PHYSICAL SCIENCES

PROSPECTS FOR THE USE OF RENEWABLE ENERGY SOURCES IN AZERBAIJAN

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Abstract
This paper provides detailed information on various types of renewable energy sources (RES). A comparative analysis of the existing types of renewable energy sources is given, their advantages and disadvantages are revealed. Identified more economical and energy-efficient types of RES sources for use in the climatic conditions of Azerbaijan. Detailed information is provided on several power plants installed in different countries of the world, in particular, on various types of power plants operating based on RES. The work done in Azerbaijan in this area is shown, statistical data are provided. Particular attention is paid to the sources of solar, wind, wave, and geothermal energy, as well as the use of biomass energy (BM).

Keywords: solar energy, wind, and wave energy, geothermal energy, biomass energy, photovoltaic power source, parabolic and parabolic cylindrical concentrators, solar collector, wind turbine, solar, geothermal, and wave power plants, wind power plants, mini-hydropower plants.

1. Introduction

As is well known, due to the technogenic and anthropogenic development since the beginning of the industrial period, the environmental situation on Earth has deteriorated and become catastrophic. On the one hand, this is due to the pollution of the soil, water, and atmosphere with various types of hazardous waste, on the other hand, it has to do with the use of conventional fuels in liquid, gas, and solid form, for the generation of heat and electricity. Thus, the use of these types of fuel causes the emissions of large amounts of greenhouse gases (GG) into the atmosphere, which have a thermal effect in the near-earth layers of the Earth's atmosphere. Taking into consideration the above, since the middle of the last century, scientists and experts from most countries pay great attention to the wider use of environmentally friendly and inexhaustible RES in the power supply of the future generation. Besides, it is necessary to abandon conventional types of fuel as much as possible. In that connection, as the future energy carriers, special attention is paid to hydrogen gas and combustible gas mixture (CGM), biogas, as well as liquid artificial fuels such as methanol, ethanol, dimethyl ether, and other biofuels. As raw materials, for the production of these types of fuel, special attention is paid to the use of inexhaustible raw materials such as water (for the production of hydrogen and combustible gas mixture), various types of BM (for the production of methanol, ethanol, biogas, etc.) and various types of solid combustible waste (SCW). The latter is also considered to be an inexhaustible energy source [1]. As the world's population grows year by year, their need for energy, various industrial and food products steadily increase, which, in its turn, leads to an increase in waste. However, presently, very serious efforts are underway worldwide to minimize the amount of various hazardous waste, as well as greenhouse gases. Annually, conferences and symposiums relating to the decrease of environmental pollution are held, different preventive and restrictive measures and decisions are made in different countries, especially in developed ones [2]. As is well known, the process of the use of RES for heating and power supply takes place without combustion, therefore hazardous waste is not released into the environment. However, this is not to say that the use of RES is not harmful to the environment. The use of these energy sources has both advantages and disadvantages. Considering this fact, a comparative analysis of the main types of RES and the possibilities of their use is provided below.

2. Promising types of RES and their classification

In general, renewable energy sources are the following:

- solar radiation (solar power);
- wind energy (wind power);
- river and stream energy (hydropower);
- tidal energy (in seas and oceans);
- wave energy (in seas and oceans);
-geothermal energy;
- dissipated thermal energy: the warmth of the air, the water of oceans, seas, and reservoirs;
- biomass energy BM (bioenergy).

BM energy, in its turn, includes the following subcategories:

- plant-based BM formed in the process of photosynthesis and containing various plant species;
- animal-based BM types, consisting of waste products of various types of domestic animals, including poultry;

- peat (under the international classification, it refers to the category of plant-based BM);
- organic solid combustible waste (SCW) formed as a result of anthropogenic activity;
- organic waste formed, in the pulp and paper, wood processing, forestry, and wood harvesting;

Summarizing all the above RES, three main global types can be distinguished:

- solar energy;
- earth energy;
- the energy of the orbital motion of the planet.

Table 1 shows the classification of the existing types of RES [3].

Table 1

Classification of the existing types of RES

Solar radiation energy	Photovoltaic converters (PVC), solar panels Various types of solar collectors (SC) Solar power plants (SPP) High-temperature solar power plants (HTSPP)
Wind energy	Wind mechanical power plants (WMPP) Wind-power plants (WPP)
Hydropower	Mini-hydropower plants (MHPP) operating on small rivers and streams (canals, waterfalls, etc.)
Tidal energy	Tidal power plant
Wave energy of seas and oceans	Wave power plant
Geothermal energy	Geothermal power plants (GPP)
BM energy (bioenergy)	Thermo-chemical, physicochemical or biochemical processing of the liquid, gasiform, and solid biofuel

The main types of promising RES are presented below. In this sense, solar energy comes first. As can be seen from Table 1, for the use of solar energy two types of energy converters (EC) are used: 1) EC which directly or indirectly converts the solar radiation energy into electricity; 2) EC which directly or stepwise convert the radiant solar energy into the thermal one. Photovoltaic converters (PVC) are used for the direct solar energy conversion into power energy, and they are connected in the solar panel in sequential and parallel combinations, the solar panels themselves are connected in the same way forming a solar power plant (SPP). Parabolic (PC) or parabolocylandric (PCC) concentrators are used for the step-by-step conversion of radiant solar energy into power energy. Power generating plants refer to the high-temperature solar power plants (HTSPP) group. PC are high-temperature EC, and they are meant to obtain a temperature up to 3000° C and parabolocylandric concentrators are average temperature EC and give a temperature up to 500° C. In some HTSPP flat heliostats are used as energy converters that concentrate the rays of the sun and direct them to a steam boiler mounted on a tower, where water is converted to steam at high pressure and critical temperature. Then, all processes occur as in a conventional thermal power plant (TPP). When using parabolic and parabolocylandric concentrators, such processes continue in the same way. The output power of the SPP depends on the number of solar panels used, and the power of HTSPP depends on the number of PC, PCC, or heliostats [4].

Silicon-based photovoltaic cells are most widely used in solar power plants as primary energy converters. Figure 1 shows a general view of a solar power plant based on PVC, and figure 2 shows a general view of an HTSPP based on flat heliostats.

Solar energy is also used for the production of hot water and heat. In this case, various types of solar collectors such as flat solar collectors (FSC) and vacuum tube collectors (VTC) are used. Depending on the type of heat carrier, the solar collectors are also divided into two groups: liquid and air. In this case, both ordinary water and substances with phase transitions (antifreeze, ethylene glycol, ammonia, etc.) are used as liquid heat carriers. The maximum heat carrier temperature for FSC is 85°- 90° C, and when using VTC collectors it is up to 250° C [5].

Figure 1. A general view of the solar power plant operating based on PVC.

Figure 2. A general view of heliostat-based HTSPP.

The largest solar power plant in the world is the Bhadla Solar Park plant installed in the Bhadla village, Jodhpur region of Rajasthan (India) which has a total capacity of 2.25 GW [13].

The advantages of using solar energy, as mentioned above, include inexhaustibility, environmental friendliness, ease of converting solar power into other types of energy, simplicity of design, noiselessness, etc. The inexhaustibility of solar power reserves is also because the remaining expectancy of the Sun's life is about 5 billion years. As for environmental benefits, this is mainly because the use of solar power does not lead to the release of emissions into the environment, and this is a crucial step in the fight against the climate crisis.

Indirectly, global warming has led to several other global environmental disasters (massive forest fires, river flooding and flooding of surrounding residential settlements, climatic anomalies, dried water sources, desertification of land, etc.). The use of solar power plays an important role in the prevention of such natural disasters. SPP with a capacity of 1 MWT generates 2 mln. kW*h of power per year, which prevents the emission of carbon dioxide into the atmosphere, which is emitted when using 11000 t of the natural gas, 1100-1500 t of oil, and 1700-2300 t of coal in the conventional TPP.

As for the disadvantages of using solar energy, first of all, the coefficient of performance of most solar power plants, especially photovoltaic converter-based SPP, is small, and the cost of 1 kW of the generated electricity is relatively high. Another disadvantage is the variation in the solar radiation intensity (SRI) flowing on the surface of the earth in a wide range, and a stochastic (arbitrary) change in semi-cloudy sky states, which hurts the operation of photovoltaic converter-based SPP. Their output parameters vary widely which requires additional measures such as the use of stabilizing and energy storage systems which require additional financial costs. Thus, energy generated by this type of solar power system in good weather conditions is accumulated in electrochemical storage batteries and is used at night, as well as in unfavorable weather conditions. Since the electric current generated by the photovoltaic converter-based solar power system is a direct current, its indirect transformation over long distances is impossible. For this purpose, firstly, it should be con-

verted to 220 V or 380 V with the use of a phase inverter system and, later, using a transformer to high voltages and to transmit this voltage over the required distance, as in conventional TPP or hydroelectric power plants. It requires extra costs, so the final price of the generating energy becomes high. Scientific and technical aspects of the efficient use of solar power have not been yet sufficiently studied, and a lot of research is needed [6].

As Table 1 shows, the second widely used type of renewable energy source is wind energy. Wind energy is the oldest type of energy used by mankind. Thus, in ancient China before AD, a rotary-type wind turbine with the horizontal axis of rotation and wooden blades was created [4]. Later, numerous windmills and mechanical wind pumping units were created. From the beginning of the last century up to the 70s, in Azerbaijan, especially in summer cottages located in Baku city, numerous low-speed wind turbines (WT) were established most of which functioned as pumps.

In general, wind energy is the conversion of mechanical wind energy in the form of a stream (airflow) into another type of mechanical energy, rotational motion, using a wind wheel (WW) which is a mechanical energy converter (EC), and in the future, the direct use of this energy in the mechanical pumps or compressors, or by transferring rotational motion from a wind wheel to the shaft of an electric generator, obtaining electrical power. Therefore, as Table 1 shows, wind turbines are divided into two groups: wind mechanical power plants and wind power plants.

However, low-energy wind power plants with both horizontal and vertical axes of rotation are called wind-power units (WPU) in the references. According to the design of WW, wind turbines are divided into the following groups: horizontally and vertically axial, rotary and carousel type, Savenius type, low-bladed (no more than 4 blades), high-speed, multi-bladed (up to 24 blades), low-speed ones, etc. However, as the WT capacity increases, this classification, which was used earlier in the references, is not fully justifiable. Thus, if earlier low-power WT (up to 30 kW) with the number of blades less than 4, including WPU referred to high-speed categories (with a WW rotation speed of 150-200 rpm and more), two or three-blade modern wind power plants cannot belong to this category. Since the number of rotations of the WW of such wind power plants is 30-50 rpm, they are low-speed. Therefore, in such types of WPP, the WW rotation speed using a multistage multiplier is increased to the number of rotations required for an electric generator (1500-1800 rpm). Fig. 3 shows a general view of a low-speed mechanical (pumping and compressor units) WT, and Fig. 4 shows a general view of a modern high-power wind power plant.

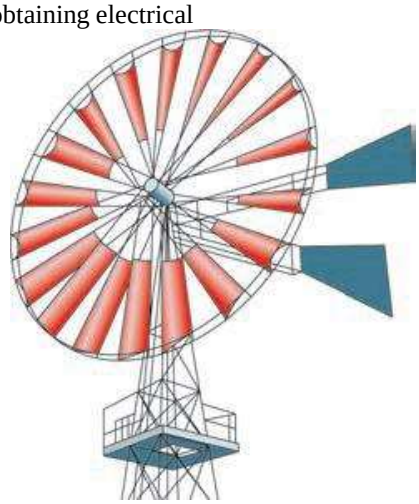

Figure 3. Diagrammatic representation of low-power, multi-blade, low-speed WT.

Figure 4. The general view of industrial three-bladed WPP.

The largest wind power plant in the world is the plant installed by Max Bögl, a German engineering company not far from Stuttgart. Wind generator GE 3.4 MW with a rotor diameter of 137 m was installed on a tower with a height of 178 m. The total height from the ground surface to the top of the blade reaches a record 246,5 m [7].

The main advantages related to solar energy also refer to wind energy and wind power installations. A distinctive feature is that all types of WT are mechanical devices subject to vibration. For this reason, they have special requirements. Since they must be provided with an orientation system in the direction of the wind, braking system, and systems to automatically change the angle of attack of the blades. Vibrations in the horizontal direction must be minimized and, in general, WT must be resistant to strong winds and capable of operating in the wider range of instantaneous wind speeds. The last requirement is because, unlike SPP, WPP generates alternate current, therefore, strict requirements for current frequency change are set for many consumers of the alternate current, especially for consumers with reactive resistance. Since voltage frequency generated by the electric generator of the WPP may differ by a maximum of 10-15% from the industrial frequency (50 Hz). For this reason, special measures are taken, automatic control systems are used on the WPP. When the current frequency reaches the maximum permissible level, power plant operation automatically stops.

Despite all the environmental benefits and inexhaustibility, the use of wind power also has several disadvantages. Thus, firstly, unlike solar power, wind energy is completely unevenly distributed throughout the planet, including the territory of Azerbaijan. From this point of view, the use of wind power is a localized phenomenon. Efficient use of wind power in Azerbaijan is possible only in the territories belonging to zone A, which includes the Absheron Peninsula and adjacent territories, as well as regions located in the narrow coastal strip of the Caspian Sea. In the territories belonging to zone C (lowland of the Kura River) wind energy can be effectively used only in certain altitudes. Another disadvantage of using wind energy is the noise of the majority of WT, especially WPP, in some cases, it causes the death of birds. There should be no obstacles in the vicinity of the WPP installation area [6].

As for the coefficient of performance (CF), the WPP CF is much higher than that of SPP, the maximum value of which is up to 46%. Due to the generation of the alternating current of the WPP, the long-range transmission of this current becomes a lot easier. Moreover, industrial WPP can operate in parallel with the grid. Since the solar and wind power changes depending on the time, differ from each other, and solar power plants operate only during the daytime and do not operate at night, recently much attention is paid to the hybrid one, that is, combined solar and wind power plants (SWPP). Figure 5 shows a general view of one of these plants.

Figure 5. A general view of the hybrid SWPP.

The use of wave energy is another type of RES that is of great significance both in other world's countries and in Azerbaijan. Since the water density is 813 times greater than the density of air, the specific density of the energy created by the wave is much higher in comparison with the density of wind energy. Therefore, since the middle of the last century, the use of this energy has been in the spotlight of all developed countries. The first functioning, commercial plant is Agucadoura Wave Farm with a capacity of 2,24 MW located on the outskirts of Povoa de Varzim in northern Portugal which is 150 m long, 3.5 m wide, and it has a serpentine structure [4]. Later, many wave power plants with different structures were created. Figure 6 shows a general view of the Australian Oceanlinx, figure 7 shows a general view of the Danish Wavestar.

Figure 6. Oceanlinx (Australia).

Figure 7. Wavestar (Denmark).

The advantages of the wave power plants are simplicity of use, large wave energy reserves, and constant renewability. The disadvantage is constructive instability to the high pressures of the watering dam. For this reason, most wave power plants have a short service life and require very high material costs.

Another type of RES is a geothermal energy source with huge reserves that are of great interest to the energy of the future. Geothermal energy is the energy released from the heat of the bowels of the earth. This energy has been released from our planet for millions of years. It must be borne in mind that the cooling rate of the earth's core over a billion years does not exceed 4000° C, and the temperature in the Earth's core exceeds 6500° C. The temperature decreases gradually towards the surface.

There is a lot of heat energy in the Earth's crust, the exact number of which is hard to determine. However, under serious estimates, if you limit it to a depth of 3 km, you can get $8x10^{17}$ GJ of geothermal energy from this layer.

2% of the geothermal energy existing in the earth's crust is constantly released and amounts to $840x10^{6}$ kW, which is considered technologically available for production.

The heat carrier temperature above 150° C is considered to be more economically efficient for production of the electric power from geothermal sources. Since the heat carrier with such temperature can be sent directly to the turbine. Devices are using geothermal waters with lower temperatures in which the geothermal water heats the heat carrier with a phase transition (freon, halon, ammonia, ethylene glycol, etc.) having a low boiling temperature and circulating along the second contour. At the same time, the generated steam rotates the steam turbine and the latter rotates the electric generator shaft. However, the output power of power plants functioning with this principle is not so great and amounts to 10-100 kW. Therefore, the cost of the energy produced in such power plants is slightly higher in comparison with geothermal heat power plants using water with higher temperatures [8].

As for the assessment of sources of the geothermal energy, then, in this regard, it can be pointed out that if you use only 1% of the thermal energy available at a depth of 10000 m, you can replace 100 times all types of conventional fuel (oil, gas, coal, etc.) that are currently being produced by mankind all over the world. However, it can lead to non-renewable depletion of the earth's crust and environmental pollution.

In Azerbaijan, the thermal energy from the deep layers of the earth has not yet been used, but there are some sources of geothermal water with relatively low temperatures that can be used efficiently. Table 2 shows the data about the physical and energy characteristics of thermal waters in these sources of thermal water. As can be seen from the above sources of thermal water, only at Khachmaz-thermal and Khachmaz-Palchig-Oba sources the water temperature is above 550° C [9].

Table 2

Physical and energy features of thermal waters
of the geothermal water sources existing on the territory of Azerbaijan

Names of the geothermal water sources	Temperature, ^{0}C	Heat capacity, C/ (kg^{0}C)	Relative density, kg
Khachmaz-Thermal	56,0	4179,6	0,9962
Khachmaz Palchig-Oba	75,0	4191,2	0,9928
Khachmaz-4th section	44,0	4175,2	0,9906
Gabala-Gamarvan	39,2	4173,9	0,9851
Gakh-Ilisu-upper Beshbulag	30,0	4174,3	0,9700

In general, depending on the water temperature of thermal sources, the energy of this water is used for different purposes. Thus, from hot water, sources of thermal water with a temperature below 55° C, it is appropriate to directly obtain heat energy, or electrical energy in a stepwise form, using heat pumps, and water from sources with a temperature above 55° C is best used directly for hot water supply and heating. Thus, as can be seen from sources of thermal water specified in Table 2, only thermal waters from Khachmaz-Thermal and Khachmaz Palchig-Oba sources can be used directly for hot water and heat supply. It is appropriate to use thermal waters of the last three sources only for the production of electric power applying the thermal pumps.

As indicated above, in this case, it is possible to build a mini geothermal power plant with a capacity of 10-100 kW. In the first case, using a geothermal power plant, the thermal energy of water is gradually converted into electrical energy and for this, an energy carrier (steam) with a critical temperature under a high pressure, which is necessary for the normal operation of the steam turbine. Several substances with a phase transition (ammonia, freon, ethylene glycol, halon, antifreeze, etc.) capable of boiling at low temperatures are used as energy carriers. The transformation ratio of such a system is very high and can even be 500-700%. This means that the amount of the final energy received is 5-7 times more than the energy consumed for the operation of the compressors of the thermal pump, which indicates the potential of this method application. When using the temperature of geothermal water in the GPP, for heating and hot water supply, the used water (cold water) from the opposite side is re-entered into the source of geothermal water. For example, Figure 8 shows a general view, and Figure 9 shows a block diagram of the GPP, in which the lines of hot (direct-flow) water are shown in red, and cold (counter-flow) water lines are shown in blue. The diagram shown in Figure 9 is usually used in installations intended for hot water supply and heating.

When using thermal pumps and a multi-circuit system, eventually, the water temperature in the geothermal source is not only non-decreasing, on the contrary, due to the use of the heat carriers with a phase transition and low temperature of boiling, the temperature of the water returning from the system may be higher than the initial temperature (water temperature at the inlet of the thermal pump).

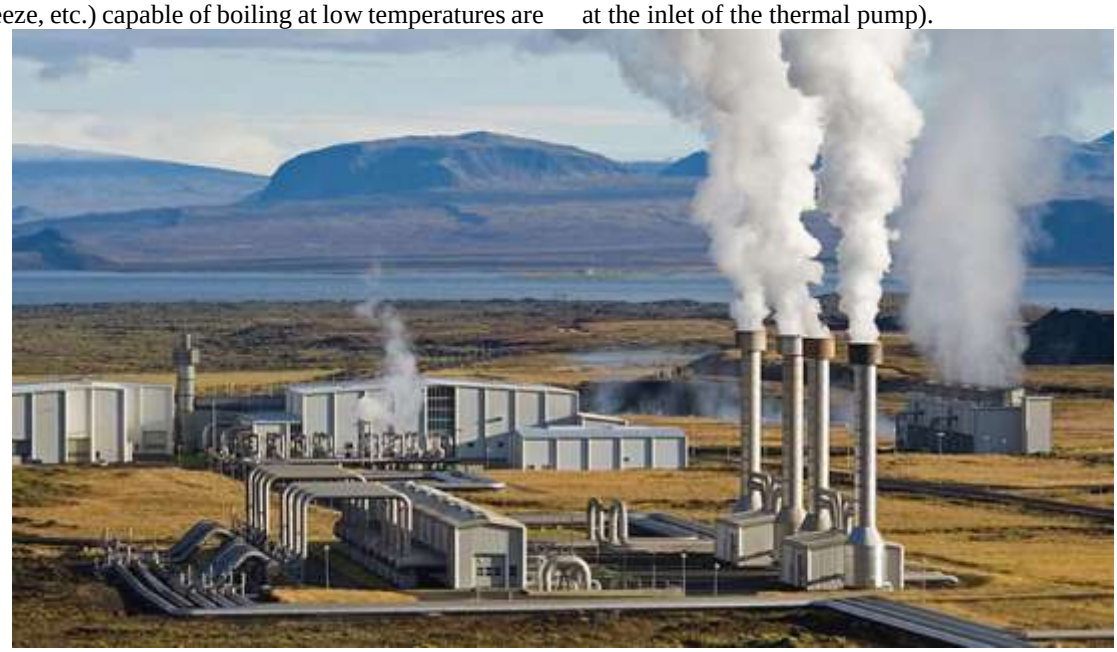

Figure 8. A general view of GPP.

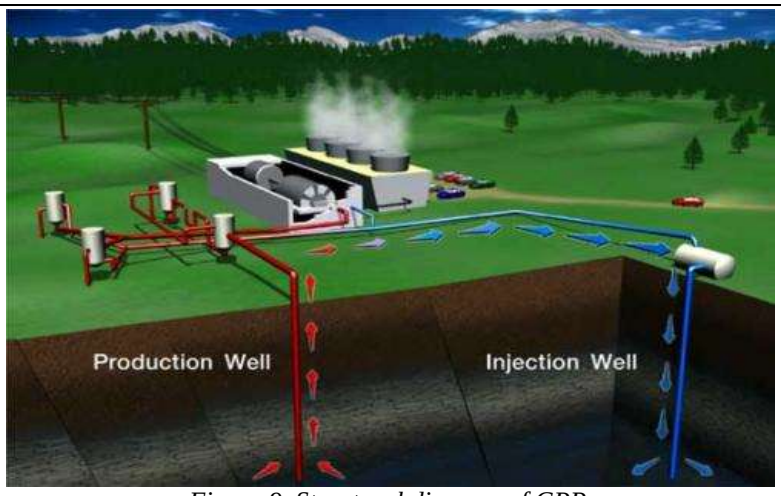

Figure 9. Structural diagram of GPP.

3. The statistics of the use of renewable energy sources in Azerbaijan

As in many countries of the world, as well as in Azerbaijan, the most promising, from the point of view of the actual use of renewable energy sources, are solar, wind, and wave energy. At the same time, the use of solar and wind energy is implemented in two directions: scientific and practical. Since the middle of the last century, numerous studies have been carried out in the field of the use of solar and wind energy and several promising practiced plants have been developed at the"Heliotechnics" laboratory (the present name is "Conversion of Renewable Energy Types") of the Radiation Research Sector of the Azerbaijan SSR (the present name is the Institute of Radiation Problems of the National Academy of Sciences of Azerbaijan). Some of them are: "the solar and wind electrolysis plant for production of high-purity hydrogen and oxygen from pressurized water", "the solar and wind anti-corrosive systems for protection of the main oil and gas pipelines from electrochemical and bacteriological corrosion", "the two-unit wind turbine for heating greenhouse type premises", "the high temperature solar plant with parabolic concentrator" for production from various types of hydrocarbons combustible gas mixture with up to 50% of hydrogen content which uses ordinary water vapor as an oxidizing agent, "the hybrid solar-wind plant for hot water and heat supply", "the two-module solar plant with flat solar collectors for dehydration and thermal treatment of crude oil", "the solar energy plant with parabolic concentrator for production of combustible gas mixture from plant-based BM", "plant with flat solar collectors for pre-sowing irradiation of cotton stems with concentrated sun rays", "Heliothermostat", "Helio kitchen", "Various modifications of the wind-electric plants with vertical axis of rotation", "Damless mini-hydropower plants operating from lowland rivers", "Pneumatic wind-pump plant", "Wave power plant", "Hybrid solar-wind biogas plant for biogas production from biomass and organic waste", etc., some of which were applied on a semi-industrial scale in different climatic conditions of the Absheron Peninsula. The results obtained from experiments have been published in refereed international scientific journals [5-9]. Other plants which are still at the level of patents can also be successfully applied not only in the remaining regions of Azerbaijan but also in territories liberated from the occupation of Armenia in 2020, territories that have large resources of solar and wind power.

As for the practical side of the use of renewable energy sources, the main works performed in this direction are owed by Nakhchivan State Energy Agency, "Azerishig" OJSC, "Azalternativenergy" LLC, and "Tamiz Shahar" OJSC. Table 3 shows statistical data on the technical potential of renewable energy sources existing in Azerbaijan, and the table shows similar data on the total generating capacity of power plants established up to 2015. As table 3 shows, solar energy accounts for 85.52% of the total RES balance. Wind energy potential is 7,68 times less as compared to solar energy [10].

Table 3

Statistical data on the technical potential of renewable energy sources in Azerbaijan

The name of RES	Technical potential	
	MW	Percentage, %
Solar	23040	85,52
Wind	3000	11,14
BM types and organic waste	380	1,41
Mini-hydropower plants	520	1,93
Total:	26940	100,0

Besides, since the airflow to the WW WPP enters in a horizontal direction, they have a much higher probability of darkening each other as compared to solar panels. Therefore, individual WPP should be installed at a large distance, relative to one another, which hurts the overall efficiency of wind energy use, and thus, in the overall balance, the share of SPP, in comparison with WPP, is increasing significantly.

Unfortunately, even though most of the territory of Azerbaijan is located on the shores of the Caspian Sea, wave energy is not yet used in our country. For this reason, tables 3 and 4 do not contain any information about the use of this energy. Several promising types of wave power plants have been developed, however, they are still at the patent level. When allocating funds, modern and cost-effective wave power plants can be installed in the future. Thus, both tables do not contain any data on geothermal energy, as well as energy obtained from solid combustible waste.

Table 4

Data on the total generating capacity of power plants established in Azerbaijan up to 2015, MW

State autonomous and private producers of electric power	Power plants						
	Total	TPP	HPP	SPP	WPP	BM	Total percentage, %
«Azerenerji» OJSC	6935	5881	1055	-	-	-	86,69
Nakhchivan State Energy Agency	237	147	68	22	-	-	2,96
Electricity producers: (BP, SOCAR, Azersun Holding)	722	722	-	-	-	-	9,03
«Tamiz Shahar» OJSC	37	-	-	-	-	37	0,46
«Azerishig» OJSC	52	-	-	-	52	-	0,66
«Azalternativenergy» LLC	16	-	-	13	3	1	0,20
Total, MW	7999	6750	1132	35	62	38	100
Percentage, %	100	84,2	14,1	0,4	0,8	0,5	-

As table 4 shows the main organizations producing electric power in Azerbaijan, with the use of renewable energy sources up to 2015, were Nakhchivan State Energy Agency, "Azalternativenergy" LLC, "Tamiz Shahar" OJSC, and "Azerishig" OJSC. HPP (water energy), SPP (solar energy), WPP (wind energy), and BM energy are the main types of renewable energy sources. Certainly, the use of HPP has an advantage over other types of renewable energy sources. However, there have been significant changes in the use of RES since 2015. A significant process has been achieved, especially in the field of waste management [11].

According to the data provided by the Ministry of Energy, 408 million kWh of electricity was generated at the WPP and SPP in Azerbaijan in 2013-2019. So, if these power plants generated 1.6 million kWh of electricity in 2013, then this indicator was 149 million kWh in 2019, which showed an increase of 93 times over the past 7 years.

Growth in electricity production was also observed at bioelectric power plants (BPP) operating based on various types of BM and SCW in the period 2013-2019. During this period, 1.19 kWh of electricity was produced at the BPP, and the total energy production increased by 46.3% as compared to 2013 [7]. There was an increase in the use of renewable energy sources in 2020. So, the hydropower plants, wind power plants, and the Solid Waste Incineration Plant operating in Azerbaijan generated 151.9 million kWh of electricity in January-May 2020, which is 0.7 million kWh more than the same data in 2019.

In general, the statistics on the use of renewable energy sources in Azerbaijan up to 2020 is as follows: hydropower capacity of 1135 MW (22 plants, including 12 MHPP), wind power capacity of 66 MW (5 plants, 1 hybrid), bioenergy capacity 38 MW (2 plants, 1 hybrid), solar power capacity 40 MW (9 plants, 1 of them is hybrid). During this period, a hybrid power plant was installed in Gobustan, consisting of a WPP with a capacity of 2.7 MW, an SPP with a capacity of 3 MW, and a BPP with a capacity of 1 MW, and there are 2 SPP with a total capacity of 27 MW in the Nakhchivan AR.

Currently, the total production capacity of electricity in Azerbaijan is 7,556 MW, and the capacity of renewable energy sources, including large hydropower plants, is 1,276 MW, which is 17% of the total capacity. The goal is to increase the share of renewable energy sources to 30% in the total energy balance by 2030. To achieve this goal, on January 9, 2020, the Cabinet of Ministers of the Republic of Azerbaijan signed Implementing Agreements between the Ministry of Energy and the "ACWA Power" Corporations from Saudi Arabia and "Masdar" from the United Arab Emirates on the implementation of pilot projects for the development of renewable energy sources in Azerbaijan. According to these agreements, it is envisaged to implement pilot projects with ACWA Power for the construction of a wind farm with a capacity of 240 MW and with Masdar for the construction of a solar power plant with a capacity of 230 MW. According to a report prepared by "VPC", to achieve the set goal of 30%, it is necessary to install new wind and solar power plants with a total capacity of 1,500 MW, of which 440 MW in 2020-2022 and 460 MW in 2023-2025. It is considered expedient to integrate 600 MW into the network within 3 years, including 2026-2030.

At present, in Azerbaijan, as well as in all countries of the world, various measures are being taken to broaden the use of renewable energy sources, contracts

are being signed with various reputable foreign companies, and large investments are being made in this area [11].

In conclusion, we can say that there are a lot of RES reserves in Azerbaijan, such as solar, wind, wave, geothermal, wave and energy of small rivers, and the use of these inexhaustible and environmentally friendly types of energy can play an important role in guaranteed energy supply for the future generation.

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