# Czech University of Life Sciences Prague

**Faculty of Economics and Management**
**Department of World Economy**

## Master's Thesis

# Transition of resource-based economies to renewable energy sources: the case of Kazakhstan

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# CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

# DIPLOMA THESIS ASSIGNMENT

Bc. Zhuldyz Igilik

World Economy

Thesis title

**Transition of resource-based economies to renewable energy sources: the case of Kazakhstan.**

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**Objectives of thesis**

The main objective of this paper is to study the potential of renewable resources in Kazakhstan and the impact of energy transition on the country's economy.

**Methodology**

The transition to a renewable energy supply is a challenging goal for the whole world. Even in countries with good availability of renewable energy, factors such as policies and regulations, the poor state of technologies, and high dependence on natural resources can hinder the transition. All of these factors are present in the case of Kazakhstan, with its energy-intensive, fossil fuel-dominated economy.

The databases of the World Bank and "Our World in Data" are used to obtain information on the share of energy produced from renewable sources and the share of energy produced from fossil sources, as well as the amounts of energy produced from various sources in Kazakhstan. Industry statistics for oil, gas, coal, and alternative energy come from Enerdata, while information on policies and future projects comes from the Asian Development Bank, the Kazakhstan 2050 Strategy, and the International Renewable Energy Agency (IRENA)

The resulting secondary information is used for quantitative analysis.

**The proposed extent of the thesis**

60 – 80 pages

**Keywords**

economics, renewable energy, fossil fuel, natural resource dependence, energy transition, Kazakhstan, wind power, solar power.

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**Recommended information sources**

Amirov A., Kozhukhova M., Koshebaeva G., Biryukov V., and Zhiyenbayev M., 2018. Economic and energy security of the Republic of Kazakhstan. International Journal of Energy Economics and Policy(2018)

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**Expected date of thesis defence**

2022/23 SS – FEM

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Electronic approval: 21. 11. 2022

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**Declaration**

I declare that I have worked on my master's thesis titled "Transition of resource-based economies to renewable energy sources: the case of Kazakhstan" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the master's thesis, I declare that the thesis does not break any copyrights.

In Prague on 31.03.2023 ___________________________ Zhuldyz Igilik

**Acknowledgement**

I want to show my appreciation to my supervisor, Doc. Ing. Vladimír Krepl, CSc., for his assistance, direction, and valuable insights throughout my work. I also thank my family for their constant support.

# Transition of resource-based economies to renewable energy sources: the case of Kazakhstan


## Abstract

This thesis explores the transition of resource-based economies to renewable energy sources, with a specific case study of Kazakhstan.

The research is to comprehend the difficulties and possibilities linked to the changeover, as well as the policies and measures implemented to support it. The research finds that Kazakhstan, as a resource-based economy heavily dependent on fossil fuels, faces significant challenges in transitioning to renewable energy.

The thesis explores the current state of the country's energy sector, including its dependence on fossil fuels and the potential for growth in renewable energy.

The paper emphasizes the crucial role of government policies, incentives, and international cooperation in supporting the transition to renewable energy. The study concludes that while the transition to renewable energy in Kazakhstan is ongoing, it is essential for the country to continue investing in and promoting the development of renewable energy sources to achieve a sustainable energy system.

This paper aims to investigate the potential of renewable resources in Kazakhstan and the impact of transitioning to these resources on the country's economy.

Overall, the study provides an overview of the current state of the energy sector in Kazakhstan and the potential for transition to renewable energy sources.



**Keywords:** renewable energy, fossil fuel, natural resource dependence, energy transition, Kazakhstan, wind power, solar power.

# Přechod ekonomik založených na zdrojích k obnovitelným zdrojům energie: případ Kazachstánu


## Abstrakt

Tato práce zkoumá přechod ekonomik založených na zdrojích k obnovitelným zdrojům energie se specifickou případovou studií Kazachstánu.

Výzkum si klade za cíl porozumět výzvám a příležitostem spojeným s přechodem, jakož i politikám a opatřením, která byla zavedena na jeho podporu. Výzkum zjistil, že Kazachstán jako ekonomika založená na zdrojích silně závislá na fosilních palivech čelí významným výzvám při přechodu na obnovitelné zdroje energie.

Práce se zabývá současným stavem energetického sektoru země, včetně jeho závislosti na fosilních palivech a potenciálem růstu obnovitelných zdrojů energie.

Příspěvek zdůrazňuje klíčovou roli vládních politik, pobídek a mezinárodní spolupráce při podpoře přechodu na obnovitelné zdroje energie. Studie dochází k závěru, že zatímco v Kazachstánu probíhá přechod na obnovitelné zdroje energie, je nezbytné, aby tato země pokračovala v investicích a podpoře rozvoje obnovitelných zdrojů energie, aby dosáhla udržitelného energetického systému.

Tento článek si klade za cíl prozkoumat potenciál obnovitelných zdrojů v Kazachstánu a dopad přechodu na tyto zdroje na ekonomiku země.

Celkově studie poskytuje přehled o současném stavu energetického sektoru v Kazachstánu a potenciálu přechodu na obnovitelné zdroje energie.



**Klíčová slova:** obnovitelná energie, fosilní paliva, závislost na přírodních zdrojích, energetická transformace, Kazachstán, větrná energie, solární energie.

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## List of the abbreviations

ADB – Asian Development Bank

CAREC - Central Asia Regional Economic Cooperation

EAEU - Eurasian Economic Union

EBRD - European Bank for Reconstruction and Development

EDB – Eurasian Development Bank

EOR - Enhanced Oil Recovery

EU - European Union

FDI- Foreign Direct Investment

g/l – gram per liter

GEF - Global Environment Facility

GDP - Growth Domestic Product

GW – Gigawatt

HAWT - Horizontal axis wind turbines

IAEA – International Atomic Energy Agency

IEA - International Energy Agency

IRENA - International Renewable Energy Agency

KEGOC - Kazakhstan Electricity Grid Operating Company

KOREM - Kazakhstan Electricity and Power Market Operator

Mtoe - Million tonnes of oil equivalent

SDG – sustainable development goals

W – watt

kWh – kilowatt-hour

m3 – cubic meter

MSW – municipal solid waste

MW – megawatt

°C – degree Celsius

m2 – square meter

EU – European Union

UNECE – United Nations Economic Commission for Europe

UN – United Nations

PV – photovoltaic

RES – renewable energy sources

UNDP - United Nations Development Program

UNESCAP - United Nations Economic and Social Commission for Asia and the Pacific

USAID - United States Agency for International Development

USD - United States dollar

# 1 Introduction

The transition of resource-based economies to renewable energy sources involves moving away from traditional sources of power generation that rely heavily on non-renewable resources, such as fossil fuels, to cleaner and more sustainable forms of energy, such as solar, wind, and hydropower. This transition can be challenging for resource-based economies as they may have to re-structure their economies and retrain workers, to adapt to new industries. However, the benefits of the transition include reduced dependence on non-renewable resources, lower carbon emissions, and a more sustainable future. The transition to renewable energy sources has become a global priority in recent years as countries strive to meet their Paris Agreement commitments to reduce greenhouse gas emissions and address the urgent issue of climate change. The urgency to shift quickly towards renewable energy sources is higher than it has ever been. The combustion of non-renewable resources like coal, oil, and natural gas is contributing to the phenomenon of climate change. This, in turn, is having a detrimental impact on ecosystems, economies, and societies worldwide, leading to adverse outcomes. Additionally, renewable energy sources are becoming increasingly cost-competitive with traditional sources, making the transition more financially viable. The transition can be supported through government policies such as tax incentives, subsidies, and regulations that encourage the growth and utilization of sustainable energy sources.

Wind and solar power generation have been encouraged by ambitious environmental policies in the European Union, the USA, China, India, Japan, and Australia. The drastic drop in the costs of developing these technologies in recent years has enabled developing countries to increase their renewable energy production capacities [1].

Renewable energies also gained popularity for their low carbon dioxide emissions compared to fossil fuels. For example, a gigawatt-hour of electricity generated by wind power releases 4 tonnes of carbon dioxide; still, the same output generated in a coal-based power plant produces 820 tonnes of carbon dioxide [2].

Kazakhstan, a country rich in natural resources, has traditionally relied heavily on fossil fuels for its energy needs. However, the country has recently demonstrated a strong commitment to transitioning to renewable energy sources, with the purpose of achieving a 50% share of renewable energy in the overall energy mix by 2050 [3].

This ambitious target, combined with the country's vast natural resources, presents a unique opportunity to explore the factors driving the transition to renewable energy in a resource-based economy. Kazakhstan has a relatively small but growing renewable energy sector with low population density. The country has significant potential for renewable energy production, particularly in the areas of solar and wind power, due to its vast open spaces and high levels of sunlight and wind.

To achieve the target, the government has implemented a number of policies and initiatives to encourage the development of renewable energy, including tax incentives and subsidies for renewable energy projects.

The UNDP estimates that the potential for wind energy alone exceeds KZ current energy consumption by ten-fold [4].

Overall, Kazakhstan has the potential to become a major player in the renewable energy market in the future, but much still needs to be done to develop the sector and attract more investment.

The thesis will provide valuable insights into the strategies and policies that can help resource-based economies successfully transition to renewable energy sources while also highlighting the unique challenges and opportunities that such economies face in this process.

## 1.1 Research Purpose

The aim is to examine the transition of resource-based economies, specifically Kazakhstan, to renewable energy sources and to analyze the economic, political, and social factors that influence this transition. This paper aims to understand the challenges and opportunities of transitioning away from a reliance on fossil fuels and to assess the potential for renewable energy to play a significant role in Kazakhstan's energy mix. Furthermore, this research aims to provide policy recommendations for a successful transition toward Kazakhstan's more sustainable energy system.

## 1.2 Research Question

What are the economic, political and social factors influencing the transition of Kazakhstan, a resource-based economy, to renewable energy sources and what are the challenges and opportunities associated with this transition?

# 2 Literature review

## 2.1 Energy Sources

Energy sources are forms of potential energy that can be used to perform work [5].
*Energy sources* are materials or processes that can be used to generate electricity or power mechanical devices. They can be classified into two main categories: non-renewable and renewable.
Non-renewable energy sources include fossil fuels such as coal, oil, and natural gas. These energy sources are finite and take millions of years to form; they cannot be replenished once we use them.
Conversely, sources of renewable energy are naturally replenished and can be utilized without limit. Examples of renewable energy include solar and wind power, as well as other forms like hydroelectric, geothermal, and biomass energy. These sources of energy are considered more sustainable because they do not produce greenhouse gas emissions and do not deplete natural resources.

### *2.1.1 Non-renewable energy*

Non-renewable energy, also called conventional energy, is energy that is generated from fossil fuels such as coal, oil, and natural gas. The reason why these energy sources are classified as non-renewable is due to their finite nature. Over time, their availability will decrease until they are completely exhausted[5]. Non-renewable energy sources are often considered more polluting and harmful to the environment than renewable sources. Examples of non-renewable energy sources include coal-fired power plants and oil and gas drilling.

### *Coal*

Coal is a type of fossil fuel that originates from plant matter that has been compressed between rock layers and transformed by heat and pressure throughout millions of years, resulting in the formation of coal deposits [6].

Coal primarily consists of carbon, with varying amounts of other elements such as hydrogen, sulfur, oxygen, and nitrogen. Coal is primarily utilized as a fuel source. Though it has been recognized and utilized for centuries, its usage was limited until the onset of the Industrial Revolution. With the development of the steam engine, the demand for coal grew. In 2020, coal accounted for about 25% of the world's primary energy and over one-third of its electricity generation [7].

The use of coal is detrimental to the environment and is the largest human-caused source of carbon dioxide, which contributes to climate change.

In 2020, burning coal resulted in the emission of 14 billion tonnes of carbon dioxide [8], which is 40% of total fossil fuel emissions and more than a quarter of the total worldwide emissions of greenhouse gases [9]. As part of the global transition to cleaner energy sources, many countries have decreased or ended their use of coal power.

The United Nations asked governments to stop constructing new coal plants by 2020 [11]. The global consumption of coal reached its peak in 2013 [10].

In order to attain the objective set forth by the Paris Agreement is to reduce in worldwide temperatures to a level that is less than 2 degrees Celsius above pre-industrial levels[12], coal use needs to be reduced by half from 2020 to 2030, and phasing out coal is part of the Glasgow Climate Pact[13]. Emission intensity is a measure of the number of greenhouse gases emitted in relation to the amount of electricity generated.

Emission intensity measures the number of greenhouse gases emitted in relation to the amount of electricity generated.

Coal power stations have a high emission intensity, releasing around 1000 grams of CO2 per kWh generated [21].

The emission intensity of coal can vary depending on the type and technology used, and in some countries, it can exceed 1200 grams per kWh. The primary impact of coal utilization is the emission of carbon dioxide, a type of greenhouse gas contributing to climate change. Coal-fired power generation releases around a ton of carbon dioxide per MW, which is double the amount released by natural gas-fired power plants.

In 2013, the chief of the UN climate agency recommended that most of the world's coal reserves should not be utilized in order to prevent catastrophic global warming. To keep global warming below 1.5 or 2 degrees Celsius, hundreds or possibly thousands of coal-fired power plants must be retired early [22].

### *Natural gas*

*Natural gas* is an energy source derived from fossils. It comprises various compounds, with methane being the primary component. Methane is composed of a single carbon atom and four hydrogen atoms (CH4). Natural gas includes NGLs, hydrocarbon gas liquids, and non hydrocarbon gases like carbon dioxide and water vapor, albeit in smaller quantities [14].

It is formed over millions of years from the decomposition of organic matter and is typically found in underground rock formations. It is often extracted through drilling, and it is utilized as an energy source for heating, electricity production, and in particular industrial procedures.

Energy is derived from natural gas for various purposes. It is a relatively clean-burning fossil fuel, meaning that in comparison to other fossil fuels like coal and oil, natural gas results in lower emissions. It is widely available and can be found in many parts of the world. It is relatively inexpensive to extract and transport. It is considered more stable in terms of price and supply than oil, which is subject to price fluctuations due to political instability or other factors.

Although natural gas is categorized as a fossil fuel that burns relatively cleaner than coal and oil, it is not considered to be a clean energy source. The primary reason for this is that methane is the primary component of natural gas, which is a powerful greenhouse gas that is responsible for a significant portion of human-caused global warming[15].

When natural gas is extracted, processed, transported, and used, it can release methane into the atmosphere. Additionally, natural gas power plants are associated with emissions of nitrogen oxides, carbon dioxide, and other pollutants.

Another issue is the process of hydraulic fracturing or fracking, which is a method used to extract natural gas from shale rock formations. This process can lead to water and air pollution and damage to the local environment[16].

Moreover, natural gas infrastructure like pipelines and storage facilities can have negative impacts on wildlife and local communities.

Moreover, natural gas infrastructure like pipelines and storage facilities can negatively impact wildlife and local communities.

***Crude oil***

Crude oil is made up of liquid hydrocarbons that are quite volatile and primarily composed of hydrogen and carbon, though there are also minor quantities of sulfur, nitrogen, and oxygen present. The combination of these elements forms a diverse array of intricate molecular structures, some of which may be difficult to identify. Despite these variances, the majority of crude oil typically contains between 82 to 87 % carbon by weight and 12 to 15 percent hydrogen by weight [23].

*Oil drilling* is the primary method used to extract petroleum. This process is preceded by an examination of the structure of the earth's surface, an analysis of sedimentary basins, and an evaluation of the characteristics of the reservoir. Innovations in technology have allowed for the extraction of oil from non-traditional sources, including but not limited to oil sands and oil shale. The use and extraction of petroleum have had numerous negative impacts on the environment and society. The processes of extracting, refining, and burning petroleum result in the release of large amounts of greenhouse gases, making it a significant contributor to climate change.

Additionally, oil spills and air and water pollution also have negative environmental effects. Some of these effects can also lead to health problems for humans.

Furthermore, petroleum production has been a source of conflicts, both in state-led wars and other conflicts.

It is projected that petroleum production will peak before 2035 due to the efforts to reduce dependency on petroleum as part of the transition toward renewable energy and electrification.

### *2.1.2 Renewable energy*

Renewable energy is derived from a source that is considered to have an indefinite lifespan, thus rendering it a sustainable source of energy. It is natural and self-replenishing and usually has a low- or zero-carbon footprint [17].

Renewable energy is gaining significance, particularly as the world confronts the predicaments of climate change, water and air pollution, and energy security.

The utilization of renewable energy sources can assist in reducing the emission of greenhouse gases and air pollution. In addition, it can promote energy security by reducing dependence on imported non-renewable resources. There is a range of renewable energy sources that are currently in use or under development, including solar, wind, hydroelectric, geothermal, and bioenergy. Each of these forms of energy has its unique advantages and challenges, and the most appropriate form of renewable energy will depend on the specific context in which it is being used.

In addition to being a cleaner and more sustainable alternative to non-renewable energy, renewable energy can also provide economic benefits, such as job creation and economic growth.

Many countries worldwide have set ambitious targets for the development and deployment of renewable energy to meet their energy needs while reducing their environmental impact.

***Solar energy***

Solar energy has the potential to meet energy demands in terms of sustainability and quality. The solar energy that falls on Earth's continents is more than 200 times greater than the annual total commercial power currently consumed by humans [18].

If effective support policies are put in place in a wide number of countries during this decade, solar energy in its various forms – solar heat, solar photovoltaics, solar thermal electricity, solar fuels – can make considerable contributions to solving some of the most urgent problems the world now faces. At present, the world is confronted with challenges such as climate change, the need for energy security, and ensuring universal access to modern energy services[19]. Photovoltaic cells or solar thermal collectors are typically used to convert the energy from the sun into usable forms of energy.

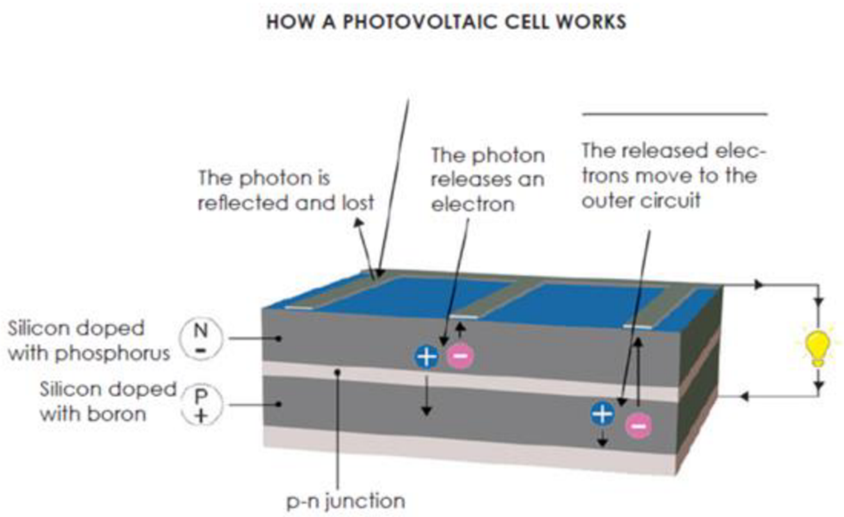


*Figure 1. Photovaltaic cell [20]*

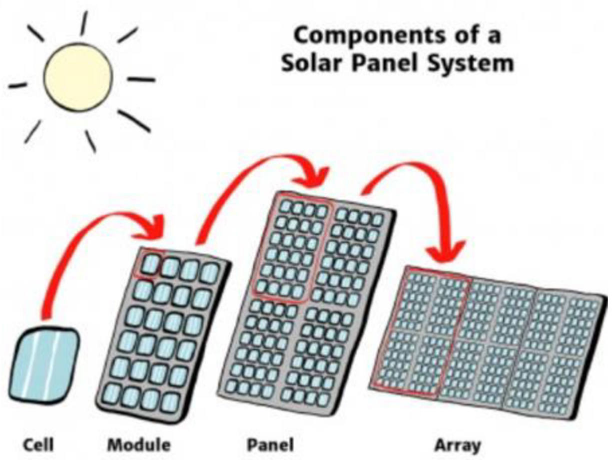


*Figure 2. Components of Solar Panel System [20]*

Solar thermal energy is utilized for diverse objectives, such as heating water and air, building interiors, and electricity generation. Two broad categories of solar heating systems exist passive and active systems.

Passive solar space heating refers to the process of sunlight entering a building through its windows and raising the interior temperature. Building designs that maximize passive solar heating in the northern hemisphere typically involve south-facing windows that allow sunlight to fall on heat-absorbing walls or floors within the building. Building materials absorb solar energy, heating the interior via natural radiation and convection. During the summer, window overhangs or shades are employed to prevent sunlight from entering the windows and maintain an excellent indoor environment.

Active solar heating systems employ a mechanism that transfers heated air or fluid to either the interior of a building or to a heat storage system, where the stored heat can be accessed as required. This is achieved by using fans or pumps to circulate the fluid through collectors that heat it before being moved to the building's interior or heat storage system. The fluid is then returned to the collector to be reheated. In the case of active solar water heating systems, a tank is typically used to store solar-heated water.

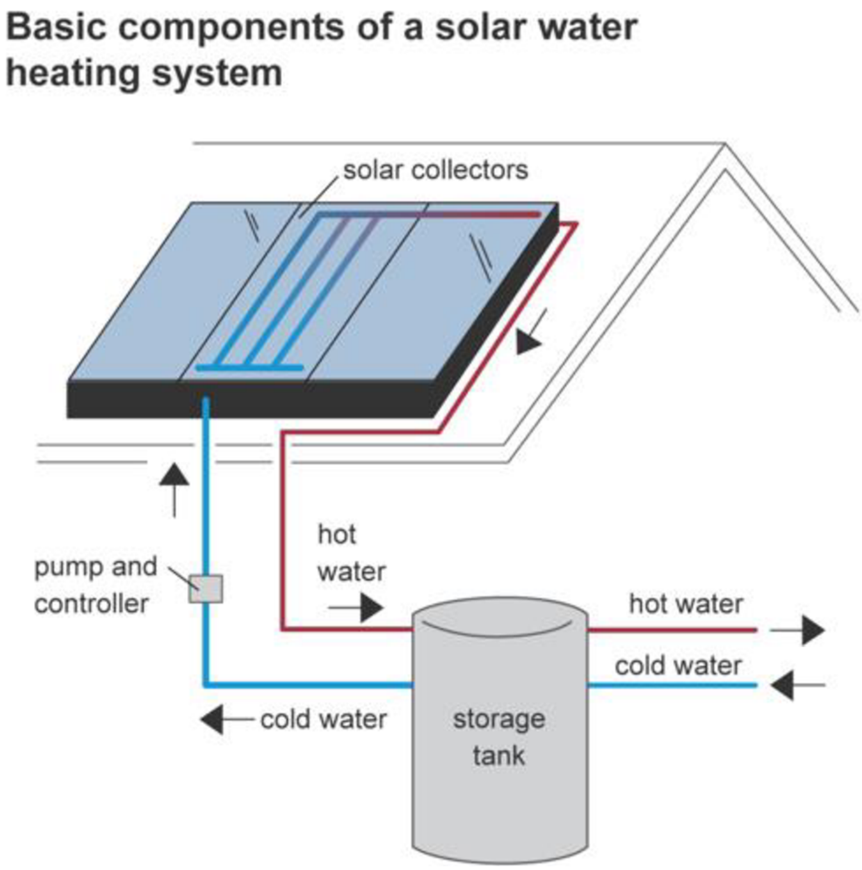


*Figure 3.Basic components of a solar water heating system [20]*

### *Wind power*

In recent years, wind energy has been the fastest-growing form of renewable energy globally, and its capacity is increasing. Electricity is produced from wind by converting the energy of moving air into electrical energy. In contemporary wind turbines, the rotor blades are rotated by the wind, converting kinetic energy to rotational energy. The rotational energy is then transmitted via a shaft to the generator, where it is transformed into electrical energy [24]. Although wind speeds differ greatly depending on location, the potential for wind energy production worldwide is greater than the current global electricity production, and many regions have the potential to install large wind energy projects.

While many regions around the world experience significant wind speeds, the most favorable locations for wind power generation may often be situated in remote areas. In such instances, offshore wind power presents an up-and-coming option[24].

Offshore wind potential refers to the potential for generating electricity from wind turbines located in the ocean or sea. This type of wind energy has several advantages over onshore wind energy, including more robust and consistent winds, larger land areas available for turbine placement, and less visual impact.

Onshore wind potential refers to generating electricity from wind turbines located on land. This type of wind energy is more widely used than offshore wind energy, primarily due to lower costs for installation and maintenance. However, onshore wind energy can be impacted by local wind patterns and terrain, which can affect the consistency and strength of the wind. Additionally, onshore wind turbines can have a more significant visual impact on the surrounding landscape.

### *Hydropower*

Hydropower is a form of energy that utilizes the force of water moving from high to low elevations. It can be generated from different sources, such as reservoirs and rivers. Hydropower plants in reservoirs use the stored water to generate electricity, while those in rivers use the natural flow of water to generate power. Hydropower reservoirs serve multiple purposes, such as supplying drinking water, irrigation, flood and drought control, navigation, and energy production. As the most significant renewable energy source in the electricity sector, hydropower depends on relatively stable precipitation patterns and can be adversely affected by droughts caused by climate change or modifications to ecosystems that impact precipitation patterns[25].

### *Ocean Energy*

Ocean energy refers to a type of sustainable energy derived from the movement of tides, waves, currents, and temperature differences in the ocean. There are several different technologies that can be used to capture ocean energy, including wave energy converters, tidal energy converters, ocean current energy converters, and ocean thermal energy converters.

These technologies are currently in their nascent stages of advancement but have the potential to provide an effective source of renewable energy in the future.

Ocean energy technologies are currently in their early stage, with various experimental wave and tidal current devices being investigated. However, the theoretical potential for ocean energy easily exceeds present human energy requirements[26]

### *Bioenergy*

Bioenergy is generated from organic matter known as biomass, which includes materials such as wood, charcoal, dung, and agricultural crops. These sources can be used to produce heat and power, as well as liquid biofuels.

Typically, biomass is utilized in rural regions for activities like cooking, lighting, and heating, especially by low-income populations in developing nations. Presently, modern bioenergy systems incorporate dedicated crops or trees, residues from forestry and agriculture, and a range of organic waste streams [27].

Generating energy from biomass releases greenhouse gases, but at a lower rate compared to using fossil fuels such as coal, oil, or gas.

Nevertheless, the use of bioenergy should be limited due to the potentially harmful environmental effects that can result from significant increases in forest and bioenergy crops and the resultant deforestation and changes in land use.

Biogas facilities have the advantage of being able to operate 24/7, almost anywhere that has biomass or organic waste.

### *Geothermal energy*

Geothermal energy harnesses the readily available heat energy from the Earth's interior through wells or other methods to extract heat from geothermal reservoirs [35]

Reservoirs with naturally high temperatures and permeability are referred to as hydrothermal reservoirs, while reservoirs artificially made hot through hydraulic stimulation are called enhanced geothermal systems [36].

After being extracted from geothermal reservoirs, fluids with different temperatures can be utilized to create electricity. The technology for producing electricity from hydrothermal reservoirs is established and dependable and has been in operation for over a century [37].

### *2.1.3 Leading countries of renewable energy capacity*

Table 1. The proportion of renewable energy sources in total electricity production in 2021

| *Unit* | *Breakdown by country ,% (Highest)* |
|---|---|
| Norway | 99 |
| New Zeland | 80.9 |
| Brazil | 78.4 |
| Colombia | 74.5 |
| Canada | 68 |
| Sweden | 67 |
| Portugal | 65.5 |
| Chile | 47.2 |
| Spain | 47.1 |
| Romania | 44.4 |
| Germany | 41.5 |
| Italy | 41.4 |

*Table compiled by the author based on Enerdata Source [41]*

Table 2. The proportion of renewable energy sources in total electricity production in 2021

| *Unit* | *Breakdown by country ,% (Lowest)* |
| --- | --- |
| Saudi Arabia | 0.1 |
| Kuwait | 0.2 |
| Algeria | 0.8 |
| Iran | 2.3 |
| United Arab Emirates | 4 |
| Taiwan | 6.5 |
| South Korea | 8.6 |
| Uzbekistan | 9.1 |
| South Africa | 9.2 |
| Egypt | 9.7 |
| Kazakhstan | 10.9 |
| Czechia | 13.9 |

*Table compiled by the author based on Enerdata Source [41]*

Europe, Asia (particularly China), North America (led by the US), and Australia are the regions that have made the most progress in renewable energy development. These areas prioritize solar and wind power as they work towards decreasing their reliance on non-renewable resources and combatting the effects of climate change.

### *2.1.4 Nuclear power*

Nuclear energy is generated by harnessing the power of the nucleus of an atom, which is made up of protons and neutrons. This energy can be generated through the process of fission, where the nuclei of atoms are split into smaller parts, or fusion, where the nuclei of atoms are fused together [28].

Nuclear power plants use nuclear fission, a process that involves dividing the nucleus of an atom, to create heat that is utilized to generate steam, which in turn powers turbines that create electricity. As an example, the nucleus of a uranium - 235 atoms can split into smaller nuclei, such as a barium and krypton nucleus, as well as two or three neutrons when it is struck by a neutron[28].

Whether nuclear energy can be considered "clean" is a matter of debate. Nuclear power generation itself does not produce greenhouse gas emissions, making it a relatively low-carbon energy source.
Nonetheless, the complete nuclear fuel cycle, encompassing activities such as uranium extraction and processing, construction and decommissioning of nuclear power plants, and nuclear waste management, entail environmental consequences. The purpose of the NEST (Nuclear Energy System Test) concept is to improve the safety, efficiency, and sustainability of nuclear power generation. It is a theoretically advanced nuclear energy system that would integrate multiple technologies and concepts to overcome the challenges that traditional nuclear power plants face.
The goal of NEST is to create a more efficient, safer, and cleaner energy system. The specific details of what NEST would entail have not yet been fully established, as it as it is still in the stage of exploration and experimentation. However, it is expected to include advanced technologies such as Small Modular Reactors (SMRs), Generation IV reactors, and new materials, as well as new approaches to nuclear waste management and better ways to handle emergency situations.

## 2.2 Energy Transition

The energy transition related to the process of moving away from traditional, carbon-emitting sources of energy to cleaner, renewable energy sources.
The motivation behind this shift is the urgent requirement to tackle the issues of climate change and achieve decarbonization of the worldwide energy system. Unlike past energy transitions that were primarily driven by economic factors, this transition is driven by the need to mitigate the effects of environmental change. Technology plays a crucial role in this transition, with advances in renewable energy sources such as solar and wind power, as well as developments in storage technologies like batteries and hydrogen, driving the shift away from fossil fuels. However, policy and regulation also play a crucial role in driving this transition, as governments must provide incentives and subsidies to encourage the shift toward cleaner energy sources. The energy transition also involves significant collaboration and cooperation between sectors, including hydrocarbon producers, zero-carbon technology developers, and government regulators. Additionally, capital markets and investors also play a crucial role in driving the transition as they seek to invest in new and emerging technologies.

The critical issues of the energy transition include policy and regulation, as well as the cost and availability of new technologies. As the transition is being driven by the need to reduce carbon emissions, policymakers must find ways to correct market failures that allow for the external costs of carbon emissions to go unpriced. Additionally, there is a need to increase the capacity and reduce the cost of technologies such as hydrogen, small modular reactors, and batteries to help balance the electric system and solve the intermittency problem of renewables.

The public sector also plays a key role in providing the initial impetus for the transition and reducing the risks associated with investing in new technologies. However, the energy transition also presents significant opportunities for technological development and the creation of new industries. Carbon capture utilization and storage is a promising solution to mitigate carbon emissions in existing energy systems and create opportunities for industrial growth.

***Why is it important to shift to clean energy sources?***

Transitioning to clean energy is necessary to address a number of environmental and public health issues caused by the use of fossil fuels. Some of the key reasons why a transition to clean energy is necessary to include:

Table 3. Reasons to transit to clean energy

| Key Reason | Description |
| --- | --- |
| Climate change | The combustion of fossil fuels is a significant contributor to the release of greenhouse gases, which are causing global temperatures to rise and leading to severe weather events, sea level rise, and other negative impacts on the planet |
| Air pollution | Fossil fuels also release pollutants into the air, which can cause respiratory and other health problems for people living in areas with high levels of air pollution |
| Economic benefits | Investing in clean energy can create jobs and stimulate economic growth |

| | |
|---|---|
| Energy security | Reducing dependence on fossil fuels from other countries can increase energy security and reduce vulnerability to price fluctuations and supply disruptions |
| Limited resources | Fossil fuels are non-renewable resources with a limited supply and will eventually be depleted. |

*Table 3 compiled by the author*

Therefore, it is necessary to transition to clean energy to mitigate the negative impacts of fossil fuel use, to ensure a sustainable energy supply, to promote economic growth and energy security.

# 3 Methodology

## 3.1 Theoretical background

Kazakhstan is situated near the center of the Eurasian continent. It borders Russia in the north, northwest, and northeast, China in the southeast, Uzbekistan in the southwest, and the Kyrgyz Republic in the south. The total land area of Kazakhstan within its current borders is 2,724.9 thousand square kilometers [38].

Administratively, Kazakhstan is divided into 14 regions and also includes three cities of national significance - Astana, the capital, and the cities of Almaty and Shymkent, which each have populations exceeding one million people.

The landscape of Kazakhstan is diverse and varied, with around 10% of the land being made up of high mountain ranges. The majority of the country consists of lowlands, plains, plateaus, and uplands.

The southwest, north, and central regions have flat terrain with elevations ranging from 200-300 meters above sea level [39]. The southeast region of the country is mountainous, with peaks reaching 5-6 thousand meters above sea level in the Tien Shan mountain system.

The highest point in Kazakhstan, Khan-Tengri peak, is located here and reaches 6995 meters in altitude[40]. Additionally, the relief of Kazakhstan is characterized by numerous drainless basins, such as the Caspian Sea, Aral Sea, and Lake Balkhash, as well as deep depressions and dry basins.

Kazakhstan is characterized by an arid climate. Kazakhstan's average January temperature varies from -18°C in the north regions and in the east of the country to -3°C in the southernmost region. The average July temperature rises from +19°C in the north to +28°C, +30°C in the south [42].

The territory of Kazakhstan is located in four climatic zones -forest-steppe, steppe, semi-desert, and desert. The forest-steppe zone includes the most moisture-provided plains regions of the north of the republic. The shortest season is spring - 1.5 months. Summer lasts three months, and winter - is from October to April. The steppe zone occupies a vast territory in the north of the republic. It is distinguished by high wind speeds.

A significant part of the territory of Kazakhstan belongs to the inland depressions of the Caspian, Aral, and Balkash.

The largest rivers of Kazakhstan, with a length of more than 1000 km - Ertys, Esil, Zhaik, Syrdarya, Tobyl, Ile, and Shu are in transit, and their sources lie outside of Kazakhstan.

The distribution of the average annual river runoff is shown on the map, without shading the territory where there is no permanent river flow.


*Figure 4. River map of Kazakhstan [43]*

As of the start of 2022, there are 134 renewable energy facilities in Kazakhstan with a combined installed capacity of 2010 MW, according to a review of the renewable energy market in the country produced by the Market Development Department of Samruk-Energy JSC[61].

The volume of electricity produced by these facilities, which include solar power plants, wind power plants, biogas plants, and small hydropower plants, reached 4,220.3 million kWh in 2021.The report states that all renewable energy projects in Kazakhstan are funded by a combination of investors' own funds and borrowed capital.

The government gives support in the form of a guaranteed purchase of all RES electricity at either fixed tariffs or auction prices, which is then distributed to traditional power stations at the RES support tariff.

Furthermore, the state partially subsidizes costs for small-scale RES projects through local executive bodies.

***Solar energy***

Kazakhstan is believed to have the capacity to generate 2.5 billion kWh of solar energy annually[60], which can be utilized across most of its land, with the best locations for this being in the Aral Sea area and southern parts of the country where there is a shortage of electricity. The government aimed to have 28 solar power plants in operation by 2021 and succeeded, now having 51 active solar power plants[44].

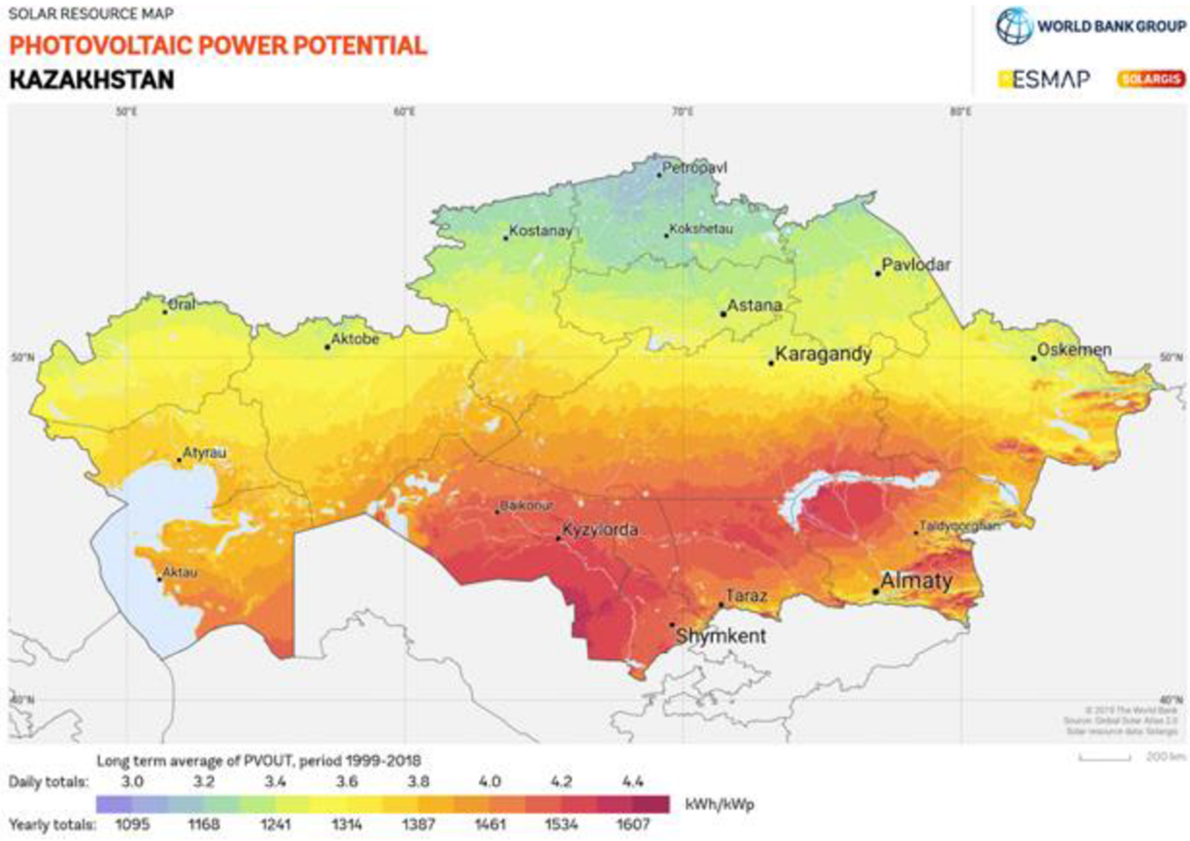


*Figure 5.Solar recourse map of Kazakhstan [43]*

Table 4. Installed solar power plants.

| N | Name | Proprietor | Installed capacity, MW | Region |
|---|---|---|---|---|
| 1 | SES Nura | Hevel Energy Group | 100 | Akmola |
| 2 | SES Burnoe | Samruk Kazyna - United Green | 100 | Zhambyl |
| 3 | SES Saran | SES Saran LLP | 100 | Karaganda |
| 4 | SES Akadyr | KazSolar50 LLP | 50 | Karaganda |
| 5 | SES Gulshat | KPM-Delta LLP | 40 | Karaganda |
| 6 | SES Kengir | Kazakhmys LLP | 10 | Ulytau |

| N | Name | Proprietor | Installed capacity, MW | Region |
|---|---|---|---|---|
| 7 | SES Kapshagay | Samruk Green Energy LLP | 2 | Almaty |
| 8 | SES Otar | Kazecowatt LLP | 0,5 | Zhambyl |

*Table compiled by the author based on Samruk Energy data [47]*

The Saran solar power plant, located in the Karaganda region and constructed by Goldbeck Solar (a German company), has generated over 125 million kilowatt-hours annually since it began operation in 2019.

*Figure 6. Saran SES [32]*

The Nura Solar Power Plant was commissioned on May 29, 2020, in the Akmola Region of Kazakhstan and was supported by the EDB. The projected annual output of the Nura SPP is estimated to be 150 million kWh, which will lead to a reduction of 79,500 tons of CO2 emissions [49]. The plant is expected to play a significant role in helping the country reach its goal of generating 50% of its electricity from renewable sources by 2050.

*Figure 7 Nura Solar Power Plant [48]*

The Burnoye Solar-1 project was established in April 2014 as a joint venture between Samruk Kazyna Invest and United Green (UK), aimed at constructing and producing alternative energy sources. Expert technicians from Europe were recruited for the project, and all equipment, including 192,192 solar panels, was manufactured in Europe [46].

*Figure 8. Burnoye Solar-1 [46]*

*The potential of wind energy*

According to the Ministry of Industry and New Technologies of Kazakhstan, the country's wind power potential is estimated to be around 920 billion kWh of electricity annually[51]. Half of Kazakhstan's land has wind speeds that are ideal for energy generation, with speeds ranging from 4 to 6 m/s. The most promising areas for wind energy are located in the Almaty region, specifically the Djungar Gates and the Chylyk Corridor, which is 100 km east of Almaty. The Djungar Gates have an estimated wind potential of 525Wm2, with the potential to produce up to 4400 kW/h/MW through wind turbines. Meanwhile, the Chylyk Corridor has a wind potential of 240Wm2, with the potential to generate 3200 kW/h/MW from wind turbines [50].

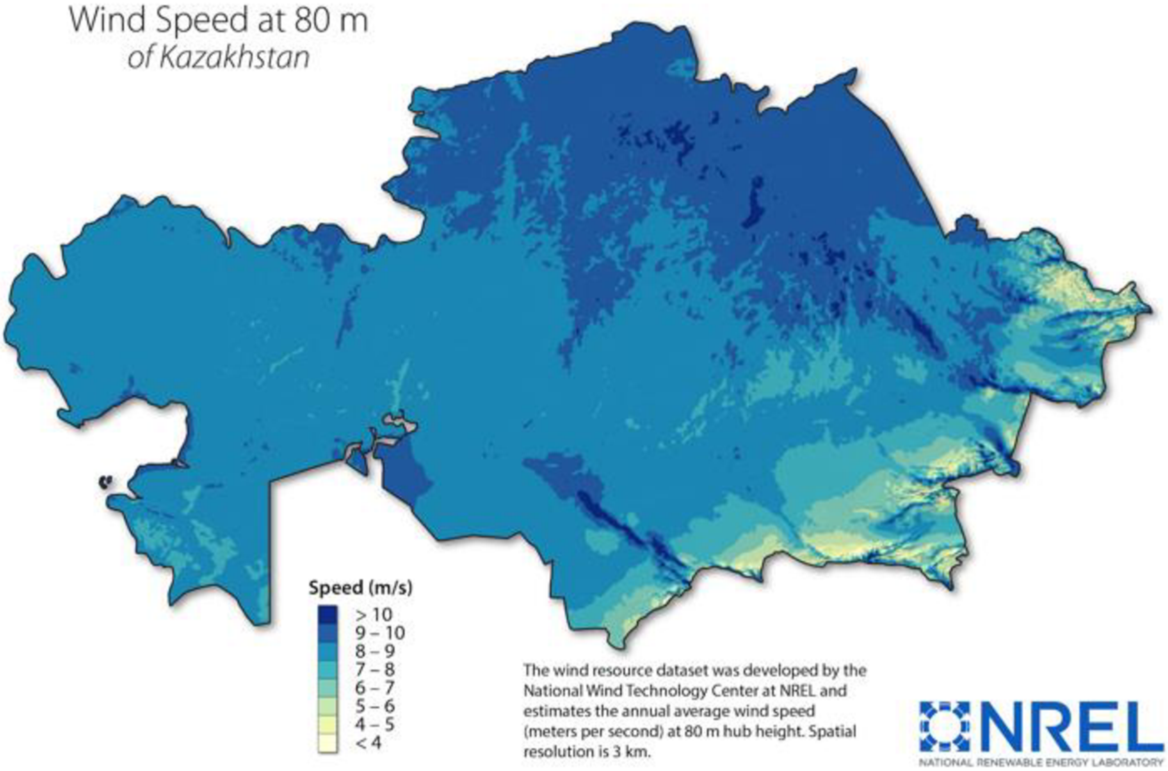


*Figure 9.Wind map of Kazakhstan [34]*

Table 5. Installed wind farms *[52]*

| | Name | Proprietor | Installed capacity, MW | Region |
|---|---|---|---|---|
| 1 | Isatay | Vetroenergotechnologii LLP | 52 | Atyrau |
| 2 | Makatay | Divitel LLP | 48 | Atyrau |
| 3 | Yerementay | PVES LLP | 45 | Akmola |
| 4 | Korday | Vista International LLP | 21 | Zhambyl |
| 5 | VES K-1 | Izen-Su LLP | 1.6 | Zhambyl |

According to the Burabay meteorological station (Lake Bolshoye Chebache), the average annual wind speed is 5.0 m/s. Only in one Burabay district can a cascade of wind turbines be installed on the hills of the Shchuchinsko-Borovskaya resort area from the meteorological station to the village of Madeniet (up to about 30 km).

Small-scale wind and solar energy can be introduced primarily in sparsely populated dispersed farms, the private sector, health areas, and tourist routes.

Institute "Kazselenergoproekt" constantly takes the initiative to organize the specific use of renewable energy sources in Kazakhstan. The Institute conducted analytical work and identified 48 excessively windy regions for placing powerful cluster wind farms.

*Figure 10. Korday wind farm[29]*

*Figure 11. Twin-rotor wind turbine with a wind flow accelerator [29]*

The Kazakhstan government, with the support of the United Nations Development Program, has developed a strategy to increase wind energy production by the year 2030, including the construction of wind farms and the addition of 2,000 MW of wind power capacity.
With the help of UNDP and the GEF, the government created a Wind Atlas for ten potential sites across the country.

***Hydroelectric power projects***

Hydropower, mainly small-scale hydropower, is seen as the most cost-effective and eco-friendly method of producing electricity. Small hydropower plants also have the added benefit of preserving the natural landscape and protecting rivers' environment, fish, and water quality.

Kazakhstan possesses plentiful water power sources primarily located in the southern and eastern regions. Hydropower plants with a combined capacity of 2.25 GW comprise around 13 percent of the country's total power generation capacity.

*Table 6. Large hydropower plants*

| N | Name | Installed capacity, MW | Proprietor | Region |
|---|---|---|---|---|
| 1 | Bukhtyrma | 750 | Samruk-Energo | East Kazakhstan |
| 2 | Shulbinsk | 702 | Samruk-Energo | East Kazakhstan |
| 3 | Ust-Kamenogorsk | 367.8 | Samruk-Energo | East Kazakhstan |
| 4 | Kapshagai | 364 | Samruk-Energo | Almaty region |
| 5 | Moinak | 300 | Samruk-Energo | Almaty region |
| 6 | Shardarinskaya | 126 | Samruk-Energo | Turkestan |

*Table complied by the author based on report of Samruk Energy [69]*

*Table 7. Medium scale hydropower plants*

| N | Name | Proprietor | Installed capacity, MW | Region |
|---|---|---|---|---|
| 1 | Almatinsky Kaskad | Samruk Energo | 43.7 | Almaty |
| 2 | Korinskaya | Korinskaya GES LLP | 28.5 | Zhetysu |

| | | | | |
|---|---|---|---|---|
| 3 | Ulbinskaya | LK GES Company | 27.6 | Zhetysu |
| 4 | Turgusun | Turgusun LLP | 24.9 | East Kazakhstan |
| 5 | Lepsy - 2 | GES Lepsy-2 LLP | 16.99 | East Kazakhstan |
| 6 | Karatalskie GES | Kaskad Karatalskih GES LLP | 11.9 | Zhetysu |
| 7 | Leninogorski Kaskad | LK GES Company | 11.8 | East Kazakhstan |

*Table complied by the author based on report of Samruk Energy [69]*

The demand for small hydropower projects has risen due to their affordability, reliability, and environmentally friendly nature. The equipment for these plants is consistent and widely used. Additionally, Kazakhstan has enormous potential for energy production from small rivers, with a total potential of 8 billion kWh from plants with a unit capacity of less than 10 MW [60].

*Table 8. Small scale hydropower plants*

| N | Name | Proprietor | Installed capacity, MW | Region |
|---|---|---|---|---|
| 1 | Tasotkel HPP LLP | "Company A&T - Energo" | 9.2 | Zhambyl region |
| 2 | Verkhne-Baskanskaya HPP-1 | Baskan Power LLP | 4.5 | Almaty region |

| | | | | |
|---|---|---|---|---|
| 3 | Merken cascade (3 stations) | Hydropower Company LLP | 3.6 | Zhambyl region |
| 4 | HPP cascade on the river. Keles (2 stations) | Kelesgidrostroy LLP | 3.3 | Turkestan region |
| 5 | Talgar HPP | LLP "AlmatyEngineering" | 3.2 | Almaty region |
| 6 | HPP "Mankent" | LLP "Aksu-Energo" | 2.5 | Turkestan region |
| 7 | Sergeevskaya HPP | RGC "Kazvodkhoz" | 2.46 | North-Kazakhstan region |
| 8 | Sarkand HPP | FIRM TAMERLAN LLP | 2.39 | Zhetysu region |
| 9 | Karakystak HPP | Zhambyl HPP LLP | 2.1 | Zhambyl region |
| 10 | Zaisan HPP | Samruk-Energy | 2.0 | East Kazakhstan region |
| 11 | Aksu HPP-1 | TATEK JSC | 1.9 | Almaty region |
| 12 | Uspenovskaya HPP | LLP "Kainar-AKB HPP-4" | 1.9 | Almaty region |
| 13 | Antonovskaya HPP | Kainar-AKB HPP-3 LLP | 1.6 | Zhetysu |
| 14 | Turgen HPP | LLP "Plant Elektrokabel" | 1.4 | Almaty |
| 15 | HPP "Dostyk" LLP | LLP "Salem Consulting" | 0.975 | Turkestan |
| 16 | Experimental HPP | JSC "KazNII of Energy named after. Academician Sh. Ch. Chokin" | 0.75 | Almaty |
| 17 | Intumak HPP | Karaganda branch of RSE REM | 0.63 | Karaganda |
| 18 | Intalinskaya HPP | Tatiana farm | 0.6 | Almaty |

| | | | | |
|---|---|---|---|---|
| 19 | HPP "Energo Almaty" | LLP "HPP-ENERGO ALMATY" | 0.43 | Almaty |
| 20 | HPP "Karash" | LLP "ZHETYSU-ENERGO" | 0.125 | Almaty |

*Table complied by the author based on report of Samruk Energy[69]*

China is the leading country in producing small hydropower plants, with 60,000 out of 90,000 operating plants having a capacity of less than 25 kW (micro HPPs). India also has a significant presence in small hydropower with an installed capacity of over 200 MW and plans for the construction of over 150 MW.

***Biomass energy***

In Kazakhstan, a stable source of biomass for energy production can be agricultural waste, plant-growing products of a technical nature, the organic fraction in the morphological composition of MSW which reaches up to 40% in the total mass of MSW on average in Kazakhstan.

***Groundwater***

Groundwater is a crucial resource in Kazakhstan, with 2905 locations for extracting it identified. The daily water extraction capacity is 42,765.16 thousand m3, which is about 24% of the total estimated resources that have a salinity of up to 10g/l and 38% of the resources that have a mineralization of up to 1g/l. Of the extractable water, 36,892.60 thousand m3 is fresh water, making up 86% of the total extractable amount[70].

Geothermal systems can harness groundwater as a renewable energy source. Geothermal systems employ the steady subsurface temperature of the Earth to regulate the temperature of buildings, providing both heating and cooling as necessary. By drilling a well into an aquifer, it is possible to extract the groundwater, which is at a relatively constant temperature, and use it as a source of energy for heating and cooling. This is known as a "ground-source heat pump" system. It's also possible to generate electricity using the water flow through hydroelectric power plant. This approach is less common as it required a high discharge rate and head but it can be an alternative in some locations.

Sustainable management is crucial when utilizing groundwater as a source of energy to prevent negative impacts on the environment. Over-pumping of groundwater can lead to a decline in the water table, and can also lead to the drying up of wells, streams, and wetlands. Therefore, it is important to carefully assess the potential impacts of using groundwater as a source of energy and to implement sustainable management practices.

***Generation of electricity and heat***

The majority of electricity in Kazakhstan is generated by 37 thermal power plants that use coal from different basins such as Ekibastuz, Maikuben, Turgai and Karaganda. The largest of these power plants is GRES-1 Ekibastuz, which has 8 units with a capacity of 500 MW each, with a total capacity of 3500 MW.

The total installed capacity of all power plants in Kazakhstan is 18,992.7 MW of electricity [71].

The breakdown of the electricity generation by type of power plant is as follows:
Thermal power plants (TPPs) - 87.7%, including:

- condensing power plants (CPS) - 48.9%,
- combined heat and power plants (CHPP) - 36.6%,
- gas turbine power plants (GTPP) - 2.3%,
- hydroelectric power plants (HPPs) - 12.3%.

About 70% of the electricity in Kazakhstan is generated from coal, 14.6% from hydro resources, 10.6% from gas and 4.9% from oil. source
In addition to electricity, thermal power plants also generate heat, which is distributed to nearby towns and cities through heat networks. This is particularly important in colder regions of the country, where heating is a critical need during the winter months.
KEGOC, the entity responsible for the national transmission grid, has intentions to execute 15 initiatives with a total worth of $3 billion. These projects aim to either renovate existing or build new power transmission lines and substations.
The head of Samruk-Energo, which oversees the country's electricity generation, has announced Kazakhstan's goal to add 14 GW of fresh power generation capacity by 2030. The government has outlined a plan to invest $63 billion in the energy sector over the following 18 years. Of that total, $37 billion will be allocated for power generation, $9 billion

for power distribution networks, and $17 billion for regional power distribution organizations [66].

Several power plants are expected to be renovated over the next five years as follows:

- Balkhash Coal-Fired Power Plant, Ulken
- Ekibastuz GRES-2 Unit 3 Power Plant, Pavlodar
- Karabatan Combined Cycle Power Plant, Atyrau
- Almaty CHP (Combined Heat and Power)

The table below indicates that there are plans to establish multiple renewable energy source (RES) plants in the coming years.

*Table 9. Predicted balance of electricity 2019 – 2029, including RES*

| N | Name | Current and Forecast, billion kilowatts per hour | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 |
| 1 | Energy Consumption | 110.1 | 112.1 | 114.1 | 121.13 | 124.84 | 129.25 | 133.63 | 137.28 | 141.78 | 146.01 |
| 2 | Energy Production | 116.4 | 119.7 | 122.4 | 119.54 | 123.27 | 127.66 | 134.99 | 138.97 | 140.5 | 140.53 |
| 3 | Existing power plants | 104 | 102.1 | 99.9 | 117.48 | 116.85 | 116.76 | 115.26 | 115.02 | 114.78 | 114.82 |
| 4 | Planned power plants | 12.4 | 17.6 | 22.5 | 2.06 | 6.42 | 10.89 | 19.73 | 23.94 | 25.71 | 25.71 |
| 5 | Including, RES, | 3.1 | 4.0 | 4.8 | 1.3 | 1.4 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| 6 | Deficit(+) Surplus (-) | -6.3 | -7.5 | -8.3 | 1.59 | 1.57 | 1.58 | -1.36 | -1.68 | 1.28 | 5.47 |

*Table complied by the author based on Order of the Minister of Energy of the Republic of Kazakhstan dated January 20, 2023 No. 20. On approval of forecast balances of electric energy and capacity for 2023-2029 [72].*

Table 9 displays information on energy consumption, production, and projections, which includes renewable energy sources (RES).

*Table 10.* Targets for the development of the RES sector, MW

| Type of RES | 2020( approved) MW | 2025 (forecast) MW |
|---|---|---|
| Wind farms | 933 | 1200 |
| Solar farms | 467 | 1100 |
| Small hydropoweplants | 290 | 219 |
| Biogas plants | 10 | 15 |
| Total power | 1700 | 2615 |

*Table complied by the author based on National Sustainable Energy Action Plans – from Commitments to Actions Workshop UNECE and UN ESCAPE.*

### *3.1.1 The strong dependence on hydrocarbons*

The country's oil industry is a significant contributor to its economy, and oil exports make up a large portion of its total export revenue. The oil reserves in Kazakhstan are located mainly in the western region of the country, with the largest oil field being the Tengiz Field, which is considered one of the largest in the world. Other significant fields include the Kashagan Field, the Karachaganak Field, and the Aktobe Region[58].

Kazakhstan's main source of income is from its oil and gas industry, which makes up around 15% of the country's GDP, over 50% of its energy exports, and more than 40% of its government revenues. Consequently, Kazakhstan is a net exporter of energy[62]. The entire mining sector provides over 30% of GDP and over 60% of industry. Revenues from the oil and gas sector form half of the country's fiscal revenues. Almost 70% of the country's total exports in value terms are exports of oil and gas condensate.

***Peak oil***

As of January 2018, Kazakhstan has the second-largest proven crude oil reserves in Eurasia, following Russia and ranking twelfth globally, just behind the US. It holds the largest oil reserves in the Caspian Sea region. Kazakhstan's production of crude and condensate in 2021 was 1.8 million barrels per day, which decreased slightly from 1.842 million bpd in 2020 and 1.965 million bpd in 2019 [53].

The idea of "Peak oil" was first introduced by geologist M. King Hubbert in the 1950s and suggests that the production of oil will eventually reach its maximum point and start to decline. This concept has since become a subject of much discussion and research by energy industry experts and academics [54].

One prominent voice in the discussion on peak oil is Colin Campbell, a retired petroleum geologist, who argues in his book "The Coming Oil Crisis" [55] that the world is on the brink of an oil production peak with significant implications for global energy security and the economy. In contrast, Daniel Yergin, chairman of IHS Markit, holds the belief that peak oil oversimplifies the complexity of the oil market and that technological and market advancements will ensure a continuous supply of oil to meet demand.

The topic of peak oil is a complex one, and the literature reflects a range of opinions and perspectives, from those who see the peak as imminent to those who believe that oil production will continue to meet demand. The ongoing debate highlights the intricate nature of the subject.

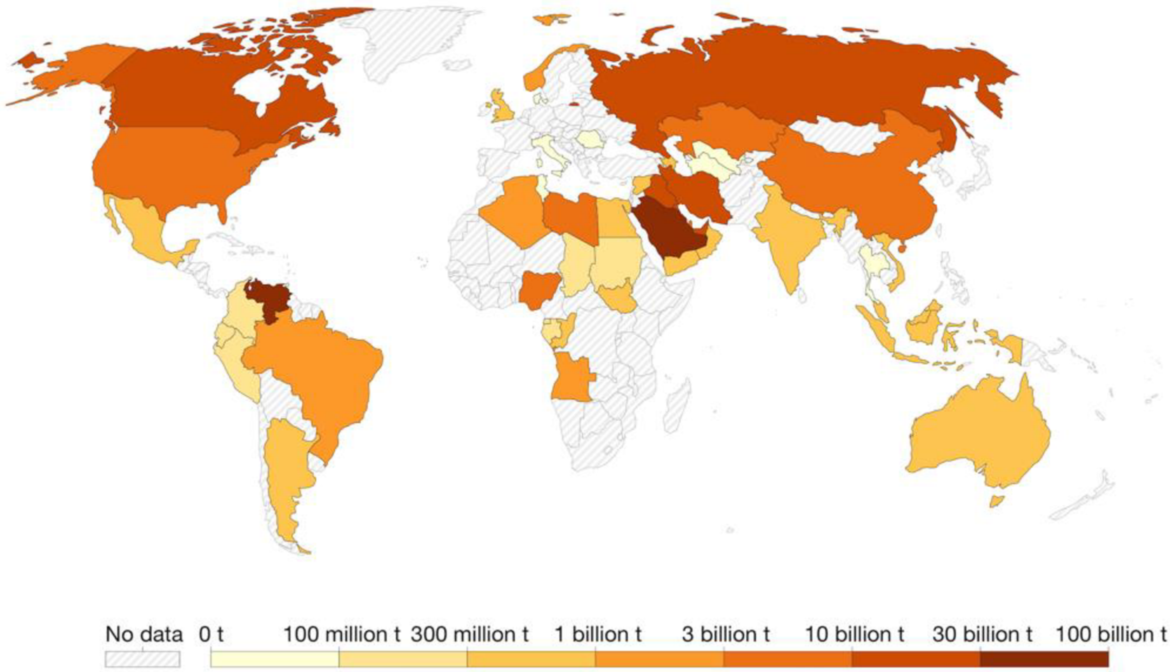


*Figure 12.Oil reserves in the world, 2020 [45]*

Ahmed Zaki Yamani once said that the world's reliance on oil would come to an end well before the oil supply is depleted, similar to how the Stone Age ended not because of a lack of stones[67], this quote highlights the fact that technological advancements and changes in society, rather than resource depletion, are the driving forces behind the transition from one era to another.

The primary source of wealth for Kazakhstan is crude oil. And this work also raises important and relevant questions such as: how much oil remains once it runs out, how long will it continue to support the economy of Kazakhstan, and can Kazakhstan have a future without hydrocarbons?

European countries have made the decision to fully transition away from oil and gas by 2050 and instead rely on renewable energy sources [56]. This is demonstrated by actions such as the law prohibiting the sale of vehicles with internal combustion engines, which will take effect in 2035. The transformation will have a notable influence on the automobile sector, leading to a rise in electric vehicles and a reduction in the exportation of oil and gas from Kazakhstan.

Additionally, Kazakhstan faces challenges with the Caspian Pipeline Consortium, which is controlled by Russia. When the war in Ukraine comes to an end, EU be able to rebuild their economy on a new path that does not involve Russian hydrocarbons. This means that countries such as Turkey, Libya, and Iran will be in a position to supply hydrocarbons to the EU market, which will mark the beginning of a decline in the economy of Kazakhstan.

The oil and gas industry will come to an end when it is no longer profitable, and this could happen soon. Kazakhstan has already experienced a decline in demand and oil prices during the pandemic and lockdown, leading to inflation and a budget deficit. The situation has been temporarily resolved by using resources from the National Fund, but these resources are not limitless. It is possible that the petrodollar pipeline, which supports the economy and enables a consumer lifestyle, is nearing the end of its life. It is challenging to determine the precise point when Kazakhstan's oil reserves will be depleted since it depends on several variables, such as the discovery of fresh reserves, the pace of extraction, and the global demand for oil. However, it is generally accepted that the country's oil resources are finite and will eventually be depleted. According to economist Almas Chukin, the peak of the oil era will be in 2030, and in 2040-2050 demand will begin to gradually decline [57].

## 3.2 Measurement of variables

The present study endeavors to investigate the impact of economic factors on citizens attitudes and preferences toward renewable energy consumption while identifying the determinants of increased energy consumption.
The research methodology will utilize multiple regression and correlation analysis to detect discernible patterns and trends within the data.
The examination was carried out with the aid of SPSS 17 software, which is proficient in generating tables for statistical analysis.
Excel was used to create tables and plots that display the changes of individual variable values over time, while scatter plots were produced using the R software.
This study will employ correlation and regression analyses to evaluate the impact of transitioning from fossil fuels to renewable energy consumption on economic variables. In addition, the primary energy consumption data, which encompasses all forms of energy consumption in the country and represents expenditure on fossil fuels, will be compared to data on renewable energy sources. This comparison will help to assess the economic effects of shifting towards renewable energy consumption.

### 3.2.1 Data Description

The following factors were selected to investigate their impact on the quantity of renewable energy consumption:

- GDP (1990-2021)
- Inflation rate (1994-2021)
- Population (1990-2021)
- Renewables (% equivalent primary energy)
- Primary energy consumption (1986-2021)
- Unemployment(1991-2021)
- Minimum wage (2000-2021)

The linear regression model was computed using variables that encompassed data from all years. Accordingly, the model utilized 20 rows (2000-2020) of variable values, each representing data from all years.

Table 11. Selected variables for the analysis. *The table was created by the author using data obtained from both the World Bank and the Agency of the Republic of Kazakhstan on Statistics.*

| **Year** | **GDP (current US$)** | **Inflation, consumer prices (annual %)** | **Population** | **Renewables (% equivalent primary energy)** | **Primary energy consumption (TWh)** | **Unemployment, total (% of total labor force) (national estimate)** | **Minimum wage, (kzt)** |
|---|---|---|---|---|---|---|---|
| 1985 | | | | 1.9355252 | | | |
| 1986 | | | | 1.7365297 | 814.25055 | | |
| 1987 | | | | 2.035726 | 832.59485 | | |
| 1988 | | | | 2.3956873 | 862.9574 | | |
| 1989 | | | | 2.5382574 | 849.49603 | | |
| 1990 | 26932729103 | | 16348000 | 2.534389 | 859.4254 | | |
| 1991 | 24923076923 | | 16451711 | 2.4798362 | 858.5374 | 0,050000001 | |
| 1992 | 24917355372 | | 16439095 | 2.3956668 | 847.4754 | 0,400000006 | |
| 1993 | 23409260880 | | 16380672 | 3.0152724 | 748.1537 | 1,110000014 | |
| 1994 | 21250792886 | 1877,372395 | 16145766 | 4.0728307 | 666.42114 | 7,539999962 | |
| 1995 | 20374302652 | 176,1552989 | 15816243 | 4.114585 | 598.716 | 10,97999954 | |
| 1996 | 21035368251 | 39,18254237 | 15578227 | 4.1591706 | 521.20215 | 12,96000004 | |
| 1997 | 22165932063 | 17,40804106 | 15334405 | 4.181545 | 459.5783 | 13,01000023 | |
| 1998 | 22135254836 | 7,146326655 | 15071640 | 4.1937065 | 433.00296 | 13,13000011 | |
| 1999 | 16870821840 | 8,296027653 | 14928374 | 4.455529 | 406.96085 | 13,46000004 | |
| 2000 | 18291994909 | 13,18089059 | 14883626 | 6.0228243 | 369.7474 | 12,75 | 2680 |
| 2001 | 22152694162 | 8,354137772 | 14858335 | 5.704264 | 416.19168 | 10,43000031 | 3484 |
| 2002 | 24636593223 | 5,836924521 | 14858948 | 6.120414 | 423.94363 | 9,329999924 | 4181 |
| 2003 | 30833699703 | 6,438218101 | 14909019 | 5.3825555 | 464.69077 | 8,779999733 | 5000 |
| 2004 | 43151647003 | 6,88205439 | 15012984 | 4.701576 | 493.8026 | 8,399999619 | 6600 |
| 2005 | 57123671734 | 7,579999291 | 15147029 | 4.4324117 | 507.509 | 8,130000114 | 7000 |
| 2006 | 81003884545 | 8,721693861 | 15308085 | 4.047025 | 546.1618 | 7,789999962 | 9200 |
| 2007 | 104849886825,58 | 10,84683621 | 15484192 | 3.8181744 | 605.14886 | 7,260000229 | 9752 |
| 2008 | 133441612246,80 | 17,13989978 | 15776938 | 3.2849119 | 638.1466 | 6,630000114 | 12025 |
| 2009 | 115308661142,93 | 7,316078583 | 16092822 | 3.3547347 | 572.664 | 6,550000191 | 13470 |
| 2010 | 148047348240,64 | 7,400463567 | 16321872 | 3.6240573 | 614.3876 | 5,769999981 | 14952 |
| 2011 | 192626507971,58 | 8,424887619 | 16557202 | 3.1190946 | 697.2462 | 5,389999866 | 15999 |
| 2012 | 207998568865,79 | 5,09791485 | 16792090 | 2.8572173 | 733.16974 | 5,289999962 | 17439 |
| 2013 | 236634552078,10 | 5,846409173 | 17035551 | 2.8628833 | 736.4637 | 5,199999809 | 18660 |
| 2014 | 221415572819,50 | 6,706578291 | 17288285 | 2.982452 | 751.8685 | 5,059999943 | 19966 |
| 2015 | 184388432148,72 | 6,665776115 | 17542806 | 3.5664272 | 713.38214 | 4,929999828 | 21364 |
| 2016 | 137278320084,17 | 14,54602379 | 17794055 | 4.4041133 | 728.59064 | 4,960000038 | 22859 |
| 2017 | 166805800595,70 | 7,440004373 | 18037776 | 4.0426664 | 766.60187 | 4,900000095 | 24459 |
| 2018 | 179339994859,38 | 6,019130966 | 18276452 | 3.3888385 | 851.43896 | 4,849999905 | 28284 |
| 2019 | 181667190075,54 | 5,245476796 | 18513673 | 3.468928 | 843.3182 | 4,800000191 | 42500 |
| 2020 | 171082379532,99 | 6,749001838 | 18755666 | 3.9000363 | 803.6175 | 4,889999866 | 42500 |
| 2021 | 197112255360,61 | | 19000988 | 3.988574 | 791.5689 | | 42500 |

The *Table 12 Descriptive Statistics* represents the descriptive statistics of the variables, such as Average value, maximum and minimum values, and Standard deviation of the variables. The last two columns show the Skewness and Kurtosis of variables. Those measurements help to see how symmetric variables are, which is one of the methods to access the Normality of the data. If any value is more than |2|, the variable reveals to be non-symmetric, which will be further inspected with the appropriate statistical tests.

Table 12. Descriptive Statistics.

| | N | Minimum | Maximum | Mean | Std. Deviation | Skewness | | Kurtosis | |
|---|---|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic | Std. Error |
| GDP (current US$) | 32 | 1.687082E10 | 2.366346E11 | 9.62251926E10 | 7.750616570E10 | .384 | .414 | -1.544 | .809 |
| Inflation, consumer prices (annual %) | 27 | 5.09791484976E0 | 1.87737239518E3 | 8.5111075271334E1 | 3.59676525955065E2 | 5.130 | .448 | 26.501 | .872 |
| Population | 32 | 14858335 | 19000988 | 16335703.97 | 1256145.261 | .645 | .414 | -.634 | .809 |
| Renewables (% equivalent primary energy) | 37 | 2 | 6 | 3.66 | 1.087 | .421 | .388 | -.027 | .759 |
| Primary energy consumption (TWh) | 36 | 370 | 863 | 661.90 | 159.836 | -.335 | .393 | -1.291 | .768 |
| Unemployment, total (% of total labor force) (national estimate) | 30 | 5.000000074506E-2 | 1.346000003815E1 | 7.15766665401558E0 | 3.673706854497067E0 | .113 | .427 | -.382 | .833 |
| Minimum wage, (kzt) | 24 | 2680 | 70000 | 21453.08 | 17986.622 | 1.356 | .472 | 1.362 | .918 |
| Valid N (listwise) | 21 | | | | | | | | |

*Produced by the author using SPSS 17 software.*

The following plots display Kazakhstan's economic factors over time:

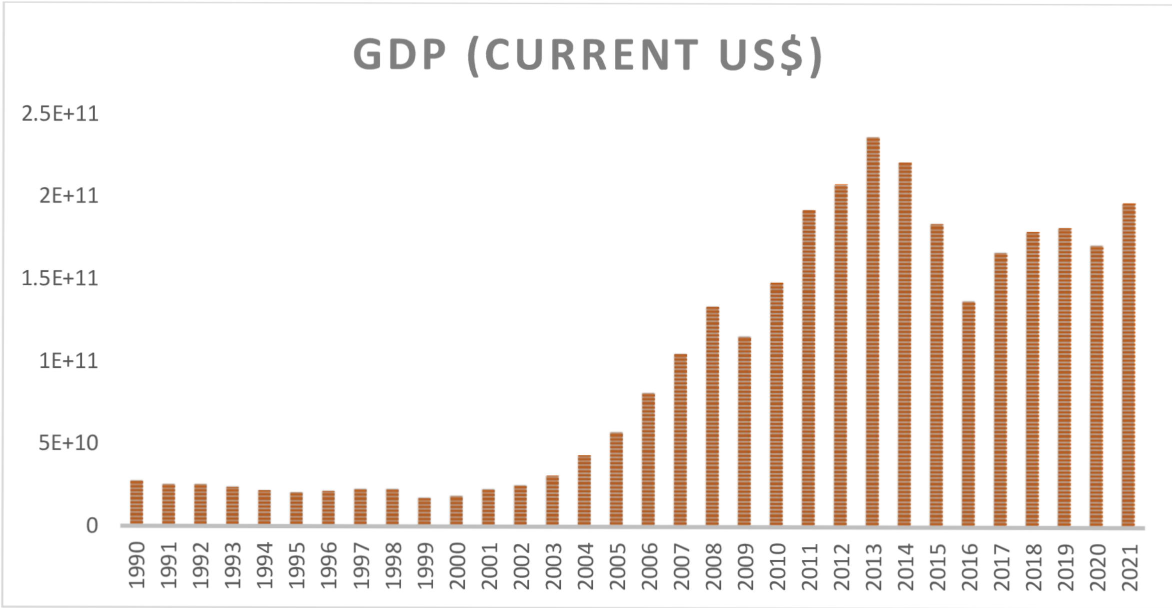


*Figure 13. GDP (current US$) of Kazakhstan.*

*Produced by the author using R software.*

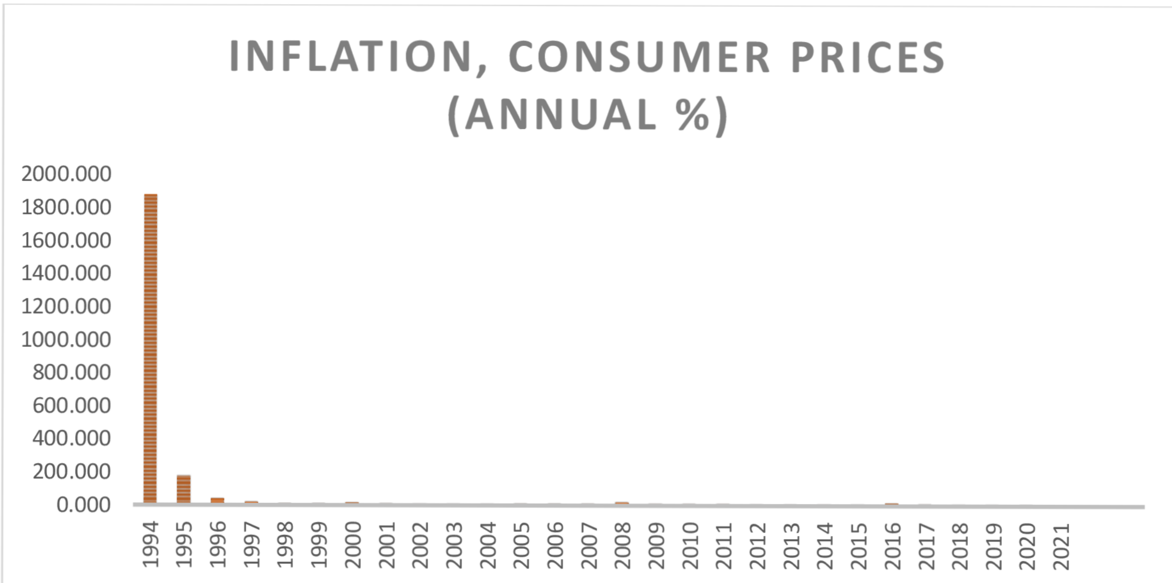


*Figure 14. Inflation, consumer prices (annual %).*

*Produced by the author using R software.*

Figure 14 displays an extreme value in the inflation variable. To analyze the remaining values, the variable was plotted without this value in the chart located adjacent to it.

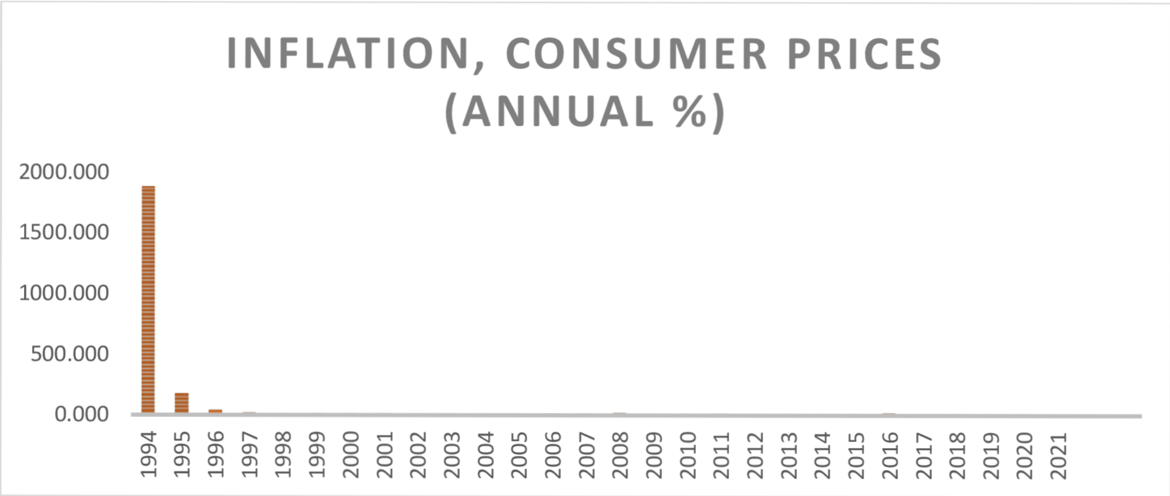


*Figure 15. Inflation, consumer prices (annual %). Verse 1.*

*Produced by the author using R software.*

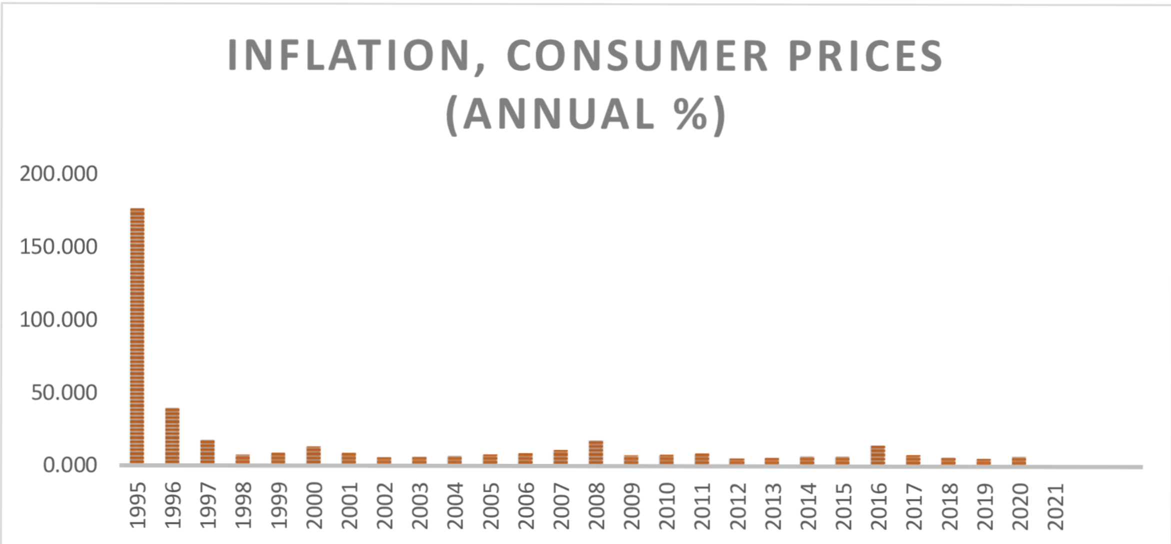


*Figure 16. Inflation, consumer prices (annual %). Verse 2.*

*Produced by the author using R software.*

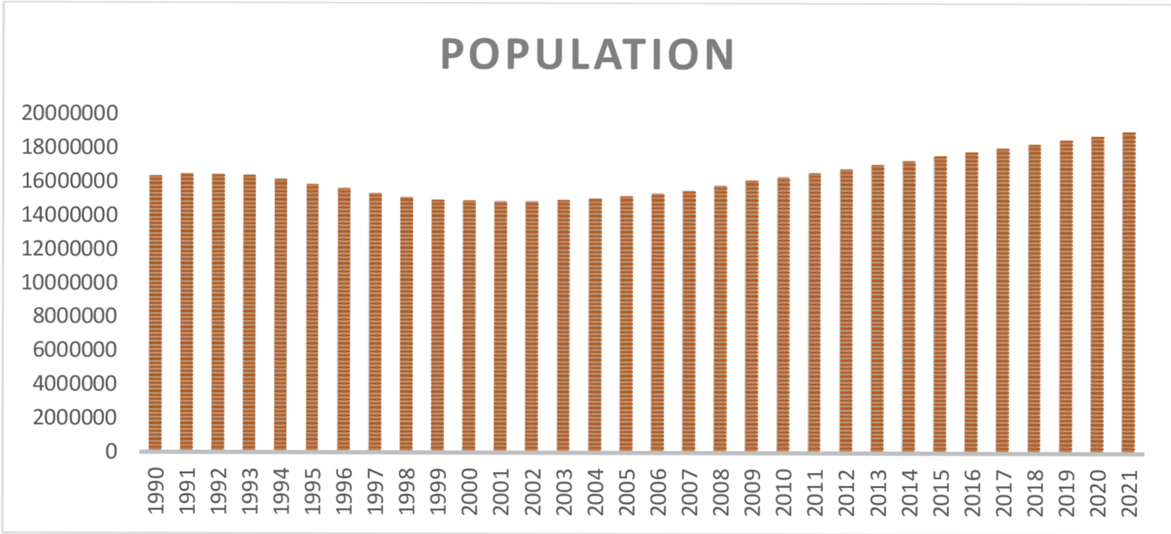


*Figure 17. Population of Kazakhstan.*

*Produced by the author using R software.*

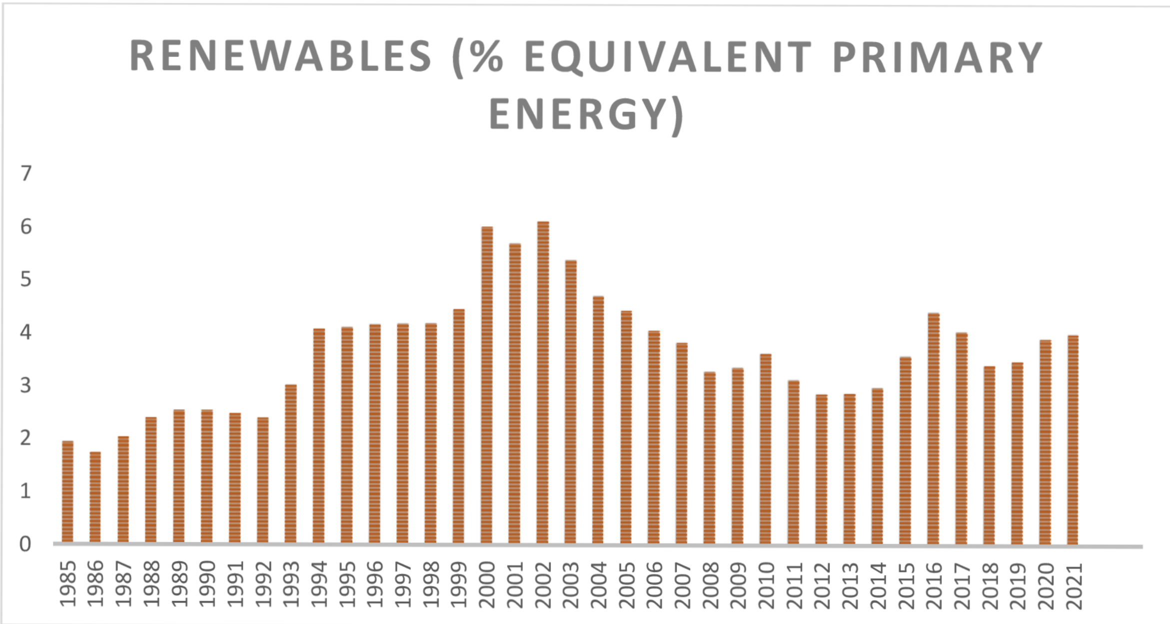


*Figure 18. Renewables (% equivalent primary energy).*

*Produced by the author using R software.*

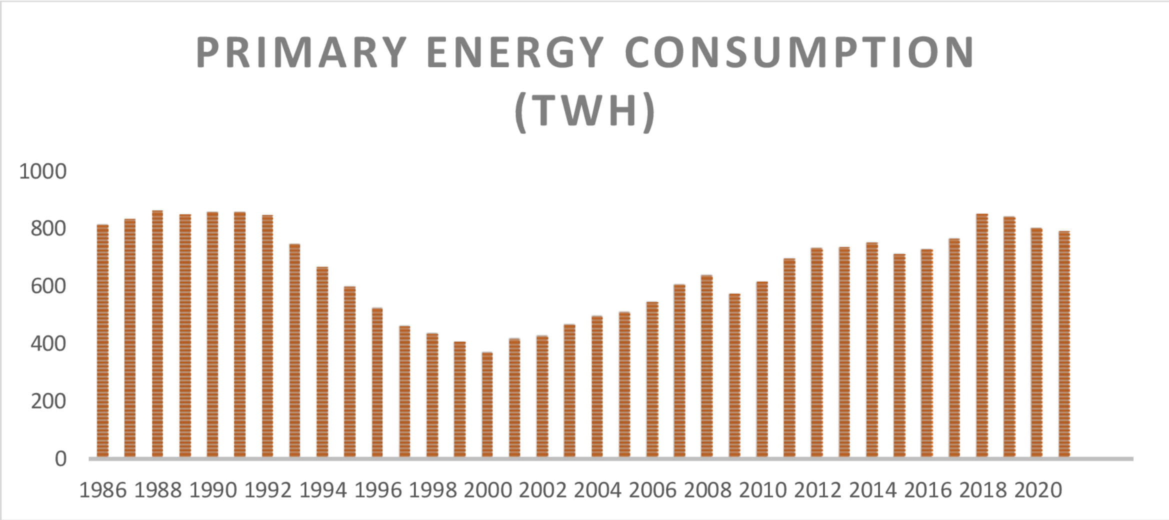


*Figure 19. Primary energy consumption (TWh).*

*Produced by the author using R software.*

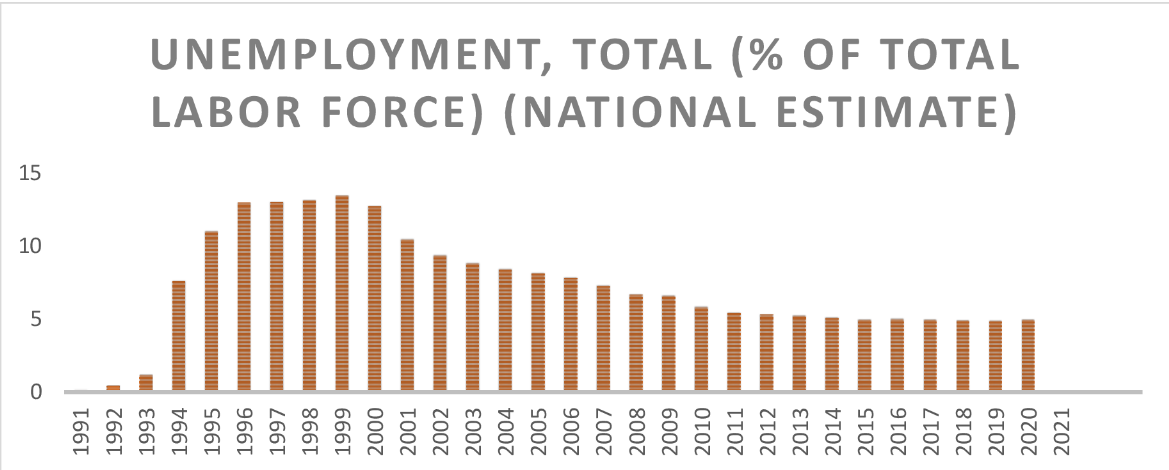


*Figure 20. Unemployment, total (% of total labor force) (national estimate).*

*Produced by the author using R software.*

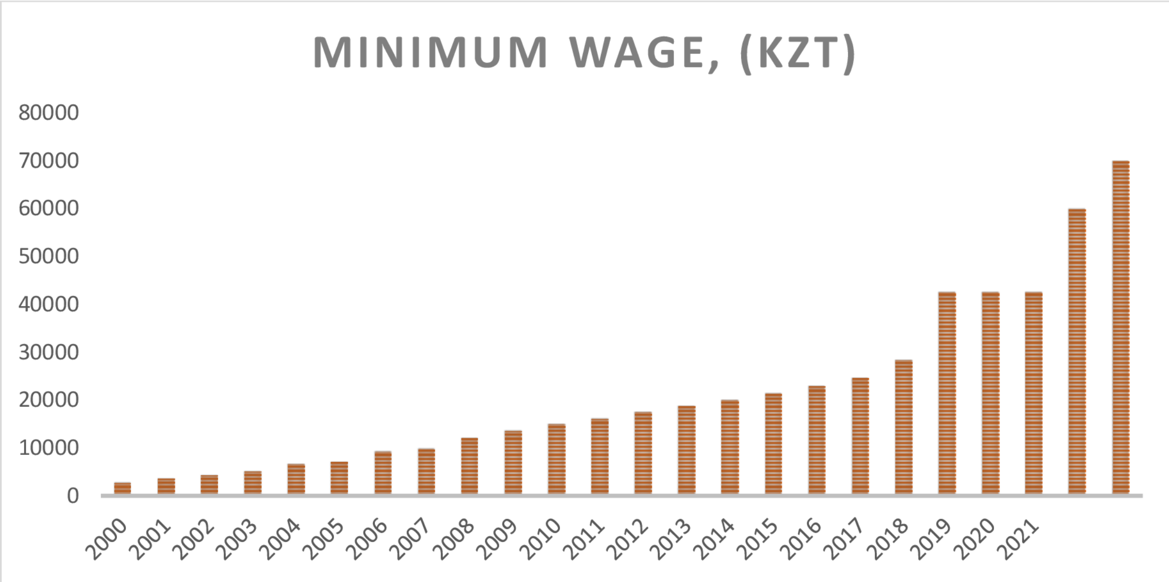


*Figure 21. Minimum wage, (kzt.).*

*Produced by the author using R software.*

### 3.2.2 Data analysis

The study aims to construct a regression model where renewable energy consumption serves as the dependent variable, and other variables act as predictors. *The Table 13 Correlation matrix* represents a correlation matrix between the selected variables, which will be utilized in the analysis.

Table 13. Correlation matrix

| | | Renewables (% equivalent primary energy) | GDP (current US$) | Inflation, consumer prices (annual %) | Population | Primary energy consumption (TWh) | Unemployment, total (% of total labor force) (national estimate) | Minimum wage, (kzt) |
|---|---|---|---|---|---|---|---|---|
| Renewables (% equivalent primary energy) | Pearson Correlation | 1 | -.415* | .000 | -.480** | -.817** | .698** | -.492* |
| | Sig. (2-tailed) | | .018 | .999 | .005 | .000 | .000 | .020 |
| | N | 37 | 32 | 27 | 32 | 36 | 30 | 22 |
| GDP (current US$) | Pearson Correlation | -.415* | 1 | -.237 | .750** | .548** | -.462* | .719** |
| | Sig. (2-tailed) | .018 | | .234 | .000 | .001 | .010 | .000 |
| | N | 32 | 32 | 27 | 32 | 32 | 30 | 22 |
| Inflation, consumer prices (annual %) | Pearson Correlation | .000 | -.237 | 1 | -.023 | .078 | .003 | -.259 |
| | Sig. (2-tailed) | .999 | .234 | | .911 | .699 | .988 | .257 |
| | N | 27 | 27 | 27 | 27 | 27 | 27 | 21 |
| Population | Pearson Correlation | -.480** | .750** | -.023 | 1 | .831** | -.639** | .958** |
| | Sig. (2-tailed) | .005 | .000 | .911 | | .000 | .000 | .000 |
| | N | 32 | 32 | 27 | 32 | 32 | 30 | 22 |
| Primary energy consumption (TWh) | Pearson Correlation | -.817** | .548** | .078 | .831** | 1 | -.873** | .879** |
| | Sig. (2-tailed) | .000 | .001 | .699 | .000 | | .000 | .000 |
| | N | 36 | 32 | 27 | 32 | 36 | 30 | 22 |
| Unemployment, total (% of total labor force) (national estimate) | Pearson Correlation | .698** | -.462* | .003 | -.639** | -.873** | 1 | -.775** |
| | Sig. (2-tailed) | .000 | .010 | .988 | .000 | .000 | | .000 |
| | N | 30 | 30 | 27 | 30 | 30 | 30 | 21 |
| Minimum wage, (kzt) | Pearson Correlation | -.492* | .719** | -.259 | .958** | .879** | -.775** | 1 |
| | Sig. (2-tailed) | .020 | .000 | .257 | .000 | .000 | .000 | |
| | N | 22 | 22 | 21 | 22 | 22 | 21 | 24 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed)

### 3.2.3 *Correlation*

Thus far, it has been observed that primary energy consumption and renewable energy consumption have a strong negative linear relationship, with a Pearson correlation coefficient of r=-0.817. Unemployment has a significant positive linear relationship, with r=0.698. This relationship is logical since a stable job generates a higher income, which in turn may lead to a greater willingness to adopt renewable energy sources. Additionally, minimum wage demonstrates a moderate positive linear relationship with the dependent variable. As the population becomes wealthier, they are more likely to prioritize ecological issues after fulfilling their basic needs. Both GDP and population display a moderate negative correlation with renewable energy consumption.

The investigation of the correlation between the chosen variables and primary energy consumption presents an intriguing and worthwhile research opportunity of scholarly significance. Notably, unemployment also exhibits a significant relationship with primary energy consumption, although the correlation is negative (r=-0.873). This suggests that a larger unemployment rate may lead to greater primary energy consumption, possibly through the involvement of a mediator variable. Additionally, the minimum wage is a significant factor with a positive linear relationship to the amount of primary energy utilized. The population displays a strong positive correlation, indicating that the greater the population, the higher the primary energy consumption.

### 3.2.4 *Regression*

Prior to calculating the regression model, it is necessary to evaluate the assumptions of linear regression. Linear regression is a parametric technique that, like other parametric statistical methods, necessitates that the data meet specific assumptions. It is critical to highlight the significance of adhering to these assumptions as if the data fails to do so, the resulting regression model may be biased, and unrepresentative, and its interpretation may be incorrect. Such a model should not be utilized for prediction purposes, as it is more likely to provide inaccurate predictions.

### *3.2.5 The assumptions*

Linearity

There are several methods to check the linearity assumption in a linear regression model: Scatterplot plots the independent variable against the dependent variable and visually inspects if there is a linear relationship. Next, calculate the correlation matrix and check the correlation between independent and dependent variables. A correlation close to 1 or -1 indicates a strong linear relationship.

Homoskedasticity

This assumption tells that the variance of the Dependent variable is constant, which means that the residual variance does not change as the fitted values changes.
The Bartlett test tests the null hypothesis stating that all variances are equal.

Normality

The normality of the data can be checked in different ways, starting from plots such as Q-Q plots, histograms, and P-P plots. Another way is to calculate the kurtosis and skewness coefficients. Skewness can be interpreted as a lack of symmetry.
Another option is to run a statistical test. For example, the Kolmogorov-Smirnov test is based on an empirical and a theoretical distribution functions comparison or a Shapiro-Wilk test. Shapiro-Wilk test tests the null hypothesis that data follows a Normal distribution.
The normal distribution is observed in all variables except for Unemployment. Based on this, the null hypothesis is accepted at the 1% alpha level.

Table 14. Tests of Normality

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| GDP (current US$) | .142 | 21 | .200* | .924 | 21 | .104 |
| Inflation, consumer prices (annual %) | .246 | 21 | .002 | .787 | 21 | .000 |
| Population | .143 | 21 | .200* | .909 | 21 | .053 |
| Renewables (% equivalent primary energy) | .169 | 21 | .123 | .894 | 21 | .027 |
| Primary energy consumption (TWh) | .147 | 21 | .200* | .950 | 21 | .345 |
| Unemployment, total (% of total labor force) (national estimate) | .210 | 21 | .016 | .840 | 21 | .003 |
| Minimum wage, (kzt) | .116 | 21 | .200* | .899 | 21 | .033 |

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Multicollinearity

The regression model required independent predictors to be linearly independent. If this assumption is violated, it is called multicollinearity. In order to determine whether the assumption is valid, the calculation of the Variance Inflation Factor (VIF) is necessary.
VIF above 10 indicates high correlation and is cause for concern.

### *3.2.6 Linear regression model*

The following model shows a linear regression output. T-test of the significance of regression coefficients tests a null hypothesis stating that the variable does not significantly influence Renewable energy consumption. The test reveals that at the 95% significance level, GDP and Population statistically significantly influence the dependent variable (p-value<0.05).

Table 15. Coefficients

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | p-value |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -7.922 | 3.656 | | -2.167 | .048 |
| | GDP (current US$) | -1.156E-11 | .000 | -.815 | -3.764 | .002 |
| | Inflation, consumer prices (annual %) | -.024 | .026 | -.075 | -.930 | .368 |
| | Population | 9.355E-7 | .000 | 1.239 | 3.720 | .002 |
| | Primary energy consumption (TWh) | -.004 | .003 | -.532 | -1.234 | .238 |
| | Unemployment, total (% of total labor force) (national estimate) | .171 | .106 | .372 | 1.619 | .128 |
| | Minimum wage, (kzt) | -3.539E-5 | .000 | -.398 | -1.438 | .172 |

a. Dependent Variable: Renewables (% equivalent primary energy)

The following plots also represent the linearity between Renewable energy consumption and predictors.

We see that the Minimum wage reveals more of a quadratic parabolic relationship with the amount of Renewable energy consumption.

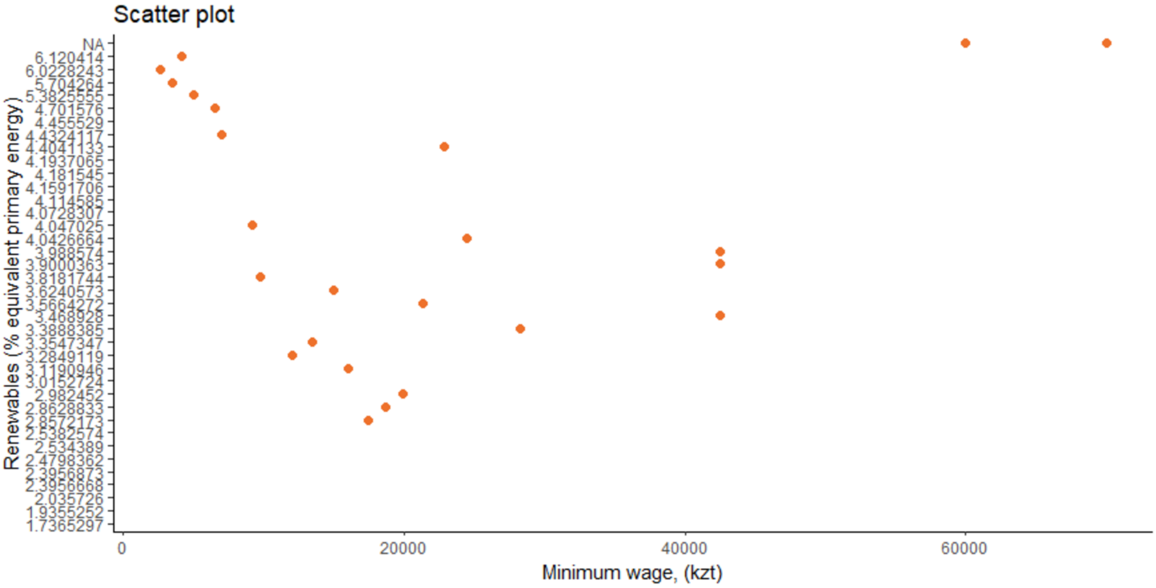


*Figure 22. Scatter plot of Minimum wage and Renewables (kzt)*

The population has a non-linear relationship with the dependent variable as it reveals a positive trend but only till a certain level.

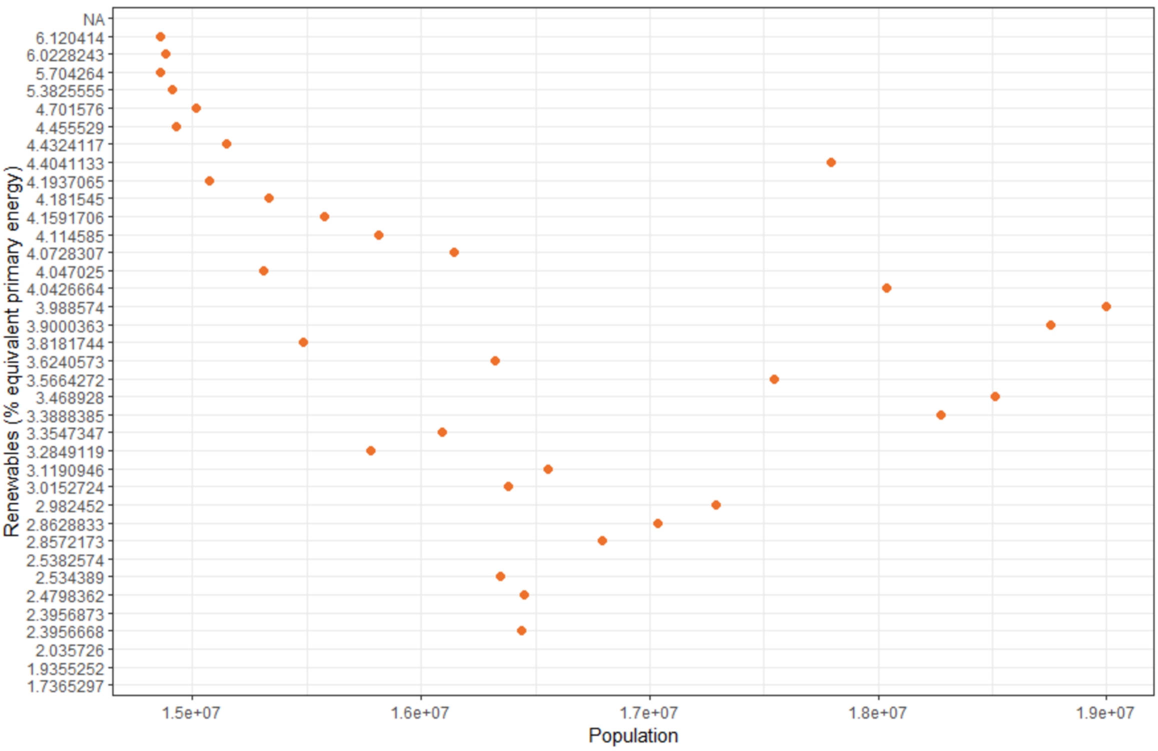


*Figure 23. Scatter plot of Population and Renewables.*

The GDP, which is revealed to be a significant predictor in a plot, also shows a more parabolic relationship with the dependent variable.

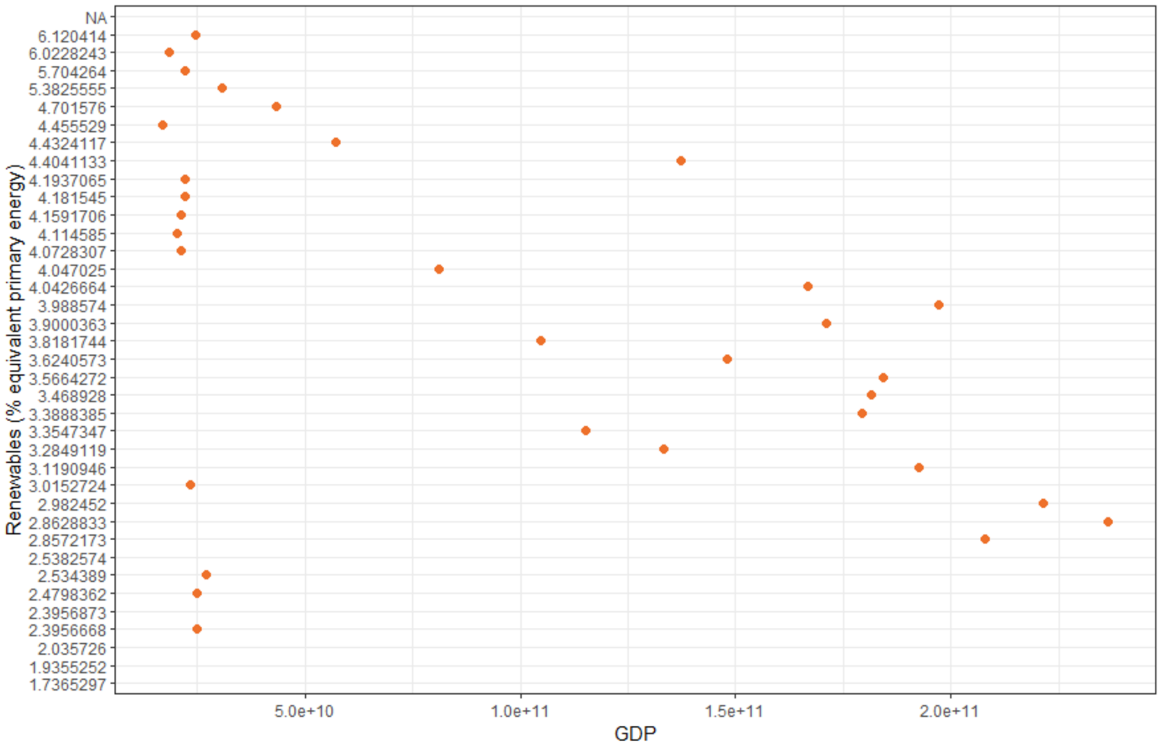


*Figure 24. Scatter plot of GDP and Renewables*

The Inflation plot appears to be highly influenced by an extreme value. Overall, the variable was revealed to be a non-significant predictor of Renewable energy consumption.

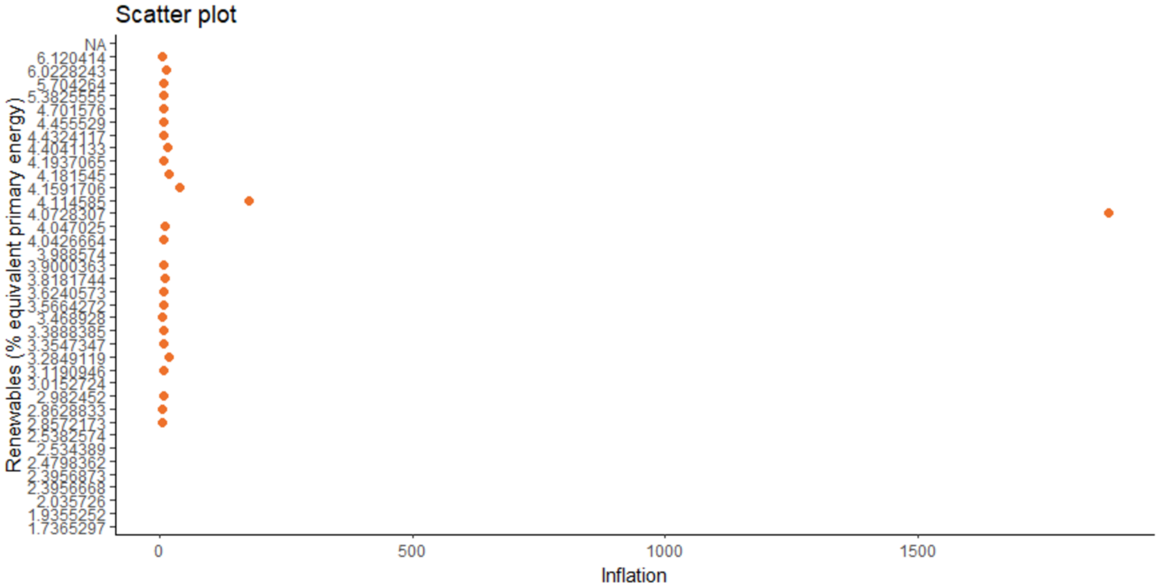


*Figure 25. Scatter plot of Inflation and Renewables*

Unemployment shows a linear positive trend.

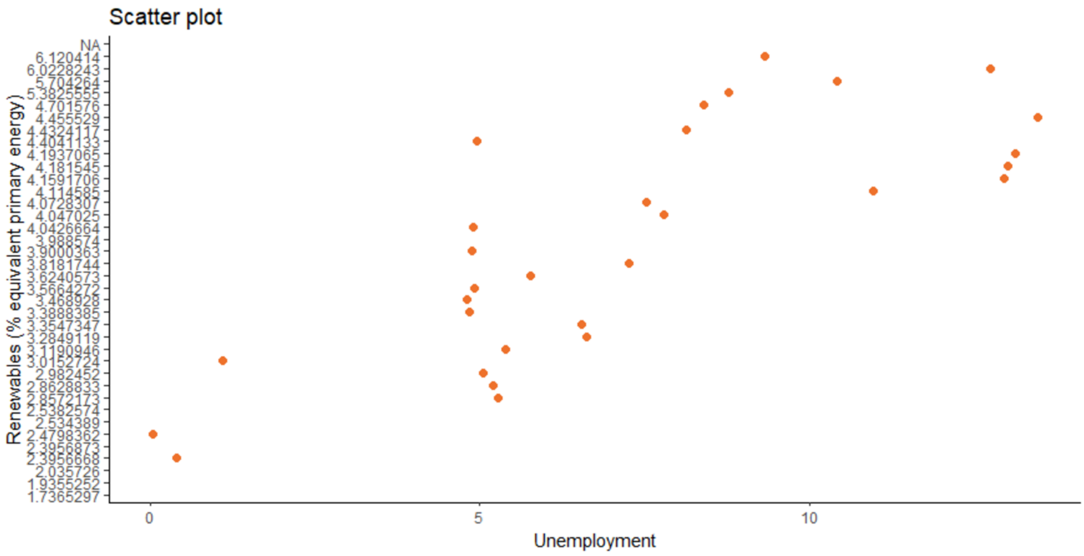


*Figure 26. Scatter plot of Unemployment and Renewables.*

Whereas the Primary energy consumption plots shows a negative linear trend which makes sense that both energy types are self-replaceable.

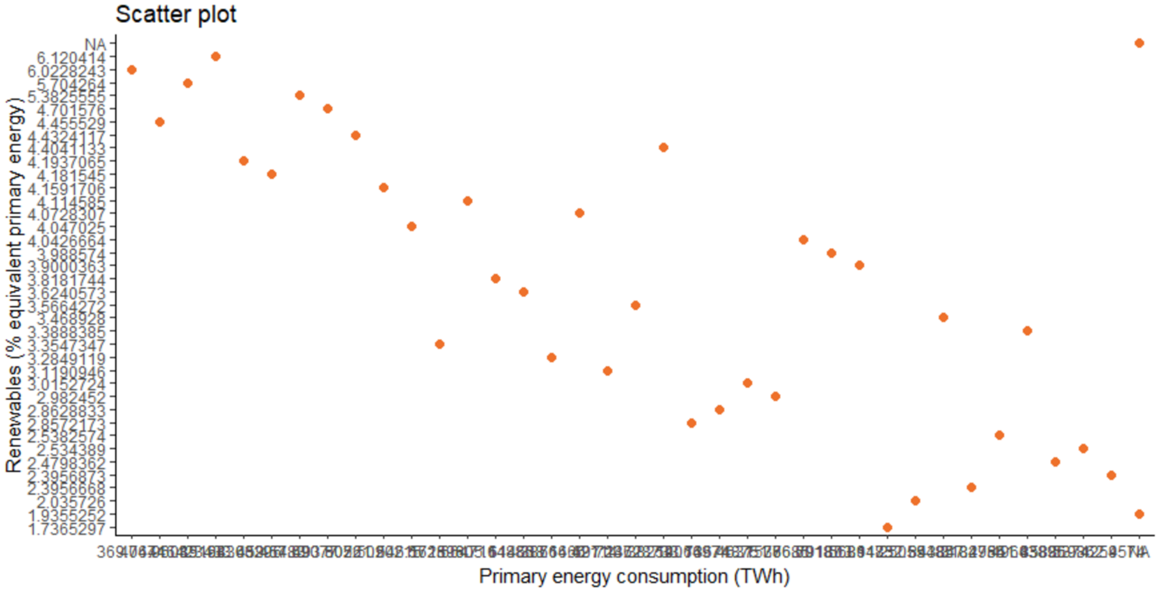


*Figure 27. Scatter plot of Primary energy consumption and Renewables.*

The following tables reveal a coefficient of determination value which reveals the amount of variation of Renewable energy consumption explained by the model (predictors).
The adjustment to the amount of the predictors R2 value reveals that 89.1% of the variation of Renewable energy consumption explained by the model.

*Table 16. Model summary*

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .961[a] | .923 | .891 | .335 |

a. Predictors: (Constant), Minimum wage, (kzt), Inflation, consumer prices (annual %), GDP (current US$), Unemployment, total (% of total labor force) (national estimate), Population, Primary energy consumption (TWh)

In the following table are the results of the F-test, which tests the null hypothesis stating that the model is not statistically significant. It reveals (F=28.111, p<<0.0001) that we do not accept the null hypothesis at the 5% alpha level. The model is statistically significant.

*Table 17. ANOVA*

**ANOVA**[b]

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 18.985 | 6 | 3.164 | 28.111 | .000[a] |
| | Residual | 1.576 | 14 | .113 | | |
| | Total | 20.560 | 20 | | | |

a. Predictors: (Constant), Minimum wage, (kzt), Inflation, consumer prices (annual %), GDP (current US$), Unemployment, total (% of total labor force) (national estimate), Population, Primary energy consumption (TWh)

b. Dependent Variable: Renewables (% equivalent primary energy)

## 3.3 Results

A linear regression model was constructed in order to investigate the potential relationships between various economic factors and the consumption of renewable energy in Kazakhstan. The findings of the analysis of multiple linear regression suggest that the utilization of renewable energy is significantly affected by both GDP and population. Additionally, the model was determined to be statistically significant.

Furthermore, a correlation analysis was conducted to examine the linear relationships between pairs of variables. It was found that primary energy consumption was strongly and negatively correlated with the consumption of renewable energy, as evidenced by the scatter plot.

Moreover, unemployment was positively correlated with the consumption of renewable energy, suggesting that as employment rates increase, the government may be able to devote more attention to the issue of renewable energy usage. The minimum wage also exhibited a moderate positive relationship with both renewable and primary energy consumption. Interestingly, the transition from fossil fuels to renewable energy appeared to have a positive effect on unemployment rates but a negative effect on the minimum wage. Moreover, the level of GDP was found to have a negative influence on renewable energy consumption, suggesting that resource-based countries with higher GDP rates tend to consume less renewable energy and rely more on fossil fuels.

# 4 Discussion

Kazakhstan has witnessed substantial economic expansion following its independence, which is primarily attributed to the exportation of fossil fuels and metals.

However, there is a downside to this growth. In the absence of adequate policies, the environmental situation is likely to deteriorate as a result of greenhouse gas emissions.

This puts at risk the nation's adherence to the Paris Agreement's target of diminishing carbon dioxide emissions by 15% by 2030 and carbon neutrality by 2060.

In 2023, the European Union is implementing a carbon tax on imports to fight global warming. This poses a challenge for Kazakhstan's economy since the EU is the biggest trade partner, accounting for about 40% of its exports.

Kazakhstan's GDP has a carbon intensity that is double that of the global mean and three times higher than that of the EU, which indicates that the competitiveness of its exports will significantly reduce.

The worldwide movement towards a sustainable economy has resulted in a decrease in the demand for Kazakhstan's coal imports in favor of more environmentally friendly alternatives.

Also, the gradual decline in domestic carbon consumption will result in substantial policy challenges, including the loss of employment for a significant number of people, as it is a leading source of employment in the country. However, with thoughtful planning, Kazakhstan can transition to clean energy sources and decarbonize its economy without jeopardizing the welfare of its citizens.

Despite having a substantial potential for renewable energy production, particularly in solar and wind power, the renewable energy industry in Kazakhstan has not progressed as much as it could have.

There exists a multitude of causative factors that have contributed to the relatively slow pace of development within the renewable energy sector:

| **Economic and financial** | **Technical** | **Political** |
|---|---|---|
| Small market size | Lack of infrastructure | Weak regulatory |
| High up-front capital costs for investors | Lack of specialized technology for the needs of market | Weak legal frameworks to stimulate the use of renewable energy in the electricity sector |
| Low electricity tariffs | Lack of skilled training facilities | Lack of government support: |
| Lack of investor interest from the private and public sector | Inefficient technologies | Bureaucracy |
| Lack of financial resources | Lack of experience<br>Inadequate levels and quality of scientific support | Corruption and lack of transparency |

*Table 18. Problems and existing limitations*

The transition to a more diversified economy is a wise decision for resource-rich countries like Kazakhstan. While exploiting natural resources can provide a quick fix to economic problems, it is not a long-term sustainable solution. Depending solely on a solitary industry may expose nations to susceptibility to fluctuations in global commodity prices and shifts in demand. Moreover, extractive industries are often associated with high levels of pollution and carbon emissions, which can have long-lasting effects on the environment and public health [65].

Electricity generated from environmentally friendly sources is added to the national power supply. The government guarantees to purchase it from companies for 20 years, with tariffs that adjust according to inflation. Since 2018, Kazakhstan has implemented a system of electronic bidding to attract investment in renewable energy.

Resource-rich countries face the challenge of balancing investment in natural resource extraction with investment in other sectors to prevent crowding out and macroeconomic imbalances that can hinder economic growth. Additionally, the income from natural resources can be unstable, causing economic instability [59].

It is expected that renewable energy will generate 2.7 times more electricity globally between 2010 and 2035. In addition, it is anticipated that there will be a substantial rise in the utilization of biofuels, t is expected that the consumption will increase significantly, reaching 4.5 million barrels of oil equivalent per day by 2035. the amount of oil equivalent per day recorded in 2010, which was 1.3 million barrels, has increased by more than three times.

While nearly all biofuels are currently used in road transport, there is expected to be an increase in the use of aviation biofuels by 2035. Additionally, the use of modern renewables to produce heat is anticipated to nearly double, rising from 337 million tonnes of oil equivalent in 2010 to 604 million tonnes of oil equivalent by 2035 [63].

Kazakhstan's experience shows that resource-rich countries are not immune to economic volatilities. The crisis of 2008 highlighted the need for diversification and prompted the government to begin transitioning to an active industrial policy. However, in the modern world, economic diversification must also include a focus on renewable energy and reducing carbon emissions. As we approach 2023, Kazakhstan should begin to think about how it can transition to the new standards of the world with renewable energy.

Investing in renewable energy will provide long-term economic stability while also reducing the country's impact on the environment. It will also help Kazakhstan to improve its global reputation and attract investment from environmentally-conscious companies and investors. Additionally, promoting renewable energy will create new industries and jobs, helping to boost economic growth and increase opportunities for its citizens.

While exploiting natural resources can provide a temporary solution to economic problems, it is not a sustainable long-term solution. Kazakhstan's move towards diversification is a wise decision. However, it must also focus on renewable energy and reducing carbon emissions to ensure long-term economic stability and environmental sustainability.

Electricity from renewable energy sources is more expensive than electricity from non-renewable sources in resource-based countries, such as Kazakhstan.

It is due to factors such as an abundance of fossil fuel resources, the lower capital costs of traditional fossil fuel power plants, and the lack of incentives or policies that support renewable energy adoption.
Kazakhstan has typically well-established fossil fuel industries that have long dominated its energy mix and provides a stable source of revenue.
Consequently, there is a lack of investment in renewable energy infrastructure and policies and incentives that promote renewable energy adoption.
However, it is worth noting that renewable energy costs have been declining globally in recent years, and some resource-based countries are starting to invest in renewable energy infrastructure as a way to broaden their range of energy sources and diminish their carbon footprint. As a result, they are turning to this solution.
Renewable energy expenses are projected to keep decreasing as technology advances, and larger production volumes lead to economies of scale, making it increasingly cost-competitive with fossil fuels in resource-based countries and beyond.
According to a 2018 article by Amirov et al. titled "Economic and Energy Security of the Republic of Kazakhstan," over the 15 years studied, Kazakhstan has managed to improve its energy security primarily through increased accessibility and affordability of energy. However, the country's environmental stewardship and energy efficiency have both decreased during this time. The energy and economic efficiency dimension experienced the most significant decline, with a decrease of 2.8 points [64].

Despite having ample potential for wind, solar, hydro, and biomass energy, Kazakhstan has not been able to fully harness these resources due to various technical, institutional, social, and economic barriers. Therefore, to promote the development of renewable energy, the government adopted the "National Concept for Transition to a Green Economy - 2050" in 2013.
Under this concept, the government has taken steps to attract more investment in the renewable energy sector, such as introducing a 15-year feed-in-tariff mechanism and, more recently, renewable auctions.
Currently, there are approximately 130 facilities for generating renewable energy in Kazakhstan, and the country has substantial potential for producing environmentally friendly energy.

By 2050, the government plans for non-thermal sources to generate at least half of the country's energy needs, which includes starting a domestic nuclear energy program and significant growth in non-hydro renewables. The EBRD also plans to invest around USD 244.2 million in Kazakhstan's renewable energy sources[68]. In 2021, electricity generation from renewable energy sources in Kazakhstan increased by 15%, and there is a space to grow.

Kazakhstan could also potentially export renewable energy to neighboring countries such as China, Russia, or the countries in Central Asia. However, it would require investment in the necessary infrastructure and agreements with the importing countries.

To transport renewable energy to other continents, particularly Europe, the most common method is to use direct high-voltage current (HVDC) transmission lines. These lines are more efficient than traditional alternating current (AC) lines, allowing for transmitting more significant amounts of electricity over long distances with less energy loss. This approach has been demonstrated by Morocco, which has invested significantly in renewable energy by building large-scale solar and wind power plants. Morocco is already connected to the European electricity grid via an undersea cable, and there are plans to expand this connection in the future, which would enable the country to export its excess renewable energy to Europe.

It is evident that transitioning towards renewable energy sources requires not only government assistance but also international organizations' support.

Moreover, several organizations can help improve the situation of renewable energy in Kazakhstan.

Asian Development Bank has actively promoted renewable energy in Kazakhstan through its financing and technical assistance programs.

International Finance Corporation is a member of the World Bank Group and provides financing and advisory services to private sector companies to promote renewable energy projects in the country. In addition, IFC can provide financing for renewable energy projects, advisory services for project development, and technical assistance for policy and regulatory reform.

The United Nations Development Programme collaborates with the government of Kazakhstan and other relevant parties to encourage sustainable development and aid the nation's shift towards an eco-friendly economy. UNDP can provide technical assistance for policy and regulatory reform, capacity building, and project development.

The EBRD offers funding and expert guidance to renewable energy initiatives in Kazakhstan, encompassing wind, solar, and hydroelectric power.

Global Green Growth Institute is an organization that supports the development of green growth policies and projects in developing countries. GGGI can provide technical assistance for policy and regulatory reform, capacity building, and project development in renewable energy and other green growth sectors.

These organizations have the potential to enhance the state of renewable energy in Kazakhstan.

Kazakhstan's government and private sector can also play a significant role in promoting renewable energy through policy and regulatory reform, financing, and capacity building.

The Asian Development Bank (ADB) has supported several Kazakhstan-related renewable energy and climate projects.

In 2016, ADB approved a framework to facilitate the advancement of renewable energy projects in the country. The framework aimed to provide up to $1 billion in loans and guarantees to support the development of wind, solar, hydropower, and other renewable energy sources in the country.

In 2015, ADB provided Kazakhstan with a $245 million loan to construct a bypass road around Atyrau. The road was designed to reduce city traffic congestion and air pollution.

In 2014, ADB provided a $200 million loan to improve the energy efficiency of the district heating system in Almaty, Kazakhstan's largest city. The project aimed to reduce greenhouse gas emissions and improve air quality in the city.

In 2010, ADB provided a $200 million loan to rehabilitate the district heating system in Astana, Kazakhstan's capital city.

ADB continues to partner with Kazakhstan's government and private sector to foster sustainable development and curtail greenhouse gas emissions, evidenced by several upcoming initiatives.

ADB plans to support the development of green cities in Kazakhstan and support improving solid waste management systems. The projects will aim to improve the urban environment and reduce greenhouse gas emissions through investments in sustainable urban infrastructure and energy-efficient buildings and reduce greenhouse gas emissions by promoting waste reduction, recycling, using renewable energy in waste management.

ADB also plans to support the CAREC program, which aims to promote regional cooperation and integration in Central Asia. The program includes several initiatives related to renewable energy and climate, such as developing regional energy markets and promoting energy efficiency and renewable energy.

To better understand the potential for the transition to renewable energy sources in Kazakhstan, a SWOT analysis was conducted:


*Figure 28. SWOT analysis of the transition to renewable energy sources in Kazakhstan.*

To obtain a comprehensive understanding of the transition from fossil fuels to renewable energy sources, a SWOT analysis was conducted related explicitly to the development of renewable energy sources in Kazakhstan:


*Figure 29. SWOT analysis of the development of renewable energy sources in Kazakhstan.*

*Figure was complied using by Creately.com [74]*

Overall, the SWOT analysis highlights the potential for Kazakhstan to develop and transition to renewable energy sources, but also identifies several challenges that must be addressed to ensure a successful transition. These challenges include the need for increased investment in infrastructure and transmission capabilities, the development of domestic expertise and capacity, and the implementation of effective policies and incentives to support the growth of the renewable energy industry.

On the basis of this paper is recommended to insert renewable power plants in the regions of the country, which is described in the map below:

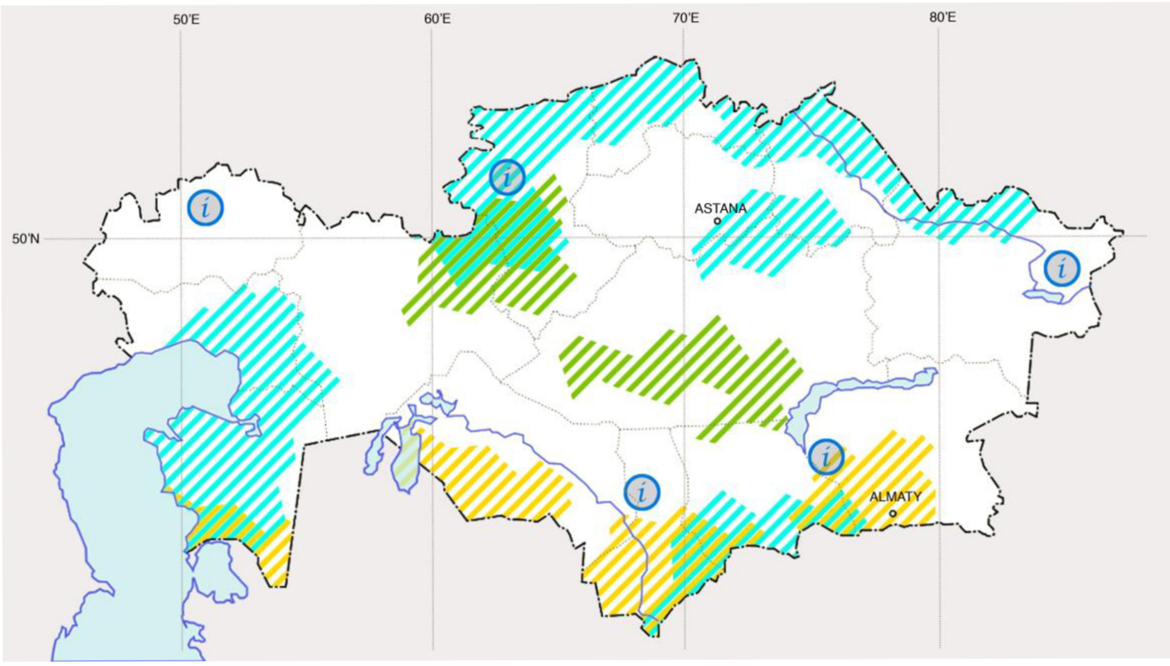


*Figure 30. Map depicting potential locations for the installation of renewable energy plants.*

*The image was produced by the author in Photoshop software.*

wind power plants
biomass plants
solar power plants
hydropower

# 5 Conclusion

Based on the findings described in this paper, it is advisable to propose several measures to advance economic stability and environmental security.

First, it suggested providing tax incentives or subsidies for companies that invest in renewable energy. It would encourage businesses to adopt sustainable practices and reduce their carbon footprint. Additionally, it proposed that the government mandates that a certain percentage of energy production must come from renewable sources. Such a policy would signal to investors that the government is committed to renewable energy and would encourage the development of renewable energy infrastructure.

Furthermore, it is recommended that the government introduce a policy that allows households and businesses to sell surplus energy generated by their renewable energy systems back to the grid. It would provide an additional revenue stream for producers and encourage investment in renewable energy.

Additionally, it suggested running public education campaigns to raise awareness about the benefits of renewable energy and the negative impacts of fossil fuels. Such campaigns would help build public support for the transition to renewable energy and increase demand for sustainable practices.

Finally, during the research, a lack of qualified professionals and an insufficient educational system related to renewable energy was discovered. Consequently, it is necessary for the government to allocate funds toward research and development in order to enhance the efficiency and effectiveness of sustainable energy technologies. Furthermore, this investment would help accelerate the adoption of renewable energy by making it more competitive with fossil fuels.

Kazakhstan will continue to welcome foreign investment to bring in the capital and expertise needed to achieve its goals. However, investor uncertainty about the operating environment may hinder the government from reaching its targets. The country's electricity sector needs modernization in terms of generation and transmission infrastructure.

There is a strong possibility that Kazakhstan could emerge as a frontrunner in renewable energy within the region, providing a model for other nations to emulate.

The behavior of consumers is largely influenced by economic incentives. As a result, most individuals do not have the autonomy to make choices based on environmental or ethical considerations but rather are driven by the financial realities of their situation. It is particularly relevant in low-income communities, where energy costs can be a significant burden.

To mitigate this, governments have a responsibility to redistribute wealth and ensure that no segment of society is disproportionately impacted by the transition to cleaner energy sources. It could manifest in providing subsidies, grants, or other monetary aids to facilitate the accessibility and affordability of renewable energy for everyone.

Additionally, policies and regulations should be implemented to ensure that energy companies are held accountable for providing access to clean energy for all, regardless of income or location.

As a fledgling nation with a new economy, Kazakhstan was heavily dependent and still dependent on fossil fuels, which is reasonable. Furthermore, as demonstrated in the methodology section, countries that rely on natural resources and have higher GDP rates tend to utilize less renewable energy and rely more on fossil fuels. Hence, it would be judicious to collaborate with countries that have made strides in this domain and push the country toward sustainability in the near future.

As demonstrated in the methodology section of the study, it is established that secure employment generates increased earnings, which may consequently result in a greater inclination toward embracing renewable energy sources. Furthermore, as the population becomes more affluent, they are prone to placing ecological concerns as a higher priority after meeting their fundamental necessities.

It has also been established that non-renewable and renewable energy sources are interchangeable in energy generation. This presents an opportunity to substitute fossil fuels with renewable sources at a faster rate.

It is important to note that the energy transition is not only about the environment but also about social justice. It is not solely about technology but also about the economy and individuals. Therefore, governments must play a crucial role in providing a social safety net for vulnerable communities and ensuring the transition is inclusive and fair for all.

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