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 «Features of functioning and scenarios of development of the world energy market»

By **Yaroslava Lomova** (Signature)
(Student's name, surname)

Academic Supervisor PhD, Associate Professor
(Scientific degree, academic status)
Nataliya Moskalyuk
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Bachelor Thesis has been approved for defense at Attestation Examination Commission (EC)

Head of the Department of International Economics Dr.of Science, Professor
Y. Stoliarchuk
(Signature)

KYIV 2023

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AGREED Head of the project group (guarantor) of the educational-professional program _______________ Y.Stoliarchuk *(Signature)* _______________ 2023	**APPROVED** Head of the Department _____________ Y. Stoliarchuk *(Signature)* ____________________ 2023

INDIVIDUAL TASK
higher education applicant Yaroslava Lomova
Name, Surname
full-time forms of education

Bachelor Thesis

Title: **«Features of functioning and scenarios of development of the world energy market»**

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

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

Chapter 1. Theoretical foundations of the functioning and development of the world energy market
Chapter 2. Analysis and scenarios of development of the world energy market

Object of research:	World energy market its structure, processes, and relationships.
Subject of research:	Functioning mechanisms and development scenarios of the world energy market, taking into account geopolitical, economic and and technological factors.
The purpose of the Thesis:	Study the peculiarities of the functioning of the market, analyze its current state and identify development scenarios, taking into account energy supply and demand, competition, political and economic factors, the impact of technological innovations, alternative energy sources and environmental aspects.

Specific tasks applicant has to accomplish to meet the objective:

In Chapter 1

Conduct a literature review on the topic of the world energy market, its main aspects and theoretical concepts; explore key concepts and theoretical models used to analyze the energy market, such as supply and demand, competition, regulation and others; investigate the features of the global energy market, its structure, participants and relationships between them; analyze the key factors affecting the functioning and development of the global energy market, such as technological innovations, political and economic factors, environmental challenges.

In Chapter 2

Collect statistical data on energy consumption and production in different countries and regions of the world; conduct an analysis of the current state of the world energy market, including the study of the main trends, problems and challenges; determine scenarios of energy market development based on existing trends and possible changes in the political, economic and technological environment; assess the impact of various factors, such as the increase in the use of renewable energy sources, changing climatic conditions.

The task has been set
by the Academic Supervisor ____________ Nataliya Moskalyuk
(Signature) *(Name, Surname)*
"10" 01. 2023

The task has been given to
Applicant ____________ Yaroslava Lomova
(Signature) *(Name, Surname)*
"11" 01. 2023

ABSTRACT

The qualifying bachelor thesis contains 97 pages, 5 tables, 15 figures, a list of used sources with 78 items, and appendices.

The *object* of the research is the world energy market, its structure, processes and relationships.

The *subject* of the study is the functioning mechanisms and development scenarios of the world energy market, taking into account geopolitical, economic and technological factors.

The *purpose* of this qualifying bachelor thesis is to reveal the main features of the functioning and the definition of development scenarios of mainly the global energy market, as well as Ukrainian. To achieve this goal, the following tasks have been defined:

- To analyze the current trends in the development of the world energy market.
- To Identify the key factors affecting the functioning of the market.
- To study various scenarios of the development of the world energy market and their possible consequences.
- To assess the impact of innovative technologies and renewable energy sources on market processes.
- To analyze geopolitical aspects in the context of the development of the world energy market.

The topic has great significance from the theoretical, methodical and practical points of view.

The *theoretical significance* lies in the introduction of new knowledge and generalizations in the field of energy economy and market processes. The work examines the key aspects of the functioning of the world energy market, determines the factors affecting its development and predicts future development scenarios. The obtained results

expand the theoretical base of knowledge and contribute to the further research of energy markets.

Methodological significance lies in the development of approaches and methods of analysis of the world energy market. The research includes the analysis of statistical data, economic models, prognostic techniques and other research methods. The developed methods can be used both for educational and research purposes to study energy markets and their development.

The *practical significance* lies in the possibility of applying the obtained results in the real energy sector. The study provides information and recommendations that can be used in decision-making in energy policy, development of energy projects, planning of market strategies and investment decisions. The obtained results contribute to understanding and adaptation to changes in the global energy market and contribute to improving the efficiency and sustainability of energy systems.

The year of defense: 2023.

Key words: world energy market, energy market dynamics, energy demand and supply, energy pricing, energy policy, renewable energy sources, fossil fuels, energy trading and investments, energy security, energy market regulations, market competition and monopolies on energy arena, energy market forecasting, scenarios for the development of renewable energy.

Review
on the bachelor's thesis
of the student of the Faculty of International Economics and Management
of the bachelor’s degree program "International Economics"
Yaroslava Lomova
on the topic of **Features of functioning and scenarios of development of the world energy market**

1. Relevance of the topic: In today's conditions, the global energy market makes up a significant share of world economies and needs changes under the influence of crisis challenges. Therefore, the research of these features of functioning and scenarios of development of the world energy market is relevant.

2. Positive aspects of the bachelor’s thesis: a high level of quality research on the theoretical foundations of the functioning and development of the world energy market, in particular, the essence, subjects and classification of energy sources of the world energy market, supply and demand on the world energy market, pricing mechanisms are determined, forms and methods of regulating the world energy market are systematized. The Thesis contains a high level of information support.

3. Presence of author’s independent developments: the analysis of the structural dynamics of the world energy market, the author identified the main factors of influence and modern trends in the development of the world energy market. A positive aspect of this Thesis is the analysis of the state of the energy market of Ukraine.

4. Value of theoretical conclusions and practical recommendations: lies in the possibility of using the generalizing trends in the development of the world energy market for building scenarios for the development of renewable energy on the world energy market and to determine the prospects for the development prospects of the energy market of Ukraine.

5. Presence of drawbacks: the author should have considered more broadly the aspects of legislative regulation of the energy market in Ukraine. However, it does not significantly affect the content of the Bachelor's Thesis.

6. Overall assessment of the bachelor’s thesis and its admission to defense: the research topic is fully disclosed, at a high level, the work is written according to the requirements, it is allowed to be defended before the Examination Committee with an assessment of **48 points.**

Supervisor:

PhD in Economics, Associate Professor
of the Department of International Economics of KNEU Moskalyuk N
“ 12 ” June 2023year

CONTENT

INTRODUCTION

Today's reality of the world energy market is characterized by constant changes provoked by geopolitical and technological transformations, as well as the impact of sustainable development and challenges related to climate change. Understanding the features of the functioning and development scenarios of the world energy market is becoming a key factor for establishing a sustainable energy sector and achieving global energy goals.

The relevance of the topic lies in the fact that the world is observing the growing importance of the energy market and its impact on the global economy and geopolitical landscape. Studying the functioning and development scenarios of the world energy market is an urgent task, as it allows you to assess potential risks and opportunities, identify trends and innovative solutions, and also contributes to the formulation of effective strategies and policies in the field of energy.

The *purpose* of this qualifying bachelor thesis is to reveal the main features of the functioning and the definition of development scenarios of mainly the global energy market, as well as Ukrainian. To achieve this goal, the following *tasks* have been defined:

- To analyze the current trends in the development of the world energy market.
- Identify the key factors affecting the functioning of the market.
- To study various scenarios of the development of the world energy market and their possible consequences.
- Assess the impact of innovative technologies and renewable energy sources on market processes.
- Analyze geopolitical aspects in the context of the development of the world energy market.

The *object* of the research is the world energy market, its structure, processes and relationships.

The *subject* of the study is the functioning mechanisms and development scenarios of the world energy market, taking into account geopolitical, economic and technological factors.

To achieve the objectives, the following *research methods* were used: analysis of scientific literature, statistical data analysis, comparative analysis, scenario analysis, econometric methods, expert evaluations.

The obtained research results has the theoretical, methodical and practical significance.

The *theoretical significance* lies in the introduction of new knowledge and generalizations in the field of energy economy and market processes. The work examines the key aspects of the functioning of the world energy market, determines the factors affecting its development and predicts future development scenarios. The obtained results expand the theoretical base of knowledge and contribute to the further research of energy markets.

Methodological significance lies in the development of approaches and methods of analysis of the world energy market. The research includes the analysis of statistical data, economic models, prognostic techniques and other research methods. The developed methods can be used both for educational and research purposes to study energy markets and their development.

The *practical significance* lies in the possibility of applying the obtained results in the real energy sector. The study provides information and recommendations that can be used in decision-making in energy policy, development of energy projects, planning of market strategies and investment decisions. The obtained results contribute to understanding and adaptation to changes in the global energy market and contribute to improving the efficiency and sustainability of energy systems.

of *theoretical importance*, as they allow us to reveal the peculiarities of the functioning and development scenarios of the world energy market. In addition, the obtained results are of practical importance, as they can be used to forecast market development and make effective management decisions.

The research was based on the use of scientific literature, statistical data, reports of international organizations, official documents and publications in the field of energy and economics.

Structure of work. The thesis consists of an introduction, the main part, which in turn has two sections and a conclusion. The qualifying bachelor thesis contains 97 pages 5 tables, 15 figures, a list of used sources from 78 items and appendices.

CHAPTER 1.
THEORETICAL FOUNDATIONS OF THE FUNCTIONING AND DEVELOPMENT OF THE WORLD ENERGY MARKET

1.1. The essence, subjects and classification of energy sources of the world energy market

Energy is the lifeblood of modern society, and the world energy market is the engine that drives it forward. From the discovery of new oil reserves to the growth of green energy technologies, the energy market plays a central role in shaping the economic, political, and environmental landscape of the world.

At the same time, the global energy market is driven by a diverse array of energy sources, each with unique characteristics and implications for global energy security, economic growth, and environmental sustainability. Understanding the essence, subjects, and classification of energy sources is important for developing a comprehensive understanding of the global energy market. As the interrelationships between energy resources and the world energy market are essential for developing effective energy policies, promoting sustainable energy development, and ensuring global energy security.

In economics, *energy sources* can be defined as physical materials or elements that are used to produce energy and fuel economic growth. These resources can be transformed into useful energy for various applications, including electricity generation, manufacturing transportation, heating, and many other aspects of modern life. From an economic perspective, energy sources are considered a critical input in the production process, and the availability and price of these sources can have a significant impact on economic growth and development. For example, the Industrial Revolution of the 18th and 19th centuries was largely driven by the widespread use of coal as an energy source for powering steam engines, which revolutionized transportation and manufacturing, that

helped to drive economic growth and transform society. The use of coal also led to the growth of the iron and steel industries, as well as the development of new technologies such as the telegraph and the railroad.

In addition to coal, people also used wood as a source of energy during this period. Nowadays the world energy market comprises a variety of energy sources. Each energy source has its unique properties, including availability, accessibility, and environmental impact. However, these are not the only criteria for classification of energy sources. Let's take a closer look at each of these approaches.

1. *Physical State Classification*
   According to the approach, energy resources are categorized into three categories: solids, liquids, and gases based on their physical states. In the oil and gas sector, the classification is still used to describe hydrocarbon reserves.

2. *Geological Origin Classification*
   In accordance with the classification, energy sources are divided into fossil fuels and nuclear energy due to their geological origin. It is important to note that the concept of classifying energy sources based on their geological origin existed without a specific author, however, M. King Hubbert contributed to its development and popularization. He created the idea of "peak oil", which postulates that eventually, as reserves run out, the world's oil production will peak and then begin to decline.

3. *Energy Return on Investment (EROI) Classification*
   Due to this approach, energy resources should be categorized according to their EROI, which measures the amount of energy required to produce one unit of energy.

Categorized energy resources as high-EROI (e.g., coal, oil, and natural gas), mid-EROI (e.g., wind, solar, and nuclear power), and low-EROI (e.g., biofuels).

4. *Degree of Concentration Classification*
It assumes a classification of energy resources based on their degree of concentration, which measures the amount of energy per unit of mass or volume. Energy resources are divided into three categories: highly concentrated (e.g., nuclear energy and some fossil fuels), moderately concentrated (e.g., oil and gas), and weakly concentrated (e.g., solar and wind power).

5. *Physical Quality Classification*
Relying on it, energy resources can be categorized according to their physical quality, which considers factors like energy density, stability, and ease of transport. The classification includes such energy resources as primary (e.g., coal, oil, and natural gas) that are obtained directly from the Earth, secondary (e.g., electricity and hydrogen) that are derived from primary sources through conversion processes, and tertiary (e.g., synthetic fuels and chemical energy storage) that involves further processing and transformation of primary or secondary energy sources to create alternative fuels or energy storage solutions.

6. *Environmental Impact Classification*
It is a way of classifying energy resources based on their environmental impact on such categories: hard, soft, and benign. Hard sources, such as fossil fuels, have significant environmental impacts. Soft sources, such as nuclear energy, have fewer impacts, of course, if it is controlled and will not lead to a nuclear disaster. Benign sources, such as solar and wind power, have minimal or no environmental impacts.

7. *Energy Density Classification*
The division of energy resources is based on their energy density. It includes four categories: low-density fuels (e.g., wood, crop residues), medium-density fuels (e.g.,

coal, oil, natural gas), high-density fuels (e.g., nuclear energy), and extremely high-density fuels (e.g., antimatter).

8. *International Energy Agency (IEA) approach* The International Energy Agency (IEA) was founded in 1974 as an intergovernmental organization with the goal of fostering international cooperation and energy security. The IEA classifies energy resources based on their source of origin, categorizing them as fossil fuels (coal, oil, and natural gas), nuclear energy, and renewable energy.
9. *World Energy Council (WEC) approach* The World Energy Council is a global energy network that was established in 1924 with the purpose of promoting sustainable energy systems. Primary and secondary energy sources, renewable and non-renewable energy sources, and commercial and non-commercial energy sources are the categories into which the WEC divides energy resources.
10. *United States Energy Information Administration (EIA) approach* The Energy Information Administration is a statistical agency of the U.S. government that collects and analyzes data on energy production, consumption, and prices. The EIA splits energy resources based on their primary use, categorizing them as electricity, transportation, industrial, residential, and commercial.

So, the various classifications of energy highlight the complexity of understanding energy systems. Each one offers a unique perspective on the nature of energy resources, based on different criteria such as physical state, geological origin, energy return on investment, degree of concentration, physical quality, environmental impact, and energy density. Energy sources can also be classified based on their primary use. For example, some are used primarily for transportation, such as gasoline and diesel fuel, while others are used for electricity generation, such as coal and natural gas. In addition, some sources are more commonly used in certain regions of the world than others. For example, coal is more prevalent in Asia, while natural gas is more commonly used in North America.

These classifications can be useful in understanding the strengths and limitations of different energy resources, as well as the trade-offs involved in choosing among them.

Let’s focus more on renewable and non-renewable energy - two broad categories of energy resources, that are often discussed in the context of sustainability and energy transition. *Renewable energy* refers to sources that are replenished naturally and sustainably over time, such as solar, wind, hydro, geothermal, biomass, tidal, and wave energy. *Non-renewable energy* refers to sources that are finite and depleted over time, such as fossil fuels (coal, oil, and natural gas) and nuclear energy. Let’s take a closer look at each type:

Renewable Energy Resources:

1. *Solar Energy*

It harnesses the energy from the sun using photovoltaic (PV) panels or solar thermal systems. PV panels convert sunlight directly into electricity, while solar thermal systems use the sun's heat to generate electricity or provide heating and cooling.

Sunlight is practically limitless, which is one advantage of solar energy. Solar energy has an infinite supply and could replace fossil fuels if the technology to harness it is developed. Relying on solar energy rather than fossil fuels also enables us to enhance environmental and public health conditions. Long-term energy cost elimination and immediate energy bill reduction are both possibilities for solar energy. Many local, state, and federal governments offer tax credits or rebates to encourage the purchase of solar energy systems.

Even though using solar energy will save you money in the long run, most households cannot afford the typically high upfront costs. The number of people who can realistically adopt this technology at the individual level is constrained by the need to have sufficient sunlight and space to arrange their solar panels.

2. *Wind Energy:*

Wind farms use turbines to harness the energy of the wind flow and turn it into electricity. The differences in air pressure in the atmosphere combined with the rotation of Earth and the geography of the planet, all contribute to the phenomenon that we refer to as "wind." The systems used to convert wind energy come in a variety of shapes and sizes. Single-wind turbines are used to support pre-existing energy organizations, whereas commercial-grade wind-powered generating systems can power a variety of different organizations. Utility-scale wind farms are another type and can be bought in contract or wholesale.

Wind energy doesn't emit carbon dioxide or any other harmful substances that could harm the environment or people's health, such as smog, acid rain, or other heat-trapping gases. Due to the ongoing servicing and maintenance requirements of farm-based wind turbines, investing in wind energy technology can also create new job opportunities.

Since wind farms are typically constructed in rural or isolated areas, they are frequently located far from crowded cities where the greatest demand for electricity exists. Transition lines are required for the transportation of wind energy, increasing costs. Even though wind turbines barely contribute to pollution, some cities are against them because of the noise and dominance they cause to skylines. Birds, which are occasionally killed by colliding with the turbine's arms while flying, are another type of local wildlife that is threatened by wind turbines.

3. *Hydro Energy*

The most common association with hydroelectric power is dams. Pumped-storage hydropower, which uses water to power turbines on a dam, creates electricity. Instead of directing water through a dam, run-of-river hydropower uses a channel.

Both large-scale projects, like the Dnipro Dam, and small-scale projects, like underwater turbines and lower dams on small rivers and streams, can be used to generate hydroelectric power. Since hydroelectric power does not produce pollution, it is a much more environmentally friendly form of energy.

Also, most hydroelectric power plants consume more energy than they can generate for use. To pump water, the storage systems may need to use fossil fuels. Despite the fact, that hydroelectric power does not pollute the air, it disturbs waterways and has a negative impact on the creatures that live there by altering water levels, currents, and migration routes for numerous fish and other freshwater ecosystems.

4. *Geothermal Energy*

Geothermal heat is heat that was trapped beneath the crust of the Earth during its formation and as a result of radioactive decay. Sometimes a lot of this heat escapes naturally, all at once, giving rise to well-known events like geysers and volcanic eruptions. By using the steam that is created when heated water is pumped below the surface, which then rises to the top and can be used to power a turbine, this heat can be captured and used to create geothermal energy.

Although geothermal energy is less prevalent than other forms of renewable energy, it has a sizable potential as a source of energy. It has a very small environmental impact because it can be constructed underground. Geothermal energy is constantly being replenished by the earth, so there is no danger of it running out (on a human time scale).

Only the cost is a significant factor in the drawbacks of geothermal energy. The infrastructure's vulnerability to earthquakes in some parts of the world is a major concern in addition to the fact that it is expensive to build.

5. *Biomass Energy*

Biomass is the source of renewable energy known as "bioenergy." Organic material called biomass is derived from recently living plants and other organisms. The majority of people are familiar with biomass, such as wood chips, agricultural waste, and municipal solid waste. Utilizing biomass for energy production involves a variety of techniques. This can be accomplished by burning biomass or using the methane gas produced by the organic materials' natural decomposition in landfills or even ponds. In our daily lives, biomass can be utilized in numerous ways, both personally and commercially.

Despite the fact, that carbon dioxide is released into the atmosphere when biomass is used to produce energy, this carbon dioxide is also consumed when plants grow back, supposedly maintaining a balanced atmosphere. But plants take time to develop even though they require carbon dioxide to grow. Additionally, we do not yet have widespread technology that can replace fossil fuels with biomass.

6. *Tidal Energy*

Tidal energy is a form of renewable energy that harnesses the power of ocean tides to generate electricity. It relies on the predictable and regular rise and fall of tides caused by the gravitational pull of the moon and the sun twice a day.

There are two primary methods for collecting tidal energy. The first is by constructing tidal barrages, which consist of turbines that rotate as water flows through them during both high and low tides, generating electricity. And the second one is by using tidal turbines, which are similar to wind turbines, but they are specifically designed to operate underwater. Tidal turbines are placed in areas with strong tidal currents, such as straits or channels, which allows by use of kinetic energy to produce electricity.

At the same time, tidal energy is more potent than wind energy because water is denser than air. At the same turbine diameter and rotor speed, tidal energy generates exponentially more power. Additionally, compared to intermittent and unpredictable wind and solar energy, tidal power is more reliable and consistent.

The difficulty lies in finding uses for tidal energy where costs are less sensitive than those of electricity from the national grid, as well as in making it economically feasible to capture and convert the energy into usable power at scale.

It is crucial that researchers look into ways to help develop technologies and methods that increase tidal energy's viability for widespread commercial application in to fully harness it as a significant and consistent source of clean energy. The industry is still largely in its early stages and faces numerous obstacles.

7. *Wave Energy*

Both thermal and mechanical energy can be produced by the ocean. Ocean thermal energy uses a variety of systems to produce energy and is dependent on warm water surface temperatures. Ocean mechanical energy, which is produced by the rotation of the earth and the gravitational pull of the moon, harnesses the ebbs and flows of the tides to produce energy.

In contrast to other renewable energy sources, wave energy is predictable, and its output is simple to predict. Wave energy is much more reliable than relying on varying factors like the sun and wind. The most populous cities frequently lie close to harbors and bodies of water, making it simpler to harness this renewable energy for the local populace. It means that wave energy has incredible potential but is still largely unexploited.

Wave energy is beneficial to those who live near the ocean, but it is not readily available to those who reside in landlocked states. Although it is a very clean source of energy, it can disturb the ocean floor and the marine life that lives there because large machinery must be built nearby to help capture this form of energy. Weather should also be taken into account because it affects the waves' consistency and reduces their energy output compared to waves that don't experience stormy weather.

Non-Renewable Energy Resources:

1. *Fossil Fuels*

These are the most commonly used non-renewable energy sources, which include coal, oil, and natural gas. All contain carbon and were formed as a result of geologic processes acting on the remains of organic matter produced by photosynthesis. Fossil fuels are widely used for electricity generation, transportation, heating, and industrial processes.

The energy density of fossil fuels is one of their main benefits. They are very effective at producing energy because they have a large amount of stored energy per unit of volume or weight. To meet the demands of expanding populations and industrial activities, fossil fuel power plants are capable of producing large amounts of electricity. Additionally, compared to alternative energy sources, fossil fuels have been relatively inexpensive, making them economically appealing to many nations. The availability and abundance of fossil fuel reserves across the globe have made them a dependable and affordable energy source, promoting economic development.

Fossil fuel use, however, has a number of significant drawbacks and challenges. Their effect on the environment, particularly in terms of greenhouse gas emissions and climate change, is one of the most urgent problems. Carbon dioxide (CO_2) and other greenhouse gases are released into the atmosphere when fossil fuels are burned, causing the greenhouse effect and global warming. As a result of the buildup of these gases, temperatures have increased, ice caps have melted, the sea level has risen, and weather patterns have changed. The finite nature of fossil fuel reserves is another major concern. As these resources run out, it gets harder and more expensive to extract them, raising costs and escalating geopolitical tensions. The reliance on fossil fuels exposes nations to risks to energy security because supply chain disruptions or political unrest can affect the supply and price of these resources.

2. *Nuclear Energy*

Nuclear energy is a type of power produced by the nuclear fission process, which involves breaking up the atom's nucleus, usually made of uranium or plutonium, into smaller pieces. Huge amounts of energy are released during this process in the form of heat, which is then used to create electricity. To capture and transform this energy into a form that can be used, nuclear power plants were created.

Comparing nuclear fuel to conventional fossil fuels like coal or oil, nuclear fuel has millions of times more energy per unit of mass. That is highly efficient and capable of supplying large-scale energy demands. It is also regarded as a low- or zero-carbon energy source. Because of it, nuclear energy is appealing when it comes to combating climate change and minimizing the environmental harm caused by carbon emissions. Electricity is also consistently and reliably supplied by nuclear power plants. It is a reliable source of electricity that supports the power grid because it is not dependent on environmental factors. To meet baseload demand, which is the minimum amount of electricity required to satisfy ongoing energy needs, this reliability is particularly crucial.

However, nuclear energy is not without its challenges and concerns. One of the primary concerns is the issue of nuclear waste disposal. Nuclear fission generates radioactive waste materials that remain hazardous for thousands of years. The possibility of accidents at nuclear power plants is another issue. Although modern nuclear power plants are built with multiple layers of safety systems, including containment structures and emergency shutdown mechanisms, accidents like the Chornobyl and Fukushima disasters have brought attention to the necessity of constant vigilance and strict safety procedures.

Security risks are also posed by the spread of nuclear technology and materials. Due to the dual-use nature of nuclear technology, there is a chance that nuclear materials will be mishandled or diverted for illegal uses, such as the production of nuclear weapons. To stop the unauthorized acquisition of nuclear weapons capabilities, strict international safeguards and non-proliferation controls are in place.

The information above provides an overview of the different types of renewable and non-renewable energy resources that are used around the world. While non-renewable energy sources like fossil fuels and nuclear energy have been the dominant sources of energy for many years, there has been a growing shift towards renewable energy sources like solar, wind, hydro, geothermal, biomass, tidal, and wave energy.

As renewable energy continues to grow and become a larger part of global electricity generation, it is important to consider both the advantages and disadvantages of renewable and non-renewable energy sources. In the table 1.1 below, we outline some of the key advantages and disadvantages of these energy sources.

Table 1.1- Advantages and disadvantages of renewable and non-renewable energy

Renewable energy resources		
Energy type	advantages	disadvantages
Solar Energy	No waste products Low operating costs Can be used off-grid	Initial high installation cost Intermittent power generation Takes up space
Wind Energy	Energy-efficient Low maintenance Can be used off-grid	Weather-dependent Impacts on wildlife Noise and visual pollution
Hydro Energy	Water Storage and Flood Control Reliable Power Supply Low Cost of Energy Production	Specific geographic conditions Ecological problems Expensive to build High-maintenance
Geothermal Energy	No fuel requirements No waste Reliable	Not suitable everywhere (requires access to geothermal energy) Expensive

Continuation of Table 1.1

Energy type	advantages	disadvantages
Biomass Energy	Availability Versatility Reduces waste	Fuel costs Unsustainable harvesting practices can lead to soil degradation and biodiversity loss
Tidal Energy	Predictable and reliable No waste products Energy efficient	Ecological problems Not suitable everywhere (requires a large tidal range)
Wave Energy	Minimal visual impact No land damages	Technical challenges Expensive to build
Non-renewable energy resources		
Energy type	advantages	disadvantages
Fossil fuels	Energy density Easily stored and transported Not dependent on weather or seasonal changes Cheaper than renewable energy resources	Environmental impact Finite, non-renewable resources Health and safety risks to workers Threat to political stability
Nuclear fission	Longevity Large capacity and density Scalable source of energy Carbon free, clean energy source Reliable	Dangerous radioactive waste Nuclear accidents Difficult and expensive to store safely Destructive mining

Source: compiled by the author based on his own research

Based on the table above, we can draw the following conclusions. First, renewable energy sources offer a sustainable and clean source of energy, with reduced greenhouse gas emissions and lower environmental impact. However, their implementation requires investment in infrastructure and technological advancements. Second, non-renewable energy sources have been the primary source of energy for many years due to their abundance, efficiency, and low cost, but their negative impact on the environment and limited availability make them unsustainable in the long run.

According to all information mentioned above, the ***subjects of the world energy market*** are the energy resources themselves, as well as the various participants involved in their exploration, production, distribution, and consumption. These include national governments, multinational corporations, energy companies, and individual consumers. The companies and governments that extract, refine, and distribute energy sources like coal, gas, and oil are thus the main producers. Companies that transport and distribute energy sources via pipelines, ships, and other modes of transportation are known as distributors. While consumers include people, companies, and governments who use energy resources for industrial processes, transportation, heating, and electricity production.

The exploitation of natural resources, whether renewable or non-renewable, is driven by a range of economic, social, and political factors. The desire for economic growth and development often leads to the overuse and depletion of natural resources, while the unequal distribution of natural resources can create social and political tensions, leading to conflict and instability. The exploitation of natural resources can also have a significant impact on the environment, affecting biodiversity and ecosystem services.

Understanding the interrelationships among market participants and the different types of energy sources is essential for developing a comprehensive understanding of this complex system: it is supply and demand and price mechanisms.

1.2. Supply and demand on the world energy market, pricing mechanisms

The world energy market is a complex system influenced by a variety of factors, including technological advancements, geopolitical tensions, environmental policies, and market forces. One of the key elements affecting the global energy market is the interaction between supply and demand, which plays a crucial role in determining the pricing mechanisms of the world energy market. As energy demand increases or supply decreases, prices tend to rise. Conversely, when demand falls or supply goes up, prices tend to be a downturn. That's a basic law of supply and demand, but let's get into the details.

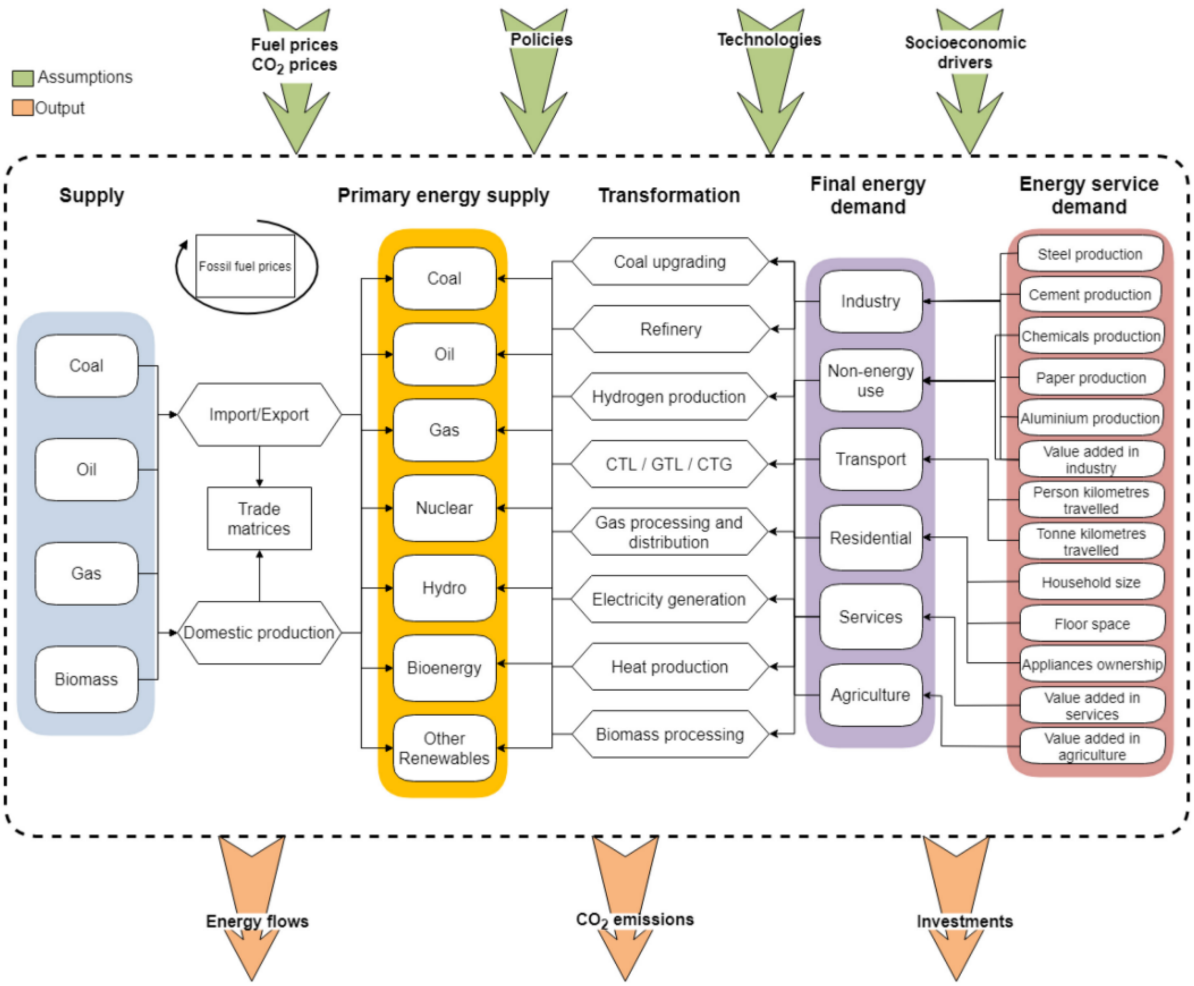
To start with, the world energy market as was mentioned before is a sophisticated and dynamic system that involves the production, distribution, and consumption of energy resources on a global scale. Several features of the functioning of the world energy market are worth exploring. They can be broadly classified into two categories: supply-side factors and demand-side factors.

On the *supply side*, the production and distribution of energy sources are shaped by factors such as resource availability, geopolitics, technology and investment. For example, the abundance or scarcity of oil reserves in a particular region can impact production and distribution patterns, as can advances in drilling technology. Investments in new production capacity and infrastructure can also have a significant impact on the supply of energy sources.

On the *demand side*, energy consumption patterns are driven by factors such as economic growth, population growth, and energy efficiency. As economies grow and populations increase, the demand for energy sources tends to rise. Energy efficiency policies and technologies, on the other hand, can help to reduce demand for energy sources by promoting the use of more efficient technologies and reducing waste.

Understanding these various factors and how they interact with each other is essential for predicting the future of the world energy market and making informed decisions about energy investments. In the following section, we will explore the concepts of supply and demand and examine how they interact with pricing mechanisms in the world energy market.

To have a greater look at the structure of the global energy supply and demand, we will consider the World Energy Model presented in the figure 1.1 below with further explanation.



Note: CTL = coal-to-liquids, GTL = gas-to-liquids, CTG = coal-to-liquids.

Figure 1.1 – World Energy Model Overview (WEM)

Source: International Energy Agency.

World Energy Model Documentation October 2021, p.12

The World Energy Model ***(WEM)*** is a simulation model covering energy supply, energy transformation, and energy demand. It is used by energy companies, policymakers, and researchers to explore different energy scenarios and their potential impacts on the environment and economy. The model provides insights into how different energy technologies and policies could affect the world's energy mix, emissions, and economic performance.

Analyzing the components of the structure of the World Energy Model, we will start from the top and move down. The top of the figure represents *assumptions* that include fuel and carbon prices, policies, technologies, and socioeconomic drivers, that help forecast future energy supply and demand movement. Let's take a closer look at them.

Fuel prices are a key consideration in the model, that have a significant impact on energy supply and demand. It takes into account the current and projected future prices of various fuels, such as oil, coal, and natural gas. For example, if the price of oil increases, it may become more cost-effective to use alternative energy sources.

Another crucial model assumption is *carbon prices*, which reflect the cost of carbon dioxide emissions. Policies like a carbon tax or a cap-and-trade system (which limits the overall amount of certain pollutants that can be emitted by businesses or industries) can be used to set these prices. As a result, a higher carbon price can encourage the use of cleaner energy sources and reduce carbon emissions.

Policies and regulations related to energy and the environment are also taken into account in the model. These include renewable energy targets, energy efficiency standards, emissions regulations, and renewable energy subsidies. Such legislation can influence the deployment of different energy technologies and increase the share of renewable energy sources in the energy mix.

Technological advancements in energy sources are also accounted for. The model considers current and projected advancements in energy technologies, such as solar and wind power, energy storage, and carbon capture and storage. These advancements can impact the cost and competitiveness of different energy sources.

Socioeconomic drivers, such as population growth, economic growth, and urbanization rates can impact energy demand. As populations grow and economies develop, energy demand is likely to increase.

Other various model elements are depicted inside the dash-dot frame and help to track the flow of energy through different stages of the energy system. The first stage is *primary energy supply*, which refers to the raw energy sources that are extracted from the earth, such as coal, oil, natural gas, nuclear, and renewable energy sources like wind, solar, hydropower, etc. At the same time, *supply* is defined as the total amount of energy that is available for use in the energy system. After being extracted from the environment, these primary energy sources *need to be transformed into* a form that can be utilized for various tasks. This covers operations like processing crude oil to produce gasoline or diesel, turning coal into electricity, and processing biomass into biofuels. Energy transformation is a crucial stage in the energy system, as it determines the efficiency and environmental impacts of the energy used.

Once energy is transformed into a usable form, it needs to be transmitted and distributed to end-users. And *final energy demand* refers to the energy that is consumed by end-users, such as households, businesses, and transportation sectors. Finally, *energy service demand* refers to the services that are provided to end-users, such as lighting, heating, cooling, and transportation. This stage of the energy system is crucial for understanding how energy is used in different sectors and for identifying opportunities for energy efficiency improvements and demand-side management.

Besides, the World Energy Model produces a range of *outputs* that provide insights into global energy systems. One of the key outputs is *energy flows*, which track the movement of different energy sources across different sectors and regions. These energy flows can help to identify trends and patterns in energy consumption and production.

Another important output is *CO2 emissions*, which are estimated based on the energy flows and assumptions about the carbon intensity of different energy sources. The model can help to project future emissions under different scenarios, such as the adoption of renewable energy or the implementation of carbon pricing policies.

Moreover, it can also provide insights into *investments* in the energy sector. The model can estimate the capital expenditures required to meet future energy demand, as well as the operational costs of different energy sources. This information can be useful for policymakers and investors who are interested in identifying opportunities for investment in the energy sector.

So, by incorporating various factors mentioned above such as supply and demand, assumptions, and output, we can conclude that the WEM model allows for a comprehensive assessment of the energy landscape. It also enables policymakers, researchers, and industry stakeholders to evaluate the potential impacts of different scenarios and policies on energy production, consumption, prices, and environmental outcomes. It helps identify trends, risks, and opportunities in the energy sector, supporting informed decision-making and the development of effective energy strategies.

Nevertheless, all of this is impossible to assume without consideration of how responsive fuel supplies and demand are, to different economic variables. For instance, high-income growth regions like the Asia Pacific regions before 1997 will have increased needs for fuel production and imports, as well as the infrastructure that goes along with such fuel growth. Additionally, if production is highly responsive to price changes, only a modest price increase might be required to stimulate the production required to meet the increase in demand. Such market responsiveness on the supply and demand sides also affects how taxes, subsidies, and other energy policies affect the cost and consumption of energy products.

Demand and supply elasticities are one way that economists gauge how responsively production and consumption are. That is why firstly we must consider demand and supply equations in a ***competitive market*** in order to develop such elasticities. A stylized market that meets several criteria is said to be competitive. The first is that there are so many buyers and sellers that no one can control the price. Second, the product being sold is identical, like electricity, where every kilowatt-hour sold is the same as every other. Third, entry and exit are both free. As a result, businesses will enter highly profitable markets while leaving markets where they are losing money. There is also perfect information. We can represent consumers by a demand equation and producers by a supply equation if all of the previous four properties are true.

At the same time, there aren't many perfectly competitive energy markets, but many of them might be workably competitive. Coal is not the same and can differ in terms of energy, ash, and sulfur content. A good example is brown coal and anthracite. The various grades are close substitutes, but one might still be able to calculate an accurate coal demand curve. Gasoline is produced and sold by very large companies like *ExxonMobil*, which may also have some pricing influence. However, ExxonMobil's pricing power is limited because the various gasolines are excellent substitutes and because it must compete with other very big companies like *Chevron* and *BP*. As the market changes, businesses can and do enter and exit the gasoline refining industry. No market has perfect information, but there is a lot of published and easily accessible information in the capitalist energy markets.

Due to the intense competition present in many energy markets, supply and demand equations and the resulting elasticities provide a reasonable approximation of how the two sides of the market will behave. Supply equations won't be useful in markets where governments intervene and permit or mandate supply monopoly. This has frequently been the case for the production of electricity or in markets where very powerful suppliers, like OPEC on the global oil market, have monopolies and can control prices. Demand equations would also be useless in situations where a sizable buyer has monopsony power and can affect the price.

For now, let's examine the energy demand, which drives the energy markets, in more detail. Without demand, no need for production, and consequently no market would exist.

Energy demand is the quantity of energy needed at any given time to meet the needs of a specific industry, sector, or population. The total amount of energy used over a given time period, such as a day, month, or year, can be used to express it. It is frequently expressed in terms of power units like watts, kilowatts, or megawatts.

The demand for energy is derived. This implies that all consumers, businesses, and governments are not merely seeking energy for itself but rather for the benefits that the energy can make available. A consumer might desire energy for lighting, air conditioning that provides heat in the winter and cool air in the summer, as well as energy to power cars and other appliances. These needs are frequently shared by businesses as well, along with the need for energy to run motors and process heat.

The cost of energy (*P*), the cost of other related goods (*Ps*, *Pc*), the amount of disposable income (*Y*), and additional factors (*O*) like personal preferences, way of life, weather, and demographic factors all affect how much energy consumers demand (*Qdc*). If it is an aggregate demand, the number of consumers (*#C*) also plays a role.

Take the amount of electricity a household consumes as an example. In that case, if electricity prices go up, less electricity is being used by consumers. Consumers may switch from electric water heaters, clothes dryers, and furnaces to ones that use natural gas if the price of natural gas, a substitute for electricity in consumption (*Ps*) declines. This will increase the demand for natural gas as a substitute good. If the cost of complementary goods (*Pc*) like electric appliances rises or falls, so does the electricity demand. As customers might purchase fewer appliances, using less electricity as a result.

Also, consumers with more disposable income are likely to purchase bigger homes and more appliances, which will increase the amount of electricity used. However, an increase in income need not have a positive impact. For instance, in the past, homes that were heated with coal switched to cleaner fuels like fuel oil or gas as income increased. Kerosene is typically used for lighting in developing countries, but as households become wealthier, they switch to electricity. Coal and kerosene are inferior products in these situations, and as income rises, so does their consumption.

The demand for natural gas and other energy products may also be influenced by other factors *(O)*. Personal preferences, way of life, demographic factors, and weather are a few examples of such variables. Even though electricity is typically more expensive to use than gas, some people prefer to cook with it because they feel safer doing so. Families with everyone working outside the home might use less fuel to heat the house. While in cold climates more electricity may be used for heating in the winter, in hot climates more electricity may be used for air conditioning in the summer.

After analyzing all the factors above, we can write a **general consumer energy demand function in a competitive market** (1.1), that can be expressed as follows:

$$Qdc = f(P^{-}, Y^{+-}, O^{+-}, \#C^{+}, Ps^{+}, Pc^{-},)\ , \qquad (1.1)$$

where

Qdc – quantity of energy demanded by consumers;

P – the own price of energy;

Y – income;

O – other variables;

#C – the number of consumers;

Ps – the price of substitutes;

Pc – the price of complements;

The variables' inverse (-) or direct (+) relationships to energy consumption are indicated by the signs placed above them. The variables move in the opposite direction if they are inversely related. A variable's increase results in a decrease in consumption. And on the contrary, the variable and consumption will both rise or fall together if they are directly related. As a result, the consumption of energy by consumers will be affected negatively by rising in the own price of energy and the price of complements (*P*, *Pc*), while consumption will be grow impacted by the number of consumers spike and the price of substitutes (*#C*, *Ps*).

The sign for income would be (+) for a normal good and (-) for an inferior good. The sign for the additional variable O depends on both the product and the additional variable. For instance, if the demand is for solar collectors and the variable is the number of hours of sunshine, the result may be positive; conversely, if the demand is for gasoline and the variable is the percentage of the population over 50, the result may be negative.

In addition to being needed by households, energy is also a factor in production. Electricity and heat are produced using coal, oil products, gas, and uranium. To transport goods to markets, gasoline, and diesel are used. Our factories and businesses' motors, air conditioners, and lighting all run on electricity.

Consider the demand for coal in the production of electricity as an example of factor demand. If electricity generators acted competitively, the price of coal (*P*), the cost of other production factors, such as land, labor, and capital – that are complements to coal in producing of electricity (*Pc*) and the cost of other fuels, such as gas and oil, that are substitutes (*Ps*), which can be used in place of coal to produce electricity, would all affect how much electricity is demanded. The demand for coal would be affected by changes in electricity prices or output (*Po*), as well as by technological advancements (*T*). Environmental policies (*Er*) that limit the amount of carbon dioxide that can be emitted or the amount of sulfur that can be added to coal would make coal less desirable. The quantity of businesses (*#B*) would also be included in the total business energy demand.

According to it, we got a **general business energy demand function in a competitive market** (1.2), that could be expressed as follows:

$$Qdb = f(P^{-}, Pc^{-}, Ps^{+}, Po^{+}, T^{+-}, Er^{+-}, \#B^{+-}) , \qquad (1.2)$$

where

Qdb – quantity of energy demanded by businesses;
P – the price of the energy factor;
Pc – the price of complements;
Ps – the price of substitutes;
Po – the price of output;
T – technology;
Er – environmental policy;
$\#B$ – the number of businesses;

Technology and environmental policy are showing mixed signs, depending on the specific technology, fuel, and policy. For instance, environmental regulations requiring lower sulfur emissions would favor gas over coal, while new technologies that make oil more affordable to use could increase oil demand at the expense of other fossil fuels. The same situation with the number of businesses as it can both hinder and push the demand for energy. What we can say for sure, is that the consumption of energy by businesses will be affected negatively by rising in the own price of the energy factor and the price of complements (P, Pc), while consumption will be grow impacted by the price of substitutes and the price of output (Ps, Po).

To sum up, the general demand functions for both consumer and business energy demand offer a framework for comprehending the variables that affect the amount of energy required. These functions consider various factors such as price, income, prices of related goods or inputs, preferences, technology, other factors specific to the sector, availability of energy-efficient options, and government policies or regulations.

After we have observed the factors that influence the energy demand, let's delve into the concept of elasticity. To begin with, the ***elasticity*** in general is calculated as the ratio of the quantity change over the variable change.

Demand elasticities measure the responsiveness of consumption. For instance, the percentage change in consumption divided by the percentage change in price represents the price elasticity of demand. Raising the price reduces the quantity demanded, so it is detrimental. The demand elasticity can be used to calculate what would happen to sales. If a tax on gasoline results in a price increase of 10% and the short-term demand elasticity is -0.3, then the production of gasoline would decrease by 3%. The long run quantity change would be as follows if the long run elasticity was -0.7, leading to 7% fall in production.

The demand for gasoline, natural gas, and residential electricity has the highest elasticities across studies. Studies on these three markets have produced more consistent results, which may be due to the more homogeneous use of energy products there, as opposed to the industrial demands, which vary greatly across industries and over time. With short-run elasticities being more certain than long run elasticities, more products appear to be price- and income-inelastic. For the majority of energy products, short-term price elasticities for a year are most likely between 0 and -0.5. Despite the fact that their exact values are unknown, long run elasticities have a tendency to be significantly larger in absolute terms.

Let's observe the energy supply. **Energy supply** is the total amount of energy available for consumption within a given system or market. The cost of bringing an energy source to market and the price a supplier is paid for that energy source in the market are two factors that affect the amount of energy that is supplied. For instance, in a competitive market the quantity of coal (Qs) supplied depends on the price received for the coal (P); price paid for the resource inputs such as chemicals (Pi), price of the capital required to produce the coal, such as drag lines, cutting tools, and loaders (*Pk*); the cost of labor, which includes wages, salaries, and indirect labor costs, such as employment taxes (*Pl*); the price of using land or any other natural resource or other factors of production (*Pn*); and technological change that improves the production process for this fuel (*T*). If there are market externalities, such as environmental damage, that are not reflected in the market price, the supplier still responds to the market prices that they have to pay. The product will then be produced in excess because the market has set its price too low.

Quantity supplied is also influenced by the prices of other related goods. Vanadium, for instance, may be a byproduct of the production of uranium. As a result, vanadium and uranium are complementary materials (*Pc*) or materials that are produced together. Uranium production becomes more profitable and will go up as vanadium prices rise. Another example is associative gas, which is found alongside oil and thought to be complementary to oil production. If the price of oil goes up, drillers may look harder for oil and find more gas to produce as well.

Alternatively, goods can also be substituted for one another during production. For example, coal producers may search for other minerals and produce less coal, if their price is significantly higher than coal. Or if gas is found without oil in the production, relatively it is a substitute for oil in supply rather than a complement. In that case, drillers may spend less time looking for oil and more time looking for and producing nonassociated gas if the price of natural gas, a substitute good (*Ps*), or any energy source that could be produced instead of oil, rises, which would reduce oil production.

Governments frequently interfere in energy markets and their policies may have an impact on the amount supplied. For example, environmental regulations (*Er*) that require less pollution or greater safety during the manufacture of fuels reduce the quantity of fuel supplied. The removal of sulfur from fuels, the addition of oxygenates to gasoline in some regions, and increased safety in coal mines are a few examples of such regulations. The quantity supplied should decline because of new environmental regulations that raise costs.

The number of suppliers (*#S*) in the industry has an impact on aggregate market supply as well.

According to all factors mentioned above, we can compose a **general energy supply function in a competitive market** (1.3) as follows:

$$Qs = f\left(\overset{+}{P}, \overset{-}{Pi}, \overset{-}{Pk}, \overset{-}{Pl}, \overset{-}{Pn}, \overset{+}{T}, \overset{-}{Ps}, \overset{+}{Pc}, \overset{-}{Er}, \overset{+}{\#S} \right), \qquad (1.3)$$

where

Qs – quantity of energy supplied;

P – the own price of the energy;

Pi – the price of resource input;

Pk – the price of capital;

Pl – the price of labor;

Pn – the price of land or other natural sources;

T – technical change;

Ps – the price of substitutes;

Pc – the price of complimentary goods;

Er – environmental regulation and policy ;

#S – number of suppliers in the industry;

Again, the variables' inverse (-) or direct (+) relationships to coal production, which we have chosen as an example, are indicated by the signs placed above them. The variables move in the opposite direction if they are inversely related. A variable's increase results in a decrease in production. The variable and production will both rise or fall together if they are directly related. As a result, production will be affected negatively by rising production costs, the cost of substitute goods, and environmental regulations (*Pi*, *Pl*, *Pk*, *Pn*, *Ps*, *Er*), while production will be positively impacted by rising costs for production complements, advances in technology, and an increase in the number of suppliers (*P*, *Pc*, *T*, *#S*).

After we have discussed the inverse and direct relationships between different variables and production, let's take a closer look at the **elasticity of supply** that shows how responsive a quantity supplied is to that variable. It is the quantity's percentage change divided by the variable's percentage change. When the price of coal increases by 1%, the quantity supplied increases by 0.90% if the supply price elasticity of coal is 0.90. The **cross-elasticity of supply** shows the relationship between supply volume and another good's price. For instance, if the cross-elasticity of gasoline supply with respect to distillate price is 0.4, the amount of gasoline produced decreases by 0.4% for every 1% increase in distillate price.

Also, the length of time used to measure the supply elasticity has an impact on its magnitude. If the price of coal rises over the short term, say one year, coal mines might only be able to slightly increase production. Buying new equipment takes time because coal mining requires a lot of capital and uses specialized equipment, and it typically takes 4 to 7 years to open a new mine. As a result, the short-term elasticity may be very low. However, production may change significantly over the long run, or in the amount of time needed to fully adjust to a price change, and the long run elasticity is likely to be much larger than the short run elasticity. The difference between the long- and short-term elasticities increases as an industry's capital intensity and capital stock longevity increase.

Although it may differ from product to product, the long run is generally well defined. It is merely the amount of time needed for a complete adjustment to occur. The short run, which typically depends on the period of interest and is typically a year or less, is less clearly defined. The short run is frequently the periodicity of the data when performing statistical analysis on actual data. For instance, periodicities might be daily or weekly energy prices, monthly data on the amount of natural gas in storage, quarterly data on economic indicators, or annual data on oil consumption.

Now, let's generalize all the information we have received by describing pricing mechanisms for energy. As we already know, quantity supplied has a direct relationship with price, so it slopes upward, and quantity demanded has a direct relationship with price, so it slopes downward. Price is typically placed on the vertical axis and quantity is placed on the horizontal axis in economics literature, resulting in demand and supply as shown in Figure 1.2.

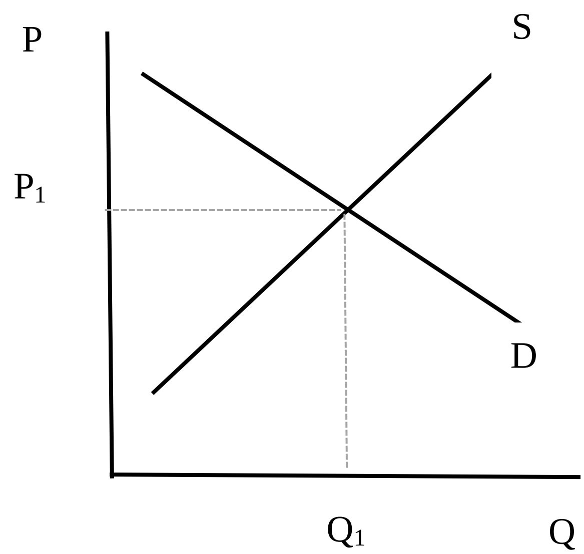


Figure 1.2 – Supply and demand for energy in a competitive market

Source: compiled by the author based on his own research

This graph shows the equilibrium price of P_1, where the quantity supplied by energy producers is exactly equal to the quantity demanded by energy consumers. This balance ensures that the market operates efficiently, with neither excess supply nor shortages.

However, if the price is set higher than P_1, the quantity supplied by energy producers will exceed the quantity demanded by consumers. This surplus in supply creates market pressure to lower prices. As prices decrease, consumers may increase their demand, helping to alleviate the surplus until a new equilibrium is reached.

Conversely, if the price is set below P_1, the quantity demanded by consumers will exceed the quantity supplied by producers. This shortage in supply leads to increased competition among consumers, driving prices upward. The rising prices incentivize producers to increase their supply, ultimately addressing the shortage until a new equilibrium is established.

The preceding examples presuppose competitive markets in which consumers and producers compete to buy and sell goods while accepting the market price as given. The majority of energy product purchasers probably fall into this category. Market power, though, can exist on occasion.

As energy pricing mechanisms can vary depending on the market structure in which energy companies operate, let's explore the energy pricing mechanisms in competitive markets, monopolistic markets, monopoly situations, natural monopolies, and oligopolies.

To reiterate, there are numerous producers and consumers operating in a **competitive energy market**, and supply and demand market forces determine prices. This market structure's pricing mechanism is primarily based on market-based pricing, like wholesale electricity markets. The intersection of supply and demand curves is used to determine prices when producers and consumers engage in competitive bidding. This mechanism encourages efficient resource allocation and sends consumers price signals to help them change their consumption habits. But in competitive markets, affordability issues and market power abuse can appear, necessitating regulatory oversight to guarantee fair competition and safeguard consumer interests.

There is only one dominant supplier in a **monopolistic market**, and there are no close competitors. In such a market, cost-based pricing is typically used as the pricing mechanism. Prices are set by the monopolistic energy provider by considering production, transmission, and distribution costs as well as a reasonable profit margin. Monopolistic markets, on the other hand, can lead to higher prices and fewer incentives for efficiency and innovation. To avoid inflated prices and safeguard the interests of consumers, regulatory bodies frequently keep an eye on pricing and impose price controls.

A **monopoly**, on the other hand, happens when one business or other entity has total authority over the market. In this case, the monopolist will frequently choose the pricing strategy. The monopolist, who acts as the sole supplier, is able to set prices to maximize profits, frequently by utilizing cost-based pricing or price discrimination techniques. Monopolies can result in increased costs, constrained consumer options, and a decline in innovation. Governments frequently regulate monopolies to stop the exploitation of their market dominance and to guarantee fair pricing and accessibility to energy services.

When economies of scale make having a single supplier in the market more effective, a **natural monopoly** develops. This frequently happens in sectors with high fixed costs, like energy infrastructure. Cost-based pricing and regulatory oversight are frequently combined in natural monopolies' pricing mechanisms. To avoid inflated prices, guarantee cost recovery, and advance efficiency, regulators impose price controls. The goal is to strike a balance between the demand for reasonably priced energy services and the need to keep the natural monopoly financially viable for infrastructure investment.

When a small number of powerful companies control the market, we have an **oligopoly**. In an energy oligopoly, the majority of the market share is dominated by a small number of important suppliers. Although pricing policies in oligopolistic markets can differ, major players frequently make strategic pricing decisions. Factors like market dynamics, production costs, and competitive strategies can have an impact on prices. Oligopolies may lead to price manipulation, constrained competition, and collusive behavior. To ensure fair competition and safeguard consumer interests, regulatory authorities keep an eye on these markets.

Therefore, different energy pricing structures correspond to different market structures. Market-based pricing is essential in competitive markets, cost-based pricing is essential in monopolistic markets, regulated pricing mechanisms are essential in monopolies and natural monopolies, and strategic pricing decisions are essential in oligopolies. To guarantee fair pricing, consumer protection, and sustainable energy practices, regulatory oversight is essential in all market structures.

To conclude, equations for energy demand and supply can be used to represent consumers and producers in a market that is competitive. They show how adjustments to other pertinent variables have an impact on the quantities demanded and supplied. They also take into account the elasticities of supply and demand for energy, which show how responsive the quantity demanded and supplied is to other pertinent factors.

Elasticities are helpful for predicting the future and analyzing policy. While income elasticities will determine how the budget share of a product changes as a nation gets richer, demand price elasticities will determine whether price increases will increase or decrease total expenditures in a market. Cross-price elasticities show how other related prices affect the amount of a good that is demanded or supplied. Demand elasticity can be used to predict how a disruption in the energy supply will affect an energy product's price. Using econometric methods, many energy demand and supply elasticities have been calculated.

Equations for supply and demand can be made using these unit-free elasticities. Demand may be competitive, and demand elasticities may help to indicate the degree of monopoly power in a market or help forecast demand for rate of return, even though supply equations and supply elasticities may not be relevant for monopoly markets.

1.3. Forms and methods of regulating the world energy market

In a world that heavily relies on energy for its functioning and development, effective regulation plays a pivotal role in ensuring stability, fairness, and long-term sustainability. It is through regulation that governments, international organizations, and industry stakeholders strive to steer the energy market toward a harmonious equilibrium, where the needs of the present are met without compromising the future. By understanding the various forms of regulation and the methods used to enforce them, we can gain valuable insights into how the world energy market operates and evolves.

To start with, at its core, **regulation** refers to the set of rules, policies, and mechanisms established by governments, regulatory bodies, and other relevant entities to guide and control the behavior and activities of individuals, organizations, and markets.

The level of regulation in non-liberalized markets is directly decided by politics and is explicitly linked to policy objectives. In theory, lowering regulation can be accomplished by introducing competition. In a purely economic sense, regulations in competitive markets should only be used when they have the potential to lower consumer costs more than they would be otherwise, such as when limiting market abuse. It is frequently asserted that "competition is the best regulator," i.e., that strong competition will result in the most effective market operation because businesses will have incentives to meet consumers' needs.

However, this does not necessarily imply that regulation is no longer required in areas with competition. Regulation may be necessary to maintain effective competition, such as to stop firms with market dominance from engaging in anti-competitive behavior that could harm customers and rival businesses. When competition alone is insufficient to guarantee the provision of certain goods or services, regulation may also be necessary.

Therefore, markets are typically regulated to ensure economic efficiency and to prevent market failures so that socially desirable goods and services are provided or protected. The following are a few reasons for regulation in highly competitive markets:

- Consumer protection (e.g., lowering prices);
- Economic efficiency (e.g., preventing market abuse);
- Social justice (e.g., ensuring universal supply);

- Environmental protection (e.g., reducing harmful emissions like CO, SO, and NO);
- Supply security (to keep the lights on);

Most of these reasons could also be used to justify regulation in non-competitive markets.

Some of these motives may seem incompatible with one another; for instance, promoting renewable energy sources, which can be more expensive than traditional sources of energy, may not be compatible with keeping prices low. To address these issues, policymakers and regulators will need to take into account a variety of other variables, such as the time frames for which the regulation is intended. Energy prices may rise temporarily as a result of, for instance, increased production of renewable energy or energy efficiency measures, but over the long term, as new technologies become less expensive (due to learning effects) and oil prices rise, prices may fall. Similar to the above, ensuring universal supply may raise prices, but this must be balanced against upgrading citizens' quality of life, such as by reducing poverty through job creation, improving their health, and promoting the environment.

Therefore, even though regulation may be conceptualized as institutionally distinct from the political choice of how to balance policy objectives, in the real world, it may well be up to regulators to make decisions on particular issues on a case-by-case basis. Because of their knowledge of economics and the logistics involved in creating and enforcing rules to implement policies, regulators also advise policymakers on their choices. As a result, they frequently have a significant amount of influence in the policy debate, and they are not simply carrying out decisions made elsewhere.

Nevertheless, energy policies and regulations play a crucial role in shaping the energy market and ensuring the sustainable and efficient use of energy resources. They aim to address various concerns, including environmental protection, energy security, and promoting fair trade practices. Let’s explore some key policies and regulations that govern the energy market, focusing on environmental regulations, trade policies, and energy security policies.

Environmental regulation plays a crucial role in shaping and governing the energy market. It encompasses a wide range of policies, laws, and regulations designed to mitigate the negative environmental impacts of energy production, distribution, and consumption. The primary objective of environmental regulation in the energy sector is to promote sustainable development, reduce greenhouse gas emissions, protect natural resources, and ensure a cleaner and healthier environment for present and future generations.

One of the key areas of environmental regulation in the energy market is the promotion of renewable and clean energy sources. Governments around the world have implemented various measures to encourage the deployment and use of renewable energy technologies such as solar, wind, hydro, geothermal, and biomass. These measures often include financial incentives, tax breaks, feed-in tariffs, and renewable portfolio standards, which require a certain percentage of electricity to be generated from renewable sources. By supporting renewable energy, environmental regulation aims to reduce reliance on fossil fuels, decrease carbon emissions, and mitigate the impacts of climate change.

Another important aspect of environmental regulation in the energy market is the imposition of emission standards and regulations on polluting energy sources. Power plants, refineries, and other energy-intensive industries are typically subject to strict emission limits, which aim to control air pollution and protect public health. These regulations often require the use of pollution control technologies such as scrubbers, catalytic converters, and particulate filters to reduce the release of harmful pollutants like sulfur dioxide, nitrogen oxides, and particulate matter. Additionally, environmental regulation may impose caps or taxes on greenhouse gas emissions, creating economic incentives for companies to reduce their carbon footprint and transition to cleaner technologies.

Environmental regulation also plays a role in energy efficiency. Governments establish energy efficiency standards for appliances, vehicles, and buildings to promote the efficient use of energy resources. These standards encourage the development and adoption of energy-efficient technologies and practices, which not only reduce energy consumption but also lower greenhouse gas emissions and decrease the overall environmental impact of energy use.

Furthermore, environmental regulation often includes provisions for environmental impact assessments and permitting processes for energy projects. These assessments evaluate the potential environmental consequences of proposed projects such as power plants, pipelines, and transmission lines. The goal is to identify and mitigate any adverse environmental effects and ensure that projects comply with relevant environmental laws and regulations. By incorporating environmental considerations into the decision-making process, the regulation aims to prevent or minimize ecological damage and protect sensitive habitats and ecosystems.

In recent years, there has been a growing recognition of the need to address climate change and accelerate the transition to a low-carbon economy. As a result, environmental regulation in the energy market has become more stringent and comprehensive. Governments are increasingly setting ambitious targets for renewable energy deployment, implementing stricter emission standards, and exploring innovative policy instruments such as carbon pricing and cap-and-trade systems. Additionally, international agreements have provided a framework for global cooperation on climate action, driving countries to strengthen their environmental regulations and align their energy markets to limit global warming.

However, it's worth noting that environmental regulation in the energy market is often a complex and contentious issue. Balancing environmental protection with economic growth and energy security can be challenging. Critics argue that stringent regulations may increase energy costs, hinder economic competitiveness, or lead to job losses in certain sectors. Therefore, effective environmental regulation requires a careful assessment of the costs and benefits, stakeholder engagement, and a long-term vision that recognizes the interdependence between the environment, the economy, and society.

To control it there are several organizations involved in environmental regulation of the energy market at various levels, including international, national, regional, and local entities. These organizations work to develop and enforce policies, standards, and regulations that promote environmental protection and sustainable practices within the energy sector. Here are some key organizations involved in the environmental regulation of the energy market:

United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC is an international treaty that provides the framework for global cooperation on climate change. It organizes the Conference of the Parties (COP) meetings where countries negotiate and implement climate agreements, such as the Paris Agreement. The UNFCCC aims to stabilize greenhouse gas concentrations in the atmosphere and mitigate the impacts of climate change.

International Energy Agency (IEA)

The IEA is an autonomous agency under the framework of the Organisation for Economic Co-operation and Development (OECD). It promotes energy security, economic growth, and environmental sustainability worldwide. The IEA conducts research, provides policy advice, and coordinates efforts to address energy-related environmental issues, including climate change, energy efficiency, and renewable energy.

Environmental Protection Agency (EPA)

The EPA is an agency of the United States federal government responsible for protecting human health and the environment. It develops and enforces regulations related to air quality, water pollution, hazardous waste, and other environmental issues. The EPA sets emission standards, oversees environmental impact assessments, and implements programs to reduce pollution in the energy sector.

European Environment Agency (EEA)

The EEA is an agency of the European Union (EU) that provides environmental information and assessments to support EU policies. It collects data, conducts research, and guides on environmental issues, including energy and climate change. The EEA plays a key role in monitoring and reporting on the progress of EU member states in meeting their environmental targets.

National Regulatory Authorities (NRAs)

NRAs are government agencies that oversee and regulate the energy sector at the national level. They set rules and standards for energy production, distribution, and consumption, including environmental requirements. NRAs ensure compliance with environmental regulations, issue permits for energy projects, and monitor the environmental performance of energy companies.

Regional Environmental Agencies

In some cases, regional environmental agencies are responsible for regulating the energy market within a specific geographic area. For example, the California Air Resources Board (CARB) in the United States sets and enforces air pollution regulations for the state of California. These agencies work in collaboration with national authorities to develop and implement environmental policies tailored to regional needs.

Non-Governmental Organizations (NGOs)

NGOs play a vital role in advocating for environmental protection and influencing energy policy. Organizations like Greenpeace, the World Wildlife Fund (WWF), and Friends of the Earth work to raise awareness, conduct research, and push for more stringent environmental regulations in the energy sector. They often engage in lobbying efforts, public campaigns, and legal actions to promote sustainable energy practices.

To sum up, the specific roles and responsibilities of these entities may vary depending on the country or region, but collectively, they work towards the common goal of ensuring a cleaner and more sustainable energy sector that minimizes environmental impacts and addresses climate change.

Another aspect is **trade policy** in the energy market, which refers to the rules, regulations, and agreements that govern the international trade of energy products and services. It plays a significant role in shaping the global energy landscape, influencing the flow of energy resources, promoting market access, and addressing trade-related issues in the energy sector. Trade policy in the energy market aims to foster competitiveness, ensure energy security, and promote sustainable development. Let’s observe some key aspects of trade policy in the energy market:

Tariffs and Trade Barriers

Tariffs and trade barriers can impact the import and export of energy products. Governments may impose tariffs on energy imports to protect domestic industries or to generate revenue. Conversely, they may reduce or eliminate tariffs on energy exports to encourage trade and enhance market access for domestic energy producers. Non-tariff barriers, such as quotas, licensing requirements, and technical regulations, can also affect the energy trade by influencing the conditions under which energy products can be imported or exported.

Free Trade Agreements

Free trade agreements (FTAs) are bilateral or multilateral agreements that reduce or eliminate trade barriers between participating countries. Many countries have entered into FTAs that cover the energy sector, facilitating the trade of energy goods and services. These agreements often include provisions that address tariffs, intellectual property rights, investment protection, and regulatory cooperation. FTAs can enhance market access for energy exporters, promote cross-border investments, and foster cooperation on energy-related issues.

Energy Subsidies

Energy subsidies can have significant implications for trade policy in the energy market. Subsidies provided by governments to support domestic energy production or consumption can distort international trade by giving domestic producers an unfair advantage. Subsidies can lead to overproduction, increased exports, and lower global energy prices. In recent years, there has been a push to address fossil fuel subsidies and promote a level playing field in the energy market through international agreements and negotiations.

Energy Security Considerations

Energy security is a critical factor in trade policy related to the energy market. Countries seek to ensure a reliable and diverse supply of energy resources to meet their domestic demand. Energy security concerns can influence trade policy decisions, including the development of strategic energy partnerships, diversification of energy sources and routes, and investment in infrastructure to support energy imports and exports. Governments may also implement policies to reduce dependence on energy imports by promoting domestic energy production and diversifying their energy mix.

Environmental Considerations

Environmental concerns are increasingly integrated into trade policy in the energy market. Governments may impose environmental requirements or standards on energy imports to ensure that imported energy products meet certain environmental criteria. For example, carbon pricing mechanisms, such as carbon taxes or emissions trading systems, can be implemented to address the carbon footprint of energy products. Environmental provisions are also included in some free trade agreements to promote sustainable development and encourage the adoption of clean energy technologies.

Dispute Settlement Mechanisms

Trade disputes related to the energy market can arise from issues such as unfair trade practices, non-compliance with trade agreements, or disagreements over energy subsidies. Dispute settlement mechanisms, such as those provided by the World Trade Organization (WTO) or specific provisions in FTAs, help resolve these disputes through negotiation, mediation, or legal processes. These mechanisms provide a means for countries to address trade-related conflicts and ensure compliance with trade rules and agreements.

To conclude, trade policy in the energy market is influenced by a complex interplay of economic, political, environmental, and security considerations. Governments strive to strike a balance between protecting domestic industries, ensuring energy security, promoting sustainable development and fostering international cooperation. The evolving nature of the global energy landscape, technological advancements, and the need to address climate change present ongoing challenges and opportunities for trade policy in the energy sector.

And last, but not least **energy security policies** are measures implemented by governments to ensure a reliable, affordable, and sustainable supply of energy resources. These policies aim to safeguard a nation's energy infrastructure, diversify energy sources, promote efficiency, and reduce vulnerability to disruptions or price fluctuations in the global energy market. Energy security policies address both short-term concerns, such as emergency preparedness, and long-term strategies for sustainable energy systems. Let’s look at some key components and approaches commonly found in energy security policies:

Diversification of Energy Sources

One crucial aspect of energy security is reducing dependence on a single energy source or a limited number of suppliers. Governments promote diversification by encouraging the development and use of multiple energy resources, such as fossil fuels (coal, oil, and natural gas), renewables (solar, wind, hydro, geothermal), and nuclear power.

Diversification helps mitigate risks associated with supply disruptions, price volatility, and geopolitical tensions.

Energy Infrastructure Resilience

Governments invest in maintaining and strengthening the resilience of energy infrastructure, including power plants, pipelines, transmission lines, storage facilities, and transportation networks. This involves conducting risk assessments, implementing preventive measures, and establishing contingency plans to minimize disruptions caused by natural disasters, accidents, or cyber-attacks. Adequate maintenance, upgrading aging infrastructure, and ensuring redundant systems can enhance energy security.

Strategic Reserves and Emergency Response

Building and maintaining strategic petroleum reserves (SPRs) is a common practice to address sudden disruptions in oil supplies. Governments stockpile emergency fuel reserves that can be released during periods of supply disruptions, natural disasters, or geopolitical crises. Similar strategic reserves can also be established for other critical energy resources, such as natural gas or coal. Additionally, governments develop emergency response plans and coordination mechanisms to manage energy crises effectively.

Energy Efficiency and Conservation

Energy security policies often emphasize energy efficiency and conservation measures. Governments promote the efficient use of energy resources across sectors, including industry, transportation, and buildings, through regulations, standards, and incentives. Energy efficiency reduces overall energy demand, lessens reliance on imports, and enhances energy security by stretching available resources further.

Renewable Energy Deployment

Encouraging the deployment of renewable energy technologies is another strategy for enhancing energy security. Governments establish targets, provide incentives, and implement supportive policies to accelerate the transition to clean and sustainable energy sources. By diversifying the energy mix and reducing dependence on fossil fuels, renewable energy reduces vulnerability to price fluctuations, supply disruptions, and environmental risks associated with traditional energy sources.

International Energy Cooperation

Energy security policies often include efforts to strengthen international energy cooperation. This includes building relationships with energy-producing and consuming countries, participating in multilateral energy organizations, and engaging in bilateral energy agreements. By fostering dialogue, sharing information, and collaborating on energy projects, countries can enhance energy security through mutual support, resource sharing, and market stability.

Research and Development

Governments invest in research and development (R&D) initiatives to promote innovation in the energy sector. R&D programs focus on developing advanced energy technologies, improving efficiency, and exploring alternative energy sources. By supporting technological advancements, governments aim to reduce reliance on traditional energy sources, increase resilience, and contribute to long-term energy security.

Environmental Sustainability

Energy security policies increasingly integrate environmental sustainability considerations. Governments recognize the importance of addressing climate change, reducing greenhouse gas emissions, and transitioning to low-carbon energy systems. By promoting clean energy technologies and sustainable practices, energy security policies align with broader environmental goals and contribute to mitigating the risks associated with climate change.

In conclusion, it's worth noting that energy security policies are highly context-specific, shaped by a country's available resources, geopolitical considerations, economic priorities, and environmental commitments. Each nation develops its energy security strategy tailored to its unique circumstances and priorities.

Summarizing everything mentioned above, the forms and methods of regulating the world energy market are critical for ensuring stability, fairness, and long-term sustainability. Regulation plays a vital role in guiding the behavior and activities of individuals, organizations, and markets in the energy sector. It aims to promote economic efficiency, protect consumers, ensure social justice, safeguard the environment, and maintain energy security.

Environmental regulation is a key aspect of energy market regulation, focusing on mitigating the negative environmental impacts of energy production, distribution, and consumption. It involves promoting renewable and clean energy sources, setting emission standards, encouraging energy efficiency, and conducting environmental impact assessments. International organizations such as the UNFCCC, IEA, and national entities like the EPA and EEA are instrumental in developing and enforcing environmental regulations.

Trade policy is another crucial dimension of energy market regulation. It encompasses rules, agreements, and measures governing the international trade of energy products and services. Trade policy aims to foster competitiveness, ensure energy security, and promote sustainable development. It includes aspects such as tariffs, trade barriers, free trade agreements, energy subsidies, energy security considerations, environmental considerations, and dispute settlement mechanisms.

Energy security policies are implemented by governments to ensure a reliable, affordable, and sustainable supply of energy resources. These policies focus on diversifying energy sources, strengthening energy infrastructure resilience, establishing strategic reserves, and developing emergency response plans. By reducing dependence on a single energy source and enhancing infrastructure reliability, energy security policies aim to mitigate risks associated with supply disruptions and price fluctuations.

Overall, effective regulation of the world energy market requires a careful balance between economic, environmental, social, and security considerations. It necessitates collaboration among governments, international organizations, industry stakeholders, and civil society to address the complex challenges and opportunities presented by the evolving energy landscape. Through comprehensive and well-designed regulation, we can strive for a more sustainable, efficient, and equitable energy future for all.

CHAPTER 2.

ANALYSIS AND SCENARIOS OF DEVELOPMENT OF THE WORLD ENERGY MARKET

2.1. Analysis of the structural dynamics of the world energy market

The dynamics of the world energy market are undergoing significant transformation as countries strive to address environmental concerns, ensure energy security, and meet the growing energy demand. This intricate and ever-evolving system encompasses various factors, which we have explored previously, including energy sources, production and consumption patterns, pricing mechanisms, market participants, and policy frameworks. By examining these dynamics, we can gain insights into the underlying forces shaping the energy market and identify the key factors of influence and modern trends that are driving its development.

The world's energy landscape is constantly evolving, driven by the ever-increasing demand for power to fuel our modern societies. The energy consumption has been steadily increasing due to factors such as population growth and urbanization (Appendix 1, Table A.1), industrialization, and technological advancements. As more countries develop and improve their living standards, the demand for energy rises across various sectors, including industrial, transportation, and buildings (Appendix A: Table A2; Table A3; Table A4).

The Figure 2.1. represents the total energy consumption trend by region from 1990 to 2021. The numbers are measured in Mtoe, that stands for "Million Tones of Oil Equivalent." This is a unit of measurement used to compare and quantify energy from different sources based on their energy content. Mtoe allows for the standardization and conversion of various energy forms, such as oil, natural gas, coal, nuclear energy, and renewable sources, into a common unit.

However, it's important to note that Mtoe does not consider the specific characteristics, efficiencies, or environmental impacts of different energy sources. It serves as a useful tool for understanding and comparing energy consumption and production on a large scale.

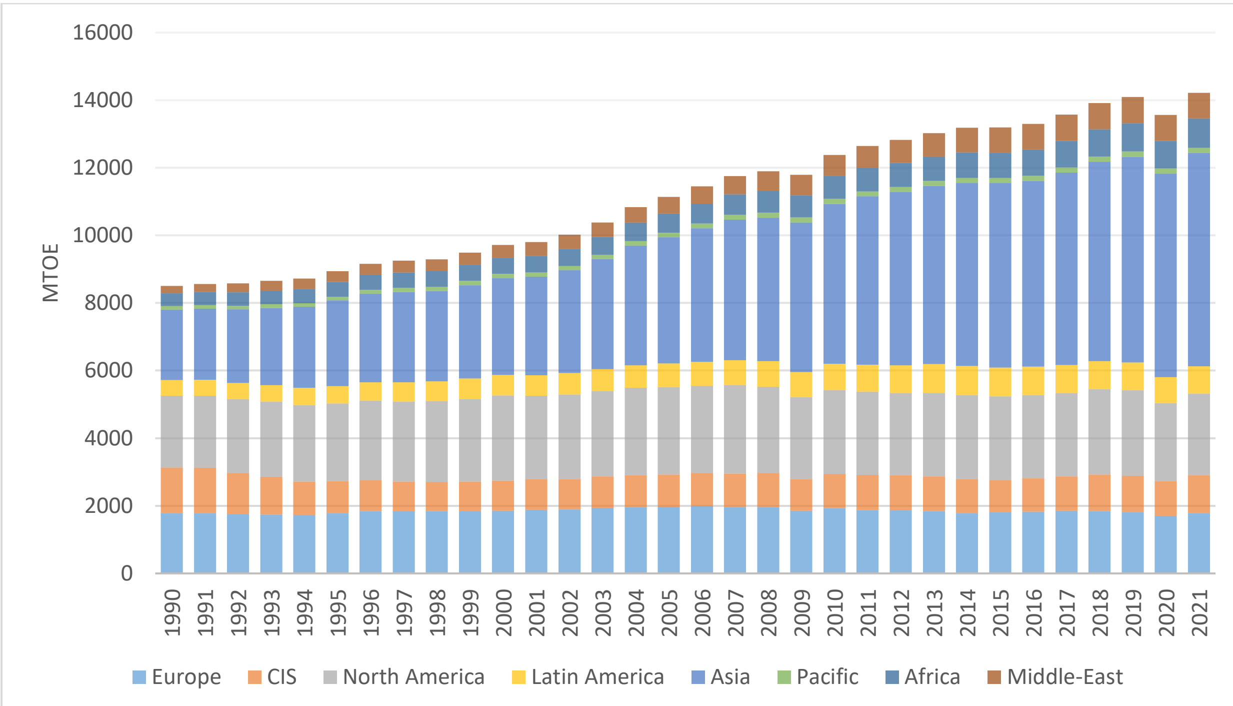


Figure 2.1 – Total energy consumption trend over 1990-2021 by region (Mtoe)

Source: compiled by the author based on [49]

From the figure above, we can see that the top consumers of energy are such regions as Asia, North America, and Europe. Its consumption is driven by its developed economies, extensive industrial sector, transportation networks, and high standards of living. Energy-intensive industries and economic activities, particularly in sectors like manufacturing and heavy industries, play a significant role in driving energy consumption in the CIS region and Middle East. At the same time, energy consumption is remaining low in the Pacific and African regions. So, Africa has limited access to modern energy services, low levels of industrialization, and economic development challenges. While the Pacific region is small both by population and by itself.

After conducting a thorough analysis, we now shift our focus to the comprehensive list of leading countries by energy consumption for the year 2021, as presented in the Figure 2.2. By examining this visualization, we can develop a clear understanding of the significant players driving energy demand and consumption.

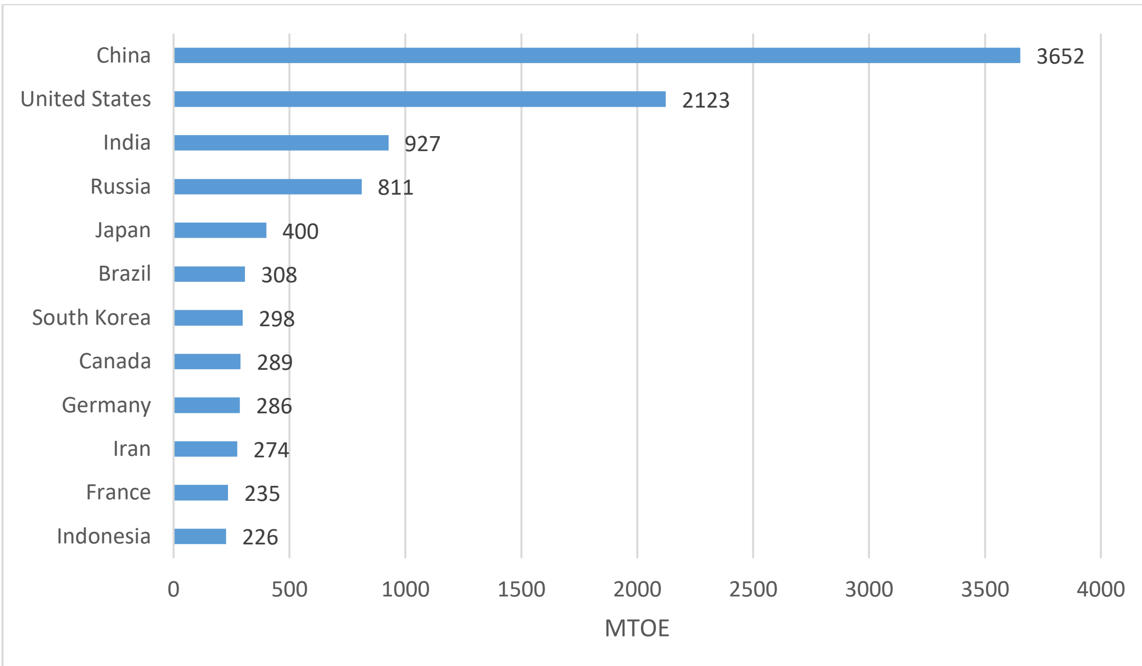


Figure 2.2 – Energy consumption by country 2021 (Mtoe)

Source: compiled by the author based on [49]

Nevertheless, besides mentioned factors that shape energy demand for countries, such factors as the price of energy resources, also play a crucial role. One country heavily reliant on energy imports can face challenges when energy resource prices rise. Higher energy prices can result in increased costs for industries, transportation, and households. This can lead to inflationary pressures, reduced competitiveness, and a strain on national budgets.

At the same time, on the contrary for another country, it can become a driver for economic prosperity by selling energy resources and reaping significant revenue from exports. This is particularly true for countries rich in fossil fuel reserves, such as oil or natural gas. When global energy prices are high, these countries can benefit from increased export revenues, which can stimulate economic growth and development.

The visual representation in Figure 2.3 offers a comprehensive overview of the historical evolution of energy production across different regions, shedding light on the changing dynamics of global energy supply.

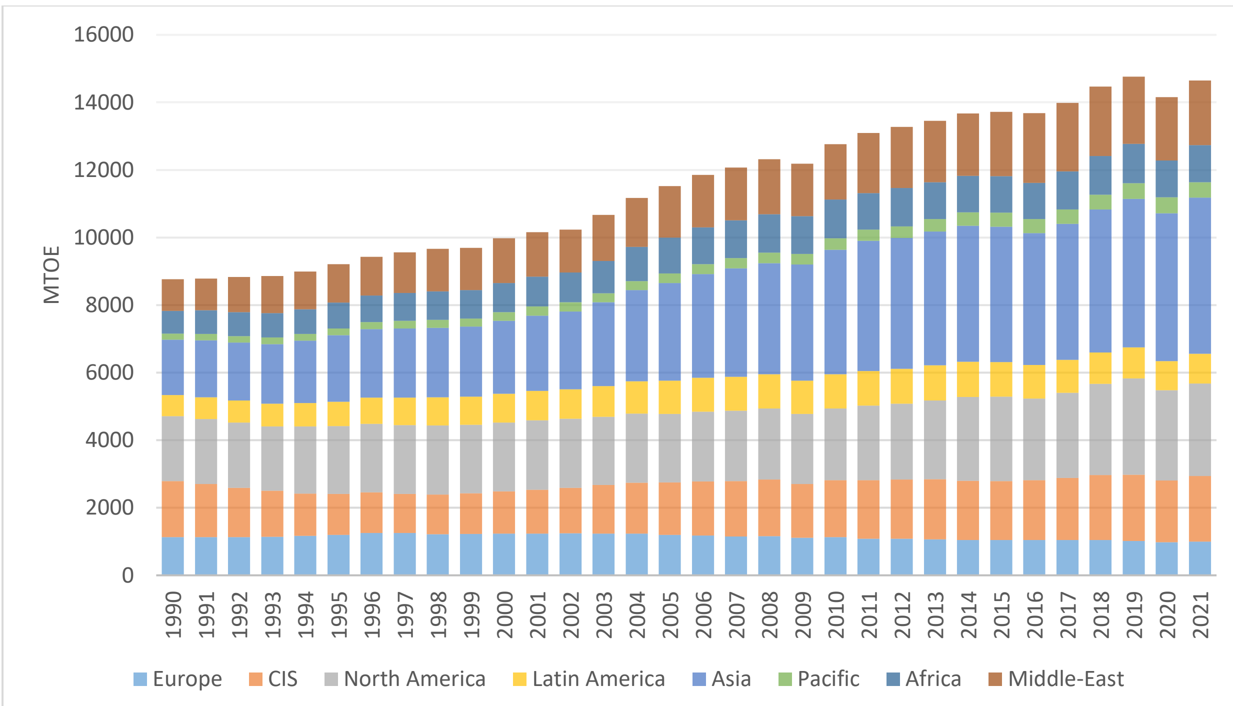


Figure 2.3 – Total energy production trend over 1990-2021 by region (Mtoe)

Source: compiled by the author based on [50]

Europe has been at the forefront of efforts to transition to cleaner and more sustainable energy sources. Many countries in Europe have set ambitious renewable energy targets and are actively reducing their reliance on fossil fuels. Germany has been a global leader in renewable energy, particularly in solar and wind power generation. Other countries like Denmark, Sweden, and the Netherlands have also made significant progress in increasing their renewable energy capacity. Nuclear energy plays a notable role in the energy mix of several European countries, including France and the United Kingdom. While coal remains in use in some parts of Europe, there is a growing shift away from coal-fired power plants due to environmental concerns and efforts to decarbonize the energy sector.

The CIS (Commonwealth of Independent States) comprises several countries that were formerly part of the Soviet Union. The region is rich in natural resources, particularly oil, gas, and coal. Russia is the largest producer and exporter of natural gas globally and is also a major producer of oil. Kazakhstan and Azerbaijan are other significant oil and gas producers in the CIS region. These countries heavily rely on their fossil fuel resources for both domestic consumption and export revenues. However, there are increasing efforts to diversify energy sources and promote renewable energy. Countries like Ukraine and Belarus have been expanding their renewable energy capacity, particularly in solar and wind power.

North America has a diverse energy production landscape. The United States has experienced a shale revolution, leading to a significant increase in domestic production of oil and natural gas. The country is now one of the largest producers of oil and natural gas globally. Canada is also a major player in the energy sector, particularly in oil production from its oil sand reserves and natural gas extraction. Both the United States and Canada have been investing in renewable energy, with significant growth in solar and wind power installations. In terms of electricity generation, the United States has been reducing its reliance on coal and increasing its use of natural gas and renewable sources. Mexico has been undergoing energy sector reforms, aiming to attract investments and diversify its energy mix, including an increased focus on renewables.

Latin America has a varied landscape for energy production as well. Several countries in the region have rich oil and gas reserves, such as Venezuela, Brazil, and Mexico. These countries are significant players in the global energy market and heavily rely on fossil fuel extraction for both domestic consumption and export. However, there is also growing interest in renewable energy sources, particularly hydropower. Countries like Brazil and

Colombia have invested in large-scale hydroelectric projects, capitalizing on their abundant water resources. Additionally, countries like Chile and Mexico are exploring solar and wind energy as part of their renewable energy expansion plans.

The Pacific region encompasses a wide range of countries, each with its energy production profile. Australia, a key player in the region, has abundant coal and natural gas reserves and is one of the largest exporters of liquefied natural gas (LNG) globally. The country is also making strides in renewable energy, with significant investments in solar and wind power. Pacific island nations, on the other hand, face unique challenges due to their small size and limited resources. Many of these nations heavily rely on imported fossil fuels for energy, but there is increasing interest in developing local renewable energy sources to reduce dependence and mitigate the impacts of climate change.

Asia is the largest consumer of energy globally and has a wide energy production mix. China and India have seen rapid growth in energy demand driven by their expanding economies. China is the world's largest producer and consumer of coal but has also been investing heavily in renewable energy, particularly solar and wind power. India has been focusing on increasing its renewable energy capacity, with ambitious targets for solar and wind energy installations. Other countries in the region, such as Japan and South Korea, have limited domestic energy resources and heavily rely on imports, including fossil fuels and nuclear power.

Africa has vast untapped energy potential, with abundant solar, wind, hydro, and geothermal resources. Many countries in Africa, especially those with limited access to electricity, are embracing renewable energy as a means to expand energy access and promote sustainable development. Countries like South Africa, Morocco, and Kenya have made significant progress in renewable energy deployment, particularly in solar and wind power projects. However, fossil fuels still play a significant role in some African countries, such as Nigeria and Angola, which have substantial oil and gas reserves.

The Middle East region is renowned for its abundant oil and gas reserves, which have been a primary driver of economic growth and development in the region. Countries like Saudi Arabia, Iraq, Iran, and the United Arab Emirates are major oil producers and play a significant role in global energy markets. The Middle East has also been exploring alternative energy sources. For instance, the United Arab Emirates has invested in renewable energy projects, including solar power, and aims to diversify its energy mix to reduce dependence on fossil fuels.

Now that we have examined the energy production trends across various regions, let us shift our focus to a compilation of countries that emerge as frontrunners in overall energy production presented in the figure 2.4 below.

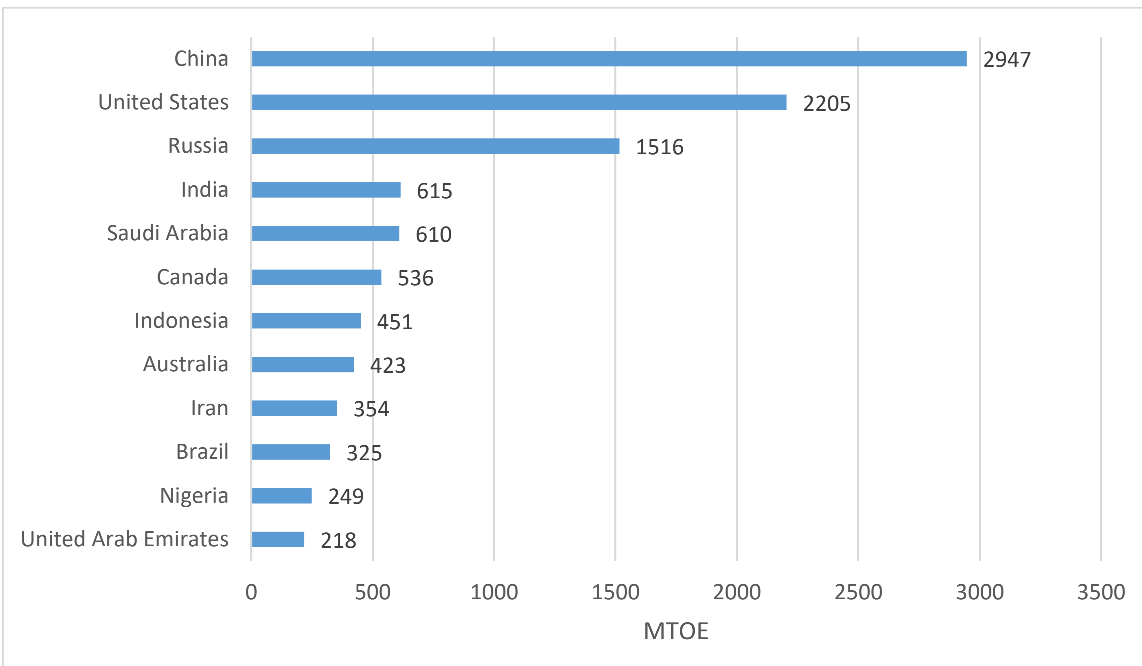


Figure 2.4 - Energy production by country 2021 (Mtoe)

Source: compiled by the author based on [50]

After we analyzed the consumption and production by regions, as well as their leaders and key characteristics. Let's take a closer look at the structure of the energy market, namely, the percentage of various energy sources in the global energy mix presented in figure 2.5 below.

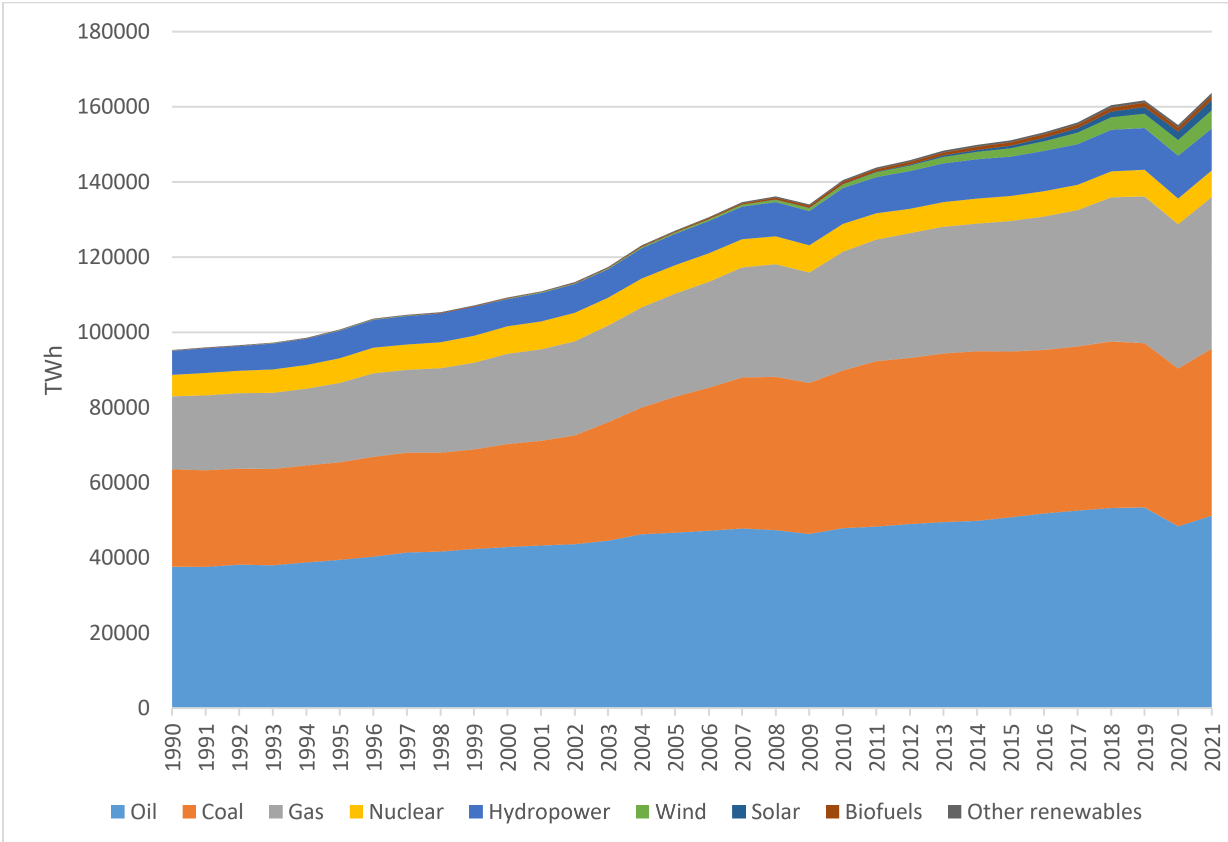


Figure 2.5 – The world energy mix 1990-2021 (TWh)

Source: compiled by the author based on [14]

From 1990 to 2021, the world energy mix has undergone significant transformations, driven by factors such as technological advancements, policy changes, and increasing awareness of environmental sustainability. Globally, oil provides the majority of the energy we use, with coal, gas, and hydroelectricity following. Nevertheless, we can see the growth in other renewables indicating a shift towards a more diversified and sustainable energy mix. The pie chart 2.6 below illustrates the composition of the world energy mix in 2021. Each sector represents a specific energy source and shows its percentage share in the overall global energy consumption.

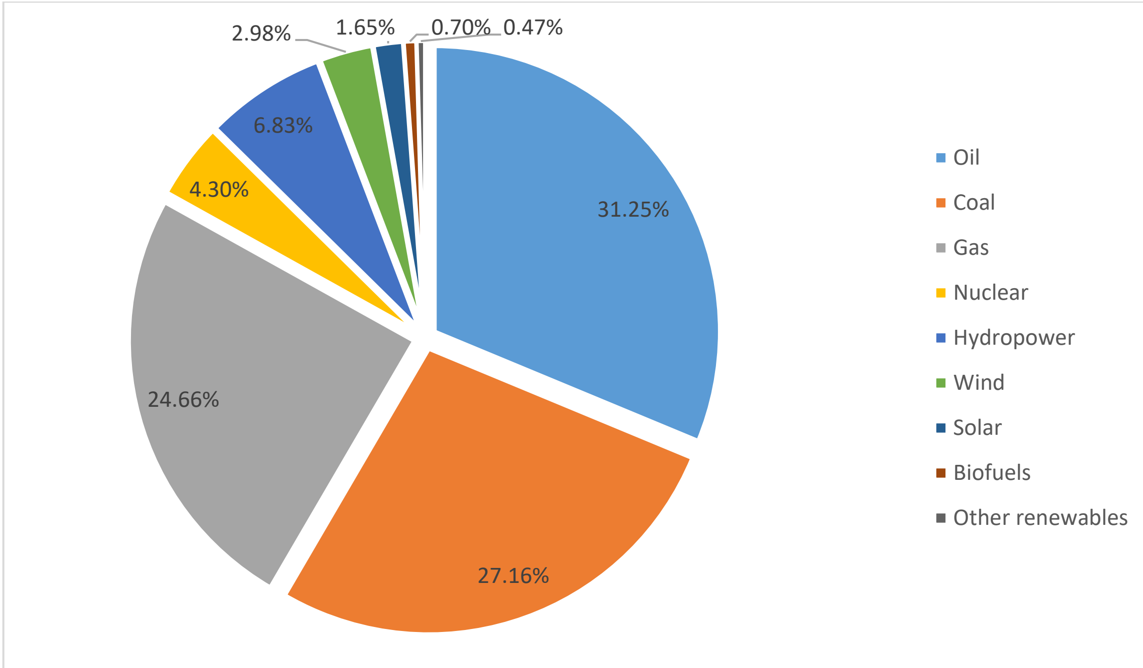


Figure 2.6 – The share of energy resources in the world energy mix in 2021

Source: compiled by the author based on his own calculation from [14]

Now, let's explore the main producers of main energy resources and their significance in driving the global energy market.

Oil is one of the most crucial energy resources globally, serving as a major source of fuel for transportation, industrial processes, and power generation. According to the U.S. Energy Information Administration (EIA), the average daily production of oil and other petroleum liquids was 100.1 million barrels (b/d) in 2022 and is predicted to reach 101.8 million b/d in 2023.

In 2022, the top oil producing countries were: United States, Saudi Arabia, Russia, Canada, China, Iraq, United Arab Emirates (UAE), Brazil, Iran, Kuwait. With a production of 18,875,000 barrels per day (bpd), the US topped the list. With a production of 10,835,000 BPD and 17% of the world's proven petroleum reserves, Saudi Arabia came in second.

Founded in 1960 The Organization of Oil Producing Countries (OPEC) which includes 13 oil-producing nations: Algeria, Angola, Congo, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates and Venezuela - continues to be a potent cartel of oil producers that can affect the price of the world market in addition to these individual nation producers. For instance, OPEC surprised the markets in April 2023 by announcing output reductions totaling about 3.66 million b/d, or 3.7% of the world's demand. This caused the price of oil to soar by 7%.

The table 2.1 below presents the biggest oil companies, some of them also are gas producers) ranked by revenue, with their net income, market cap, country of operation, and ownership type.

Table 2.1 – List of 10 biggest oil companies in 2022

Rank	Name	Revenue *(in billions, $)*	Net Income *(in billions, $)*	Market Cap	Country	Ownership type
1	Saudi Arabian Oil Co. (Saudi Aramco)	590.3	156.5	$1.8 trillion	Saudi Arabia	State-owned
2	China Petroleum & Chemical Corp. (SNPMF)	486.8	10.5	$55.7 billion	China	State-owned
3	PetroChina Co. Ltd. (PCCYF)	486.4	20.9	$78.7 billion	China	State-owned
4	Exxon Mobil Corp. (XOM)	386.8	51.9	$445 billion	United States	Privately-owned
5	Shell PLC (SHEL)	365.3	43.4	$201.8 billion	England	Privately-owned
6	TotalEnergies SE (TTE)	254.7	23.1	$157.1 billion	French	Privately-owned
7	Chevron Corp. (CVX)	227.1	34.2	$337.8 billion	United States	Privately-owned
8	BP PLC (BP)	222.7	-11	$105.3 billion	England	Privately-owned
9	Marathon Petroleum Corp. (MPC)	173	12	$57.1 billion	United States	Privately-owned
10	Valero Energy Corp. (VLO)	170.5	9.4	$47.3 billion	United States	Privately-owned

Source: compiled by author based on [47]

As we can see from the table 2.1 above, the top three companies are state-owned which means the government has direct control over the exploration, production, and distribution of oil within its territory. That allows the government to capture a significant portion of these profits, providing a substantial source of revenue for the country's treasury. This revenue can be used to fund public infrastructure, social programs, education, healthcare, and other essential services.

State ownership of oil companies can be seen as a way to protect national interests and sovereignty. By having control over critical energy resources, the government can make strategic decisions to safeguard the country's interests, both economically and geopolitically. It allows the government to have a strong voice in global energy markets and enables it to negotiate favorable terms and agreements with international partners.

Nevertheless, it does not always have a good effect if the country overdoes it. A bright example is the Russian Federation, which has a long history of using its energy resources as a political tool to influence neighboring countries and exert pressure on Europe. The dependence of some European countries on Russian natural gas supplies, delivered through pipelines such as the Nord Stream and TurkStream, has created vulnerabilities and potential for energy leverage. Russia is guilty of using its energy dominance to advance its geopolitical objectives, such as gaining political influence, dividing European unity, and undermining European energy diversification efforts.

Gazprom, as the state-owned Russian energy company, plays a pivotal role in Russia's energy sector. As the world's largest producer of natural gas, Gazprom holds a significant share of Europe's gas market. The company's close ties to the Russian government provide it with the ability to align its actions with Russia's political interests. This state control allows Russia to exercise influence over energy pricing, supply disruptions, and investment decisions, enabling it to assert its geopolitical agenda.

Returning to the topic, it is important to note that the coal industry has faced increasing scrutiny due to its environmental impact, particularly in terms of greenhouse gas emissions and air pollution. Due to it in the first half of 2022, global coal prices reached a record high. In 2021, especially in the first half of the year, coal production lagged recovering coal demand, which reduced stock levels and increased prices. Major coal producers, led by China and India, introduced policies to increase production and alleviate domestic coal shortages. This was made possible by the substantial participation of state-owned enterprises in the coal industry. However, the main coal exporting nations experienced a supply shortage, in part because of several weather-related disruptions, including flooding in Indonesian mines and infrastructure problems.

In some nations, investing in nuclear power is also becoming more popular. There have been announcements of new construction, for instance in Japan and France, as well as announcements of lifetime extensions for existing reactors, frequently as a response to the current crisis.

Summing up, the structural dynamics of the world energy market are undergoing significant changes driven by various factors. The transition towards cleaner and more sustainable energy sources, concerns over climate change, technological advancements, and shifting geopolitical landscapes are all influencing the way energy is produced, consumed, and traded globally.

Renewable energy sources, such as solar, wind, and hydroelectric power, are experiencing rapid growth and becoming increasingly competitive in terms of cost and efficiency. This shift towards renewables is driven by a desire to reduce greenhouse gas emissions, diversify energy sources, and enhance energy security. Governments, international organizations, and private companies are investing heavily in renewable energy projects, leading to the expansion of renewable capacity and the gradual integration of renewables into the mainstream energy market.

In parallel, there is a concerted effort to reduce reliance on fossil fuels, particularly coal, due to its significant environmental impact. Natural gas, being a cleaner-burning fossil fuel, has often been considered a transition fuel and continues to play a crucial role in the energy mix, especially as a replacement for coal in electricity generation and industrial processes. However, the gas industry is also facing increasing pressure to reduce methane emissions, improve efficiency, and explore low-carbon alternatives, such as renewable natural gas and hydrogen.

The geopolitical landscape is shaping the energy market as well. Geographically diverse regions are emerging as energy hubs, with some countries gaining prominence as major energy producers and exporters. The interdependencies between energy-producing and energy-consuming nations influence market dynamics, trade relationships, and energy security considerations. Additionally, geopolitical tensions, energy infrastructure developments, and the influence of international agreements and policies impact the flow of energy resources across borders.

2.2. Factors of influence and modern trends in the development of the world energy market

The world energy market is undergoing a significant transformation, driven by various factors and modern trends that are reshaping the way energy is produced, consumed, and traded globally. These factors of influence and evolving trends are not only shaping the present energy landscape but also set the course for the future of the global energy sector. Understanding these factors and trends is essential for stakeholders in the energy industry, policymakers, and investors to navigate the complexities of the evolving market and capitalize on emerging opportunities.

In this section, we will explore the key factors of influence and modern trends that are driving the development of the world energy market. We will delve into the challenges and opportunities presented by these factors and examine the implications they have for the energy industry and the wider global community.

Recently all countries faced the global energy crisis, which is unprecedented in its scope and complexity. That leads to far-reaching effects on numerous households, businesses, and entire economies. Market pressures existed before Russia invaded Ukraine. However, the actions of the first broke not only the peaceful life of the Ukrainians but also weak supply chains and production capacity. That leads to full-blown turmoil in the energy markets, seriously harming the world economy. As both countries are key players in the energy arena, the full energy market was shaken.

As a result, many countries started to take action to minimize the existing damage and protect themselves from future uncertainties. Some of them did it beforehand, some only after it had happened. These actions include:

- Maximizing the use of currently operating power plants in the country: Japanese plan to restart as many nuclear reactors as possible;
- Diversifying of supply sources: European liquified natural gas (LNG) imports;
- Acceleration of adoption of clean energy technologies: The European Union's REPowerEU Plan, which is a European Commission proposal to end reliance on Russian fossil fuels before 2030 in response to the 2022 Russian invasion of Ukraine;
- Implementation of programs to protect consumers from high prices: establishing price caps, increasing targeted support, or reducing fuel costs;
- Trade-offs between short-term security benefits and emissions reduction goals: relying more on coal-fired power plants for electricity generation;

However, the prices of energy, including gas and electricity, went up as Russia decided to suspend deliveries of gas to some EU member states, using it as a tool of pressure and ultimatum. It caused record high prices for electricity in the EU as we can see from the figure 2.7 below.

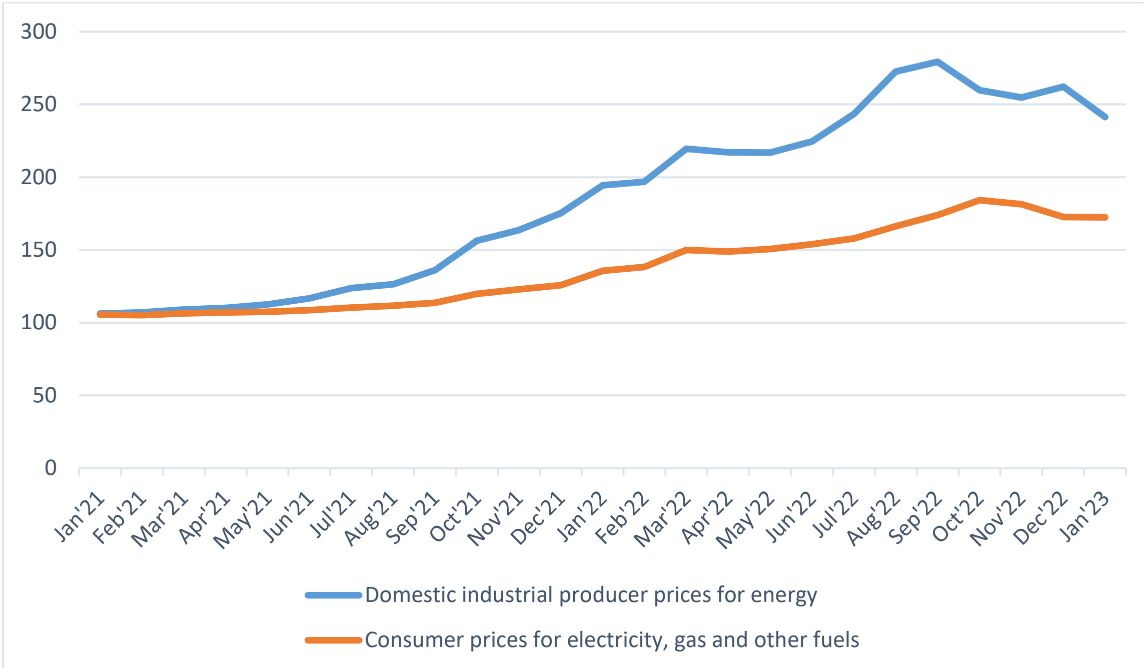


Figure 2.7 - Producer and consumer energy prices in the EU

Average index (2015=100), unadjusted

Source: Council of the European Union [27]

But such a spike in prices was caused not only in European Union but besides its borders, hitting developing countries. Low-income households have been disproportionately affected by the rise in energy prices, which has also made energy insecurity worse. On average, households spend 7% of their income on energy, with half of that amount going toward various home-end uses like heating, cooling, lighting, and cooking. This, however, fails to account for the fact that, even though poorer households use less energy, they spend a much higher proportion of their income on energy than wealthy households do.

At the same time, high fuel prices can be seen as a catalyst for accelerated transition and a powerful driver of innovation, as was the case during the oil price crisis of the 1970s, as evidenced by the European Union's REPowerEU plan and the U.S. lower inflation. The high cost of fuel also increases the likelihood that policymakers will pay less attention to emissions reduction and financing due to affordability and safety concerns. Financing a clean energy transition could become more difficult if importing countries end up paying significantly more on their fuel import bills. Such additional costs will bring windfall benefits to fossil fuel exporters, but there is no guarantee that they will be a net benefit for the transition period.

According to the most recent data, which was presented in the World Energy Investment 2022, global clean energy spending is finally picking up after remaining flat for several years and is predicted to surpass USD 1.4 trillion in 2022. However, China and advanced economies account for almost all of the growth.

Furthermore, the plans of advanced economies contain more than 90% of the USD 1.1 trillion set aside for clean energy as part of post-pandemic stimulus packages. Except for China, emerging markets and developing economies, which together make up two-thirds of the world's population, invest less than one-fifth of the total in clean energy. This lack of investment in developing and emerging market economies is alarming. These economies will either experience high-carbon growth or energy shortages if there is no practical route to inclusive low-emission growth for them. There are significant risks attached to each of these options.

From an economic standpoint, investments in clean energy are appealing, particularly at this time when fossil fuel prices are high and unstable. Additionally, it is the world's most economical means of preventing further emissions: According to an IEA analysis, the average cost of avoiding emissions in emerging markets and developing economies is roughly half that of advanced economies. So why aren't these investments happening?

The high cost of capital is one of the major obstacles preventing emerging markets and developing economies from investing in clean energy. Investment opportunities are hampered by a high cost of capital, especially for capital-intensive projects like renewable energy that have high initial capital costs but low operating costs. Lack of information on the cost of capital at the project and corporate level, particularly for emerging markets and developing economies, has made it difficult to assess this problem. This acts as a deterrent to investors who want to put money into these areas.

To increase the visibility and accessibility of data on financing costs in the energy sector and to encourage investor confidence, a Cost of Capital Observatory was established in September 2022 by the International Energy Agency, the World Economic Forum, ETH Zurich, and Imperial College London. This table 2.2 is presented below.

Table 2.2 - Indicative weighted average cost of capital of utility-scale solar PV projects, 2021

	Cost of debt (after tax)	Cost of equity	Share of project debt	WACC (nominal, after tax)
Europe	2.5% - 3.0%	6.0% - 11.0%	75% - 85%	3.0% - 5.0%
United States	3.0% - 3.5%	5.0% - 7.0%	55% - 70%	3.5% - 5.0%
China	3.5% - 4.0%	7.0% - 9.0%	70% - 80%	4.0% - 5.5%
Brazil	11.5% - 12.0%	15.0% - 15.5%	55% - 65%	12.5% - 13.5%
India	8.0% - 9.0%	12.5% - 13.5%	65% - 75%	9.0% - 10.5%
Indonesia	8.5% - 9.5%	12.0% - 12.5%	60% - 70%	9.5% - 10.5%
Mexico	8.0 % - 8.5%	12.0% - 12.5%	60% - 70%	9.5% - 10.0%
South Africa	8.0 % - 9.0%	12.0% - 14.0%	65% - 70%	9.5% - 11.0%

Source: compiled by the author based on [14]

- The cost of debt refers to the interest rate or yield a company pays on its debt, such as bonds or loans. It represents the cost incurred by the company to borrow funds from creditors.
- The cost of equity represents the return required by equity investors (shareholders) to compensate them for the risk associated with investing in the

company's stock. It reflects the potential return shareholders expect to receive on their investment.

- Share of Project Debt refers to the portion of the project's financing that is funded by debt. It represents the percentage or proportion of the project's total capital structure that is composed of debt financing. It helps determine the overall capital structure and financing mix of the project.
- WACC (Weighted Average Cost of Capital): The WACC is the average rate of return required by all capital providers (both equity and debt) to finance the project or company. It represents the weighted average of the cost of equity and the cost of debt, taking into account the proportion of each in the capital structure. The WACC is used as a discount rate to evaluate the feasibility and profitability of investment projects.

The main indicators in the table below have been clarified, and we can say that in 2021, emerging markets and developing economies had capital costs for typical solar PV plants that were two to three times higher than those in advanced economies and China (Table 2.2).

This was caused by a combination of factors, including a lack of bankable projects, higher sectoral risks, which translated into higher premia for debt and equity, and higher country risk, which is reflected in higher rates for sovereign bonds. Regulational risk, off-taker risk, and land acquisition risk are among the dangers. A poor or erratic energy policy, a lack of thorough infrastructure planning, or ineffective market structures all contribute to regulatory risk. Offtaker risk is caused by the financially precarious state of distribution companies, which are frequently the main off-takers for developers. As a result, power purchase agreements may not be signed or payments made under them may be delayed, raising the cost of financing.

Even in nations with abundant renewable resources, rising borrowing costs and higher capital costs pose a threat to the economic appeal of investments in clean energy in emerging market and developing economies. In these regions in 2021, financing costs made up about half of the total levelized costs of a solar PV plant that had reached the final investment decision, which is significantly higher than the equivalent 25–30% figure in advanced economies and China (Figure 2.8). Inward investment levels are inevitably impacted by this.

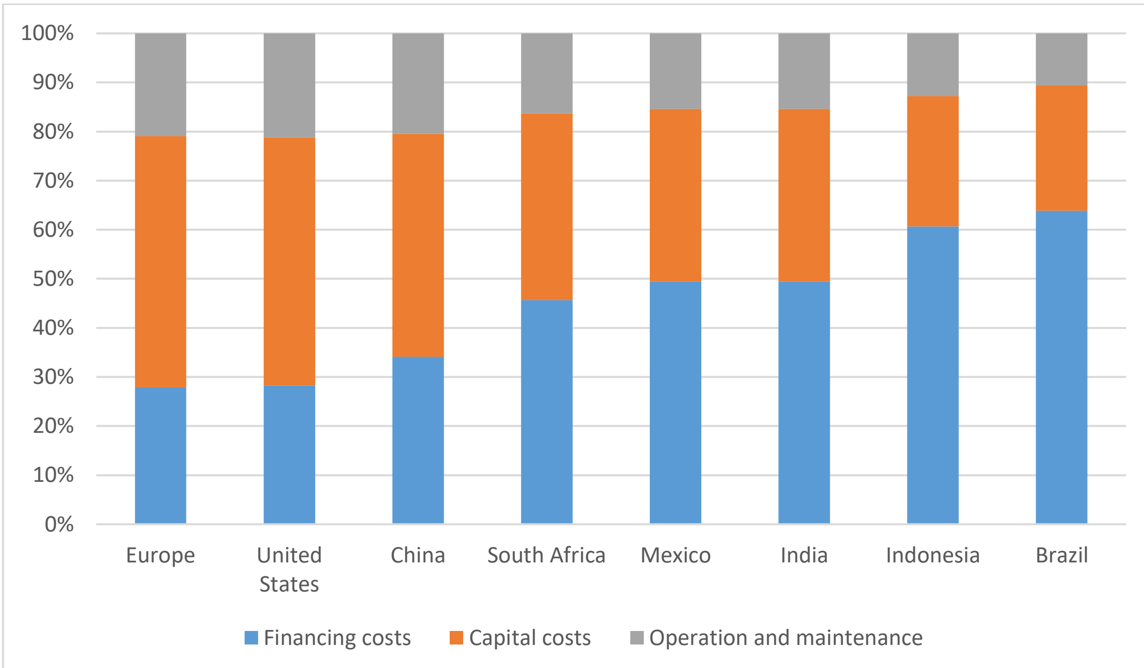


Figure 2.8 - Composition of levelised cost for a utility-scale solar PV plant with final investment decision secured in 2021

Source: compiled by the author based on [14]

In emerging markets and developing economies, financing costs make up about half of all levelized costs, which is a significant difference from advanced economies and China. This implies that the cost of obtaining financing, such as loans or investments, plays a more substantial role in determining the overall cost of energy projects in emerging economies.

Several factors contribute to this disparity. First, emerging markets and developing economies often face higher borrowing costs due to perceived risks associated with investment in these regions. Lenders and investors may demand higher interest rates or returns to compensate for these risks, increasing the financing costs. Second, limited access to affordable financing options in emerging economies can further drive up financing costs. The lack of developed capital markets, limited availability of long-term loans, and higher perceived risks can restrict access to low-cost financing, making it more expensive for companies and governments to fund energy projects. Third, political and regulatory uncertainties in emerging economies can add to the financing costs. Unstable policy frameworks, legal complexities, and governance issues can raise concerns among investors and lenders, leading to higher risk premiums and higher financing costs.

Also, the transition to clean energy requires a strong focus on the supply of the minerals, materials, and manufacturing capacity required to deliver clean energy technologies, in addition to the traditional aspects of global energy security relating to the supply of fossil fuels. Demand for essential minerals from the energy sector is expected to increase as clean energy transitions quicken. Such materials as Copper, Nickel, Graphite, Lithium, Manganese, and Cobalt become critical components for the production of renewable energy technologies such as solar panels, wind turbines, electric vehicle (EV) batteries, and energy storage systems.

With the increasing digitalization of various industries and the need for clean energy technologies, the demand for these resources is projected to rise. Ensuring a sustainable and responsible supply chain for these materials becomes crucial to meet the growing demand while minimizing environmental impacts and social concerns associated with their extraction and production.

The significance of securing sufficient supplies of sustainable and reasonably priced critical minerals will increase along with the dependence of the energy sector on minerals. There are noticeable differences between the security of critical minerals and the security of oil or gas: a price spike in oil affects all consumers who drive cars that burn oil, whereas a shortage or price spike in critical minerals only has an impact on the production of new EVs or solar panels for the market.

However, as evidenced by recent price increases, supply chain disruptions, and rising mineral costs pose a threat to raising the price of clean energy technologies and impede their adoption. Higher mineral prices mean that critical minerals now contribute to a sizeable and growing portion of the total cost of clean energy technologies. More durable and resilient mineral supplies are necessary, as well as a redoubling of efforts to cut costs through alternative methods, such as technological innovation, recycling, efficiency improvements, and economies of scale.

The fact that clean energy technology supply chains are highly concentrated increases the risk of supply chain disruptions and volatile prices. Critical mineral extraction is geographically concentrated, with one nation producing more than 50% of the world's supply of several important minerals, including lithium (Australia, 55%), cobalt (Democratic Republic of the Congo - DRC, 70%), and graphite (China, 79%). For processing operations, there is an even higher degree of concentration, with China dominating on all fronts.

Transitioning to a clean energy system brings new energy trade patterns, countries, and geopolitical considerations into play as we can see from the following Figure 2.9. Manufacturing and assembly of clean energy technologies are also very concentrated, with China accounting for 75 percent of the production and assembly of solar PV modules and electric vehicle batteries. Manufacturing tends to be dominated by a small number of companies due to its capital-intensive nature and technical complexity. For instance, only three companies produced 65% of the world's battery cells in 2021.

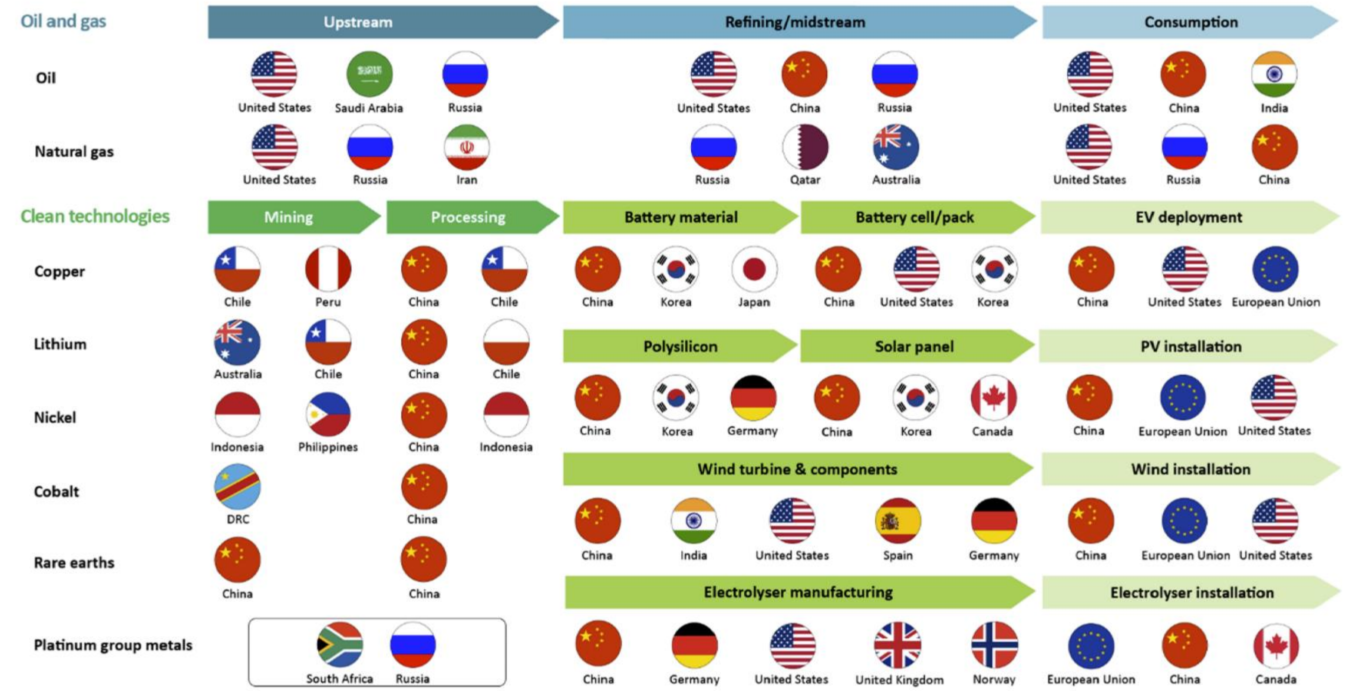


Figure 2.9 – Indicative supply chains for oil and gas and selected clean energy technologies

Source: International Energy Agency.
World Energy Outlook 2022, p.219

Significant risks are related to the effects of mining projects on the environment, society, and governance (ESG), in addition to risks from high prices and supply chain problems. It takes coordinated efforts to address and minimize the ESG impacts of mining and mineral processing, including water use, air pollution, CO2 emissions, and loss of biodiversity, to ensure an adequate supply of minerals for clean energy transitions. To align with the sustainable and people-centered transitions that policymakers and the general public are increasingly demanding, clean energy transitions must be carried out using minerals that prioritize the mitigation of these impacts. These kinds of risks are particularly prevalent in the cobalt supply chain in the Democratic Republic of the Congo (DRC), where artisanal and small-scale mining is common and where serious allegations of child labor, forced labor, and other human rights violations.

Climate change is another significant factor that can unexpectedly influence the energy system and its development. The consequences of climate change are becoming increasingly evident, with systemic changes in climatic conditions and a rise in the frequency of extreme weather events. Over the past few decades, global temperatures have been on the rise, leading to more frequent heat waves in many regions. Additionally, tropical cyclones and windstorms are intensifying, and rainfall patterns are changing in noticeable ways.

These climate-related anomalies pose a threat to the energy infrastructure. For example, standard wind power installations are designed to operate in specific temperature ranges, and extreme heat can lead to the shutdown of wind turbines to protect their vital components (if it exceeds 45°C). Similarly, thermal power generation may be reduced if water temperatures exceed regulatory thresholds in regions like the United States, France, and Germany. A significant number of power outages at coal-fired power plants in the United States between 2000 and 2015 were caused by water temperatures exceeding cooling requirements.

Another issue arising from climate change is the growing scarcity of water in arid regions. The production of many fuels and minerals, including shale resources, coal, copper, lithium, biofuels, and hydrogen, requires substantial amounts of water. Declining water availability at critical production sites could disrupt the supply chain, impacting various industries. Furthermore, hydropower, which relies heavily on water availability, may experience significant declines in regions where water flows are expected to decrease.

Extreme droughts can also have a detrimental impact on energy supply chains that rely on the transportation of materials and fuels. For instance, severe heatwaves and droughts in Europe in 2022 led to low water levels in important rivers like the Rhine, hampering the transportation of coal, chemicals, and other materials. Additionally, changes in wind speed due to extreme weather events can directly affect wind power production, leading to fluctuations in power output. Even a 10% drop in wind speed corresponds to a 27% drop in power output.

Even though thermal power plants typically have structures for flood protection, floods brought on by storms and heavy rains could still disrupt energy supplies. For instance, when flood waters engulfed more than five gas-fired power stations in Sylhet, Bangladesh, in June 2022, they were put out of commission in advance. The Fort Calhoun nuclear power plant in the United States had to be shut down for nearly three years as a result of flooding along the Missouri River in June 2011 because water had seeped into the turbine building. Coal mining and coal-fired power plants may experience disruptions as a result of floods and heavy rain.

That’s why to mitigate the impact of extreme weather events on the energy system, governments must take proactive measures to enhance resilience and adaptation. This can include improving public access to reliable climate and weather data, providing financial support, and implementing regulations to incentivize private sector investment in resilience measures. Encouraging the adoption of more resilient technologies, such as advanced solar PV cooling systems, dry cooling systems for thermal power plants, and wind turbine designs that can operate at higher temperatures, can also be beneficial. Physical system hardening, such as enhancing floodwalls, relocating substations to higher ground, and increasing the capacity of spillways at hydroelectric facilities, can further enhance resilience.

In areas vulnerable to tropical cyclones, installing wind power plants with stronger towers, customized rotor sizes, and reinforced foundations can also have sense. Extreme weather events may cause less physical harm if electricity networks are improved with underground lines, upgraded towers, and tightly interconnected systems. According to our analysis, these measures would generally be more advantageous than costly in the long run. However, it should be noted that one of the most effective ways to reduce the exposure of energy infrastructure to various climate risks is by reducing emissions.

Nevertheless, it is crucial to address the root cause of these changes by reducing the consumption of fossil fuels. The burning of fossil fuels such as coal, oil, and natural gas releases greenhouse gases into the atmosphere, primarily carbon dioxide (CO_2), which is a major contributor to climate change. The accumulation of these greenhouse gases traps heat in the Earth's atmosphere, leading to global warming and the associated impacts on the climate. Due to it several scenarios for the development of renewable energy were created and implemented.

2.3. Scenarios for the development of renewable energy on the world energy market

The world is at a pivotal moment in its energy history, facing both environmental and economic challenges that call for a transition to sustainable and renewable energy sources. The development and widespread adoption of renewable energy technologies are key to addressing climate change, reducing reliance on finite fossil fuels, and promoting a more secure and resilient energy system. As we navigate this critical juncture, it becomes essential to explore various scenarios that could shape the future of renewable energy in the global energy market.

It is crucial to acknowledge that the outcomes are not definitive predictions but rather thought-provoking possibilities. The path toward renewable energy transformation will be influenced by a complex interplay of factors, including political will, technological innovations, financial investments, public awareness, and international cooperation. The scenarios serve as a framework for envisioning potential futures, helping us to better comprehend the implications and considerations surrounding renewable energy development.

In the realm of energy analysis, four distinct scenarios have emerged, reflecting the current state of affairs. These scenarios, namely the **Net Zero Emissions by 2050 Scenario (NZE)**, the **Announced Pledges Scenario (APS**), the **Stated Policies Scenario (STEPS)**, and the **Sustainable Development Scenario (SDS)**, are a product of rigorous modeling and analysis. They are grounded in the latest energy data, policy announcements, investment trends, and technological advancements, providing a comprehensive outlook on renewable energy development.

Each scenario encompasses a meticulous evaluation of national circumstances, taking into account diverse factors such as available resources, technological capabilities, and potential policy options. Through this holistic approach, these scenarios offer valuable insights into the potential trajectories for renewable energy development on a global scale. To start with let’s take a look at the definitions and objectives of each of the scenarios presented in the table 2.3 below.

Table 2.3 - Definitions and objectives of the WEO scenarios

	Net Zero Emission by 2050 Scenario	Announced Pledges Scenario	Stated Policies Scenario	Sustainable Development Scenario
Definition	A scenario that outlines a challenging but doable path for the global energy sector to reach net zero CO2 emissions by 2050. To accomplish its objectives, it does not rely on emissions reductions from sources other than the energy industry.	A scenario in which all climate commitments, including Nationally Determined Contributions (NDCs) and longer-term net zero targets, will be fully and on schedule met by governments around the world.	A scenario that reflects current policy settings based on an evaluation of the specific policies that are implemented as well as those that have been announced by governments around the world, sector by sector	A comprehensive scenario outlining a course of action to: guarantee universal access to affordable, dependable, sustainable, and modern energy services by 2030; significantly reduce air pollution; and take effective climate change mitigation measures.

Continuation of Table 2.3

	Net Zero Emission by 2050 Scenario	Announced Pledges Scenario	Stated Policies Scenario	Sustainable Development Scenario
Objectives	To demonstrate what is required in order for the world to achieve net zero CO2 emissions from industrial processes and energy-related activities by the year 2050 while also achieving other energy-related sustainable development objectives.	To highlight the "ambition gap" that must be closed to achieve the goals decided upon in Paris in 2015, demonstrating how close current commitments bring the world to the target of limiting global warming to 1.5 °C.	To serve as a benchmark for evaluating the possible successes (and constraints) of current developments in energy and climate policy.	To demostrate that it is possible to simultaneously achieve universal energy access, set a course for achieving the goals of the Paris Climate Agreement, and significantly reduce air pollution.

Source: compiled by the author based on [20]

When evaluating the potential trajectories for renewable energy development on a global scale, it is essential to consider diverse factors such as available resources, technological capabilities, and potential policy options. This holistic approach is necessary for the meticulous evaluation of national circumstances. Moreover, while regulations play a role in environmental protection, they can be more expensive and less economically efficient compared to energy taxes and subsidies, which offer an effective complement in correcting market imperfections and externalities.

As part of the "command and control" approach to environmental protection, regulations specify the kind of technology or equipment that must be used to protect the environment, as well as the maximum rate of emission that can be allowed for a given pollutant or a minimum energy efficiency standard. Standards and other regulations give decision-makers more assurance that environmental policy objectives will be met at any cost, but they are frequently more expensive and less economically efficient than taxes or tradable emission permits.

Because it subjects all businesses to the same regulatory standard regardless of the variations in their marginal costs of reducing emissions, a standard would be economically less efficient than a tax. Therefore, with regulation, the variations in utilities, plants, and generating units' capacities to reduce emissions would not be taken into account. As a result, businesses with high marginal abatement costs would be required to reduce pollution to the same extent as businesses with lower marginal abatement costs. Because of these price variations, utilities have a wide range of options and strategies for lowering emissions from power plants.

For instance, some utilities may choose to simply reduce output, while others may decide to invest in pollution control technology or even replace their coal-fired units entirely. The total costs of reducing emissions with the regulatory standard would be higher (i.e. less efficient) than any of the market-based approaches if there are enough variations among utilities and their marginal abatement costs.

In contrast, a tax would give each polluter the incentive to cut pollution in the least expensive way possible, up until the point where the tax just matches the polluter's marginal abatement cost. As a result, a utility with a relatively low marginal cost of pollution abatement would take on more pollution abatement than a utility with a relatively high marginal cost of pollution abatement. The overall cost of abatement, or the overall cost of meeting the standard, would be reduced in this way. Instead of using a standard, all anti-pollution measures that are less expensive would be implemented.

Accordingly the pricing of CO_2 emissions affects the demand for energy by changing the relative costs of using various fuels. In order to price carbon, a number of nations have already implemented emissions trading schemes, and many more have similar plans in the works. Other nations have already implemented carbon taxes on fuels based on the emissions they produce when burned or are considering doing so. The Stated Policies Scenario considers all national and subnational carbon pricing schemes that have been announced or are currently in place.

The Sustainable Development Scenario assumes that CO_2 pricing has been established in all advanced economies, that prices in these markets begin to converge in 2025, and that prices in most advanced economies will reach $140/tone CO_2 in 2040. Additionally, it is anticipated that several developing economies will implement plans to regulate CO_2 emissions. Due to the availability of offsets across all regional markets, price convergence is anticipated as presented in the table 2.4 below.

Table 2.4 – CO_2 prices for electricity, industry and energy production in selected regions by scenario

USD (2020) per tone of CO_2	2030	2040	2050
Stated Policies			
Canada	55	60	75
Chile, Colombia	15	20	30
China	30	45	55
European Union	65	75	90
Korea	40	65	
Announced Pledges			
Advanced economies with net zero pledges	120	170	200
China	30	95	160
Emerging market and developing economies with net zero pledges	40	110	160
Sustainable Development			
Other advanced economies	100	140	160
Other selected emerging market and developing economies	-	35	95
Net Zero Emissions by 2050			
Advanced economies	130	205	250
Major emerging economies	90	160	203
Other emerging market and developing economies	15	35	55

Source: compiled by the author based on [25]

Summing up the information above, CO2 prices are expected to increase across different scenarios for the development of renewable energy. Whether it is a rapid expansion of renewable energy, a gradual transition, or a disrupted energy market, the need to reduce greenhouse gas emissions and mitigate climate change remains a global priority. Increasing

CO2 prices incentivize a shift away from carbon-intensive energy sources and as we can see from Figure 2.10 encourage investments in renewable energy technologies.

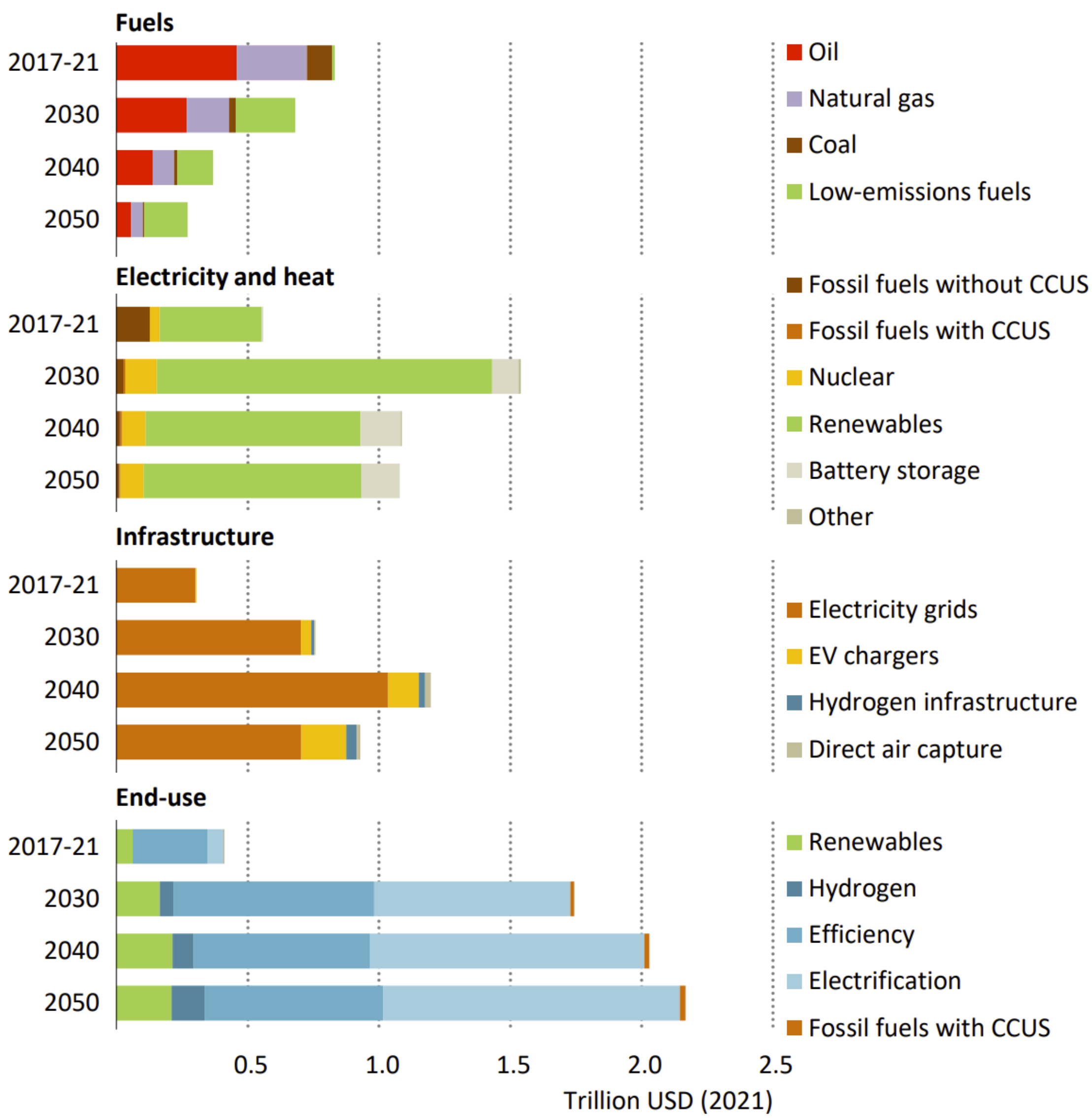


Figure 2.10 - Global average annual energy investment by sector and technology in the NZE Scenario

Source: *International Energy Agency.*
World Energy Outlook 2022, p.163

Investment grows quickly in the electricity, infrastructure, and end-use sectors while fossil fuel investments decline and investments in low-emissions fuels rise.

In 2021, annual investments in clean energy were about USD 1.3 trillion. By 2030, in the STEPS scenario, this rises by more than 50% from current levels, more than doubles in the APS scenario, and triples in the NZE scenario (As shown in Figure 2.11). The APS and NZE scenarios both show a decrease in fossil fuel investment, whereas the STEPS scenario shows an increase.

Investment in clean energy includes a significant portion of end-use investments. It covers the price of making buildings, appliances, industry, and vehicles more energy efficient as well as switching to alternative fuels. In 2021, investments in energy efficiency and end uses will total about USD 500 billion. This is anticipated to rise in 2022, in part due to post-pandemic government stimulus packages that are supporting retrofits, heat pumps, and electric vehicles. Sales of electric vehicles have increased especially quickly.

In the STEPS, end-use investments make up half of the USD 700 billion increase in annual clean investment over today's levels, with investments in the building sector and continued growth in EV sales serving as the main drivers. Although end-uses are not the main factor driving investment growth in the APS and NZE, switching from the STEPS to the NZE Scenario by 2030 will require an additional USD 900 billion annually, which is more than twice the growth in annual end-use investment required in the STEPS between now and 2030. By 2030, APS and NZE adopt EVs and heat pumps much more widely than STEPS do, but the investment costs are significantly lower due to these technologies' declining prices.

To reach the levels necessary in the NZE Scenario by 2030, investment in end-uses would need to almost quadruple; EV sales are already anticipated to quadruple in the STEPS.

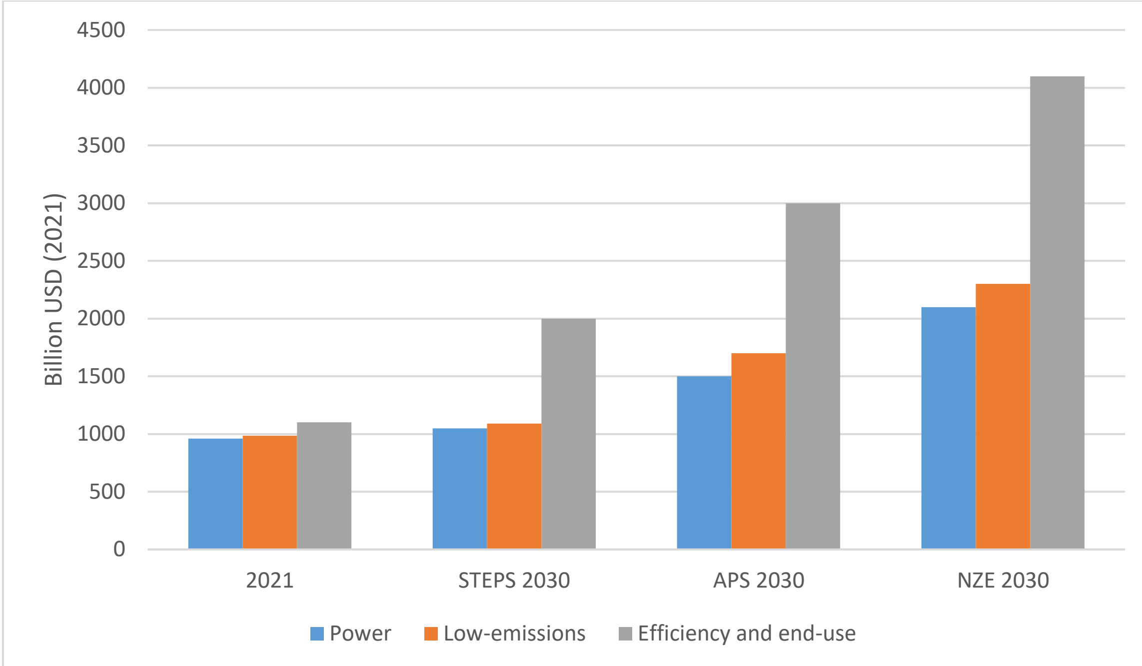


Figure 2.11 - Annual clean energy investment by sector and scenario, 2021 and 2030

Source: compiled by the author based on [25]

Nevertheless, rising interest rates and inflation could deteriorate the short-term outlook for end-use investment, particularly in the building and transportation sectors, which are closely related to disposable income and consumers' access to affordable credit.

Over the 2020–50 period, recovery packages have committed roughly USD 440 billion to the end-use segments, which might support investment levels. But the majority of this support is front-loaded and concentrated in advanced economies. It will be necessary to strengthen enabling conditions and support for new investment as future stimulus funding dwindles. This will depend on the state of the global economy, how quickly technology costs are coming down, and how quickly new, more effective technologies are being adopted.

So, the global energy landscape is undergoing significant transformations as countries worldwide implement strategic plans and enact legislation to combat climate change and transition towards cleaner and more sustainable energy systems. This is evident in recent developments such as the US Inflation Reduction Act, the European Commission's REPowerEU plan, and Japan's 6th Strategic Energy Plan.

Solar, wind, electric vehicles, carbon capture, and hydrogen all receive major boosts from the US Inflation Reduction Act, which was signed into law in August 2022. Nearly USD 370 billion in investments in energy security and climate change resilience are included in the STEPS under the new legislation.

The European Commission's REPowerEU plan outlines ways that energy efficiency, supply diversification, and quicker adoption of renewable energy can help the European Union become less dependent on Russian natural gas. The APS largely meets - and in some cases exceeds - many of the Fit for 55 plan's targets, enabling the EU and its member countries to fulfill their GHG reduction commitments and achieve crucial energy security goals. The REPowerEU Plan's primary goal of ending EU imports of Russian natural gas before 2030 in the APS will be achieved thanks to the acceleration of important measures, especially renewable energy in the power sector and fuel switching.

The STEPS were taken into consideration when Japan's 6th Strategic Energy Plan, which sets goals for 2030, was passed into law.

A portion of Japan's nuclear power fleet will be restarted as part of the country's Green Transformation plan, which also outlines a longer-term strategy for efficiency, renewable energy, storage, and advanced nuclear to help the country meet its 2050 goal of carbon neutrality.

In conclusion, the importance of scenarios for countries cannot be overstated. These frameworks provide a comprehensive approach to addressing energy challenges, combating climate change, driving economic growth, and promoting social development. By embracing these initiatives, countries can unlock numerous benefits and contribute to a more sustainable and prosperous future for both present and future generations.

2.4. Analysis of the state and development prospects of the energy market of Ukraine

The energy market of any country is a vital component of its economy and plays a critical role in shaping its development and sustainability. Access to reliable and affordable energy sources is fundamental for powering industries, fueling transportation, supporting households, driving overall economic growth, and ensuring the well-being of its citizens. In the face of relentless attacks by the terrorist state on vital infrastructure facilities, Ukraine not only tenaciously upholds its energy system but also perseveres in operating and exporting its own valuable energy resources.

However, before delving into the current situation, it is crucial to examine the previous state of affairs in Ukraine's energy market. That’s why firstly we observe the energy mix of Ukraine presented in figure 2.12 below.

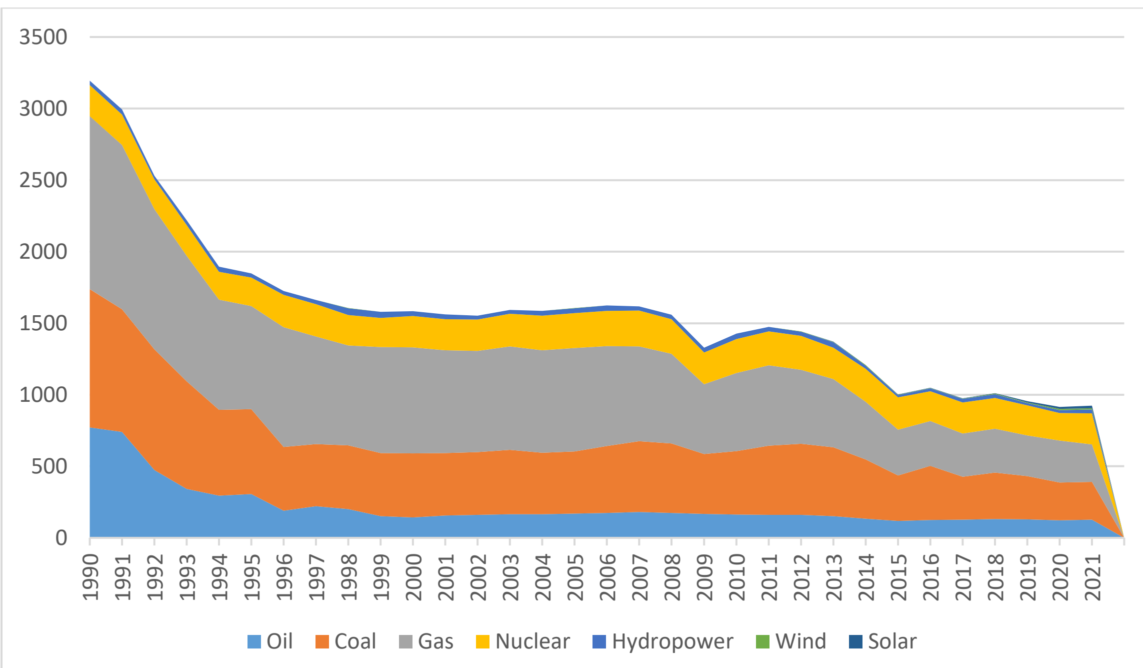


Figure 2.12 – The energy mix of Ukraine 1990-2021 (Twh)

Source: compiled by the author based on [14]

Historically, Ukraine has heavily relied on coal and natural gas for its energy needs. Coal has been a primary source for electricity generation and district heating, while natural gas has been used for heating as well, industrial processes, and electricity production. There were no issues with the exporting of the last one. Ukraine received gas from Russia under conditions that were often considered below market prices. This was due to historical and economic factors, as well as special arrangements between the two countries. However, it has changed. In the result, the share of gas declined, the government started to rely more on itself, increasing nuclear power and the role of renewables in the country's energy strategy. The figure 2.13 below demonstrates this transition trend.

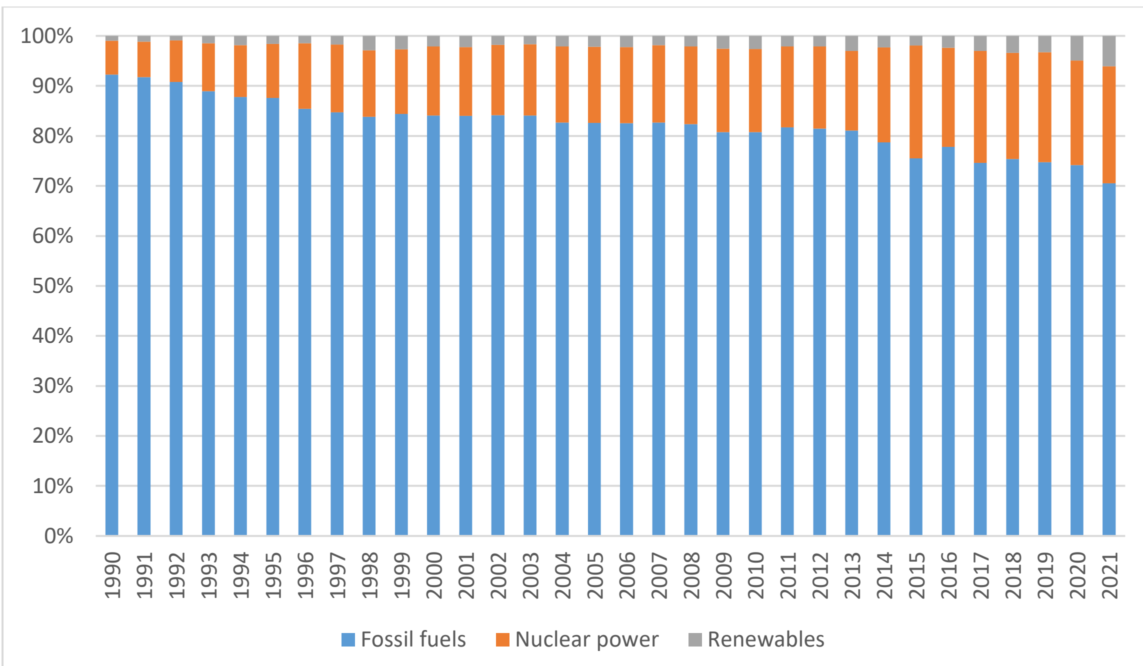


Figure 2.13 – Share of primary energy by type 1990-2021

Source: compiled by the author based on [14]

So, despite increased diversification efforts since 2014, Ukraine has continued to rely heavily on Russian energy sources to meet domestic demand. Russia frequently benefited from this dependence. After cutting off gas supplies to Ukraine in 2006 and again in the winter of 2008–09 over price and pipeline tariff disputes, Russia also aimed to lessen the significance of Ukraine to the security of the natural gas supply in Europe by setting up alternative pipeline routes to European consumers. In 2015, Ukraine decided to stop purchasing Russian gas. Instead, it was able to make contracts with its western neighbors for the gas it required, though these new agreements still relied on Russian transit volumes for their delivery in practice. Additionally, Ukraine continued to rely heavily on oil supplies from Russia and Belarus, which satisfied about 75% of domestic demand. But the situation has changed dramatically since February 24, 2022.

More generally, Russian attacks on vital energy infrastructure and other targets are compromising decision-makers ability to guarantee power and heat for civilians.

According to the World Energy Outlook 2022, 90% of the wind generation capacity, 30% of the thermal and solar generation capacity, and all oil refining capacity were either offline or destroyed by the middle of September 2022, respectively. These figures predate Russia's coordinated missile attacks against Ukraine in October, which included targets such as electricity grid infrastructure and other energy resources. Falling tax revenues, which are largely caused by deteriorating utility collection rates, are another significant problem, that the government faced.

For Ukraine, the winter of 2022–2023 was very challenging. Ukraine purchased as much gas as it can to fill its infrastructure for underground storage, but the amount that can be done has been constrained by high costs and tight budgets. Unless production facilities are attacked, domestic production levels are likely to reach 16–17 billion cubic meters (bcm). The amount of land occupied and the amount of infrastructure lost will determine how much less gas is needed than the 27 bcm consumed in 2021, possibly even as low as 18 bcm. The government was considering possible demand-restraining strategies.

Ukraine's electricity supply deficit remained at 20–30% from December 21, 2022, to January 24, 2023. It prompted the continuation of emergency measures, including rolling blackouts and restrictions on how much electricity could be used by homes and businesses. Employees in the energy sector made an effort to ensure that Ukrainians had access to electricity for at least ten hours each day, but the planned shutdowns weren't always carried out because Russian military forces continued to attack the Ukrainian power system. Due to damage to the power grid that drastically reduced its ability to transmit electricity to consumers, many power units of thermal power plants (TTPs) and combined heat and power plants (CHPs) were undergoing emergency repairs or were unable to operate.

Following Russia's attacks, Ukraine increased its use of coal-fired TTPs and hydropower plants to generate electricity because nuclear power plants (NPPs) were temporarily disconnected from the grid. The latter made extensive use of the water that was kept in reservoirs for emergencies. Many power units of thermal power plants and combined heat and power plants were undergoing emergency repairs or were unable to operate due to damage to the power grid, which significantly reduced its ability to transmit electricity to consumers.

To lessen the effects of significant attacks on energy infrastructure, the Ukrainian government continued to work in two directions: 1) increasing energy generation and distribution, and 2) implementing energy efficiency measures that can help people survive the winter and consume less energy. The government specifically approved the Regulation on the Special Import Conditions for Electricity during the heating season of 2022–2023. The Regulation lessens the application of new restrictions to consumers who use imported electricity, whose cost is significantly higher than the market price for electricity in Ukraine. Power generators, Starlink terminals, and restoration equipment were all exempt from value-added tax (VAT) and customs duties until May 2023.

Different co-financing programs were implemented by the local authorities in Ukraine to buy generators. The demand for power generators in Ukraine increased from roughly 6,000 units in January 2022 to 310,000 units in December 2022 as a result of these coping mechanisms and rolling blackouts. In total, 669.4 thousand generators were imported into Ukraine in 2022, including 643.8 thousand generators for businesses and 25,5 thousand generators for households.

Ukraine is working toward integrating with the energy infrastructure of Europe over the long term. The transmission service provider for Ukraine, Ukrenergo, made the decision the day before the invasion to cut its connection to the Integrated Power System, which connected Ukraine's power system to that of Russia and Belarus, and to conduct a test run in "island mode." The system had to operate in this mode for 21 days before it could be synchronized with the ENTSO-E power system of the European Union. This move towards integrating with the European energy infrastructure is a significant step for Ukraine in enhancing its energy security and aligning its systems with European standards.

In fact, this integration into another electrical system stored electricity as such in general. It doesn't mean that the energy system of Ukraine is not developed at all. Nevertheless, the recent events shacked the system once again as the enemy made more damage.

Nowadays, Zaporizhzhia nuclear power plant is occupied. According to the State Atomic Energy Regulatory Commission, two power units are in operation, two reactors are undergoing scheduled repairs and two are in reserve. Officially, the station is managed by the Ukrainian NEC "Energoatom". Ukrainian workers who manage the ZNPP remain there. The station itself is still connected to the Ukrainian power system. Nevertheless, its functioning is under question. Recently Kakhovka Hydroelectric Power Plant the sixth and last stage of the Dnipro cascade of hydroelectric power plants was destroyed. The primary purposes of the dam were hydroelectric power generation and irrigation. But also the water from Kakhovka Reservoir supplies water for cooling the Zaporizhzhia Nuclear Power Plant. If the level of water will be not enough for cooling it stops functioning. What will stop electricity production? It is also unclear how it will influence the Hydroelectric system.

The government has created a detailed recovery and reconstruction plan with a focus on increased energy security and self-sufficiency. The Verkhovna Rada of Ukraine signed the relevant law on the approval of the Energy Strategy of Ukraine for the period up to 2050 dated April 21, 2023, which provides for deep modernization and decentralization of the domestic power grid [78]. The fact that Ukraine is a prospective member of the European Union supports its desire to develop a "future-proof" energy system.

Rebuilding Ukraine's energy sector will be expensive; according to preliminary government estimates, it will cost $128 billion between now and 2032. This estimate is speculative given the ongoing hostilities, but the rebuilding efforts will give Ukraine's energy sector a chance to envision a new, cleaner future.

The plan aims to increase investment in renewable hydrogen and biogas, boost the proportion of renewable energy sources, and rebuild cities with energy-efficient infrastructure. Striking a balance between these long-term goals and necessary short-term repairs, such as combined heat and power plants that were severely damaged by the Russian bombing, will be incredibly challenging.

CONCLUSIONS

In the bachelor thesis, the main features of the functioning and development scenarios of the predominantly global energy market, as well as the Ukrainian one, were considered and identified.

The global energy market is a complex and dynamic system that plays a pivotal role in shaping the economic, social, and environmental landscape of our world. Energy sources, as the fundamental building blocks of this market, form the basis for meeting the ever-increasing demand for power across various sectors. At the same time, they are inherently diverse, encompassing a wide range of options such as fossil fuels, renewable sources, and nuclear energy, each with distinct characteristics, availability, and environmental impacts.

This diversity highlights the need for a comprehensive understanding of these resources to effectively navigate the complexities of the world energy market and ensure a sustainable and resilient energy future. On the contrary, an uneven redistribution of resources across regions and countries leads to disparities in energy access, economic development, and geopolitical dynamics. All these factors affect the economic development of the state, which uses energy for industries, transportation, buildings, and other sectors of daily life.

Moreover, pricing mechanisms play a crucial role in the energy market, influencing resource allocation, investment decisions, and market competition. The establishment of fair and transparent pricing mechanisms is essential for achieving efficiency, promoting innovation, and balancing the interests of energy producers, consumers, and the environment.

But not only the price play nowadays a crucial role as industrialization and population go up and climate changes. Any country needs to adopt its strategy for minimizing both dependences on fuels from energy supply countries as well as create its scenario in with accordance to the following scenarios: Net Zero Emissions by 2050

Scenario (NZE), the Announced Pledges Scenario (APS), the Stated Policies Scenario (STEPS), and the Sustainable Development Scenario (SDS).

For Ukraine, as with any country, the choice of development scenario depends on various factors such as available resources, technological capabilities, policy priorities, and national circumstances. Ukraine has significant potential for renewable energy, particularly in solar and wind power, which can contribute to achieving the goals outlined in the different scenarios. Additionally, diversifying the energy mix, enhancing energy efficiency, and promoting sustainable development can help reduce dependence on energy imports and enhance energy security.

Indeed, the current geopolitical situation and the Russian invasion have added a new dimension of importance to Ukraine's energy development and security. The invasion has not only had severe implications for Ukraine's economy and existence but has also disrupted regional energy flows and raised concerns about energy security in the broader context. One key response to this situation has been the policy adopted by partner countries of ending EU imports of Russian natural gas before 2030. As a result, Russia will be unable to use its energy as leverage.

In general, the situation will change in the next decades in the energy market with digitalization. As a result, new supply chains will emerge with the development of renewable energy sources. At the same time, fossil fuels will not disappear and will be used but not in such an amount as it was before.

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APPENDIXES

Appendix A

Table A.1 - Population assumptions by region

	Compound average annual growth rate			Population *(million)*			Urbanization *(Share of population)*		
	2000-21	2020-2030	2030-2050	2020	2030	2050	2020	2030	2050
North America	0.9%	0.7%	0.5%	496	526	578	82%	84%	89%
United States	0.8%	0.5%	0.5%	330	349	379	83%	85%	89%
C & S America	1.1%	0.7%	0.5%	522	562	603	81%	84%	88%
Brazil	1.0%	0.5%	0.2%	213	224	229	87%	89%	92%
Europe	0.3%	0.0%	-0.1%	700	701	690	76%	78%	84%
European Union	0.2%	-0,1%	-0.2%	451	448	429	75%	77%	84%
Africa	2.5%	2.3%	2.1%	1372	1686	2487	44%	48%	59%
Middle East	2.1%	1.5%	1.1%	252	289	348	73%	76%	81%
Eurasia	0.4%	0.3%	0.2%	144	142	134	75%	77%	73%
Asia Pacific	1.0%	0.6%	0.4%	4250	4496	4734	50%	55%	65%
China	0.5%	0.2%	-0.1%	1423	1443	1383	63%	71%	80%
India	1.3%	0.8%	0.6%	1393	1504	1639	35%	40%	53%
Japan	-0.1%	-0.5%	-0.6%	125	120	105	92%	93%	95%
Southeast Asia	1.2%	0.8%	0.6%	674	726	792	51%	56%	66%
World	1.2%	0.9%	0.7%	7835	8507	9692	57%	60%	68%

Source: compiled by the author based on [6]

Table A.2 – Industry consumption by region

	Historical			Stated Policies		Announced Pledges	
	2010	2020	2021	2030	2050	2030	2050
World	143.2	160.4	166.7	189.4	208.8	178.1	173.7
North America	17.9	18.3	18.6	20.9	22.1	20.0	18.4
United States	14.2	14.5	14.7	16.2	16.8	15.6	13.8
C & S America	7.2	6.7	7.0	8.2	9.8	7.7	8.2
Brazil	4.0	3.8	4.0	4.5	5.1	4.2	4.3
Europe	19.6	18.4	18.9	18.9	17.7	18.1	15.5
European Union	14.3	13.4	13.9	13.7	11.7	13.1	10.3
Africa	3.9	4.0	4.2	6.1	10.3	5.9	8.7
Middle East	7.8	9.7	10.2	12.7	15.3	11.9	12.9
Eurasia	8.4	9.3	9.5	9.3	10.3	9.0	9.3
Asia Pacific	78.4	94.1	98.3	113.3	123.4	105.5	100.7
China	49.4	59.4	61.5	66.7	62.4	62.4	51.2
India	7.9	11.5	12.4	18.1	27.5	16.1	21.6
Japan	6.1	5.0	5.3	5.1	4.5	4.8	3.8
Southeast Asia	6.2	8.4	8.8	11.4	15.2	10.7	12.6

Source: compiled by the author based on [6]

Table A.3 – Transport consumption by region

	Historical			Stated Policies		Announced Pledges	
	2010	2020	2021	2030	2050	2030	2050
World	101.7	105.0	113.4	129.8	147.0	123.7	112.5
North America	29.6	26.9	29.1	28.4	24.9	26.7	18.0
United States	25.0	23.0	25.1	24.0	20.4	22.5	15.0
C & S America	6.1	6.5	7.2	8.3	10.6	7.9	7.3
Brazil	2.9	3.4	3.6	4.0	4.6	3.8	3.4
Europe	15.6	14.4	15.3	14.5	11.7	13.6	8.4
European Union	11.7	10.6	11.1	10.0	7.5	9.4	5.5
Africa	3.7	4.7	5.0	6.3	11.3	6.3	10.1
Middle East	4.9	5.3	5.7	6.4	8.9	6.1	6.9
Eurasia	4.7	4.8	5.2	5.4	5.8	5.2	5.1
Asia Pacific	22.1	30.1	32.0	40.3	45.5	38.4	33.7
China	8.3	13.6	15.0	16.9	15.3	16.2	11.8
India	2.7	3.9	4.2	6.8	10.3	6.5	7.5
Japan	3.3	2.6	2.5	2.2	1.7	2.1	1.1
Southeast Asia	3.7	5.3	5.4	8.4	9.9	7.8	6.9

Source: compiled by the author based on [6]

Table A.4 – Buildings consumption

	Historical			Stated Policies		Announced Pledges	
	2010	2020	2021	2030	2050	2030	2050
World	116.8	127.6	132.4	136.5	158.3	121.3	122.0
North America	23.7	23.8		23.3	22.6	21.3	16.4
United States	20.5	20.3	20.8	19.7	18.4	18.2	13.6
C & S America	4.4	4.8	4.9	5.4	7.1	4.9	5.2
Brazil	1.4	1.7	1.7	1.9	2.9	1.7	2.1
Europe	24.3	21.2	22.2	20.3	19.0	18.4	13.3
European Union	17.6	15.1	15.9	14.4	12.7	12.8	8.6
Africa	12.5	15.8	16.2	18.3	24.0	14.2	16.5
Middle East	5.3	6.5	6.7	8.9	14.3	8.4	13.1
Eurasia	8.4	9.9	10.5	10.2	10.8	9.8	9.8
Asia Pacific	38.2	45.5	47.7	50.0	60.6	44.3	47.8
China	15.6	22.2	23.7	24.4	28.8	23.6	24.2
India	7.0	8.1	8.5	9.2	12.2	6.6	7.8
Japan	4.3	3.8	3.9	3.5	3.0	3.2	2.2
Southeast Asia	5.3	4.5	4.5	5.4	8.0	4.6	6.3

Source: compiled by the author based on [6]

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