

Research Article

Alternative Energy Resources of Uzbekistan and Possibilities of Their Effective Use

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Abstract: This article provides information on the need to use alternative energy sources, which are environmentally friendly natural energy resources. The results of the study on the potential of alternative energy resources of Uzbekistan, the possibilities of their effective use and the large-scale reforms carried out in this regard are also presented.

Keywords: Alternative energy sources, Solar energy, Wind energy, Hydropower resources, Waste-free energy production technologies.

I. Introduction

Currently, traditional fuel and energy resources (oil, gas, coal, peat, shale, etc.) are widely used for the production of electricity in many countries of the world. This leads to severe air pollution with harmful greenhouse gases (CO₂, CO, CH₄, etc.). As a result, the problem of “global climate change”, which worries all mankind, is getting worse every year and causes worse consequences. To make this situation better, large-scale activity is being carried out in many developed countries of the world on the efficient use of alternative energy sources, reducing the use of traditional fuel and energy resources as much as possible. For example, in 2019, Germany produced more energy from renewable energy sources than from coal and nuclear power plants. The share of electricity generated from the sun, wind, biomass and water was 47.3% (www.kun.uz, 2019).

It is worth noting that the energy that serves humanity without harming the environment is environmentally friendly natural energies that exist in nature. These types of energy can include water, sun, wind, geothermal waters, geysers, waves, rising and falling water levels, volcanoes, lightning, all kinds of



currents in the oceans and seas, biomass, hydrogen fuel, urban waste, photosynthesis; photoelectric modifiers, chemical (galvanic) elements, among others. These types of energy are called non-traditional and renewable energy sources (Majidov, 2014).

The use of water energy, one of the renewable energy sources, for the first time in our country began in 1926, when the Bozsuv Hydroelectric Power Station was built (National, 2001). In 1987, a solar furnace was put into operation in Tashkent, collecting heat over 3000°C (www.alternativenergy.ru, 2022). In December 2014, one of the first 130 kWh solar photovoltaic power plants in our country was built and put into operation in the Pap district of Namangan region (www.kun.uz, 2017). The theory and methods of using wind energy were developed in the 1950s, and the first wind energy devices in the Republic were used by breeders of the Tomdi district of Navoi region in 1983 (Imomov, 2013).

Over the past 5 years, our government has carried out huge reforms on the efficient use of renewable energy sources and broad attraction of investments in this area. In this regard, the decisions and decrees announced by our President are a serious impetus for the development of the industry. In particular, the PD-3012 of the President of the Republic of Uzbekistan SH.M.Mirziyoev dated May 26, 2017 “On the program of measures for the further development of renewable energy in 2017 – 2021, increasing energy efficiency in sectors of the economy and social sphere” should be noted (Decision, 2017). Because there are the target indicators of the program of measures for the further development of renewable energy presented on this decision. According to it, in the structure of energy production facilities in our country, it is planned to increase the share of energy production facilities generated by renewable energy sources by 19.7% by 2025. Of this, it is established that 15.8 percent corresponds to hydropower, 2.3 percent to solar energy, and 1.6 percent to wind power. To achieve this goal, implementation of large investment projects for the development of renewable energy is planned. Among these, the construction of solar photovoltaic power plants with a capacity of 100 MW each in Samarkand, Navoi and Surkhandarya regions, a wind power plant with a capacity of 102 MW in Navoi region, as well as construction projects for 18 new hydroelectric power plants in various parts of the republic from 2017 to 2025.

II. The main part

Uzbekistan is rich in renewable energy resources, which is estimated at about 51.0 which is equivalent to billion tons of oil (Toshpo‘latov et. al., 2020). Of these, the most important include solar, wind and hydropower resources. Uzbekistan has great differences in the potential of this type of renewable energy sources (Table 1).

Table 1: The potential of renewable energy sources in Uzbekistan (Toshpo‘latov et al., 2020).

Potential	Total (mln. t.o.e.)	Energies (mln. t.o.e.)			
		Solar	Hydro	Wind	Geothermal
Gross	50984,6	50973,0	9,2	2,2	0,2
Technical	179,0	176,8	1,8	0,4	-
Acquired	0,6	-	0,6	-	-

If we analyze the data (Table 1) on the technical potential of renewable energy resources in Uzbekistan (a part of the gross potential that can be exploited based on existing technologies), the potential of solar energy is about 98.8 %, while hydropower resources make up 1.0%, and wind energy makes up 0.2% (Fig. 1).

For information, it is worth saying that Uzbekistan is one of the countries with a sufficiently high technical potential for renewable energy. In particular, the potential of Uzbekistan to generate electricity from solar energy can reach 525-760 billion kWh per year, and the potential to generate electricity from wind energy can exceed 1 billion kWh (Avezova et. al., 2022).

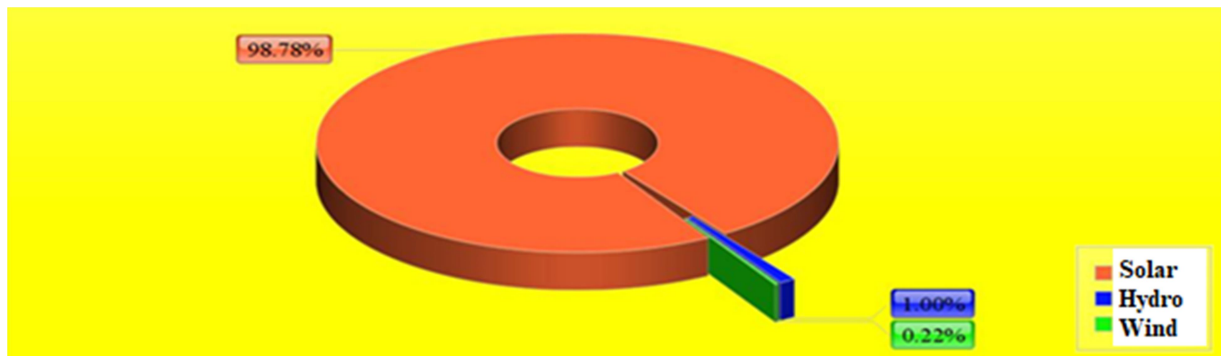


Fig. 1: Distribution of renewable energy resources in Uzbekistan according to the technical potential **Solar power.** The Republic of Uzbekistan is one of the prosperous countries, on average in one year:

- 300 days are considered sunny days;
- 2980 ÷ 3130 hours, the average temperature is +42°C, the length of the day is 14-16 hours;
- the temperature rises to +50°C in the desert regions;
- up to 1900-2000 kW of solar radiation can be generated in each m² area in 1 year (Majidov, 2014).

According to the specialists of "Uzbekenergo" SJSC, the territory of the Republic of Uzbekistan has a huge potential for solar energy. It was found that 99% of all renewable energy sources in the country were solar energy, equivalent to 50 billion tons of oil (Majidov, 2014). According to the latest data, Uzbekistan has the opportunity to generate a total of 600 billion kWh of electricity by building solar plants. This is 8 times higher than the total need of the Republic for energy today (www.gazeta.uz, 2017).

The southern regions of Uzbekistan (Surkhandarya, Kashkadarya, Samarkand, Bukhara, Navoi) are rich in solar energy compared to other regions. This can be seen on the map of the solar energy potential of Uzbekistan below (Fig. 2).

Since the southern regions of Uzbekistan are rich in solar energy (fig.4), the construction of solar photovoltaic plants is being built in these regions. For example, a modern solar photovoltaic plant with a capacity of 100 megawatts was launched in Karmana District of Navoi region. 252 million kilowatt-hours of electricity are generated here per year. At the expense of this, 80 million cubic meters of natural gas are saved, and 160 thousand tons of evaporative gases are prevented from escaping into the atmosphere (www.gazeta.uz, 2017). Also, on May 24 of this year, a modern solar photovoltaic installation with a capacity of 100 megawatts was put into operation in the Nurabad district of the Samarkand region. It is reported that this power plant generates 260 million kilowatt-hours of electricity per year and supplies electricity to more than 80 thousand households. Also, as a result of the operation of the station, 78 million cubic meters of natural gas per year will be saved, and 100,000 tons of harmful waste will be prevented from being released into the atmosphere (www.daryo.uz, 2022). In addition to this, from May 24, 2022, a large solar photoelectric plant with a capacity of 100 megawatts, built in the Nurabad district of Samarkand region, began transmitting power to the unified electricity grid of Uzbekistan. According to the press service of the Ministry of Energy, this power plant produces 260 million kilowatt-hours of electricity per year and supplies more than 80,000 households with electricity. Also, as a result of the operation of the station, 78 million cubic meters of natural gas will be saved per year, and 100,000 tons of harmful waste will be prevented from being released into the atmosphere (www.daryo.uz, 2022).

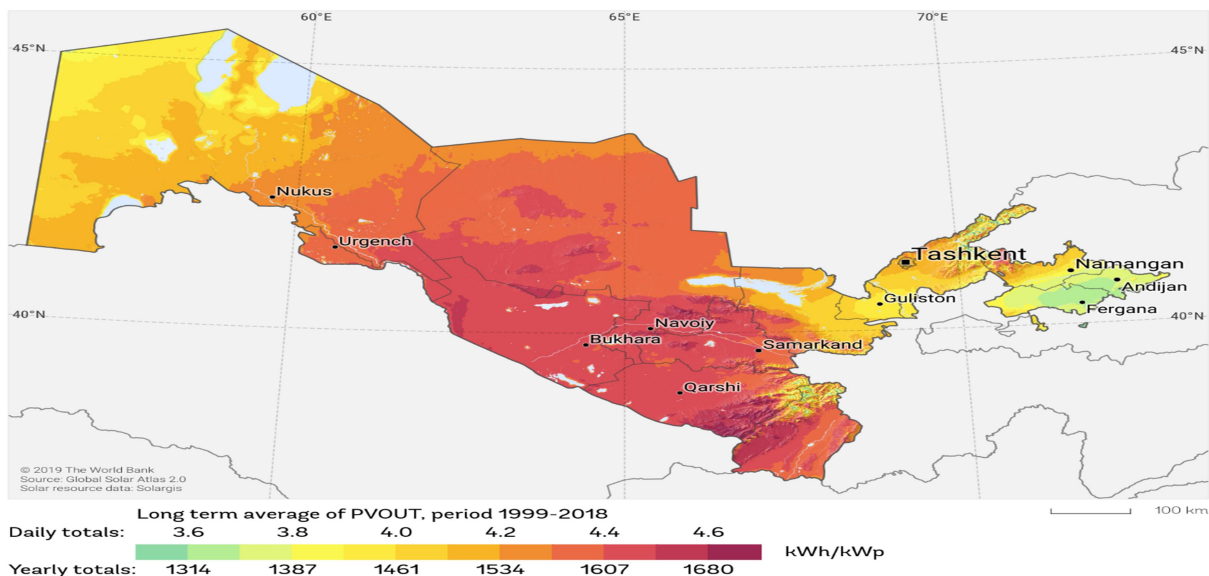


Fig. 2. Solar power potential map of Uzbekistan (Global Solar Atlas, 2022).

As can be seen from the information provided, Uzbekistan is a country rich in solar energy, and efforts are being made to use this energy efficiently. Solar energy is rich not only in the southern regions of Uzbekistan, but also in all its corners. For example, an analysis of data from the last 5 years (2016-2021) of the Namangan

weather station located in Namangan region shows that the territory of Namangan region is sunny, that is, rich in solar energy (Table 2).

As can be seen from Table 2, Namangan region receives 2000-2500 hours of sunlight (on average 2400 hours) during the year. In May, June, July, August, September, the sun shines 250-350 hours (an average of 300 hours). This indicates that Namangan region is rich in solar energy, and its effective use is one of the important issues.

A number of practical works on the effective use of available solar resources have been carried out in Namangan region. For example, in December 2014, with the support of the Ministry of Trade, Industry and Energy of the Republic of Korea, a 130 kW solar photovoltaic plant was built and put into operation in the Pop district of Namangan Region (www.kun.uz, 2017).

Table 2: Solar effulgence data from the last 5 years (2016-2021) according to the data from the Namangan meteorological station of the Namangan Region (Statistical data, 2022)

MM YY	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
2016	99,7	209,9	167,3	221,2	288,8	225,1	106,3	359,3	291,4	203,4	148,4	47,5	2368,3
2017	115,0	105,5	158,4	198,1	316,9	309,9	317,9	296,6	269,9	193,4	151,3	42,4	2475
2018	64,6	108,3	114,5	178,0	230,2	300,3	349,7	301,9	278,5	164,7	122,5	79,8	1926
2019	78,9	92,6	183	156	335,1	278,5	367,6	354,2	275,2	243,6	142,1	61,0	2568
2020	74,0	144,8	178,8	241,3	301,0	313,5	303,7	266,0	260,4	216,6	120,4	18,9	2439
2021	121,5	115	23	275,8	270,1	327,2	325,5	326,6	309,4	189,1	112,5	93,8	2479,5

Note: This information was compiled by the authors on the basis of the statistical data of the hydrometeorological department of Namangan region.

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In addition, in the resolution of the Cabinet of Ministers of the Republic of Uzbekistan "On additional measures for the integrated socio-economic development of the districts of Namangan region in 2022-2026 and further improvement of the standard of living of the population" of the photovoltaic plant in Pop district of Namangan region in order to increase its capacity to 150 MW, it is planned to select investors in 2022 and launch in 2024 a solar photovoltaic power plant in the Pop district with a capacity of 150 MW (Decision, 2022).

Wind power. Wind is the movement of air masses caused by changes in pressure due to the intensity of sunlight (Majidov, 2014).

The annual theoretical reserve of winds is 100 times more than all energy reserves on Earth and is 3300×10^{12} kWh. But only 10-12% of this energy can be used. For example, in 1987, 10×10^1 kWh of energy was produced by all wind installations on Earth, that is, only 0.3% of the annual reserve was used (Majidov, 2014).

Today, the maps of winds of Uzbekistan is compiled, according to which the gross capacity of wind energy is estimated at 2.2 million (the equivalent of a million tons of oil), and its technical capacity is 0.427 million (the equivalent of a million tons of oil) (Safarov et. al., 2022). 75% of the country's territory is unsuitable for use to generate energy using wind power. Because, economically, it is advisable to use wind generators if the wind speed in the place is not less than 5 m/s. On a large territory of our country, wind power cannot reach such speeds. We can see this through the table below (Table 3).

Table 3: average monthly wind speed (m/s) in some regions of Uzbekistan (Safarov et. al., 2022).

Regions	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Tashkent	1,1	1,2	1,5	1,3	1,4	1,4	1,3	1,3	1,2	1,2	1,2	1,1
Nukus	3,4	4,3	4,0	3,5	3,8	3,6	4,1	3,7	2,6	2,6	2,7	3,8
Urgench	3,6	4,4	4,1	3,3	3,1	3,3	2,7	2,7	2,3	2,4	2,8	4,0
Bukhara	2,9	2,9	3,7	2,6	3,2	3,7	4,6	4,0	3,7	2,2	2,3	3,4
Navoi	3,7	4,0	5,1	2,5	2,8	2,5	3,6	1,9	2,6	2,7	3,1	4,2
Samarkand	1,6	1,4	1,6	1,5	1,3	1,3	1,5	1,0	0,9	0,7	0,8	0,8
Jizzakh	1,5	1,6	2,1	1,8	2,1	1,7	1,5	1,4	1,6	1,1	1,5	1,3
Sirdarya	1,2	1,2	1,5	1,2	1,3	1,0	0,9	1,0	1,0	1,1	1,1	1,1
Karshi	2,7	3,1	3,6	2,7	3,0	3,3	3,5	2,7	2,5	2,1	2,1	2,5
Termiz	2,9	3,7	4,6	2,7	2,9	2,5	2,6	2,3	2,4	2	2,4	2,4
Andijan	0,8	1,2	1,7	2,1	2,1	2,3	1,9	1,4	1,5	0,8	0,8	0,8
Namangan	1,7	1,8	2,3	2,4	2,6	2,8	2,5	2,2	2,3	2,1	1,9	1,5
Fergana	0,7	0,8	1,0	1,2	1,1	1,1	1,0	0,9	0,9	0,8	0,9	0,8

As can be seen from the data of Table 3, the monthly average wind speed in Nukus, Urgench, Bukhara and Navoi regions is slightly higher than in other regions. The rest of the territories, on the other hand, are characterized by having much less capacity in this regard.

It is possible to more accurately describe the capabilities of the regions in this regard through the wind speed map of Uzbekistan below (Fig. 3).

As you can see from the map information, the mountainous regions of Uzbekistan (Tashkent, Kashkadarya, Surkhandarya, Jizzakh regions) are slightly better provided by wind speed. Therefore, the first wind power plant in Uzbekistan was built in the mountainous area of the Tashkent region.

In particular, a wind power plant was installed for the first time in the Republic of Uzbekistan in the recreation area of the Charvok reservoir (Tashkent region). The installation of a wind power plant with a capacity of 750 kWh was carried out with the help of the company of South Korea's "Doojin Co. LTD". This

Wind Power Plant produces 12.3 million kWh of electricity per year. As a result, 700 thousand m³ of natural gas can be saved per year (www.cleandex.ru, 2010).

Wind potential indicators in land areas determined for the construction of wind power plants (WPP) in Uzbekistan are higher than the average of existing wind power plants in the world. In order to effectively use the wind energy of these regions, work on the implementation of large projects in Uzbekistan is being carried out at an accelerated pace. In particular, according to the press service of the Ministry of energy, agreements were signed by the company “Masdar” of the UAE on the construction of a 500 MW wind power plant worth 600 million US dollars in the Tomdi district of Navoi region. When this station is fully commissioned in 2024, it will generate 1.8 billion kWh of electricity per year and save 546 million cubic meters of natural gas in a year (www.kun.uz, 2021).

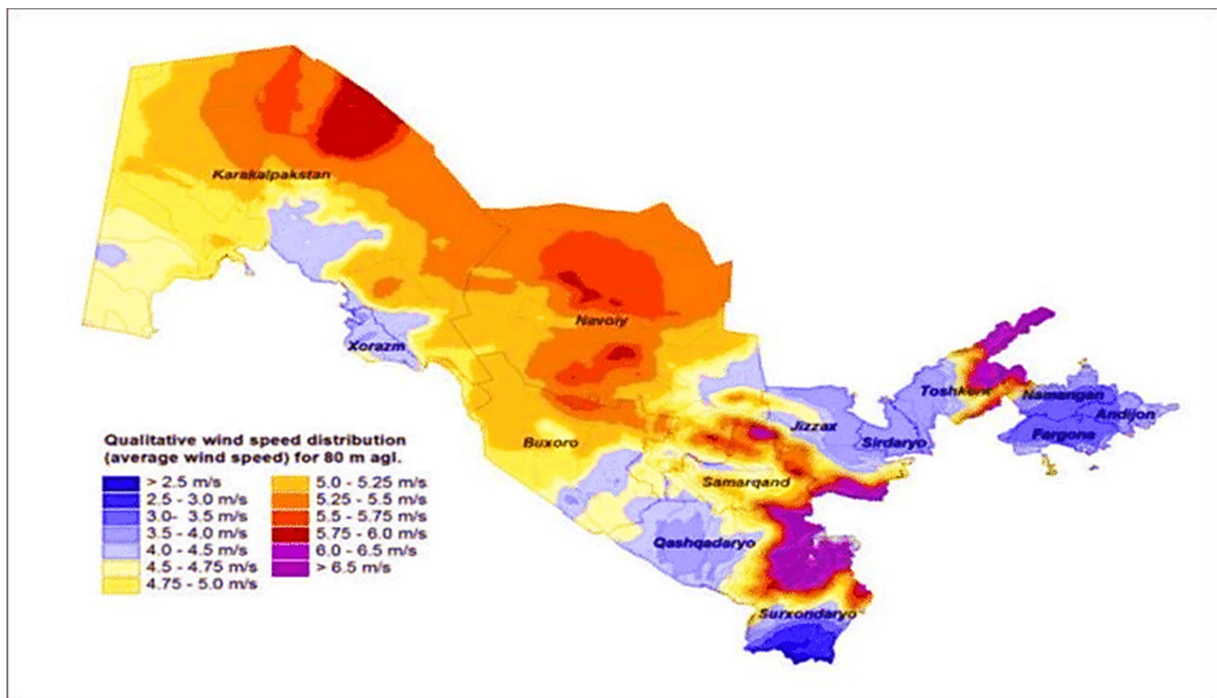


Fig. 3. Wind speed distribution map across the territory of Uzbekistan (Zakhidov, 2015).

In addition, the “ACWA Power” company of Saudi Arabia reached an agreement to build 2 WPPs which have the capacity of 1,000 MW and they are worth of US \$ 1.3 billion in Gijduvan and Peshku districts of Bukhara region, which, when these stations are launched in 2023, will provide an annual supply of 3.6 billion kWh of electricity and save 1.1 billion cubic meters of natural gas per year (www.kun.uz, 2021).

There was a joint competition with the help of the European Bank for Reconstruction and Development to construct Wind Power Plant with 100 MW which is one of such big projects with worth US \$ 110 million dollars in Beruni and Karauzak districts of the Republic of Karakalpakstan. The company "ACWA Power" won the competition with a proposal of 2.57 US cents per 1 kWh of electricity. When this station is launched in

2023, it is expected to generate 350 million kWh of electricity per year and save 106 million cubic meters of natural gas in a year (www.kun.uz, 2021).

It is noted that the Ministry of energy is fulfilling the plans outlined in the concept of development of wind power ahead of schedule. By 2030, the country is expected to increase the total capacity of WPPs to 5,000 MW. A large number of them are intended to be built in the Republic of Karakalpakstan (www.kun.uz, 2021).

Hydropower resources. Uzbekistan is a country rich in hydropower resources. The very fact of saying that the hydropower resources that can be used in our republic in this regard are equal to the volume of electricity production of 27.4 billion kilowatt hours a year suggests that we have a huge resource in this regard. At the same time, now only 6.5 billion kilowatt hours or 23.7% of the hydropower potential of our country is being used (www.kun.uz, 2017).

Theoretically, the total hydropower potential of Uzbekistan for one year is as follows:

1. Annual total (or theoretical) hydropower potential – 88.5 billion kWh, of which:

- large rivers-81.1 billion kWh;
- average rivers-3.0 billion kWh;
- small rivers-4.4 billion kWh.

2. The flow of water that generates energy faces a lot of resistance on its way and is wasted. The energy left over from wasted energy is a technical hydropower potential, equivalent to 27.4 billion kWh, of which:

- large rivers-24.6 billion kWh;
- average rivers-1.5 billion kWh;
- small rivers-2.3 billion kWh.

3. The flow of water, passing through the equipment of the Hydro Power Plant, overcomes a lot of resistance. The net cost-effective hydropower potential remaining after all resistance is 16.6 billion kWh (of which 6.5 billion kilowatt/hour has been acquired) (Toshpo‘latov et. al., 2020).

Data on the hydropower resources of the main rivers flowing through the territory of Uzbekistan are presented in Table 4.

Table 4. Main rivers and hydropower resources in Uzbekistan (Badalov et. al., 2009).

№	Rivers	Technical		Economic		Acquired	
		MW	GWt/h	MWt	GWt/h	MWt	GWt/h
1.	Chatkal	500	1,1	500	1,1	-	-
2.	Pskom	1250	3,06	1250	3,06	-	-
3.	Chirchik	1246	4,48	1228	4,78	1200	4,72
4.	Koradarya	188	0,78	188	0,78	168	0,61
5.	Sirdarya	166	0,75	166	0,75	126	0,43

6.	Surkhondarya	320	1,46	160	0,47	-	-
7.	Kashkadarya	70	0,21	12	0,065	-	-
8.	Zarafshan	168	0,62	40	0,18	40	0,18
9.	Amudarya	770	3,27	650	2,57	150	0,47
Total			16,07		13.75		6,43

As can be seen from the data of Table 4, the main rivers in Uzbekistan, rich in hydropower resources, are the Piskom, Chirchik, Amudarya and Chatkal rivers. The levels of their assimilation are also different. For example, the technical potential of the Chirchik River is equal to 1246 MW, of which 1200 MW is fully obtained. Also, the technical potential of the Karadarya is equal to 188 MW, of which 168 MW are part, the technical potential of the Sirdarya is equal to 166 MW, of which 126 MW are fully mastered. It can be seen that the amount of these rivers at the level of technical potential of hydropower resources is practically fully assimilated and used in the economy. On the contrary, the hydropower resources of Pskom, Chotkol, Surkhondarya and Kashkadarya have not been used fully at all.

In general, the hydropower resources of 650 rivers, many irrigation canals and water reservoirs flowing through the territory of Uzbekistan have the technical potential to build many hydroelectric power stations that produce 21 TWh of electricity per year (Toshpo‘latov et. al., 2020).

According to the data from 2009, there are 41 hydroelectric power plants with a capacity of 1689 MW installed in our Republic, 30 of which are in operation. At the same time, 35 small hydroelectric power stations with a capacity of 383.2 MW were built, 24 of which are in operation (Chirchik Bozsuv Hydroelectric Power Station, cascade of Hydroelectric Power Stations in Tashkent, Hydroelectric Power Stations in Andijan, Samarkand hydroelectric power stations) (Badalov et. al., 2009).

According to the data of 2014, the number of hydroelectric power stations conserved, operated, built, designed, and research projects are being carried out on small, medium and large rivers and irrigation systems in Uzbekistan is 204 units. Among them: 34 hydroelectric power stations in operation (in use) (30 units belonging to “Uzbekenergo” JSC, 4 hydroelectric power plants belonging to the association of “Suvenergo” under the Ministry of Agriculture and Water Management of Uzbekistan); conserved hydroelectric power stations 11 units; the number of hydroelectric power stations for which construction is planned and the project-research and design works are being carried out is 45; hydroelectric power stations that can be built are 12 units on rivers, 23 units on reservoirs, and 79 units on main canals (Majidov, 2014).

According to the information provided in 2017, the hydropower sector of Uzbekistan includes 36 hydroelectric power plants, of which 28 have an annual average annual production capacity of 5.2 billion kilowatt hours of electricity. 8 hydroelectric power plants with an average annual production capacity of 1.3

billion kilowatt hours are owned by the "Ozsuvenergo" association under the Ministry of Agriculture and Water Management (www.kun.uz, 2017).

Today, 25 of the 36 hydroelectric power plants existing in the field of hydropower in Uzbekistan were launched forty to eighty years ago and have practically passed its technical resources, equipment and structures need modernization and reconstruction. Therefore, the president of our country has given a number of assignments to industry experts with serious attention to this issue. In particular, in the decree No. 3012 of the president of the Republic of Uzbekistan Sh.M.Mirziyoev dated May 26, 2017 “on the program of measures for the further development of renewable energy in 2017 – 2021, increasing energy efficiency in the sectors of the economy and social sphere”, great attention was paid to the development of hydropower (Decision, 2017). In this decision, during 2017-2025, it is planned to build 18 new hydroelectric power plants with a capacity of 984.7 MW/h and modernize 14 existing hydroelectric power plants with a capacity of 1384.9 MW/h. In addition, during 2021-2030, the implementation of 24 promising projects for the construction of new hydroelectric power plants with a capacity of 637.3 MW/h and 18 promising projects with a capacity of 588 MW/h for the modernization of existing hydroelectric power plants was strictly defined, and the implementation of them was entrusted to “Uzbekgidroenergo” JSC (Decision, 2017).

Since hydropower resources are natural, environmentally friendly and renewable energy sources, the full expansion of their use corresponds to the modern development strategy of our Republic. This ensures guaranteed coverage of the growing electricity demand of industrial and municipal enterprises, agriculture and regions, rational use and conservation of organic fuel reserves in our country, as well as reduction of harmful waste emissions into the environment.

III. Conclusion

In conclusion, the Republic of Uzbekistan is considered to be very rich in the main types of alternative energy – solar, hydro and wind resources. The above proofs are a prime example of this. A very large part of these resources has not yet been used, and in recent years the first serious steps have been taken to effectively use existing capacities, large-scale events have been implemented, major projects are being implemented. The unstoppable continuation of efforts in this direction, as well as the further development of reforms, will make it possible to achieve sustainable economic development and environmental well-being.

Additionally:

- The main advantage of renewable energy sources is that they are inexhaustible and environmentally friendly, their use does not change the energy balance of the planet. Renewable energy sources play a significant role in solving three global problems facing humanity: energy, ecology, trade;

- The alternative energy sources play an important role in saving primary hydrocarbon resources (oil, gas, coal, etc.), ensure the energy security of the country;

Thus, the possibilities of reducing the anthropogenic impact on the environment will be expanded due to the broad involvement of environmentally friendly, renewable energy sources in the energy balance. This makes it possible to save hydrocarbon resources not for the production of electricity, but for use as raw materials in the petrochemical industry. It serves as a convenient and reliable source of energy in residential areas remote from central power supply.

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