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Opportunities to use solar energy in Azerbaijan

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Abstract: The use of traditional energy means has opened the way to the world's insurmountable pollution problems, and as a result, new means of energy were sought. In that regard, renewable energy resources appear of utmost important and crucial solution. In the globalized world, the use of renewable energies combines two main components. Firstly, to prevent climate change and secondly, to minimize the level of pollution in the world. İn the other hand, sustainable energy resources those which can be to produce energies again and again. Solar, wind, geothermal, and also biomass energy we can add this group. Alternative energy sources are eco and environmental friendly.

So, with the renewable energies we can save more energies and establish better environment. Last 2 decades more environmental related issues are more and more created. The world population are increased day by day in that reason of energy consumptions raised that is why we need to move alternative source of energy. Azerbaijan has made significant investments for development of renewable energy sector since 2000s. as a result of Azerbaijan has became a member of IRENA in 2008. Additionally, alternative sources of energy are widespread in here.

Natural geographical conditions of the country, the number of sunny days, as well as the sufficient annual wind rate create ample opportunities for the development and use of renewable energies. The main goal of the research is to investigate the potential of renewable energy in Azerbaijan and to use world experiences in the green energy potential of the country.

Key words: renewable energy, green energy, potential energy, solar panels, wind turbines, potential energy of Azerbaijan, world experience of alternative energies.

Introduction

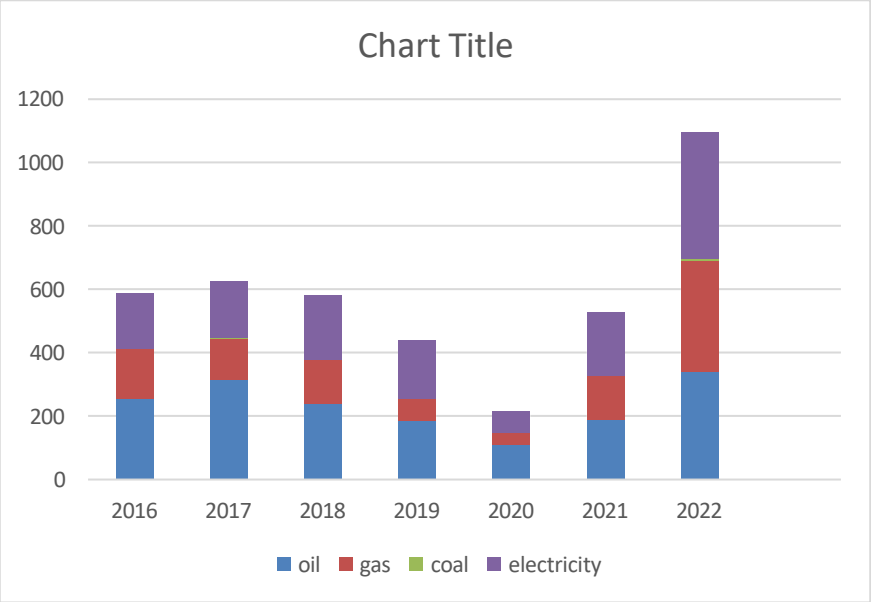
What is energy?

The most scientists prove that energy is crucial tool for human life. As we know that, energy is used everywhere namely; walking and bicycling, cooking and refrigerating food, lightning our homes, manufacturing product and so on [20]. The amount of people is increasing day by day and due to this the demand of energy for daily life has also increased [7]. Source of energies have divided into two groups:

1. Non- renewable
2. Renewable

Fossil fuels play significance role in the energy marketing. Fossil fuels still dominate the world's energy market, which is worth approximately 1.5 trillion dollars (Goldenberg 2006). Fossil fuels, containing coal, oil, and natural gas have been the main part of energy sources for industrialization and also economic development. During the Industrial Revolution, the discovery and use of these resources transformed societies, enabling unprecedented growth and technological advancements. Furthermore, today, fossil fuels continue to be dominate the energy consumption. The data of International Energy Agency (IEA) fossil fuels accounted for about 84% of the world's total primary energy consumption in 2019 (figure 1).

Figure 1



Source: https://www.iea.org/data-and-statistics/charts/fossil-fuel-consumption; 2016-2022 [18]

According to the IEA, the use of fossil fuels continues to increase year by year. And if this trend continues, it will lead to intractable problems for the future.

The use of fossil fuels has certainly not been without negative effects. When fossil fuels are burned, they release greenhouse gases such as carbon dioxide, which trap heat in the earth's atmosphere and contribute to climate change. In 2019, fossil fuels accounted for 74 percent of US greenhouse gas emissions [27]. On the other hand, using more non- renewable energy causes environmental issues namely; air pollution, water pollution, plastic pollution and oil spills and so on. Since In order to protect the environment and obtain sustainable clean energy, it is necessary to change the traditional sources and use of energy. and for this reason, the world has already started looking for new alternatives and renewable energy types have started to be used [2]. And therefore, it is necessary to replace traditional energy sources and use them to protect the environment and obtain sustainable clean energy. And for this reason the world has already started looking for new alternatives and renewable energy types have started to be used. By applying renewables energies have more chances. First of all environmental benefits and less detrimental effects, secondly, increases in energy exports, thirdly, currency saving and new job opportunities. Renewable energy sources are divided into several categories;

1. Solar energy
2. Wind energy
3. Biomass energy
4. Hydropower energy
5. Geothermal energy [3]

Main part.

1.1 Solar energy

Solar energy- In cloudless weather solar radiation having an output of 1,000 W/m2 hits the earth surface - radiation intensity. Solar energy is used by means of active and passive solar systems to generate heat or electricity.

Active solar system;

Flat solar collectors - serve to generate hot water or hot air where the solar radiation is captured by an absorber in which the heat is conveyed to the liquid or air.

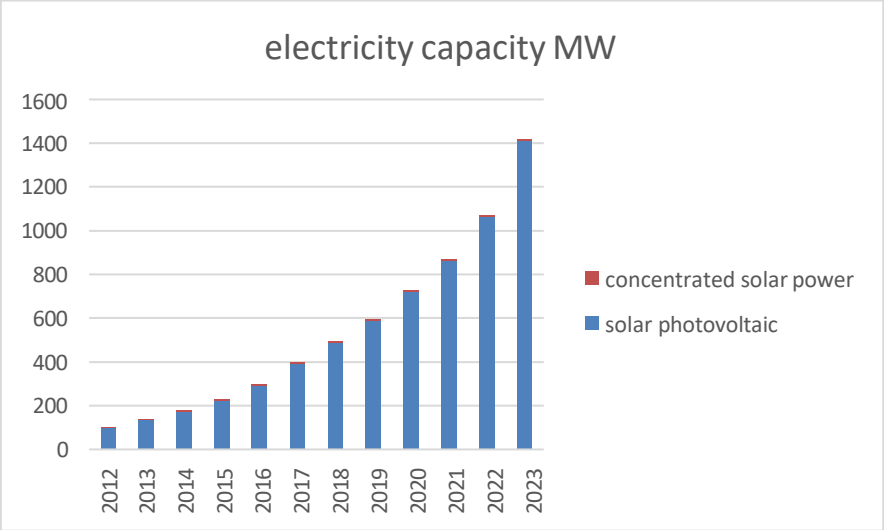
Concentric collectors - serve to prepare hot water with higher efficiency. Reflection channels with a parabolic profile concentrate the sunrays to the tubes located in the focal point with heat carrying liquid.

Solar (photovoltaic) cells - work on the principle of the photoelectric phenomenon and directly convert the light into DC electric current [13].

In 1893, the photovoltaic (PV) effect was discovered; many decades later, scientists developed this technology for the production of electricity. These PV devices have quickly become the cheapest option for new electricity generation in many parts of the world. For example, the cost of generating electricity from solar PV plants fell by 77% between 2010 and 2018 [16].

In modern times, solar energy is mainly used for two purposes; heat and electricity generation, but it is predicted that by the middle of the 21st century, about 45% of the world's energy needs could be met by solar power installations. Solar thermal has also gained significant advantages in industrial applications. It provides us with an alternative way to generate energy, heat, and even chemical processing. It has a wide range of applications in the food processing industry, the construction industry, the manufacturing sector, and several business firms. Nevertheless, electricity generated from solar radiation can serve a number of industrial and domestic needs [9].

Figure 2



Source: Energy-Transition/Technology/Solar-energy

Electricity capacity of solar energy worldwide has been swiftly skyrocketed. The electricity capacity of PV technology from 2012 to 2023 increased 100,649 to 1411,139 MW, whereas the electricity capacity of concentrated solar power (CSP) applications, where was 2,567 MW in 2012, after 11 years later it has increased to 6,876 MW. So, the stand-alone solar PV and large-scale grid-connected PV plants are widely used worldwide and used in space applications. The sustainable

development scenario is built on an economic perspective. It also examines what actions would be required to achieve shared long-term climate benefits, clean air, and energy access goals. The short-term details are based on the IEA's Sustainable Recovery Strategy, which aims to boost economies and jobs by developing a cleaner and more reliable energy [5]. On the other hand, renewable energy sectors have also had a positive impact on employment. IRENA projects global solar PV employment to increase sharply from 4.9 million in 2022 to 7.1 million in 2023 [23].

The global distribution of PV jobs by country is as follows. and the leading country is China. According to the comparison of both years, China ranks first in the world in terms of employment level and number in PV systems in 2021 and 2023, which is equivalent to half of the 7.11 million employment area.

Table 1

Countries	2021	2023
China	2.3 million	4.586 million
India	0.175 million	0.323 million
United state	0.232 million	0.285 million
Brazil	0.065 million	0.278 million
Germany	0.054 million	0.178 million
Japan	0.225 million	0.154 million
Poland	0.114 million	0.154 million
Vietnam	0.121 million	0.127 million
italy	0.057 million	0.084 million

Source; [23].

1.2 Wind energy

Wind power or wind energy is a form of renewable energy that harnesses the power of the wind to generate electricity. It involves using wind turbines to convert the turning motion of blades, pushed by moving air (kinetic energy) into electrical energy (electricity). Modern wind turbines are categorized by where they are installed, and how they are connected to the grid.(u.s deparment of energy). The technique of obtaining energy from wind is obtained in two different (geographical) ways, which are called offshore and onshore wind energy [1]. Onshore wind turbines should typically be installed in areas with abundant and consistent wind resources. and also residential areas and areas where wind flow is not interrupted are selected that is why, these areas that have been surveyed and approved for onshore wind turbine installation;

1. open areas plains and farmlands
2. hilltops and ridges
3. deserts
4. industrial and commercial areas [4].

And a special formula is used to calculate the power received from a wind turbine;

$$P = \frac{1}{2} \cdot p \cdot A \cdot v^3 \cdot C_p$$

P- power generated by the wind turbine (w)

p- air density

standart value; p= 1.225kg/$m3$

$A = \pi r^2$

v- wind speed (m/s)

Cp= power coefficient (the efficiency of the turbine to convert wind energy to electricity)

Annual energy production calculation in the onshore wind turbines;

$$E = P \cdot t \cdot CF$$

E; annual energy production (in kilowatt-hours, kWh)

P; turbine power output (in kilowatts, kW)

t; totalhours in year (8760 hours)

CF; capacity factor) [11].

Renewables set annual records, accounting for 87% of new capacity additions and 43% of global installed capacity in 2023. Offshore wind power, with its high capacity factors and increasing

competitiveness, is at the forefront of energy transition plans. Despite progress in offshore wind – with just 63 gigawatts (GW) of installed capacity in 2022 – 494 GW by 2030 and 2,465 GW by 2050 are needed to meet the 1.5°C target [21]. Offshore wind can provide cost-effective energy services to densely populated coastal areas and is becoming an attractive solution thanks to positive developments in turbine, foundation and system integration technologies. There is a push to move offshore wind project sites further offshore and into deeper waters due to the greater energy potential compared to fixed-bottom configurations. The annual financial commitment for both onshore and offshore wind energy has been on a different trend over the years. In 2013, these figures were $68.9 billion for onshore wind energy and $7.13 billion for offshore wind energy. A decade later, these figures have completely changed and increased by more than 2.5 times, while onshore wind energy was $140.90 billion and offshore wind energy was $33.75 billion. In 2020, investment in onshore and offshore wind grew by 4% from 2019 to a total of $161 billion, and preliminary data from BNEF shows that investment is expected to average $176 billion per year between 2021 and 2022, up 9% from 2020. Between 2013 and 2022, onshore wind accounted for 80% of total investment in wind technology. In 2019, onshore wind investment rose by 32% from 2018 to a record high of $133 billion, after falling by 9% in 2020 to $120 billion, before rising again to an average of $140 billion in 2021 and 2022 [17]. On the other hand, when it comes to employment in solar energy, how many jobs and potential job opportunities are mentioned. Globally, onshore and offshore wind employed an estimated 1.5 million people in 2023. Employment was highest in Asia (59% share), followed by Europe (22%), the Americas (17.6%), and Africa and Oceania (1.4%). And again china top country for empoyment in the wind energy systems.(0.785 billion). This article highlights both the job opportunities in renewable energy sources and the employment impact of the new era-renewable energy sector on the economy by country [23].

3. POTENTIAL OF RENEWABLE ENERGY IN AZERBAIJAN

Azerbaijan's favorable geographical location has meant that it has renewable energy sources. The first renewable energy type installed in Azerbaijan was hydropower, which was built in 1883 in the village of Galakand, Gadabay region. However, the mentioned energy source remained the only renewable energy source until 2009. After Azerbaijan became a member of the International Renewable Energy Agency in 2009, the installation and use of alternative energy sources began [19]. According to the research concluded by IRENA in 2020, the potential of solar and wind energy in Azerbaijan is greater than that of other renewable energy sources. Table 1 shown the renewable potential in Azerbaijan [28].

Table 1 renewable resources in Azerbaijan (by IRENA)

Renewables	*Technical capacity (MW)*
Solar	23,040
Wind	380
Hidro	520
Biomass	380
Total	26,940

the energy from flowing rivers has kinetic energy that can be captured and converted into electricity by a submerged turbine. These are called hydrokinetic or river flow systems for application in rivers. Energy from hydropower systems installed in rivers is calculated by certain formula:

$P = 1/2\rho Av3$ (9-4)

P = power possessed by flowing water

ρ = water mass density

A = the area swept by turbine blades, equal to πr^2

v = water velocity [12].

In the Republic of Azerbaijan, the energy received from strengthened hydropower systems is also calculated by this formula. There are a number of hydroelectric power stations and small hydroelectric power stations in the country, which have different energy capacities. As a result, the installed hydropower capacity reached 1154,8 MW. Namely; Mingachevir HHP(hydro power plants)- 420 MW, Shamkir HHP-380 MW, Yenikend HHP-150 MW, Fuzuli HHP-25 MW, Shamkirchay and Takhtakorpu HHP-25 MW, Araz and Bilev HHP-22 MW, Arpachay 1 Arpachay 2 HHP- 22 MW, Ordubad HHP- 36 MW. As mentioned this area also has small hydro power plants [24].

2.1 SOLAR POTENTIAL

Azerbaijan has excellent solar energy potential due to itss relatively sunny climate. According to the Ministry of Energy, the technical potential is around 23,000MW. The country's 2,400-3,200 hours of sunshine per year compares well internationally, and its solar intensity is estimated to be between 1,500 and 2,000 kW/m2 [19].The World Bank's Global Solar Atlas confirms that the specific photovoltaic power output (SPPO) for Azerbaijan ranges from 3.21–4.48 kW/kW (specific photovoltaic power output is the amount of electricity that can be produced per kW of module power over a period of time).The Direct Normal Irradiance (DNI) and Global Horizontal Irradiance (GHI) are in the range of 2.71–4.84 kW/m2 and 3.44–4.80 kW/m2 per day, respectively [26]. In order to increase energy efficiency and the use of renewable energies, Azerbaijan has started cooperation with a number of organizations in the aforementioned field. Such as the European Bank for Reconstruction and Development, the Asian Development Bank, the International Finance Corporation, the International Renewable Energy Agency, the German Energy Association, and the International Energy Agency [25]. Table 5 lists a number of solar power plants installed in Azerbaijan.

Table 5

The name of the project	planned capacity	Generation per year
Nakhchivan solar power plant	39,4 MVt	16,5 million kVt/year
Surakhani solar power plant	1,2 MVt	5,7 million kVt/year
Garadagh solar power plant	230 MVt	500 million kVt/year
Floating solar power plant	100 kVt	160 thousand kVt/year

Source: www.minenergy.gov.az

According to Table 5, the Garadagh solar power plant is the plant with the highest installed capacity in both Azerbaijan and the CIS countries. In addition, to photovoltaic solar panels, floating solar panels have also been installed in Azerbaijan and are expected to be operational by 2024. Thus, the model installed on Lake Büyükşor has an output of 100 kW [15]. The main difference between floating solar panels and traditional solar panels is that they are installed on the water, which prevents evaporation due to the cooling effect of water, making it easier to obtain energy and improving energy supply [10]. On the other hand, using floating solar power plant has more internal positive and negative aspects. Advantages of a floating power plant (internal, positive factors)

a) A floating solar power plant system typically produces more electricity than ground-based and rooftop systems the cooling effect of water.

b) Floating platforms are designed and manufactured to withstand extreme physical stress, including typhoons and storms conditions.

c) These devices reduce water evaporation and algae growth by shading the water.

Disadvantages of floating power plant (internal, negative factors)

a) Long-term maintenance requirements and sustainability of floating solar PV are yet to be seen.

b) Environmental and adverse impacts on aquatic ecosystem.

c) Relatively young and immature technology.

d) Lack of experience and knowledge.

e) High waves and salt water can damage solar panels over time [10].

According to researchof mine (the author), the areas where floating solar panels can be

installed in Azerbaijan are:

1. Mingechevir reservoir
2. Shamkirchay reservoir
3. Taxtakorpusu reservoir
4. Ceyranbatan reservoir [1].

Why should floating solar panels be installed in the above mentioned areas?

1. Large water surface
2. High annual solar radiation
3. Saving land resources
4. Proximity to grid power transmission nodes
5. Azerbaijan's green energy strategy

On the other hand, work is underway to expand the use of solar energy and increase energy efficiency to achieve zero emissions. Thus, in the "Azerbaijan 2030 National Priorities" document, it is planned to develop the green energy sector and boost up its use to 30% by 2030. Another regulation " Energy strategy 2050" is planned to lift up the share of renewable energy to 50% by 2050 [22]. And as a result of, the Azerbaijani government and the Ministry of Energy have signed agreements and memorandums with numerous foreign companies on the instruction and development of renewable energy plants;

1. "ACWA Power" of the Kingdom of Saudi Arabia
2. "Nobel Energy Management"
3. " China Gezhouba GroupOverseas Investment" of the China
4. "TotalEnergies"
5. "Komaihaltech" of the Japan
6. "A-Z Czech Engineering " of the Czech
7. "Masdar" of the Kingdom of Saudi Arabia

Cooperation with the mentioned companies will contribute to the further improvement of renewable energy in the future in Azerbaijan, as well as to the increase of renewable energy stations by transforming the liberated territories into green energy zones. At the same time, the installation of solar panels on roofs, which is a new method, will pave the way for obtaining energy not only for industry or organizations, but also for personal use.

CONCLUSION

The use of renewable energy sources is seen as the only way to prevent the pollution caused by the changing world and fossil fuel surpluses. On the other hand, it can also result in a decrease in the unemployment rate index and an increase in employment. The use of inexhaustible solar and wind energies can be used not only for industrial but also for agricultural and commercial purposes. In turn, the renewable energy potential in Azerbaijan is very high. In particular, the high number of annual sunny hours has resulted in the construction of several solar power plants in the country. In addition, the construction of a model floating solar power plant has proven that this form of solar power plant has also been successfully used in energy production in the country. In the next studies, the production of electricity from solar energy and the production of individual energy for homes and workplaces by installing solar panels on roofs will be discussed, and several steps have been taken in this regard and a Green Energy Zone has been created in the liberated territories.

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Azərbaycanda günəş enerjisindən istifadə imkanları

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Xülasə: Ənənəvi enerji vasitələrindən istifadə dünyada çirklənmə problemlərinə yol açmışdır və nəticədə yeni enerji vasitələrinin axtarılmasına artıq başlanılmışdır. Bu baxımdan, bərpa olunan enerji resursları son dərəcə vacib və həlledici həll yolu kimi görünməkdədir. Qloballaşan dünyada bərpa olunan enerjilərdən istifadə iki əsas komponenti özündə ehtiva edir. Birincisi, iqlim dəyişikliyinin qarşısını almaq, ikincisi, dünyada çirklənmə səviyyəsini minimuma endirmək.

Beləliklə, bərpa olunan enerji ilə bizlər daha çox enerjiyə qənaət edə və daha yaxşı mühit yarada bilərik. Son iki onillikdə ətraf mühitlə bağlı daha çox problemlər yaranmıdır. Enerji istehlakının artması səbəbindən dünya əhalisi alternativ enerji mənbələrindən istifadəyə keçməlidir. Azərbaycan 2000-ci illərdən bəri bərpa olunan enerji sektorunun inkişafı üçün əhəmiyyətli investisiyalar yatırmaqdadır. Nəticədə Azərbaycan 2008-ci ildə IRENA-ya üzv olmuşdur. Bundan əlavə, burada alternativ enerji mənbələri geniş yayılmışdır.

Ölkənin təbii coğrafi şəraiti, günəşli günlərin sayı, eləcə də kifayət qədər illik küləyin sürəti bərpa olunan enerji mənbələrinin inkişafı və istifadəsi üçün geniş imkanlar açmaqdadır. Məqalənin əsas məqsədi dünyanın yaşıl enerji təcrübəsindən istifadə edərək, Azərbaycanda bərpa olunan enerji potensialını araşdırmaqdır.

Açar sözlər: bərpa olunan enerji, yaşıl enerji, potensial enerji, günəş panelləri, külək turbinləri, Azərbaycanın potensial enerjisi, alternativ enerjinin dünya təcrübəsi.

Возможности использования солнечной энергии в Азербайджане

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Резюме: Использование традиционных источников энергии открыло путь к непреодолимым проблемам загрязнения в мире, и в результате были найдены новые источники энергии. В этой связи возобновляемые источники энергии представляются важнейшим и решающим решением. В глобализованном мире использование возобновляемых источников энергии объединяет два основных компонента. Во-первых, предотвращение изменения климата и, во-вторых, минимизация уровня загрязнения в мире. С другой стороны, устойчивые источники энергии — это те, которые могут производить энергию снова и снова. К этой группе можно отнести солнечную, ветровую, геотермальную, а также энергию биомассы. Альтернативные источники энергии являются экологически чистыми и безопасными для окружающей среды.

Таким образом, с помощью возобновляемых источников энергии мы можем сэкономить больше энергии и создать лучшую окружающую среду. За последние 2 десятилетия все больше и больше проблем, связанных с окружающей средой, создается. Население мира увеличивается с каждым днем, поэтому потребление энергии растет, поэтому нам необходимо переходить на альтернативные источники энергии. Азербайджан вложил значительные инвестиции в развитие сектора возобновляемой энергии с 2000-х годов, в результате чего Азербайджан стал членом IRENA в 2008 году. Кроме того, альтернативные источники энергии

широко распространены здесь.

Природно-географические условия страны, количество солнечных дней, а также достаточная годовая скорость ветра создают широкие возможности для развития и использования возобновляемых источников энергии. Основная цель исследования - изучить потенциал возобновляемой энергии в Азербайджане и использовать мировой опыт в потенциале зеленой энергии страны.

Ключевые слова: возобновляемая энергия, зеленая энергия, потенциальная энергия, солнечные панели, ветряные турбины, потенциальная энергия Азербайджана, мировой опыт альтернативной энергии.