concerns about safety and the high cost of building and maintaining nuclear power plants, many Asian countries see nuclear power as a key component of their energy security strategy.

The CIS energy mix continues to rely heavily on nuclear power to provide reliable and affordable electricity. While some countries in the region want to phase out nuclear power in favor of renewable energy sources, other countries in the region have plans to increase the capacity of their nuclear power plants. Overall, it is still unclear how nuclear power will develop in the CIS. Nuclear power in the region is expected to change over the next few years, driven by factors such as safety concerns, aging infrastructure, and competition from renewable energy sources.

Nuclear power has long been an important source of energy in North America. Nuclear power is an important source of electricity in North America, despite some recent expansion of renewable energy sources. Over the past two decades, nuclear power production in North America has varied, with some countries increasing their capacity while others have reduced or eliminated their nuclear power facilities. But overall, nuclear power is still a significant part of the North American energy mix and is expected to remain so for the foreseeable future.

Over the past two decades, nuclear power has played a significant role in meeting electricity demand in Europe. From 2000 to 2021, nuclear electricity production in Europe remained relatively stable. France was the largest producer of nuclear electricity in Europe, with more than 70% of its electricity coming from nuclear power plants [81]. Other countries with a significant share of nuclear electricity production in Europe include Ukraine and the United Kingdom. In recent years, Europe has seen a shift to renewable energy sources, with countries investing in wind and solar power. Nevertheless, nuclear power is still expected to play a significant role in meeting Europe's electricity demand in the future, as many countries are investing in research and development of nuclear technologies.

Thus, non-renewable energy sources have played an important role in the development of modern civilization and the global economy. They remain the main source of energy for many countries around the world, despite growing concerns about their environmental impact and limited reserves. Oil, coal, and natural gas are readily available and will continue to play an important role in the global energy mix for a long time to come. However, it is important to realize that non-renewable energy sources are finite and that continuing to use them without switching to cleaner and more sustainable alternatives will have a negative impact on the economy, society and the environment. As a result, a global push is needed for energy efficiency, energy conservation, and the transition to greener energy sources. The overuse of these resources has created a number of problems, such as resource depletion, climate change and environmental degradation. Energy efficiency measures should be implemented to reduce the demand for energy and reduce the negative impacts of non-renewable energy sources while they are still in use. Governments, businesses, and citizens must work together to maximize energy use, improve efficiency, and prioritize sustainable energy development.

2.3 Energy profile of key energy consuming countries

As different countries around the world rely on different energy sources to meet their growing energy needs, the global energy landscape is constantly changing. Analyzing energy resources, consumption trends, regulation, and the contribution of countries to the dynamics of the global energy market requires a deep understanding of their energy profiles. We will look at the energy profiles of the world's four largest energy consumers: China, Germany, Norway, and the United States (Appendix D Figure D.1).

The United States is an important player in the global energy market and is known for its broad energy sector, which utilizes sources such as coal, oil, natural gas, nuclear power, and renewable energy. Policymakers, especially in the U.S. Congress, continue to debate several aspects of energy policy in their decision-making. These aspects include resource availability, economic costs, environmental impacts, and social concerns. Environmental regulations also affect the energy industry, especially with regard to fuel use. The energy needs of different American industries differ: nuclear power is primarily used for electricity generation, while the transportation industry is heavily dependent on petroleum fuels, including gasoline, diesel, and jet fuel.

Crude oil is extracted and imported and then transported throughout the United States to refineries or commercial storage facilities using a variety of transportation methods. Futures contracts for West Texas Intermediate (WTI) crude oil are settled in Cushing, and the media regularly report on these prices. The majority of crude oil, both imported and domestically produced, is transported to refineries using pipeline infrastructure. The amount of petroleum products that the United States exports to various countries and regions has increased significantly. The United States has increased its imports to Latin American countries, including Peru, Brazil, and Guatemala, creating a dependence on U.S. supplies and thus supporting the U.S. refining sector. The improvement in the US net position in imports/exports of liquids, which includes both crude oil and petroleum products, is mainly due to the expansion of trade in petroleum products. Going forward, US crude oil production is likely to continue to grow, and domestic demand for petroleum products will increase slightly.

For the first time since 1957, the United States began exporting natural gas on a net basis in 2017 (Appendix D Table D.1). Low natural gas prices, supported by expanding domestic gas supplies, have helped to significantly increase the use of natural gas for electricity generation. The U.S. pipeline network is an important component of the country's energy infrastructure and provides essential connections to other critical facilities, including power plants, refineries, airports, and military installations. Over the past ten years, plans for new oil and gas pipelines have increasingly become the subject of public debate and have been the subject of controversy at both the federal and state levels.

Between 2015 and 2021, the use of coal in the United States decreased significantly. The reasons for this decline may include changes in energy legislation, technological developments, changing market dynamics, and growing environmental awareness. The increased availability of natural gas, which has become a popular substitute for coal in recent years, has been one of the key reasons for this development. Renewable energy sources, such as wind and solar power, are becoming competitive with traditional fossil fuels as they become more widely available and cheaper. Demand for coal has declined as a result of a growing trend among businesses and utilities to invest in renewable energy. Some regions of the United States continue to rely heavily on coal to meet their energy needs, despite an overall decline in coal use. States whose economies are heavily dependent on the coal industry, such as West Virginia and Kentucky, could face serious difficulties if demand for coal declines.

The United States saw significant changes and trends in the use of nuclear energy. As a reliable and low-carbon source of electricity generation, nuclear power has long been an important part of the country's energy mix. Over the past decade, the number of nuclear power reactors in operation in the United States has grown at a very modest rate in terms of capacity. Although there were plans to build new capacity, nothing was actually built and numerous older plants were closed. As a result, the country's nuclear power capacity has remained relatively stagnant. Public opinion and concerns about nuclear safety also influence the structure of nuclear energy consumption. Although nuclear energy is seen as a low-carbon energy source, public perceptions of the dangers associated with accidents and nuclear waste storage have been affected.

Solar, wind, hydro, and geothermal energy are examples of renewable energy sources that have grown significantly in popularity and integration into the country's energy mix. During this time, the use of renewable energy has increased significantly in several sectors. Declining costs, technological developments, government incentives, and a growing focus on sustainability and environmental protection are some of the reasons for this. The growing acceptance of renewable energy technologies has also had a significant impact on reducing the cost of these technologies. By developing and integrating renewable energy sources, the United States continues to work toward greater energy independence, reduced greenhouse gas emissions, and increased energy efficiency. The growth in renewable energy consumption is expected to continue in the coming years as technology advances and the cost of renewable energy continues to decline, changing the country's energy landscape and supporting its commitment to a clean energy future.

Due to russia's invasion of Ukraine on February 24, 2022, a number of trade sanctions were imposed, including restrictions on the sale of key goods to russia. The United States has imposed sanctions that apply to both goods manufactured abroad using U.S. technology and goods sold by U.S. corporations. The extraterritorial nature of these U.S. restrictions may impede exports to russia even from countries that do not have their own sanctions. In addition, the United States has announced that it will gradually reduce its purchases of russian energy. The United States quickly imposed severe export restrictions on February 24 in response to the crisis, intending to significantly limit russia's access to technology and other resources needed to maintain its military capabilities. The main targets of these export restrictions are russia's defense, aerospace, and maritime industries. The bans apply to foreign goods developed using US technology, including equipment, software, and designs, as well as to trade in goods produced in the US. In addition, on March 8, the United States imposed an embargo on imports of all Russian fuels, including coal, liquefied natural gas (LNG) and liquefied petroleum gas (LPG). The ban came into effect on April 22 for contracts concluded before that date [82].

China, which consumes more energy than any other country, has a major impact on international energy models. Over time, China's rapid industrialization and economic expansion increased energy demand. This demand has been met through a variety of energy sources, with coal historically serving as the primary fuel. However, the Chinese government has taken bold steps to restructure the energy industry in response to growing concerns about air pollution, climate change, and energy security.

As the world's largest energy consumer, China has undergone significant changes in the crude oil market in recent years. The growth of the middle class, urbanization and the need for transportation have increased the demand for petroleum products. China has largely relied on crude oil imports to meet this growing need. However, increasing dependence on imports has made it difficult to maintain price stability and energy security. The Chinese government has taken strategic steps, recognizing the need to diversify its crude oil supply to reduce vulnerability and manage risk. China continues to rely heavily on reliable sources, such as Saudi Arabia, russia, Angola, and Iran, to meet its crude oil needs. To diversify its crude oil supply, China is looking for new trade ties with countries other than its traditional suppliers. Among the countries with which China has established closer energy ties are Brazil, Venezuela, Iraq, and Kuwait. China has imposed severe restrictions on oil imports to regulate the local market. The only body authorized to import and distribute crude oil in this system is the China National Chemical Import and Export Corporation [83, p.15]. This regulatory procedure helps to limit crude oil imports and ensure the stability of the local market.

Gas consumption in China has increased significantly, reaching 378 billion cubic meters in 2021 (Appendix D Table D.1). This growth has been driven by Chinese government initiatives to improve air quality and encourage a switch from coal to gas. Gas imports have become more important for China due to the country's inability to produce enough gas to meet growing demand. China's gas sector faces ongoing challenges due to a lack of domestic resources, fluctuating international gas prices, energy security concerns, limited infrastructure, institutional difficulties, and slow progress in reforms. Turkmenistan was the main foreign supplier of pipeline gas to China, accounting for 57% of China's pipeline imports in 2021 [84, p.13]. As China continues to focus on expanding its gas industry and diversifying its gas sources, addressing challenges related to domestic production, pricing, infrastructure, and institutional reforms will be critical to ensuring a stable and secure gas supply.

China, the world's largest coal producer, has established itself as a "swing buyer" in the coal market, deliberately buying coal from foreign markets when costs are lower than at home and relying mainly on domestically produced coal when imports become less desirable. The government has tightened control over coal mining activities in an effort to address environmental concerns and reduce air pollution, which has led to mine closures and restrictions on coal production. In addition, measures to support natural gas and renewable energy sources as substitutes for coal have led to a reduction in coal production. The demand for coal in China remains high, despite decades of consistent attempts to diversify its energy mix by increasing hydro, wind, solar and nuclear power capacity (Appendix D Figure D.1). This is due to the rapid growth of energy consumption in the country, as well as the rigidity of its heavy industry.

With three key functions, nuclear power plays a crucial role in achieving China's energy and economic goals. First, it helps ensure security of energy supply by providing a significant base load with little dependence on foreign technology and fuel. Second, compared to coal, which currently dominates China's electricity generation, nuclear power produces cleaner energy in terms of carbon dioxide emissions and air pollution. Last but not least, China's overall industrial policy of reducing dependence on foreign technology is consistent with the successful localization of nuclear technology over the previous four decades. Chinese business has not been able to create a significant international footprint. In addition, many potential customers lack the financial resources to sponsor nuclear energy projects, and the Chinese leadership, with the exception of Pakistan, seems less motivated to do so.

Despite the encouraging development of renewable energy, there are still legislative and commercial obstacles that prevent its widespread adoption and effective integration, especially for dispersed renewable energy. Hydropower is the most common source of renewable energy in China, and its production and capacity are steadily increasing. However, because local hydropower resources are almost exhausted, many Chinese hydropower enterprises are now looking for chances in foreign markets. Wind power has become an important source of renewable electricity in northern China. In 2005, China adopted the Renewable Energy Law, which paved the way for wind power auctions in the following years.

When it comes to imposing sanctions on russia in response to its invasion of Ukraine, China has adopted a different strategy than other countries. While several countries have imposed sanctions, China has chosen not to participate and has even taken measures that favor some imports, such as coal, by reducing tariffs to zero. However, the fact that the bulk of transactions are still settled in US dollars complicates this issue. Chinese banks are allegedly restricting letters of credit for the purchase of russian coal and oil due to sanctions on the SWIFT payment system [85, p.4]. China will continue to receive oil from russia, although there is a possibility that the volume of supplies may decrease in the near future due to payment problems. In 2022, russia remained the second largest supplier of crude oil to China after Saudi Arabia. It is important to note that some countries are concerned about their dependence on China for the supply of necessary equipment and transition metals.

Germany, known for its technological advances and commitment to environmental sustainability, has undergone a significant change in its energy profile between 2015 and 2021. Germany's energy profile has traditionally been characterized by a combination of coal, natural gas, crude oil, nuclear power and renewable energy sources. In recent years, however, the country has made significant efforts to transition to a greener and more sustainable energy system. These efforts have been driven by domestic policies, international commitments, and public awareness of the need to mitigate climate change and reduce greenhouse gas emissions.

Oil remains the main and most important source of energy in Germany, despite the country's limited oil resources and low production rates. Germany has established diverse sources of oil imports, a well-developed supply infrastructure, and a liberal market to ensure a reliable supply of oil. However, further improvements in fiscal incentives, such as tax breaks and subsidies for low-emission vehicles and related infrastructure, could be crucial to facilitate Germany's transition to a low-carbon economy and maintain its oil security. With an import dependency rate of almost 90% in 2021, Germany is heavily dependent on oil imports from abroad (Appendix D Table D.1). Germany is seeking to accelerate its transition to a low-carbon economy and reduce its dependence on oil as the main source of energy by implementing a new fiscal policy.

After oil, natural gas is the second largest source of energy in Germany. Natural gas, a fossil fuel, continues to play an important role in the ongoing energy transition, both in power generation and in other sectors. Germany is the largest consumer of natural gas in Europe, and after many years of declining gas consumption, it has recently increased. Germany has been able to maintain a relatively high level of security of gas supply despite its heavy dependence on imports. As for renewable gas, its use in heating and transportation systems is considered to have medium- to long-term potential due to the high cost of production at the moment. The production of renewable gas for various needs is currently quite limited.

Germany has developed plans to phase out coal-fired power as part of its commitment to reduce energy-related CO_2 emissions by 50% by 2030 [86, p.50]. In June 2018, the federal government established a Coal Commission, officially known as the Commission on Growth, Structural Change and Employment, to build broad public agreement on a coal phase-out strategy. The commission included representatives of trade unions, economic and energy groups, environmental associations, academic institutions, and areas directly affected by the coal industry. Given that coal is the main fuel for electricity generation, the government could consider funding programs to help affected regions through electricity usage charges, similar to the Renewable Energy Surcharge (EEG) that promotes renewable energy development.

One of the key goals of Germany's energy transition strategy is the intention to completely abandon nuclear power by 2022. Until April 15, 2023, only three nuclear power plants (NPPs) were operating, and since 2011, 14 NPPs have been decommissioned. After the Fukushima tragedy, the Reactor Safety Commission (RSK) conducted a thorough safety assessment of the 17 operating reactors. The RSK concluded that, in contrast to Fukushima Daiichi, the safety standards of German nuclear power plants were high enough to survive difficulties such as loss of external power and flooding. Further careful analysis showed that no unambiguous conclusions can be drawn based on the original design or age of the plants alone. Germany will be much more dependent on other solutions to meet emission limits as a result of the phase-out of nuclear power.

Germany's attempts to switch to more sustainable energy sources have largely focused on renewable energy. In addition to being a world leader in biogas production, Germany has pioneered the development of rooftop solar photovoltaics (PV). However, wind power has been the source of much of the recent development of the renewable energy industry. Unfortunately, the development of these sectors has been slow, partly due to existing fuel and electricity pricing structures that are an obstacle to effective sector integration, especially in heating and cooling. By 2030, 65% of final energy consumption should come from renewable sources, according to the Coalition Agreement signed in March 2018 [86, p.27]. Due to the significant benefits granted to individual companies, most of the transition costs have been borne by energy consumers, especially households.

Before the war in Ukraine, the German economy was performing well, but the current picture is more grim. Germany's heavy dependence on relatively affordable and reliable energy supplies from russia has become a huge economic risk in the wake of the unexpected escalation. Although russian gas is still flowing into Germany, the prospect of an energy embargo from Europe or russia, as well as the German government's desire to quickly reduce dependence, has led to a tenfold increase in prices on the spot gas market year on year. Regardless of the situation with russian gas imports, Germany plays a crucial role in the European gas supply system. Due to its favorable geographical location, it is an important transit country for the transportation of natural gas within Europe. If gas imports from russia are cut off, Germany will initially receive all European gas imports, mainly from countries with liquefied natural gas (LNG) production capacities, such as Norway, Turkey, Spain and Italy. In addition, Germany has the largest gas storage capacity among all European countries.

Norway has significant oil and natural gas reserves, which have played a key role in its economic growth and prosperity. However, in recent years, Norway has also placed a strong emphasis on transitioning to a more sustainable and low-carbon energy system with a focus on renewable energy and environmental protection. During this period, Norway has undergone a shift in its energy mix, with a particular emphasis on reducing its dependence on fossil fuels and increasing the share of renewable energy. The government has implemented various measures and policies to promote cleaner energy sources, reduce greenhouse gas emissions, and strengthen energy security.

Almost 50% of Norway's total export earnings in 2021 came from the oil and gas industry, which is important for the country's economic development [87, p.13]. Norway is the third largest exporter and seventh largest producer of natural gas in the world. The main goal of Norway's petroleum policy is to maximize the value derived from oil and gas operations for the benefit of Norwegian society. Oil companies and other industry participants are responsible for operational activities, while the government is responsible for regulating the sector and maintaining a stable and favorable environment. russia's invasion of Ukraine in 2022 could be another incentive for Norway to continue to supply crude oil to the global market and possibly increase production when appropriate.

Norway, which is the third largest exporter of natural gas in the world after russia and Qatar, produces enough gas to meet about 3% of global demand [87, p.122]. Norway exports more than 98% of its natural gas production to Europe, as domestic demand is very low. Security of gas supply is not a major concern in Norway due to the low level of domestic gas consumption. Natural gas consumers often have access to the electricity grid and Norwegians have other heating alternatives during the winter. In addition, there is no seasonality or peak demand in the modest domestic gas consumption, which is mostly driven by chemical production and manufacturing.

The Norwegian state pension fund Global (the Fund) has implemented a coal policy that prohibits investments in coal mining and energy companies above a certain size. The Fund's continued influence on the coal sector is the result of three significant shortcomings of the existing coal policy. First, both the relative and absolute thresholds set by the policy are considered to be excessively high. Second, the policy does not contain requirements for companies engaged in the construction of new coal mines, power plants and related infrastructure. This omission allows investment in enterprises that are expanding their activities in the coal industry, even if their existing revenues or coal production volumes are modest. Last but not least, the policy ignores companies that propose coal infrastructure and covers only mining and power generation corporations. Accordingly, the Fund is allowed to invest in companies that provide the vital infrastructure necessary for the operation of coal mines and coal-fired power plants.

Norway ranks first among the IEA member countries in terms of the share of renewable energy in total final energy consumption. Norway uses hydropower as its main source of renewable energy, and it produces the most electricity of any IEA member country. Due to its reliability, adaptability, and low production costs, hydropower plays an important role in developing and maintaining Norway's low-carbon economy. Part of the revenue from onshore wind power is already distributed to local municipalities in Norway. Future attempts to develop renewable energy will mainly focus on the more challenging sectors, especially industry and transportation, which are more difficult to decarbonize given Norway's high share of renewable energy and almost complete reliance on heating systems using renewable energy sources. Due to good wind conditions, Norway has significant wind energy potential.

With a tenfold increase in its contribution to energy production over the past 10 years, onshore wind power has seen significant development in recent years and has overtaken thermal power to become the second largest source of generation.

Thus, the imposition of sanctions following russia's invasion of Ukraine has had a significant impact on global trade and the energy sector. While China chose not to participate in these sanctions and even introduced measures to support certain imports from russia, other countries introduced restrictions that affected imports of sanctioned goods from russia. Germany's and the European Union's significant dependence on russian energy supplies exposes them to significant economic risks, especially in connection with the possibility of an energy embargo. Germany's key role as a transit country and its significant gas storage capacities make it indispensable for maintaining a secure European gas supply system. The current geopolitical climate and growing sustainability concerns have accelerated the global transition to zero emissions, although some countries have expressed concerns about their dependence on China for the necessary equipment and transition metals. As a result, the invasion has highlighted the important role played by the United States and Norway as alternative energy importers. Given the sanctions and potential disruptions in russian gas supplies, Germany and the European Union are increasingly turning to these countries to ensure reliable and diversified energy supplies. The United States, with its restrictions on russian energy imports and significant reserves and production capabilities, has become a leading supplier of alternative energy sources to the European market. Similarly, Norway, with its significant liquefied natural gas (LNG) production capacity, is an attractive option for countries seeking to reduce their dependence on russian gas.

2.4 Ukraine as part of the European energy market

In 2023, Ukraine has a population of nearly 43 million, and its territory (603,549 km2) makes it the second largest country in Europe [88]. Ukraine has rich mineral resources, including coal, oil and natural gas, as well as excellent potential for biomass and hydropower. It is one of Europe's largest energy markets due to its large population and high energy consumption (Appendix E). The Eastern Partnership, which aims to promote political association and economic integration between the European Union and its neighboring countries (Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine), is the way in which Ukraine cooperates with the EU. The Deep and Comprehensive Free Trade Agreement between Ukraine and the European Union was also signed and ratified by the Ukrainian government in 2014, and it entered into force on January 1, 2016.

The main goal of National Energy and Utilities Regulatory Commission (NEURC) is to ensure efficient, predictable, transparent and non-discriminatory functioning of the energy market through economic regulation. In order to implement the provisions of the Energy Treaty and to establish the legal status and regulatory powers of the NEURC, Ukraine adopted the Law on the NEURC in 2016. The NEURC is a key player in setting tariffs for various energy-related services, including gas supply, distribution and transportation. It is authorized to set tariffs for energy transmission and distribution, for electricity generation at nuclear and hydroelectric power plants, and for steam coal for coal-fired power plants. The management of nuclear power plants, research reactors, and the dismantling of the Chornobyl Nuclear Power Plant (NPP) fall under the competence of another regulatory organization, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU). In addition, it is responsible for uranium mining, transportation of radioactive materials, waste storage facilities, and the creation and use of ionizing radiation sources. The SNRIU actively engages the public through its website and public discussions to ensure the safety of the country's nuclear facilities. Several regulatory organizations are crucial to ensuring that Ukraine's energy market remains functional and controlled. Through their regulatory activities, they support the overall governance of the energy sector in Ukraine and create a framework for open and efficient energy regulation.

The outdated Energy Strategy until 2030, which came into force in July 2013, was replaced by the government's adoption of the Energy Strategy of Ukraine (ESU) until 2035 in August 2017 [89]. Creating liberalized and competitive energy markets necessary for sustainable growth of the industry is a key component of the ESU. Although the ESU encourages emission reductions and the transition to cleaner energy sources, coal will remain the main source of electricity generation until 2035. The ESU implementation process is divided into three stages. The first stage, which lasted from 2018 to 2020, is aimed at minimizing state involvement in the creation of liberalized and competitive energy markets. The second stage, which will last from 2021 to 2025, is aimed at building the energy infrastructure, connecting it to the European system, and attracting the necessary investments. After achieving gas self-sufficiency in the second phase, the third phase, which will run from 2026 to 2035, aims to achieve sustainable development goals, including meeting commitments to reduce greenhouse gas emissions, accelerating the development of renewable energy sources, and ensuring energy security by increasing gas production, including unconventional gas and offshore drilling. In order to achieve long-term energy security and sustainability in Ukraine, the strategy's phased approach recognizes the need for major reforms in energy markets, infrastructure development, and environmental protection.

Following protracted negotiations with russia over gas prices, military actions in the east of the country, and the loss of political control over Crimea, Ukraine's energy security was seriously threatened in 2014. Coal production in the Donbas basin has fallen sharply. The hostilities in the region have severely damaged coal mining and energy-intensive enterprises, leaving behind several flooded mines, destroyed energy and transportation infrastructure, and consequent logistical problems. In mid-2014 and winter 2015, coal supplies from Donbas to central Ukraine and to thermal power plants almost stopped due to the suspension of railroad traffic and damaged or destroyed roads and bridges.

Due to the presence of conventional and unconventional fields, Ukraine has a significant natural gas production sector. The country's gas production is driven by domestic gas reserves, in particular, the well-known Shebelynka field. After February 24, 2022, the work of the Shebelynka GPP was suspended due to russian hostilities and the plant was later damaged by a missile attack (Figure 2.19). In September 2022, the russian military forces continued regular shelling of the Shebelynka GPP and its fuel reservoirs.

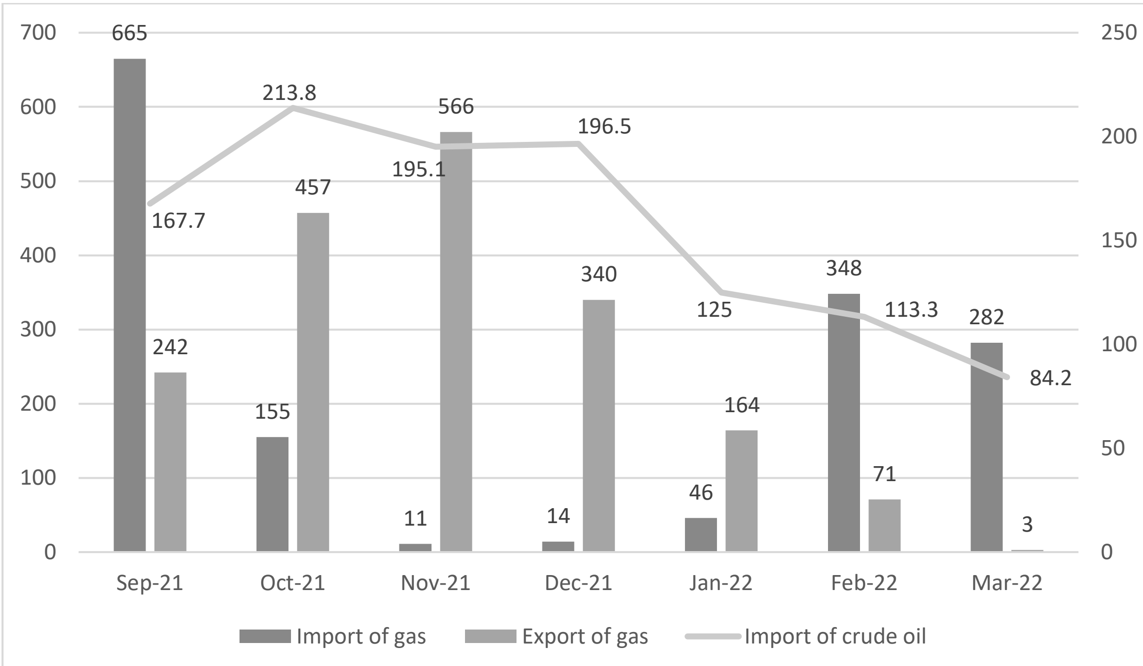

Figure 2.19. Gas imports and exports in 2021-2022, mln cubic meters with crude oil imports in 2021-2022, thousands tons [90]

In terms of reserves to production ratio (R/P), Ukraine holds an important position in Europe, ranking second in terms of proven natural gas reserves (after Norway) and fourth in terms of gas production. 94% of these registered reserves - both developed and undeveloped - are located onshore and distributed in 443 fields, with the remaining 6% concentrated in 15 fields on the continental shelf [91, p.12]. However, Ukraine faces challenges, including declining reserves, limited investment, and technological issues that affect production levels. Therefore, the country is largely dependent on imports to meet its domestic needs. Since 2014, the country has been successfully importing natural gas from Hungary, Poland, and

Slovakia through reverse flows. Ukraine can indirectly obtain gas from other sources in addition to reimporting russian gas. The Southern Corridor is being developed in cooperation with Ukraine to supply Azerbaijani gas to Southern Europe. To facilitate gas supplies from Romania, Ukraine is also reconstructing its border gas metering stations with Moldova. It has been discussed that Ukraine could build its own LNG terminal, which some believe would guarantee its independence from any one source. Ukraine has played an important role in transporting natural gas to Europe. But with the outbreak of the conflict between russia and Ukraine, the share of fossil gas in the EU's energy imports has undergone the most significant changes. Before the conflict, about 50% of the EU's total natural gas imports came from russia. In 2022, this share fell sharply to 12% in October [92]. In addition, in order to promote integration into the European energy market and deepen energy cooperation, Ukraine is actively involved in negotiations and partnerships with organizations related to the European Union as well as with neighboring countries.

Ukraine is believed to have large oil reserves of over 85 million tons. More than 51% of the total reserves are concentrated in the northern and central regions, while the western and southern regions account for only 36% and 13%, respectively [93, p.19]. The country's oil transportation system is essential for transporting oil from Ukraine's oil fields and seaports to neighboring countries such as Slovakia, the Czech Republic, and Hungary. In 2021, the Ukrainian oil transportation system successfully transported 15.7 million tons of oil. However, on February 24, 2022, three oil transportation facilities and their auxiliary equipment suffered significant damage, including several cases of cable communication system breakdowns. As a result, the destruction of these facilities and Ukrainian refineries, as well as the reduction or termination of transit to Belarus in 2022, will significantly affect the level of oil transit and transportation. Unfortunately, repeated rocket attacks destroyed the Kremenchuk refinery, and the Odesa and Lysychansk refineries were severely damaged. Although the plant had been shut down for about a decade, the Drohobych refinery was also hit. As a result, Ukraine's oil refining sector has suffered significant losses, making dependence on imports of petroleum products almost inevitable. Since February 24, 2022, the russian military has destroyed and damaged more than 30 oil depots in Ukraine. Unfortunately, information on the actual number of oil depots and their pre-war condition is not widely available due to the nature of the hostilities.

Ukraine ranks seventh in the world in terms of coal reserves and has significant coal reserves, especially in the form of hard coal. The Lviv-Volyn and Donetsk basins are home to the majority of hard coal resources. Up to 90% of the national hard coal reserves are located in the Donetsk basin, which includes Donetsk, Luhansk, and Dnipropetrovs'k regions [94, p.11]. In addition, Ukraine has 2.3 Gt of lignite reserves, most of which are located in the Dnipro basin. Coal mines are characterized by outdated infrastructure, low profitability, and a significant need for subsidies to stay afloat. Moreover, due to high mortality rates, Ukrainian coal mines are among the riskiest in the world. On average, 2.5 miners die for every million tons of coal produced [95, p.5]. The state-owned Energoatom and Rinat Akhmetov's DTEK, the latter of which produces 85% of the country's thermal coal, are currently responsible for generating over 80% of Ukraine's electricity [95]. Only a small fraction of Ukraine's thermal power plants use natural gas; the majority are coal-fired. Most of Ukraine's power plants have now reached the end of their original technical lifespan of 40-45 years, with an average age of about 49 years.

Nuclear power production in Ukraine has a long history, and the country is known for making a significant contribution to the global nuclear power industry. A significant part of the country's electricity is generated by nuclear power, which is a key component of the country's energy balance. Ukraine currently operates four nuclear power plants (NPPs) with a total of 15 reactors. These include Zaporizhzhya, Rivne, South Ukraine and Khmelnytsky NPPs. Zaporizhzhya NPP is the largest nuclear power plant in Europe and the fifth largest in the world. These reactors are operated in accordance with global nuclear safety standards and are subject to strict safety procedures. The state cooperates with international partners, such as the International Atomic Energy Agency (IAEA), to improve safety procedures and strengthen the regulatory framework in the nuclear energy sector. Thanks to agreements concluded with a number of foreign fuel suppliers, Ukraine is now able to purchase nuclear fuel from a variety of suppliers, ensuring a stable and reliable supply of fuel for its reactors. Since the beginning of March 2022, russian armed groups have been controlling the Zaporizhzhya NPP (ZNPP). The plant's installed capacity of 6,000 MW is 43% of the total installed capacity of nuclear power plants in Ukraine [96, p.9]. Attacks on the transmission system infrastructure affected Khmelnytska and Rivne NPPs. According to open source information, in December 2022, the russian government continued to implement initiatives aimed at integrating Zaporizhzhya NPP into the russian electricity system.

In November 2015, the Ukrainian government decided to stop importing gas from russia, opting instead to rely on domestic production and alternative fuel sources for electricity and heat. The government has launched a number of programs, including a feed-in tariff, tax and customs benefits, and incentives for the purchase of domestically produced equipment to promote the expansion of renewable energy projects. Ukraine's renewable energy industry is developing rapidly due to its huge renewable energy potential and effective support systems. The two companies that dominate the Ukrainian wind industry are DTEK Wind Energy, the renewable energy division of a large local energy supplier, and Wind Parks of Ukraine, which manufactures equipment under license from German supplier Fuhrlander Windtechnology. The two largest solar renewable energy companies, CNBM New Energy Engineering and Rengy Development, together account for about one-third of the market. Outside of these major players, Ukraine's wind and solar industries are fragmented, with many smaller operators and startups that have yet to produce significant amounts of energy. The country also has access to foreign capital, a robust regulatory framework, and a workforce with the experience needed to implement complex projects. A number of significant international investors are already present in the renewable energy market in Ukraine. Some of the largest investors in the sector are CNBM Engineering and Rengy Development, an international corporation operating in Kazakhstan, Armenia and Ukraine. Overall, Ukraine's commitment to renewable energy, its significant technical potential, favorable regulatory environment, access to international financing, and growing market offer domestic and foreign players ample opportunities to support the country's transition to clean and sustainable energy sources.

Thus, Ukraine's integration into the European energy market as an energy supplier has significant implications for both Ukraine and the European energy landscape as a whole. Ukraine possesses significant energy resources, including natural gas, coal, oil, and renewable sources such as wind and solar energy. By utilizing its energy resources and aligning its policies with European standards, Ukraine has strengthened its position as a reliable energy supplier in the region. Diversification of energy sources and reduced dependence on a single supplier, especially in the case of natural gas imports from russia, have increased the energy security of Ukraine and its European partners. In addition, Ukraine's efforts to modernize its energy infrastructure and improve energy efficiency have contributed to a more sustainable and environmentally friendly energy sector. The development of renewable energy sources, such as wind and solar power, has not only reduced greenhouse gas emissions but also created new opportunities for investment and economic growth. Ukraine's participation in the European energy market has fostered cooperation, technology transfer, and knowledge exchange between Ukraine and European countries. The harmonization of regulations and standards has facilitated trade and investment in the energy sector, attracted foreign companies, and stimulated economic development.

SUMMARY

This policy brief thus delves into the multifaceted nature of the energy problem, emphasizing imbalance theory as a key framework for understanding its root causes. It emphasizes the importance of correcting imbalances in supply and demand, as well as between different energy sources, to achieve a sustainable energy system. The study emphasizes the need to improve energy efficiency, introduce renewable energy sources and develop carbon capture and storage technologies. In addition, it recognizes the geopolitical implications of the energy challenge and emphasizes the importance of energy security and supply diversification. In addition, the study reviews the current state of renewable and non-renewable energy sources, recognizing the growing role of renewables in the global energy transition, as well as the importance of non-renewable energy sources. In addition, the study emphasizes the importance of the energy challenge in the context of the Sustainable Development Goals, highlighting its impact on economic growth, social well-being and environmental sustainability. It calls for integrated and sustainable solutions, including a holistic approach to energy planning, promotion of renewable energy technologies, energy efficiency and increased access to clean and affordable energy services. Finally, the document emphasizes the growing importance of renewable energy sources in mitigating the energy crisis and reducing carbon dioxide emissions. Recognizing the role of non-renewable energy sources in modern civilization, the study emphasizes the need to move to cleaner and more sustainable alternatives.

The study also discusses the impact of the war in Ukraine on the energy sector and the related changes in energy policy and practice. The study analyzes the energy profiles of key consumer countries, providing insights into consumption patterns, trends, and challenges. We also look at the implications of russia's invasion of Ukraine for the global energy market. In terms of the sanctions imposed, China has decided not to participate in them and has even introduced measures to support specific imports from russia. Conversely, other countries have imposed restrictions that have affected imports of sanctioned goods from russia. Germany's and the European Union's heavy dependence on russian energy supplies exposes them to significant economic risks, especially with regard to a potential energy embargo. However, some countries have expressed concern about their dependence on China for critical equipment and transition metals. The incursion thus shed light on the crucial role played by the United States and Norway as importers of alternative energy sources. In light of the sanctions and the possibility of disruptions in russian gas supplies, Germany and the European Union are increasingly turning to these countries to ensure reliable and diversified energy supplies. The study also examines Ukraine's position in the European energy market, assessing the dynamics of energy production, consumption and trade. The study examines the implications of Ukraine's transitional status and explores opportunities and challenges in the European energy landscape.

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APPENDIXES

Appendix A

Classifications of energy types

Renewability / Conventionality	Renewable	Non-renewable
Commercial	Hydropower Geothermal	Fossil fuels Nuclear
Traditional	Wind (wind mills) Hydro (watermills) Animal residues Crop residues	Charcoal
Newer	Biogas Solar Tidal and wave Ocean thermal Wind (wind motors)	Oil from coal

Source: Systematization by author based on International Atomic Energy Agency

Appendix B

Sustainable Development Goals (SDGs) [97]

Sustainable Development Goals (SDGs)	Description
Goal 1. No poverty	End poverty in all its forms, everywhere
Goal 2. Zero hunger	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
Goal 3. Good health and well-being	Ensure healthy lives and promote well-being for all at all ages
Goal 4. Quality education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5. Gender equality	Achieve gender equality and empower all women and girls
Goal 6. Clean water and sanitation	Ensure available and sustainable management of water and sanitation for all
Goal 7. Affordable and clean energy	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8. Decent work and economic growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all
Goal 9. Industry, innovation, and infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
Goal 10. Reduced inequalities	Reduce inequality within and among countries

Continuation of Appendix B

Goal 11. Sustainable cities and communities	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12. Responsible consumption and production	Ensure sustainable consumption and production patterns
Goal 13. Climate action	Take urgent action to combat climate change and its impacts
Goal 14. Life below water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15. Life on land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss
Goal 16. Peace, justice, and strong institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable and inclusive institutions at all levels
Goal 17. Partnership for the goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Appendix C

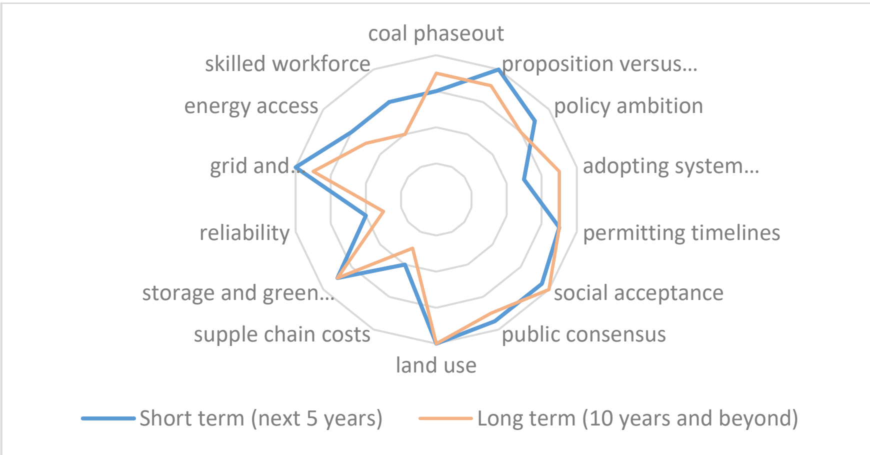


Figure C.1. Transversal challenges to wind energy's growth in the short and long term [98]

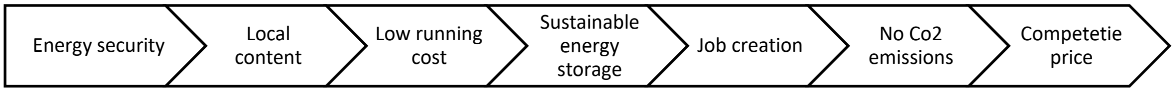


Figure C.2. Key benefits of CSP technology

Source: Systematization by author based on [99]

Table C.1. SWOT-analysis of all types of renewable energy

Strengths	Weaknesses
Hydropower energy	
– High energy efficiency; – Stable power generation; – Water storage; – Flood control	– Alteration of river flow; – High initial capital investment; – Limited availability
Wind energy	
– Zero greenhouse gas emissions; – Cost effective; – Domestic energy production	– Dependency on wind availability; – Land use; – Impact on wildlife
Solar energy	
– Limitless; – Cost effective; – Versatility	– Weather dependent; – Energy storage; – Hight initial cost; – Land use
Biomass energy	
– Carbon neutrality; – Flexibility; – Waste management solution	– Limites energy density; – Competition for resources; – Air quality concerns
Geothermal energy	
– High reliability; – Low carbon emissions; – Long-term sustaibability; – Flexibility	– Limited locations; – High initial cost; – Technical challenges; – Limited scalability
Opportunities	**Threats**
Hydropower energy	
– Grid stabilization; – Integration with other renewable sources	– Climate change impact on water scarcity; – Opposition from society; – Laws and permits
Wind energy	
– Technological advancement; – Offshore wind power; – Integration with other renewable sources	– Grid integration; – Public acceptance; – Policy

Continuation of Table C.1

Solar energy	
– Growing demand; – Create new business opportunities; – Technological progress	– Health risks; – Economic instability; – Policy changes
Biomass energy	
– Technological advancements; – Co-firing with fossil fuels; – Local energy production	– Sustainability concerns; – Price volatility; – Regulatory framework
Biomass energy	
– New technology; – Job creation; – International cooperation	– Competition; – Political instability; – Natural disasters

Source: Systematization by author based on [100, 101]

Appendix D

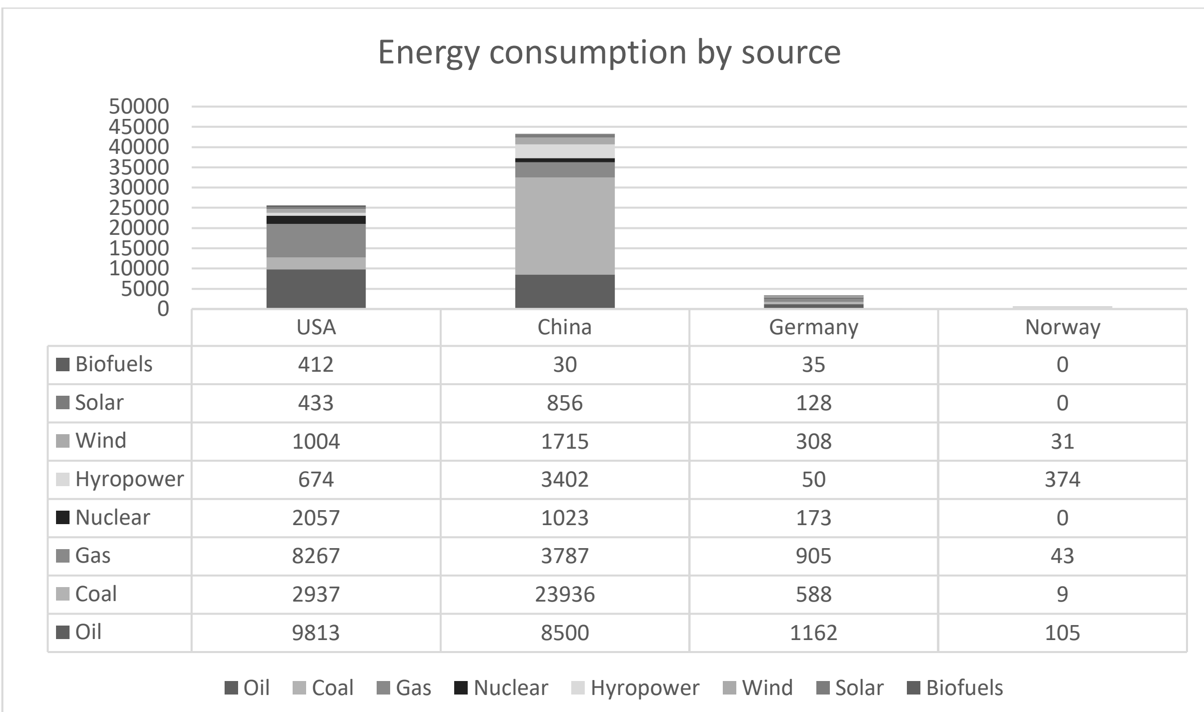
Table D.1. Import energy dependency of USA, China, Germany, and Norway in 2015-2021

	Non-renewable resources								
	Coal			**Crude oil**			**Natural gas**		
	Net imports (MMst)	Consumption (MMst)	Dependence	Net imports (thousandth of barrels per day)	Consumption (thousandth of barrels per day)	Dependence	Net imports (billion cubic meters)	Consumption (billion cubic meters)	Dependence
2015									
USA	-38.45	372.12	**export**	4888	18499	**26.42%**	26.5	743.6	**3.56%**
China	101.27	1932.74	**5.2%**	8142	11890	**68.48%**	85	194.7	**43.65%**
Germany	60.31	78.58	**76.7%**	2083	2269	**91.8%**	71.6	82	**87.32%**
Norway	-0.475	0.72	**export**	-740	217	**export**	-5.6	4.5	**export**
2016									
USA	-30.33	340.59	**export**	4979	18593	**26.78%**	19	749.1	**2.54%**
China	122.77	1915.31	**6.41%**	9012	12297	**73.29%**	108.3	209.4	**51.72%**
Germany	59.17	76.43	**77.42%**	2120	2307	**91.9%**	75.6	86.9	**87%**
Norway	-0.278	0.72	**export**	-857	210	**export**	-6.1	4.4	**export**
2017									
USA	-52.54	331.28	**export**	4269	18845	**22.6%**	-3.4	740.0	**export**
China	130.17	1924.14	**6.76%**	9794	13003	**75.32%**	145	241.3	**60.1%**
Germany	51.88	71.89	**72.16%**	2075	2374	**87.40%**	79.3	89.7	**88.41%**
Norway	0.034	0.72	**4.7%**	-831	212	**export**	-5.4	4.6	**export**

Continuation of Table D.1

2018									
USA	-65.44	317.18	**export**	2891	19417	**14.89%**	-20.4	821.7	**export**
China	136.14	1935.85	**7.03%**	10654	13642	**78.1%**	196	283.9	**69%**
Germany	48.03	69.26	**69.35%**	1959	2255	**86.87%**	85.7	95	**90.2%**
Norway	0.698	0.863	**60.24%**	-900	221	**export**	-6.8	4.4	**export**
2019									
USA	-48.25	270.85	**export**	1139	19424	**5.86%**	-54.2	850.7	**export**
China	144.74	1951.37	**7.42%**	11665	14321	**81.45%**	216.4	308.4	**70.17%**
Germany	43.62	53.74	**81.17%**	1958	2270	**86.25%**	91	98.3	**92.57%**
Norway	0.785	0.921	**85.23%**	-734	213	**export**	-6.9	4.6	**export**
2020									
USA	-38.21	219.73	**export**	-259	17183	**export**	-77.4	831.9	**export**
China	153.58	1967.61	**7.81%**	12217	14408	**84.79%**	236.6	336.6	**70.29%**
Germany	31.23	43.23	**72.24%**	1853	2049	**90.43%**	81.4	91.5	**88.96%**
Norway	0.852	0.961	**88.6%**	-916	204	**export**	-4.3	4.4	**export**
2021									
USA	-47.53	252.46	**export**	586	18684	**3.14%**	-108.9	826.7	**export**
China	149.28	2058.13	**7.25%**	12092	15442	**78.3%**	279	378.7	**73.67%**
Germany	36.41	50.63	**71.9%**	1758	2045	**85.96%**	85.4	95.9	**89.05%**
Norway	0.882	1.016	**86.81%**	-817	199	**export**	-0.2	4.3	**export**

Source: Systematized by author based on [102, 103, 104, 105, 106]



	USA	China	Germany	Norway
Biofuels	412	30	35	0
Solar	433	856	128	0
Wind	1004	1715	308	31
Hyropower	674	3402	50	374
Nuclear	2057	1023	173	0
Gas	8267	3787	905	43
Coal	2937	23936	588	9
Oil	9813	8500	1162	105

Figure D.1. Energy consumption by source in USA, China, Germany, Norway in 2021, terawatt-hour [107]

Appendix E

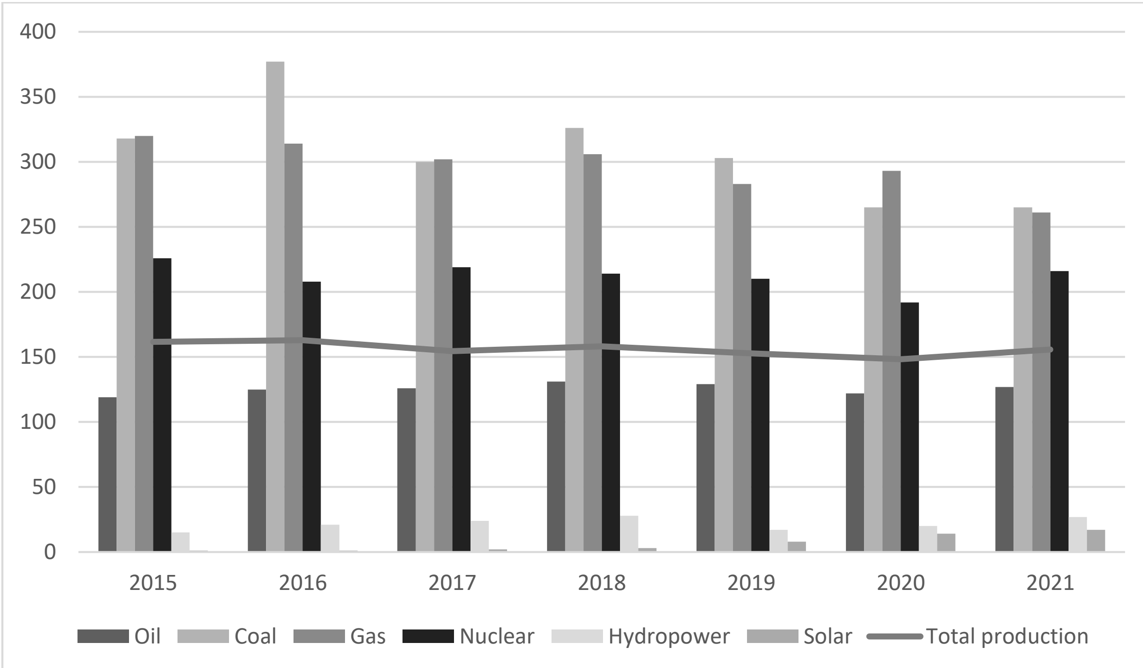


Figure E.1. Total energy production and energy consumption by source in Ukraine in 2015-2021, terawatt-hour [108]

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