Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Bachelor Thesis

Alternative energy sources in Kazakhstan

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

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Thesis title
Alternative Energy Sources in Kazakhstan

Objectives of thesis

The main objective of the thesis is to estimate the potential and efficiency of renewable energy sources in Kazakhstan. To understand and identify the appropriate trend of RES in condition of Kazakhstan.

Methodology

The work consists of two parts: theoretical and practical. The theoretical part describes alternative energy sources and working principles. The practical part is devoted to estimation of potential and prospects of using alternative energy sources using the example of a project of small solar plant in Shymkent region. The main methods are comparison, analysis and synthesis of results.

The proposed extent of the thesis 30 – 40 pages

Keywords

RES, alternative energy, wind energy, solar power, electricity generation

Recommended information sources

BOYLE, G. Renewable *energy* : [power for a sustainable future]. Oxford: Oxford University Press, 2004.
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HARRIS, J M. – ROACH, B. Environmental and natural resource economics : a contemporary approach.
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Study of the alternative energy industry of the Republic of Kazakhstan. Volume 1 General analysis, conclusions and recommendations

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Prague on 19. 03. 2020

Declaration

I declare that I have worked on my bachelor thesis titled "Alternative energy sources of energy in Kazakhstan" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 23.03.2020 ______________________________

Acknowledgement

I would like to thank doc. Ing. Karel Tomšík, Ph.D. for advices and support during my work on this thesis.

Alternative energy sources in Kazakhstan

Abstract

This thesis discusses the sources of renewable energy in condition of Kazakhstan. Thesis analyses the current status of the transition to a green economy. The evaluation of efficiency was made on example of solar power plant. The author studies all the energy sector in Kazakhstan in order to give the correct assessment of the current situation of RES, identify the main problems and obstacles of developing and suggest appropriate ways and solutions.

Keywords: RES, solar power, wind energy, power plant, potential, hydropower plant, electricity

Alternativní zdroje energie v Kazachstánu

Abstrakt

Tato práce pojednává o zdrojích obnovitelné energie ve podmínkach Kazachstánu. Práce analyzuje současný stav přechodu k zelené ekonomice. Hodnocení účinnosti bylo provedeno na příkladu solární elektrárny. Autor studuje celý energetický sektor v Kazachstánu, aby dosahl správně ohodnocení současnou situaci AZE, identifikoval hlavní problémy a překážky rozvoje a navrhnoul vhodné způsoby a řešení těchto problémů.

Klíčová slova: AZE, slunečná energie, větrná energie, elektrárna, potenciál, vodní elektrárna, elektrická energie

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List of abbreviations

CIS Commonwealth of Independent States

RES renewable energy sources

UNDP/GEF United Nations Development Programme/Global Environmental Finance

MEMR Ministry of Energy and Mineral Resources

KEGOC Kazakhstan Electricity Grid Operating Company

HPP Hydro power plant

kWh Kilowatt per hour

TW Terawatt

CSP Concentrated solar power

PV Photovoltaic Power

SPP Solar power plant

WPP Wind power plant

HPP Hydro power plant

NPP Nuclear power plant

RK Republic of Kazakhstan

CO2 Carbon dioxide

FAO Food and Agricultural Organization

UN FAO Food and Agricultural Organization of the United Nations

KAS Kansas agricultural Statistics

1 Introduction

For today there is increasing attention to the alternative energy. For all species and for all life on the Earth energy is required. On the Earth there are 7.6 billion people who consume a certain amount of energy every day. For today, traditional sources of energy are fuel and minerals. During the fuel combustion carbon dioxide is releasing into the atmosphere and it is one of the general reasons of global warming. These resources are limited and prices are continuously increasing. Further consumption and burning hydrocarbons will lead to scarcity of general resources of energy. Hydrocarbon-based industrial power is very expensive, especially for countries where territory is not so mineral-rich. It is very important for the humanity to start, as soon as possible, to implement and use all the potential of alternative energy.

2 Objectives and Methodology

The main goal of the thesis is to evaluate the potential of using alternative energy sources in Kazakhstan.

For achieving this goal, we have to solve following tasks:

- Understand what alternative sources of energy are and how we use it
- Analyze the energy balance in Kazakhstan
- Analyze the current state of green economy transition
- To determine the main obstacles
- Estimate the solar potential of Shymkent region
- Propose a plan of solar power construction and calculate it’s cost

Three following tasks were solved in the literature review.

The basic calculations were made in the practical part. The potential and prospects of usage alternative sources of energy were evaluated.

3. Literature Review

Energy can be non-renewable and renewable. Most of resources consumed from non-renewable sources are:

- Petroleum and petroleum products
- Hydrocarbon liquefied gas
- Natural gas
- Coal
- Nuclear energy

There are 5 general sources of renewable energy:

- Wind energy
- Solar power
- Geothermal heat inside the Earth
- Plant biomass

Energy can be primary and secondary.

PE is an energy form found in nature, that has not been subjected to any human engineered conversion process. It is petroleum, hard coal, natural gas, natural uranium, solar energy, wind energy, tidal.

Secondary energy sources are sources, that are not found in the nature but derived from one or some primary sources. Most popular sources are hydrogen and electricity.

3.1 Wind energy

Since ancient times, people used the wind as force replacing labor. For example, when crossing rivers or oceans, the wind was an assistant. Even in antiquity, people used mill to grind grains into flour. So today, wind power is not new.

3.1.1 Working principle of wind turbine

When the wind passes through the turbine, the blades begin to rotate due of the kinetic energy of the wind. All this comes to rotation of shaft which connected with reduction gear. Reduction gear increases the rotational speed of the shaft which is connected with the generator. Spinning rotor generator generates a three-phases voltage which should be transformed. To this end controller is provided in the construction to convert alternating current to direct current. From the direct current storage batteries are charged. Going through them current goes to inverter where acquires acceptable properties for normal work of electrical appliances. From direct current it converts to alternating current but with traditional with traditional indicators that we used to: single-phase current with 220 volts and 50 cycles.[1]

3.1.1 Advantages of wind energy

Generating electricity from wind energy reduces the need to burn fossil fuels. The use of wind energy not only reduces greenhouse gas emissions into the atmosphere but also helps to preserve mineral resources. Wind turbines have a relatively small land footprint. Wind turbines can provide electricity to remote locations.

3.1.2 Disadvantages of wind energy

Despite on advantages, wind energy has disadvantages as well.
Implementing of wind plants entails high investment cost. Also, the power of energy supply totally depends on wind power and human can't influence on it. Wind turbines generates noise which can disturb people who live around. Wind energy is a threat to birds. A lot of birds were killed in collisions with turbines spinning rotor blades and support tower. Especially, birds are at risk at night, when construction is wrapped in darkness. Also, large scale use leads to changing landscapes and climate.

3.1.3 Wind energy in Kazakhstan

Kazakhstan is favourable country for the large-scale use of wind energy. The most suitable zones are South, West, North and Central. The availability of free space will allow to develop wind power up to 1000 Megawatts.[2]
According to the results of the project "Kazakhstan is Initiative of developing the wind energy market" which was held jointly with UNDP/GEF and the ministry of energy and mineral resources (MEMR) of the Republic of Kazakhstan the most effective and favourable regions for construction of wind plants were shown.
Based on the results of the wind potential estimation the sites could be nominally divided into three groups:

[1]https://hi-news.ru/eto-interesno/kak-eto-rabotaet-vetryanaya-elektrostanciya.html
[2] *V.F. Govorun, S.M. Babashev Development of Wind energy in Kazakhstan, ISSN 1680-9165 №3-4 2015, 15.12.2015 available at https://cyberleninka.ru/article/n/razvitie-vetroenergetiki-v-kazahstane Accessed 21.01.2020*

- Highly potential sites with mean wind speed over 8.0 and wind availability around or more than 90 percent of the period (Yerementau, Fort Shevchenko and Shelek);
- Locations with mean speed higher than 7.0 and wind availability over 80 percent of the period (Astana, Karabatan, Arkalyk and Zhuzymdyk);
- Sites with lower potential than others (Karkaraly and Kordai).

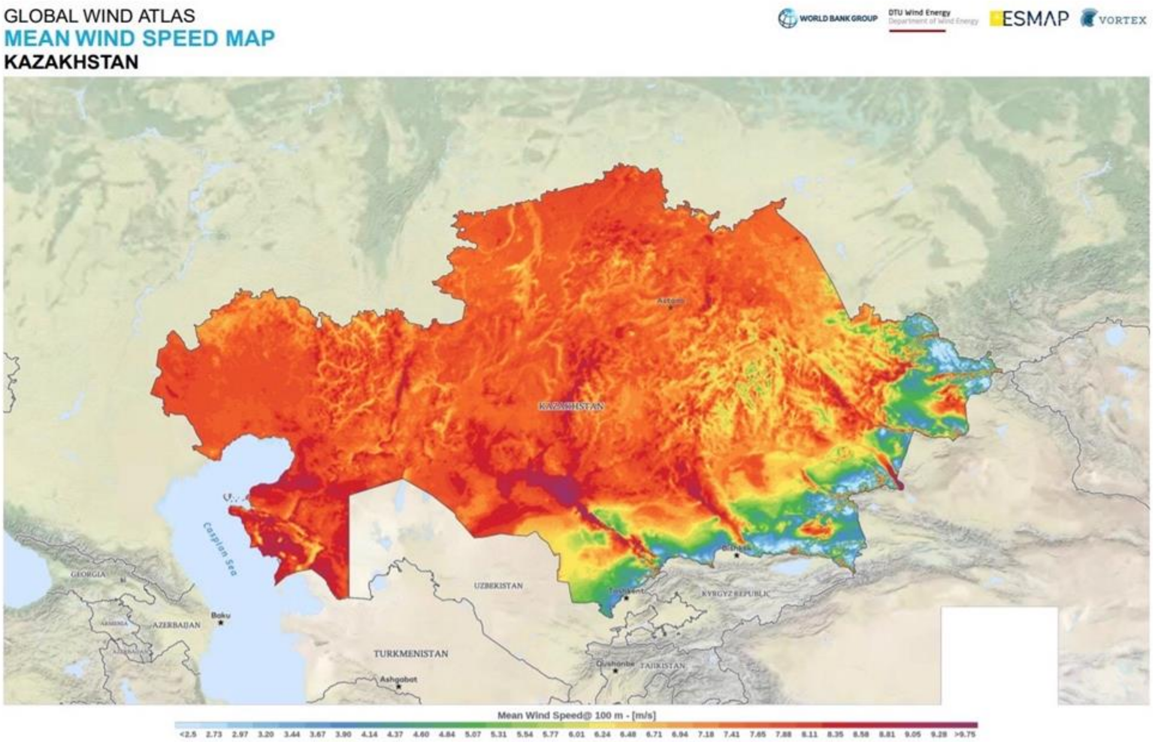


Figure 1. Mean wind speed map. Wind Atlas of Kazakhstan created by UNDP/GEF and the Ministry of Energy and Mineral resources (MEMR) Source KEGOC

Source https://globalwindatlas.info/

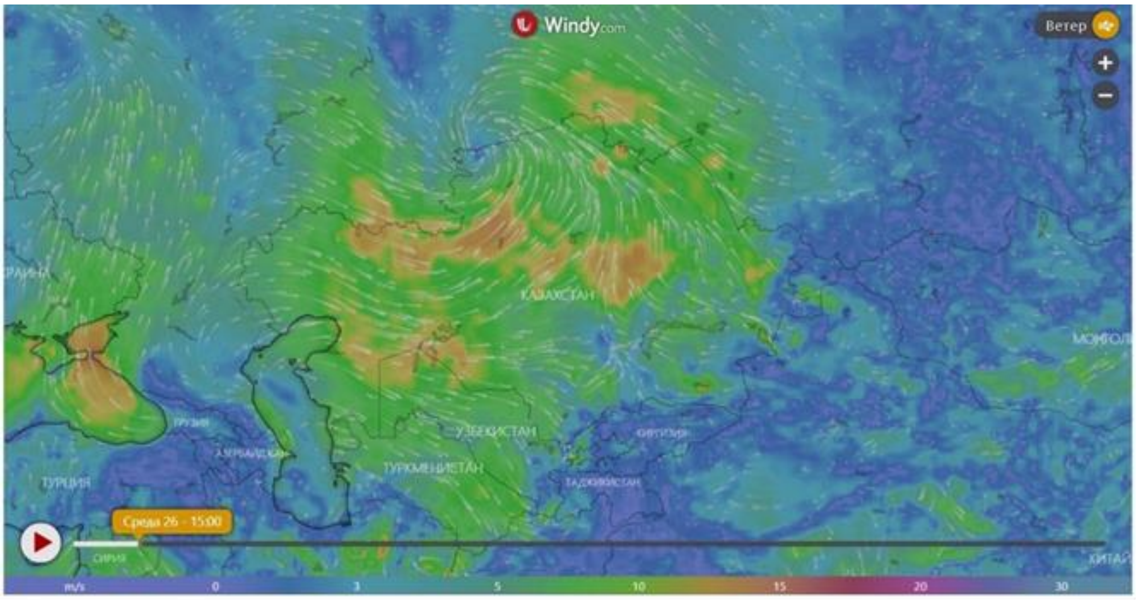


Figure 2. Wind Atlas of Kazakhstan created by UNDP/GEF and the Ministry of Energy and Mineral resources (MEMR) Source https://www.windy.com/?46.729,9.141,3

3.2 Hydroelectric power

A hydroelectric power plant is a structure that uses the energy of water stream as a source. Hydroelectric power plants are usually built on rivers by constructing dams and reservoirs. For the effective operation of the hydroelectric power station, two main factors are required: guaranteed water availability all year round and large slopes. A chain of hydraulic structures provides a pressure of water flowing through locks and pressure pipe to the blades of hydraulic turbine which makes generators generate hydroelectric power.

The power of hydropower plants depends on the pressure of the water and the efficiency of the turbines and generators used.

3.2.1 Classification of hydropower plants

Hydroelectric power plants are classified according to their power output.

- Powerful plants from 25 Megawatts and above
- Medium plants up to 25Megawatts
- Small plants up to 5 Megawatts

3.2.2 Advantages of hydroelectric plants

Electricity produced by water dam systems do not produce green gas emissions. Dams are designed to last many years and so can contribute to the generation of electricity for many years. No need to extract, process, transport fuel for the operation of a hydroelectric power station. HPP performance is easy to control (by changing the flow rate of water).

3.2.3 Disadvantages of hydroelectric plants

Dams are extremely expensive to build and must be built to a very high standard. Hydroelectric power station can create environmental pollution. The building of large dams can cause serious geological damage. Also, building a large dam alters the natural water table level.

3.2.4 Hydropower potential in Kazakhstan

Kazakhstan, due to the presence of mountainous terrain in the southern and eastern parts of the country, has significant hydropower potential. Estimated potential in Kazakhstan is 170 billion kWh per year.[3]

Hydropower is the second largest source of electricity production in Kazakhstan. According to the official report of "Samruk-Energo" hydroelectricity generated in 2019 is 12.3% of the total generating electricity capacity. Kazakhstan takes 3rd place among CIS countries in hydropower potential. The hydropower potential is estimated at approximately 170 billion kWh per year, technically feasible - 62 billion kWh. The hydro-potential of medium and large rivers is 55 billion kWh, of small rivers - 7.6 billion kWh per year. Meanwhile, the potential of small hydropower plants technically possible to use is about 8 billion kWh. Hydropower resources are distributed throughout the country. There are three largest and efficient zones: the Irtysh river basin with the main tributaries (Bukhtarma, Uba, Ulba, Kurchum, Kardzhil), the South-East zone with the Ili river basin and the South zone, Syrdarya river basins, Talas and Chu.

[3] Nurlan Iskakov, Minister of Environment [online] 20.02.2008. Available at https://www.zakon.kz/104978-gidrojenergeticheskijj-potencial.html Accessed 20.02.2020

3.3 Solar power

The sun is a specific hydrodynamic object with a diameter of 1,390,000 km, formed from a cloud of gas, mainly hydrogen. The temperature of its bowels is so high that it provides the synthesis of hydrogen into helium.

The electromagnetic radiation of the sun's photosphere spreads in the space at the speed of light 300,000 km / s in the form of diverging rays.

The average amount of solar energy entering the Earth's atmosphere is about 1.353 kW / m^2, or 178,000 TW. A much smaller amount reaches the surface of the Earth, and the fraction that can be used is even smaller. However, solar energy and renewable raw materials represent a resource potential that far exceeds the potential of fossil resources. The amount of energy supplied to the Earth by the Sun annually is 15,000 times more than the annual consumption of atomic energy and energy from fossil sources.[4]

3.3.1 Working principle

Generally, there are two types of solar power generation used in integration with gird power -concentrated solar power (CSP) and photovoltaic (PV) power.

Concentrated solar energy systems (also called concentrated solar thermal energy and CSP) use mirrors or lenses to focus a large area of sunlight or solar thermal energy. Electrical power is generated when concentrated light is converted to heat, which drives a heat engine (usually steam turbines) connected to the generator's electrical power.

Photovoltaic solar panels (PV) use sunlight through the "photoelectric effect" to generate direct current (DC). Then, direct current is converted to alternating current, usually using inverters and other components, for distribution over the mains. Photovoltaic systems do not produce or store thermal energy, since they directly generate electricity, and electricity cannot be easily stored (for example, in batteries), especially at high power levels.

CSP construction requires huge area for deployment as it includes both steam and solar plants which demand high initial costs. But, CSP systems are more attractive for large-scale power generation as thermal energy storage technologies.

[4] Plachkova Svetlana Grigoryevna, Plachkov Ivan Vasilievich, Dunaevskaya Natalya Ivanovna [online] book 1, part 1, chapter 5.2 available at http://energetika.in.ua/ru/books/book-1/part-1/section-5/5-2 Accessed 20.02.2020

3.3.2 Advantages of solar batteries

Solar batteries do not contribute harmful toxins to the atmosphere to the and have high ecological compatibility. Batteries are completely harmless to human and environment. There are no operating costs. No fuel is required for batteries, they use natural resources. Usually batteries have long service time and do not require connection to the power gird.

3.3.3 Disadvantages of solar batteries

Solar batteries require high initial costs not only for panels but also for installation. Solar batteries are dependent on the light which comes from the sun. They can’t work during rainy or cloudy days. Solar batteries have low efficiency.

3.3.4 Solar power in Kazakhstan

The potential of solar energy in Kazakhstan is quite large. Kazakhstan’s solar power potential is estimated at 3.9 to 5.4 TWh, or around 5 per cent of annual power consumption. There is high solar irradiance in most regions of the country. Kazakhstan is located in the northern hemisphere, the general trend is to develop the solar sources in the south, such as in the Burnoye area near Shymkent, which addresses imbalances in the energy network. Kazakhstan has high solar radiation in the south part of the country. As we can see on the figure 3 we can say, that south has highest photovoltaic power potential.[5]

[5]The project of the Ministry of Energy of the Republic of Kazakhstan and the UN Development Program “Supporting the Government of the Republic of Kazakhstan in the implementation of the Concept of transition to a green economy and the institutionalization of the Green Bridge Partnership Program” [online] available at http://ecosolar.kz/ru/content/potencial-razvitiya-solnechnoy-energetiki-v-rk accessed 20.02.2020

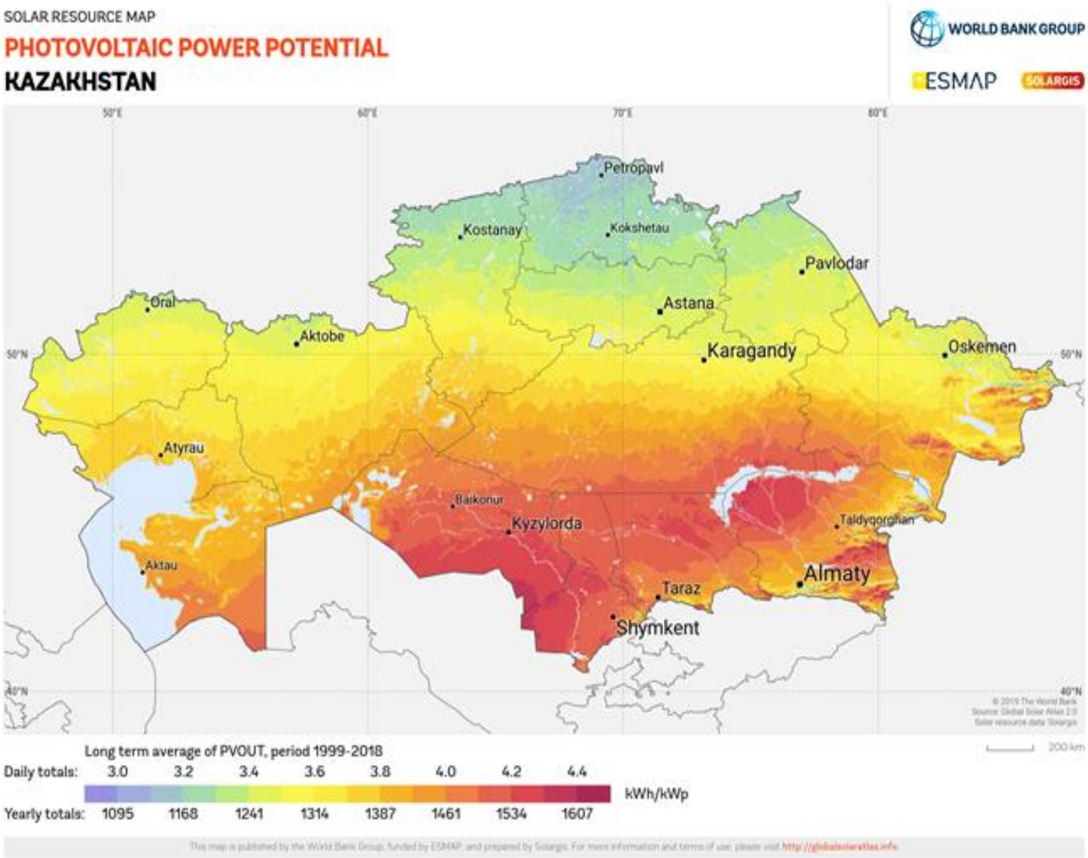


Figure 3. Photovoltaic power potential in Kazakhstan. Source https://globalsolaratlas.info/map

3.4 Plant biomass

Biomass is an organic substance that retains the energy of the Sun through the process of photosynthesis. Its transformation occurs in appropriate ways. Ultimately, it can be presented in the form of manure, fecal precipitation, household waste. Industrial biomass can be obtained from many species of plants. Biomass reserves are equivalent to 1.0-1.2 billion tons of petroleum. There are 3 main directions for thermal energy production. 1) direct combustion; 2) fermentation of biomass; 3) utilization of energy carrier derived from the process of converting biomass - biogas, alcohols. In the first direction biomass is used as a fuel. The second direction is usage of heat distinguished during fermentation of organic waste (manure, litter, sawdust). The third direction is the extraction of biogases and alcohols from biomass, which makes it possible to generate electricity.

Biogas is a gas produced by methane fermentation of biomass. For gas production various types of organic waste used. For example, fish scraps, (blood, fat, guts), production of starch and molasses (syrups and pomace), residues from processed potato (peels, rotten tubers), juice production (fruit pulp, vegetable and berry pulp, grape pomace), dairies (whey), and poultry manure, feces, animal solid waste.

Biogas output depends on content of solid matters and type of raw materials used. Maximum amount of biogas can be obtained from 1 ton of fat is 1300m^3 with methane content up to 87%. One of the biogas varieties is landfill gas. It is obtained from the domestic waste. From 1m^3 of biogas 2 to 3 kWh of electricity can be produced.[6]

3.4.1 Advantages of biomass energy

Minimize overdependence on traditional electricity. Materials are available everywhere and everybody can use it. This type of energy reduces waste in landfills. It's cheaper compared to fossil fuels. Low biomass cost makes this form of energy attractive to manufacturers and producers.

3.4.2 Disadvantages of biomass energy

Using animal and human waste to power engines may save on carbon dioxide emissions, but it increases methane gases, which are also harmful to the Earth's ozone layer. Biomass energy sources are renewable, but they have to be utilized sustainably. Uncontrolled biomass production can result in deforestation.

3.4.3 Biomass energy potential in Kazakhstan

Kazakhstan is naturally rich in fossil fuels and its economy is strongly linked to oil and gas exports. Significant coal reserves have led to an energy mix that is dominated by aging and polluting thermal power plants. Yet Kazakhstan comprises mainly grassland steppe where agriculture and livestock pastoralism dominate offering the potential for cleaner, renewable energy production from a range of agricultural and forestry wastes.

3.5 Geothermal energy

The expression "geothermal energy" literally means that it is the heat energy of the Earth ("geo" is the earth, "thermal" is thermal). The main source of this energy is a constant flow of heat

[6] S.M.Govorushko biomass energy: directions of use and environmental issues, Pacific Geographical Institute FEB RAS, UDC 504.05, 07.03.11. Ed. reg. No. 954, access 02.03.2020

from red-hot bowels directed toward the Earth's surface. The earth's crust receives heat as a result of friction of the nucleus, the radioactive decay of elements (like thorium and uranium) and chemical reactions.

Geo-electric power stations are related to renewable energy precisely because they use steam or hot water from natural geothermal sources underground as the main driving force. When immersed in the bowels of the planet, the temperature will increase by about 3 ° C every 100 meters of descent, although in different regions of the Earth this indicator (the so-called geothermal gradient) may differ. This means that some places are better for building a geothermal power plant, and some are much worse.

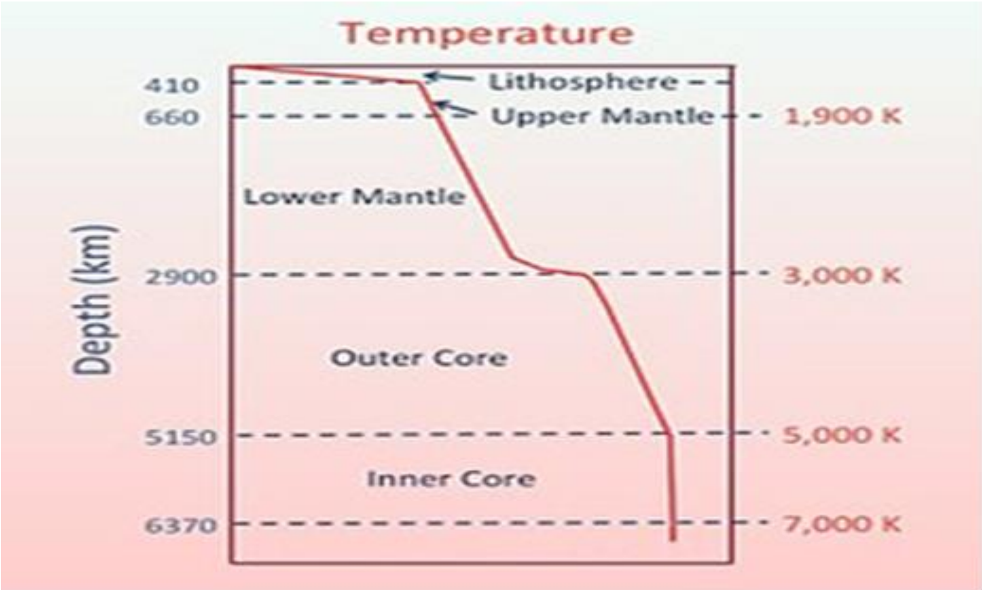


Figure 4. Temperature profile of the inner Earth, schematic view. Source https://en.wikipedia.org/wiki/Geothermal_gradient

Currently, there are three schemes for generating electricity using hydrothermal resources: direct using dry steam, indirect using water vapor and mixed production schemes (binary cycle).

3.5.1 Steam power plants

Steam power plants operate primarily on hydrothermal steam. The steam goes directly to the turbine, which feeds the generator that produces electricity. Using of steam eliminates the burning of fossil fuels (there is also no need for transportation and storage of fuel). These are the oldest geothermal power plants. The first such power station was built in Larderello (Italy) in 1904, and it is currently operating.

3.5.2 Geothermal power plants on hydrothermal steam

For the production of electricity in such factories, superheated hydrothermal (temperature above 182 ° C) are used. The hydrothermal solution is injected into the evaporator to reduce pressure, because of this, part of the solution evaporates very quickly. The resulting steam drives a turbine. If liquid remains in the tank, it can be evaporated in the next evaporator to obtain even more power.

3.5.3 Binary-cycle geothermal power plants

Most geothermal areas contain mild temperature water (below 200 0C). In power plants with a binary production cycle, this water is used to generate energy. Hot geothermal water and a second additional liquid with a lower boiling point than water, are passed through a heat exchanger. The heat of geothermal water evaporates a second fluid and vapor drives the turbines. Since this is a closed system, there are practically no emissions into the atmosphere. Moderate water temperature is the most common geothermal resource, so most geothermal power plants in the future will operate on this principle.

3.5.4 Advantages of geothermal energy

The carbon footprint of a geothermal power plant is seen as minimal. It is a stable resource and the power output of a geothermal plant can be accurately predicted. After installation, no mining or transportation activity is necessary.

3.5.5 Disadvantages of geothermal energy

Geothermal power plants require high capital costs. Suited to particular regions only. Geothermal heat pumps require electricity to operate. Can cause surface instability

Construction of geothermal power plants has the potential to cause surface instability and trigger earthquakes.

3.5.6 Geothermal energy in Kazakhstan

Geothermal energy is an untouched area in Kazakhstan, although the established thermal water reserves in the equivalent fuel equivalent amount to 97.1 billion tons, which is an order of magnitude greater than the country's combined oil and gas reserves. From geological surveys of early years, geothermal deposits were discovered by exploratory wells to a depth of 3,500 m in the Ili, Syrdarya, Irtysh, Prikaspiysky, Mangyshlak Ustyurt, Shu-Sarysusk and Zaysan artesian basins. Their distribution by regions of Kazakhstan of equivalent fuel, billion tons: Western Kazakhstan - 75.9 (78.2%); South Kazakhstan - 15.6 (16%); Central Kazakhstan - 5.3 (5.5%); Northern Kazakhstan - 0.3 (0.03%) and Eastern Kazakhstan - 0.003[7]

3.6 Energy production and consumption in Kazakhstan

The most important measure in the energy balance is the total consumption of 94.23 billion kWh of electric energy per year. Per capita this is an average of 5,156kWh.

Kazakhstan could provide itself completely with self-produced energy. The total production of all electric energy producing facilities is 101 bn kWh, which is 107% of the countries own usage. In the table we can see energy balance for electricity, crude oil and natural gas. I compared indicators with Europe.

[7]Mendebaev T.N. Research and Development Center ALMAS, Almaty, Kazakhstan, Science news of Kazakhstan № 3(133). 2017, available at http://www.vestnik.nauka.kz/wp-content/uploads/2017/09/4-%D0%9C%D0%B5%D0%BD%D0%B4%D0%B5%D0%B1%D0%B0%D0%B5%D0%B2.pdf accessed 25.02.2020

Electricity	**Total**	**Kazakhstan per capita**	**Compared to Europe per capita**
Own consumption	94.23 bn kWh	5,155.80 kWh	5,510.65 kWh
Production	100.80 bn kWh	5,515.28 kWh	5,924.84 kWh
Import	1.32 bn kWh	72.11 kWh	729.88 kWh
Export	5.10 bn kWh	279.05 kWh	707.80 kWh
Crude oil	**Barrel**	**Kazakhstan per capita**	**Compared to Europe per capita**
Production	1.86 m bbl	0.102 bbl	0.005 bbl
Import	1,480.00 bbl	0.000 bbl	0.020 bbl
Export	1.41 m bbl	0.077 bbl	0.004 bbl
Natural gas	**Cubic meters**	**Kazakhstan per capita**	**Compared to Europe per capita**
Own consumption	15.37 bn m^3	840.97 bn m^3	903.33 bn m^3
Production	22.41 bn m^3	1,226.16 bn m^3	456.57 bn m^3
Import	5.75 bn m^3	314.50 bn m^3	854.02 bn m^3
Export	12.80 bn m^3	700.35 bn m^3	398.72 n m^3

Table 1. Energy Balance compared to Europe Source https://www.worldbank.org/en/country/kazakhstan

3.7 Obstacles in the development of RES in Kazakhstan

Renewable energy is a quite new aspect in Kazakhstan. I identified the main obstacles in the development of RES. The first one is economic and financial barrier. We should understand that RES requiers very high initial costs. It follows, even if we overcome the barrier with high initial costs, we will immediately face with expensive price for consuming barrier. It is the fact that cost of tariffs from renewable sources in many times more expensive than the same coal-fired power plants. The implementation of 1 MW RE projects costs start from $1mln. Defenitely, high cost of product makes the RE produced electricity uncompetitive. Secondly it is market barriers which include such aspect as domination of traditional form of energy in the market. Reserves of coal in Kazakhstan will be enough for another 200-300 years according to the National Energy Report 2015 Comparing to the traditional sources RES definitely cedes position. The third one is long period of investment returns and financial risks. Kazakhstan doesn’t produce equipment for appropriate production. Investors have to buy it from abroad. Also, one more obstacle that I identified is lack of personnel and specialists operating in the relevant fields. Kazakhstan's Universities don't produce high quality specialist in relevant fields. From this all we can conclude the main obstacles:

- lack of competitiveness of renewable energy sources in the electricity market;
- lack of long-term contracts for the purchase of electricity, as guarantees for investments in a free market;
- lack of real, economically supported initiatives on the part of the state for the use of environmentally friendly energy sources and contribution to environmental conservation.

3.8 Legislative Issues

The law of Republic of Kazakhstan "Supporting the use of renewable energy sources" of 2009 was developed and adopted in order to achieve its objectives.

Adoption and implementation of the law facilitate:

- Legislative regulation of the mechanism for using renewable energy sources for the production of electric energy for energy supplying, energy producing organizations and consumers of electric energy;
- RES involvement in a competitive market;
- Attracting investments in the development of renewable energy for the production of electric energy;
- The development of new technologies and industries, small and medium-sized businesses in the field of renewable energy;
- Reduce emissions of greenhouse gases and harmful substances into the atmosphere

The concept for transition of the RK to the "green economy" approved by the Decree of the RK President dated May 30, 2013 provides for the achievements of the following target indicators of RES development in total generation of electricity in the RK:

- 3% by 2020 (including solar power plants (SPP) and wind power plants (WPP);
- 10% by 2030 (including SPP, WPP);
- 50% by 2050 (including SPP, WPP, HPP, NPP).[8]

[8]The Law of the Republic of Kazakhstan dated 4 July 2009 No. 165-IV. Available at https://rfc.kegoc.kz/en/vie/legislation, accessed 28.02.2020

3.9CO2 emissions

CO_2 emissions from liquid fuel consumption (% of total) from 2000-2014.
As we can see on the graph, CO_2 emissions have decreasing trend from 2013.

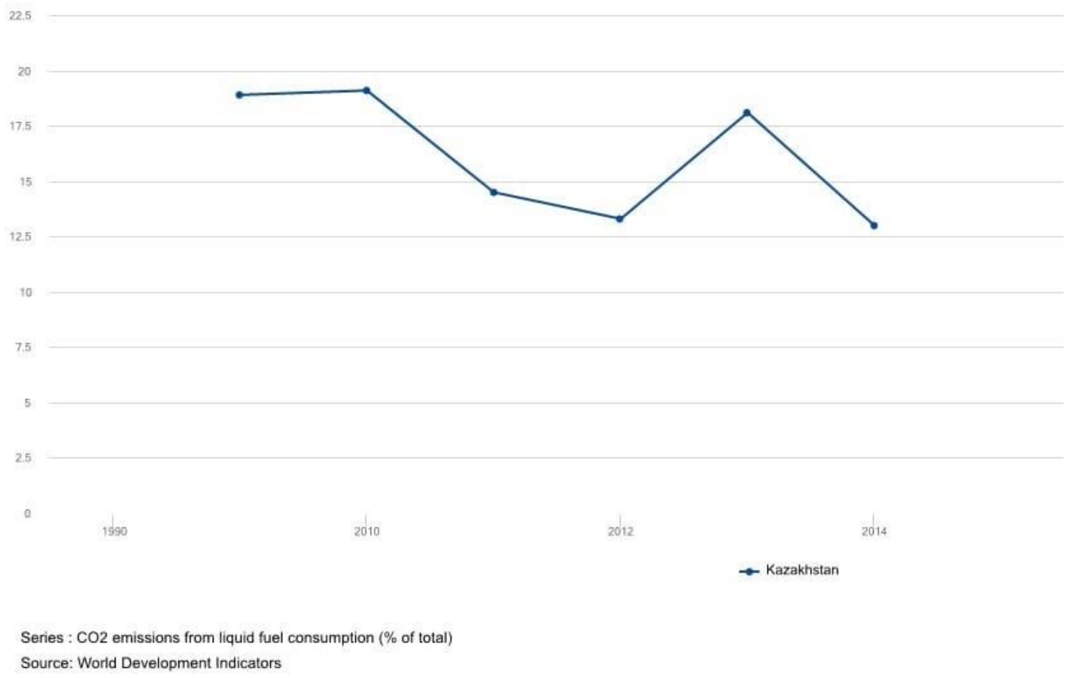


Figure 5. Source WorldBank

https://www.worldbank.org/en/country/kazakhstan

3.10 Ceiling Auction Prices for 2019

In accordance with the provisions of the Rules for the Determination of Feed-In Tariffs and ceiling Auction Prices approved by the Decree of the Government of the RK dated March 27, 2014, No. 271. This table shows us tariffs for electricity produced by RES. These tariffs were fixed and approved according to the law of Republic of Kazakhstan “Supporting the use of renewable energy sources” of 2009. As we can see the most expensive electricity is from biogas plants. The cheapest electricity is from hydropower plants. Government subsidizes RES energy and compensate inflation through indexation.[9]

[9]KEGOC, available at https://rfc.kegoc.kz/en/vie/prices/fixed-rates

Ceiling Auction Prices

No.	RES technology used to generate electric energy	Tariff, tenge/kWh (net of VAT)
1	Wind power plants for wind energy conversion	22.6 tenge/kWh
2	PV converters of solar energy for solar energy conversion	29.00 tenge/kWh
3	Hydro power plants	15.48 tenge/kWh
4	Biogas plants	32.15 tenge/kWh

Table 2. Source KEGOC https://rfc.kegoc.kz/en/vie/prices/fixed-rates

4 Practical Part

4.1Analysis of current state of renewable energy in Kazakhstan

Currently in the Republic of Kazakhstan there are already 90 operating renewable energy facilities - 19 wind power plants, 31 solar power plants, 37 hydroelectric power plants and 3 biogas plants.

The volume of electricity production by alternative sources (solar power, wind power, biogas energy, small hydropower plants) for 2019 is 2456,3 million kilowatt per hour. In 2018 production is 1 352 million Kilowatt per hour.

From 2018 until 2019 rate increased by 77,7%.

Comparatively with Europe, where the share of electricity generated by RES in 2018 was 32.8% of the total volume of electricity generation. In 2019 this number reached a record 34.6%. Solar and wind energy jointly generated nearly 18% of electricity (569 TWh). For the first time, sun and wind bypassed coal in electricity generation. (Eurostat report)

№	Name	2018г		2019г		Deviation 2019/2018	
		January-December	Percentage in Kaz%	January-December	Percentage in Kaz %	Millions kwt per hour	%
	Total production of electricity in Kazakhstan	**106797,8**	**100%**	**106030,00**	**100,0%**	**-767,8**	**-0,7%**
I	**Total RE in KZ**	**1352**	**1,3%**	**2456,3**	**2,3%**	**1104,3**	**77,7%**

Table 3. The volume of electricity production in Kazakhstan from 2018-2019. Source official report of “Samruk Energy” https://www.samruk-energy.kz/ru/press/analytical-report

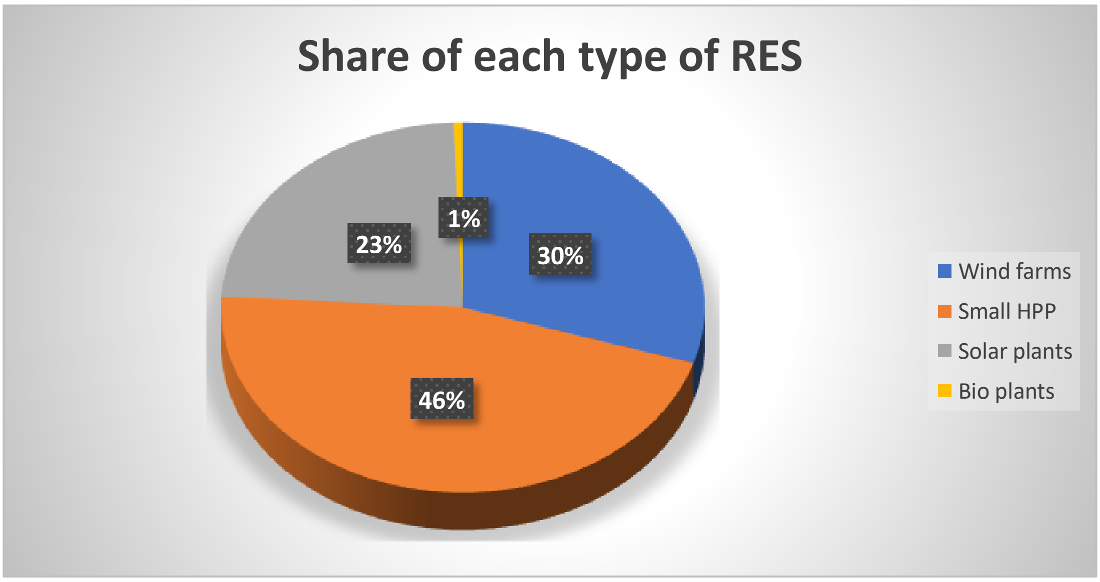
In 2019 there is a decrease in electricity production by large and small hydropower plants compared to the same period in 2018, while electricity production by wind farm, solar power plants and biogas plants has increased.

Share of generated electricity by each type of RES in 2019.

Indicators	Units	2019
Installed capacity including:		**1050,1**
Wind farms	MW	283,8
Small HPP	MW	222,2
Solar plants	MW	541,7
Bio plants	MW	2,42
Electricity production including:	Million kW/h	**2400,74**
Wind farms	Million kW/h	717,4
Small HPP	Million kW/h	1105,3
Solar plants	Million kW/h	563,14
Bio plants	Million kW/h	14,9
The share of renewable energy generated in the total volume of electricity production "	%	2,3
The increase in electricity generation by RES in 2019 compared to 2018 is - 77%		

Table 4. Source MEMR http://www.gov.kz/memleket/entities/energo/documents/1?lang=ru

In the figure 6, we can see the structure represented by share of each type of RES in total electricity production by RES in 2019. Figure 6. Source: MEMR



4.2Evaluation of solar energy in Kazakhstan

The potential of solar energy in Kazakhstan is quite large and amounts to about 1500 - 1600 kWh / m2 per year, and the number of sunny days is on average 2500 hours per year. The regions with high insolation are concentrated in the south part of the country. As we can see on the map, operating and projected solar power plants are shown. According to the Ministry of Energy's Plan of Activities for Alternative and Renewable Energy, about 28 solar energy projects are scheduled for operations by the end of 2020, with a total installed capacity of 713.5 MW.[10]

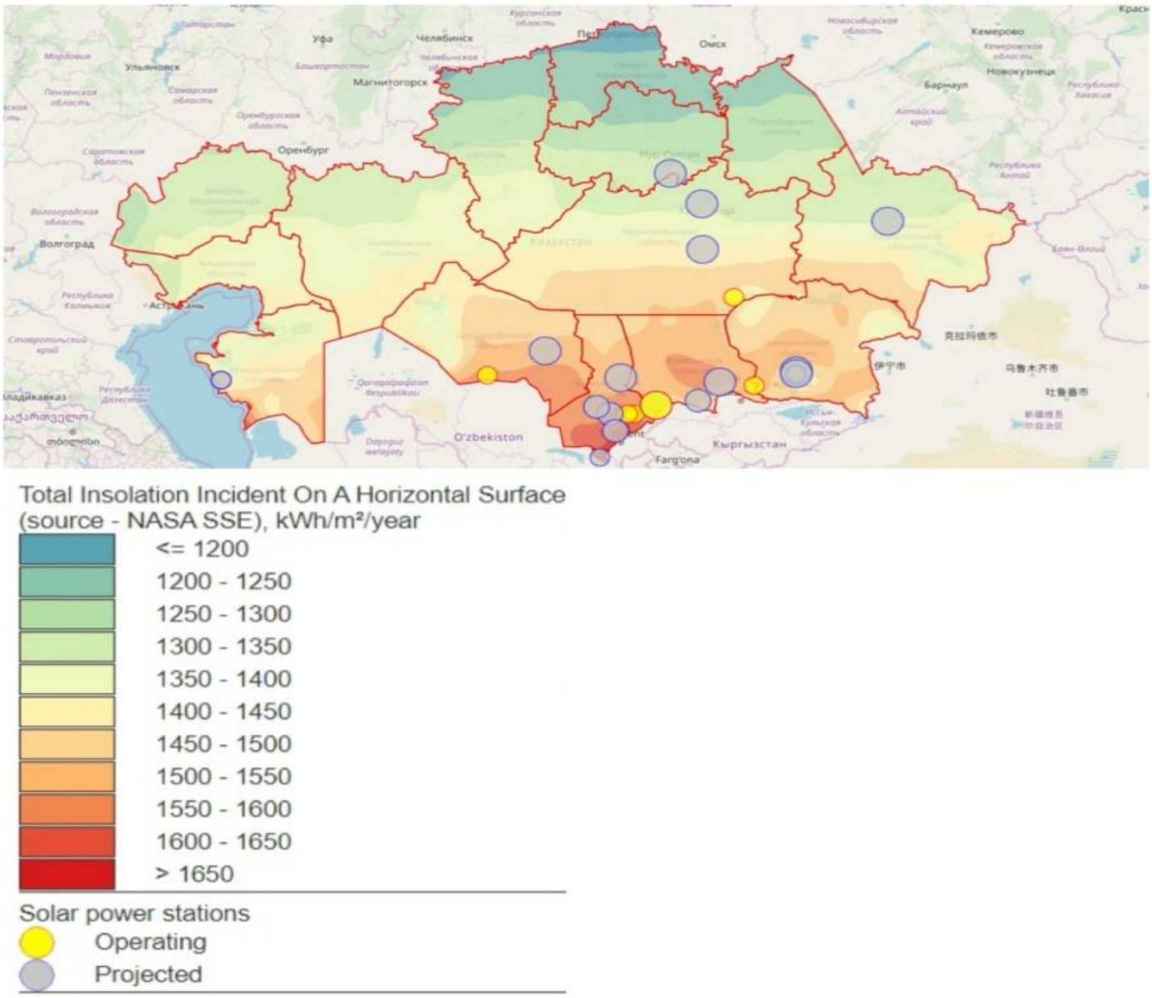


Figure 7. Source AtlasSolar http://atlassolar.kz/

[10]The project of the Ministry of Energy of the Republic of Kazakhstan and the UN Development Program "Supporting the Government of the Republic of Kazakhstan in the implementation of the Concept of transition to a green economy and the institutionalization of the Green Bridge Partnership Program" [online] available at http://ecosolar.kz/ru/content/potencial-razvitiya-solnechnoy-energetiki-v-rk accessed 20.02.2020

In April 2018, a 40 MW solar power plant was commissioned in the Karaganda region. The object was called "Gulshat". The aerial view looks like a rhombus. Construction cost $ 46 million. The project funded by European Bank for Reconstruction and Development. On an area of 164 hectares, 307 thousand voltaic panels are placed. They are converting the energy of the sun into electrical energy.

“Gulshat” solar plant

Figure 8. Source Tengri News https://tengrinews.kz/progress/solnechnaya-elektrostantsiya-gulshat-otkryita-karagandinskoy-367926/

4.3 Evaluation of hydropower in Kazakhstan

Currently, Kazakhstan has 15 large hydroelectric power plants (HPPs > 50 MW) with a total capacity of 2.25 GW or 13% of the country's total generated capacity. HPPs generate around 8 TWh per year or 8% of total power generation.

As we can see on the map (Figure 9) Kazakhstan's large hydroelectric facilities are located primarily along the Irtysh River, which flows from China across northeast Kazakhstan.

Some hydropower plants are not in operational regime due to depreciation of equipment.

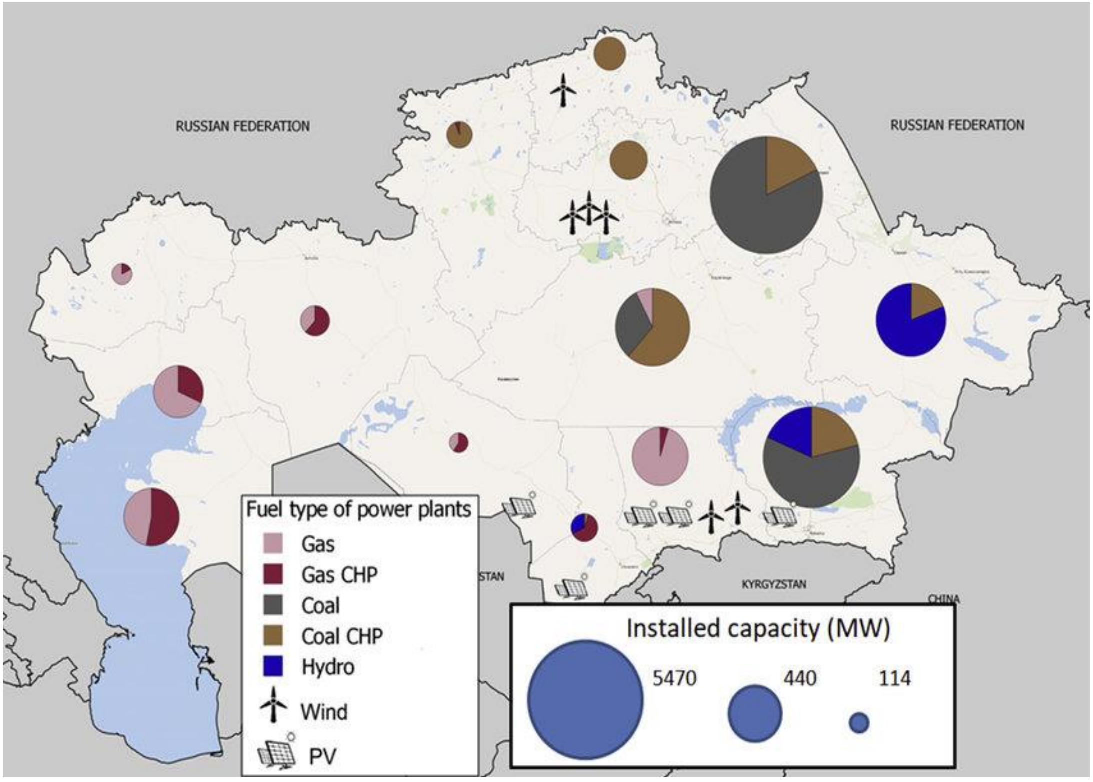


Figure 9. Source KEGOC https://rfc.kegoc.kz/en/vie/yamaps

There are the main rivers which provide hydropower electricity generation:

- Irtysh- The Irtysh River in hydropower relations has a significant degree of development with a three-stage cascade consisting of the Bukhtarma hydroelectric power station (674 MW), Ust-Kamenogorsk hydroelectric power station (331 MW) and the Shulba hydroelectric power station (702 MW).
- Tentek - It flows from the slopes of the Dzungarian Alatau, It flows into the Sasykkol lake.
- Karatal- The Karatal River with its tributaries flows from the mountain ranges of the Dzungarian Alatau.
- The river Ili- the largest river is Balkhash-Alakol basin

The Moinak Hydro Power Plant is one of the biggest hydro power plant in Kazakhstan. It is located on the Sharyn River south of Almaty in Almaty Province of Kazakhstan. It was commissioned on December 9, 2011, and became fully operational in 2013. It generates 1.027 billion kilowatt-hours of electricity per year. [11]

[11]Sourcehttps://ru.wikipedia.org/wiki/%D0%9C%D0%BE%D0%B9%D0%BD%D0%B0%D0%BA%D1%81%D0%BA%D0%B0%D1%8F_%D0%93%D0%AD%D0%A1

4.4 Evaluation of biomass energy potential in Kazakhstan

Kazakhstan has 76.5 Mha agricultural land, 10 Mha forest and 185 Mha steppe grasslands providing abundant biomass wastes and residues which have the potential to generate a range of bioenergy services. Kazakhstan produces and exports crops such as wheat (winter and spring), rye (winter), maize (for grain), barley (winter and spring), oats, millet, buckwheat, rice and pulses, with an average grain yield of 17.5-20 Mt, which equates to roughly 12-14 Mt of biomass wastes.[12]

In 2016, Kazakhstan produced nearly 27 million tons of crops.[13] The UN FAO estimated that the maximum crop production from Kazakhstan in good years exceeds 35–40 million tons.[14] Wheat is the main crop in Kazakhstan, producing around 14–16 million tons of grain annually.[13] Around 75 %–80 % of Kazakhstan wheat production occurs in North Kazakhstan including Akmola, Kostanay, and Northern Kazakhstani regions, with a small amount being produced in the south . The east and south of Kazakhstan are area of fibre and non-grain crop production includes cotton, flax, sugar beet, and tobacco. The south, east and central Kazakhstan is also major area of fodder crop production including barley, oil seed rape, grass, maize, millet, soya beans and oats.

The share of biomass that used for RES is 4% percent from total. The use of conventional plant crops for energy generation can also be expanded if the demand for food is taken into account correctly and there is space available. The potential of biomass in Kazakhstan is huge, but there is technological barrier which expresses by lack of equipment and lack of investments. That’s why the share of biomass from total RES is very low.

[14] Food and Agriculture Organization of the United Nations (FAO): FAO's Bioenergy and Food Security (BEFS) Rapid Appraisal 2017, available at: http://www.fao.org/energy/bioenergy/befs/assessment/befs-ra/en/ (last access: 18 June, 2018).

[13] Kazakhstan's Agency of Statistics (KAS): Agriculture trends 1995–2016, available at: http://stat.gov.kz/ (last access: 16 February 2018), 2016.

[12]**Spatial assessment of the distribution and potential of bioenergy resources in Kazakhstan**
Asima Koshim, Marat Karatayev, Michèle L. Clarke, and William Nock, Adv. Geosci., 45, 217–225, 2018, [online] available at https://www.adv-geosci.net/45/217/2018/ access 05.03.2020

Crop	Residue (Mt)	Equivalent standard coal (Mt)	Energy potential (MJ)
2004			
Wheat	10930.7	5465.4	159972.2
Oil-bearing crops	791.6	418.8	12258.2
Sugar crops	39.8	17.5	512.2
Cotton	1401.3	760.9	22271.5
Tubers	2059.3	1000.8	29293.4
Beans	2341.8	1271.6	37219.7
Rice	1059.7	454.6	13306.1
Total	18624.2	9389.6	274833.1
2016			
Wheat	16483.9	8242.0	241243.3
Oil-bearing crops	3804.8	2012.7	58911.7
Sugar crops	34.5	15.2	444.9
Cotton	860.1	467.0	13669.1
Tubers	3795.2	1844.5	53988.5
Beans	5428.0	2947.4	86270.4
Rice	2456.1	1053.7	30841.8
Total	32862.6	16582.5	485368.7

Table 5. Source European Geosciences Union General Assembly 2018, EGU Division Energy, Resources & Environment (ERE)[12]

Based on the results of the research of the Department of Cartography and Geoinformatics of Al-Farabi KazNU (Dr. AG Koshim and Dr. RT Bekseytov) and Nottingham University of Great Britain (Dr. Karataev M.)[12] we can say that the biomass potential in Kazakhstan is estimated at 485.36 MJ (or 16.582 million tons of coal equivalent, with an average of 14.150 Mt yr^{-1} from 2004-2016) (Table 4). This is equivalent to around 30 % of the total current energy consumption of the country. In Kazakhstan, biomass energy resource mainly consists of wheat residues (44 %), produced in the Northern part of Kazakhstan.

As I mentioned before, potential of biomass energy in Kazakhstan is high. Despite, there are in only 3 biomass plants. This is directly related to the lack of investment attention for this type of RES.

[12]**Spatial assessment of the distribution and potential of bioenergy resources in Kazakhstan**Asima Koshim, Marat Karatayev, Michèle L. Clarke, and William Nock, Adv. Geosci., 45, 217–225, 2018, [online] available at https://www.adv-geosci.net/45/217/2018/ access 05.03.2020

4.5 Project of small solar plant in Shymkent region

Based on the evaluation of solar energy, I decided to choose Shymkent region for estimation of solar potential. How is it appropriate to construct small solar power plant for domestic usage?

The goal is to estimate solar potential in Shymkent region using an actual project plan for solar power plant construction.

4.5.1 Evaluation of solar energy in Shymkent region

Shymkent region is located in the south part of Kazakhstan. Therefore, the climate here is sharply continental and very arid. The amount of sunny days prevails in comparison with other regions. The main condition for solar construction is solar radiation. The figure 6 shows the potential of photovoltaic power in each region in kWh/m^2. As we can see, Shymkent is one of the highest potential and suitable place for implementing solar construction in the country.

Figure 3.

The regions with the highest potential are located in the south part of the country. These regions are Baikonur, Taraz, Kyzylorda, Balkhash. Solar radiation in these regions starts from 1500-1600 kWh/m^2 per year. Regions with the lowest rate are Petropavlovsk, Kokshetau and Kostanay. The rate in these regions approximately 1150-1200 kWh/m^2 annualy.

Cloud

The clearer part of the year begins around May 17 and lasts for 4.9 months, ending around October 14. On August 4, the clearest day of the year, the sky is clear, mostly clear, or partly cloudy 96% of the time, and overcast or mostly cloudy 4% of the time.

The cloudier part of the year begins around October 14 and lasts for 7.1 months, ending around May 17. On January 15, the cloudiest day of the year, the sky is overcast or mostly cloudy 61% of the time, and clear, mostly clear, or partly cloudy 39% of the time.

Figure 7. Cloud cover Categories in monthes.

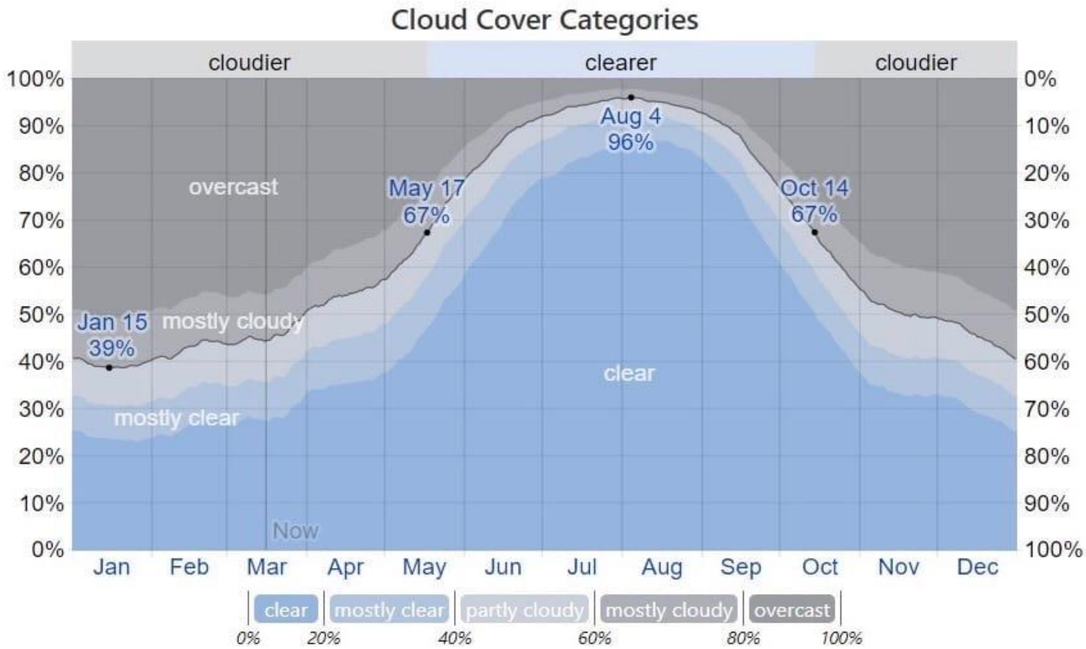


Figure 10. Source https://weatherspark.com/y/106909/Average-Weather-in-Shymkent-Kazakhstan-Year-Round

4.5.2 Solar insolation in Shymkent and Makhachkala

The average monthly insolation on horizontal surface for 2015 in Shymkent

Month	kWh/m2
January	22,06
February	50,55
March	65,77
April	102,63
May	190,61
June	213,39
July	226,06
August	208,45
September	111,55
October	57,7
November	31,46
December	35,19

Table 6. Source Atlassolar. Own table based on data provided by AtlasSolar

For comparison, we can see on the table 8 monthly average insolation on horizontal surface in Makhachkala, Russia. Makhachkala is located on the western shore of the Caspian Sea. It is one of the warm and sunny regions. In comparison we can see that Shymkent region in total have 1315.42 kWh/m^2. In Makhachkala total insolation is 1678 kWh/m^2. We can say, if insolation >1300 kWh/m^2 , it is good placement for solar plant construction.

Month	kWh/m^2
January	48,2
February	77
March	128
April	168
May	200
June	190
July	208
August	196
September	161
October	132
November	93
December	77,2

Table 7. Source SolarAtlas. Own table based on data provided by AtlasSolar

4.5.3 Own small solar plant

For energy supply of a house with monthly average consumption of 250 kW, our plant consists of 6 panels with a capacity of 260 Watt/hour each (total power 1,6kW/h). South orientation, angle slope is 50. The placement of construction will be on the roof of house. Length of service is 30 years. Material is polycrystalline.

As supplier and installer will be company TOO “GreenDem”.

4.5.4 Cost calculation of small solar plant

Calculations are based on the prices of TOO “GreenDem”.

Cost of small solar plant include the cost of solar panels (800 thousand tenge), storage battery (100,000), equipment (10 thousand tenge), installation work (20 thousand tenge), inverter and controller (60 thousand). Total price of small solar plant is 990,000 tenge.

	KZT
Solar panels	800,000
Controller	20,000
Inverter	40,000
Storage battery	100,000
Equipment	10,000
Installation work	20,000
Total	990,000

Table 8. Source: based on price of TOO "GreenDem"

4.5.5 Approximate calculation of efficiency of solar batteries

According to the data from "AstanaEnergosbyt" tariff for electricity for individuals is 19.15 tenge/kWh. Data is provided for 2020.

In average my family consumes 200 kW/h per month.

Per year, this expense is approximately 200 * 12=2400kW/h.

Annual electricity costs are 2400kW/h*19.15 tenge=45960 tenge.

Electricity costs for 30 years are 45960 tenge*30(length of service) =1,378,800 tenge.

Using the system will completely eliminate the cost of electricity from March to October and approximately reduce costs in winter period by 1.5 times. Therefore, the annual cost of electricity when using solar panels will be 10.213 tenge. Annual saving is 35,747 tenge.

Considering the equipment costs (990,000 tenge) and annual savings for electricity (35,747 tenge), payback period calculated as 990,000/35,747= 27.7 years.

Of course, payback period is very long, but the efficiency of such systems is significant. Everybody makes his own choice.

4.6 Results and Discussion

In Kazakhstan concentrated huge potential of renewable sources. Due climatic and geographical conditions, Kazakhstan has significant potential for electricity production from solar and wind energy. As expected, all renewable installations are located in the highest potential areas. Despite, indicators that show us the generation of electricity by RES are very small. This is directly related to the general obstacles and circumstances. Despite the slow growth of renewable energy, the government expects to achieve the above goals. This will be possible due to a rapid reduction in the costs of renewable energy stations, which will lead to an exponential increase in the energy generated by renewable energy from 2020 to 2030. One of the problem of usage of alternative energy sources is the location of many settlements at considerable distances from large power plants. Also, the main obstacles to the development of this area is the lack of legislation to stimulate renewable energy and economic mechanisms for its implementation, lack of funding and an integrated approach to solving this problem: science - production - widespread use.

I think, that such regulation or penalty for greenhouse emissions will help to improve today's situation with ecology in the country. People have to understand, that more people require more energy and electricity. There is a positive trend among people in favor of the alternative energetics.

On example of project plan, we conclude that even small plant requires high initial costs. But over time, these costs will pay off. We have proven, that absolutely any family can install a solar power station, with the correct assessment of potential and terrain, and be independent of carbon energy. The main disadvantage is that the operation of solar panels cannot fully provide electricity in the winter period of time. From October to March, the system can work as an additional source of energy. In the dark period of the day, we can use the energy that can be stored using the installed generator next to the solar battery.

Kazakhstan should work on introducing into practice innovative technologies and projects based on the use of renewable energy and resources, as well as energy-saving technologies that are safe for the environment.

7 Conclusion

Further development of traditional energy faced with the number of problems which can be identified as:

- environmental threat to humanity;
- rapid depletion of fossil fuel reserves;
- a significant increase in electricity prices.

In this regard, the use of renewable energy sources may be a promising direction in the electric power industry, which is confirmed by world practice.

Kazakhstan has a vast RES potential that can drive sustainable and inclusive economic growth, providing affordable electricity in the most distant regions. Based on analysis of potential assessment, we can say that Kazakhstan is one of the most favorable countries for the construction of solar and wind power plants. An analysis of the assessment of the current situation in the energy sector of Kazakhstan was made.

This paper presents an analysis of the assessment of the potential for all types of alternative energy in Kazakhstan. The best sites for the construction of renewable energy-based power plants were identified. The effectiveness of a small solar power plant for domestic usage in the Shymkent region was evaluated. The prospects for the development of renewable energy sources have great potential, especially combined-cycle power plants. The main obstacles to the development of renewable energy have been identified.

The government needs to increase the reliability and efficiency of existing financing mechanisms and adjust the incentives for investors in order to begin a large-scale transition to sustainable growth. This can be achieved through a comprehensive reform of national economic, budgetary, tax, investment and environmental programs and specific business support tools and green initiatives in Kazakhstan.

Investments are a key factor in the development of this industry. Using the project plan of a small solar power plant as an example, the basic costs for the construction were calculated. In my opinion, the implementing of a new renewable energy policy and lowering prices for electricity tariffs will help achieve development. Also, changing policies to maintain interest among people in the field of renewable energy can also contribute to development. For example, by introducing a tax on greenhouse gas emissions. For example, if a family has two cars, then the tax will be correspondingly higher.

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