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Assessment of the Benefits of Renewable Energy to the Azerbaijan Ecosystem

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***Abstract*—**The transition to renewable energy sources has become a critical component of global efforts to mitigate climate change and promote sustainable development. However, the deployment of renewable energy technologies can also have significant impacts on ecosystems and the services they provide, such as carbon sequestration, soil fertility, water quality, and biodiversity. These technologies also highlight the potential co-benefits of renewable energy deployment for ecosystem services, such as reducing greenhouse gas emissions and improving air and water quality. Renewable energy sources, such as wind, solar, hydro, and biomass, are increasingly being used to meet the world's energy needs due to their environmentally friendly nature and the desire to reduce greenhouse gas emissions. However, the expansion of renewable energy infrastructure can also impact ecosystem services, which are the benefits that humans derive from nature, such as clean water, air, and food. This geographic assessment aims to evaluate the relationship between renewable energy infrastructure and ecosystem services. Potential solutions such as the use of ecological benefit measures, biodiversity-friendly design of renewable energy infrastructure, and stakeholder participation in decision-making processes are being investigated to determine the positive effects of renewable energy infrastructure on ecosystem services.

***Keywords*—**Renewable energy, solar energy, climate change, energy production.

I. Introduction

RENEWABLE energy refers to energy obtained from natural sources that are replenished faster than they are consumed. Solar, wind, hydroelectric, biomass, and geothermal power are some examples of renewable energy sources [1]. These sources provide energy without the negative environmental impacts of fossil fuels, making them a crucial component in mitigating climate change. Ecosystem services refer to the benefits that nature provides to human well-being, including clean air and water, natural disaster protection, fisheries, crop pollination, and control of pests and diseases, as well as outdoor places for recreation, solitude, and renewal [2]. The functioning of the entire economy depends on ecosystem services, which are neither worthless nor priceless. Renewable energy and ecosystem services are intrinsically linked. While renewable energy reduces reliance on fossil fuels and thus mitigates the negative environmental impacts of energy production, it also reduces the pressure on ecosystems to provide resources to support human activities. A geographic assessment can help identify areas where the implementation of renewable energy projects could result in a reduction of negative environmental effects and enhance the provision of ecosystem services.

A geographical assessment of the relationship between renewable energy and ecosystem services can provide insights into how these two components can be integrated sustainably. This assessment can help identify areas where renewable energy technologies can be deployed to minimize environmental effects and enhance ecosystem services. A geographical assessment of the relationship between renewable energy and ecosystem services can provide insights into how these two components can be integrated sustainably. The assessment can also help identify potential trade-offs and synergies between renewable energy and ecosystem services and inform decision-making about where to locate renewable energy projects to maximize benefits and minimize negative effects. The research serves as a comprehensive guide for investors who attach importance to criteria such as choosing the most suitable location for renewable energy power plants and preventing ecosystem degradation. Research of Casalegno et al. in this area demonstrate how renewable energy can be used to enhance ecosystem services [3]. Additionally, a geospatial review article by Hastik et al discusses how renewable energy can be used to optimize ecosystem services and encourage consideration in landscape management decision-making processes [4].

Another relevant resource is an article titled "Renewable Energy Explained" [1]. This article provides information on five different forms of renewable energy: solar, wind, hydroelectric, biomass, and geothermal power. The article notes that these sources can provide energy without the planet-warming effects of fossil fuels. National Geographic's article "Renewable Energy, Facts and Information" provides additional information on the topic [1]. The article emphasizes that renewable energy can provide energy while also preserving ecosystems and reducing environmental harm.

II. Material and Method

A geographical assessment of renewable energy and ecosystem services involves evaluating the distribution and availability of these resources in different regions. The assessment can be conducted using various methods, including geographic information systems (GIS), remote sensing, and modelling. GIS analysis is a powerful tool for analyzing and visualizing spatial data, such as land use, vegetation cover, and topography. Remote sensing, using satellite or aerial images, can provide detailed information about ecosystem services such as carbon sequestration and soil moisture. GIS Modelling is used in this article to simulate the impacts of

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renewable energy development on ecosystem services and contrariwise. The assessment also involves stakeholder engagement to ensure that the perspectives and priorities of local communities and other stakeholders are taken into account. This includes consultations with indigenous peoples, local governments, industry representatives, and civil society organizations.

III. Results

Renewable energy in Azerbaijan is a topic of increasing interest, with the country having a high potential for renewable energy sources. Azerbaijan, historically recognized for its role as an oil and gas exporter, is undergoing a transformative shift towards the development of renewable energy resources. Backed by a supportive regulatory framework and a notable potential for renewable energy, the nation is actively striving to enhance its global appeal, positioning itself as an attractive destination for international investors. Demonstrating its commitment, Azerbaijan has unveiled ambitious plans, marked by significant partnerships, to initiate pioneering pilot projects within the realm of renewable energy.

Central to these efforts is the country's targeted objectives. Building upon its Nationally Determined Contribution submitted under the Paris Agreement in 2017, Azerbaijan is steadfastly aiming for a substantial reduction of greenhouse gas emissions – a 35% decrease by 2030 from the 1990 baseline. Bolstering this commitment, Azerbaijan's adoption of a new commitment during COP26 in Glasgow in 2021 aims for a 40% reduction by 2050, coupled with a resolute intention to establish a "Net Zero Emission" zone [7].

To effectively realize these ambitions, the Ministry of Energy has set forth a comprehensive strategy to elevate renewable energy's installed capacity to 30% within the country's energy mix. This roadmap outlines a targeted deployment of 1,500 megawatts (MW) of new generation capacity, distributed across different phases – 440 MW in 2023, 460 MW spanning 2023–2025, and a substantial 600 MW from 2026–2030 – all stemming from renewable sources [5]. Additionally, the Republic of Azerbaijan has undertaken a Renewables Readiness Assessment to create an efficient and sustainable energy system, making it a top priority in the country's efforts to diversify its economy [8]. With the growing global focus on transitioning to cleaner energy alternatives, Azerbaijan's Ministry of Energy has estimated a prospective capacity of 27,000 MW from various renewable sources [6]. This potential volume provides a comprehensive analysis of the economically feasible and technically feasible aspects of this renewable energy spectrum, which includes wind, solar, bio-energy and hydropower resources.

In recent years, renewable energy has emerged as a key driver of sustainable development that reduces greenhouse gas emissions and minimizes dependence on limited fossil fuel resources. Among them, wind energy with an estimated capacity of 3000 MW stands as a promising way for Azerbaijan's renewable energy aspirations [6]. There is an urgent need to investigate the geographical and meteorological factors that contribute to wind energy production in the country, to assess the ideal locations for wind farms and the technological developments required for efficient use.

Another main source is solar radiation, which allows Azerbaijan to use 23,000 MW of solar energy [6]. It is possible to ensure a full uninterrupted energy supply by using the solar energy resources in the country efficiently and implementing various solar technologies.

Bioenergy obtained from organic substances has a potential power of 380 MW within Azerbaijan [6]. By examining different sources for installing Bioenergy in power plants, such as agricultural residues and organic waste, their potential to contribute to the country's energy mix is analyzed.

The mountainous area of Azerbaijan has natural conditions for the development of 520 MW of hydroelectric power [6]. The main research idea here is to study the hydrological characteristics of mountain rivers and explore their potential benefits in terms of energy stability and environmental impact.

Although the potential of renewable energy in Azerbaijan is wide, the successful realization of this potential depends on the elimination of technological and infrastructure problems.

In his article "Overview of the Renewable Energy Developments in Azerbaijan", Yusifov evaluated the socio-economic consequences of the transition to renewable energy sources, potential employment creation, increased energy security and economic growth rate [9]. In addition, environmental benefits, including reduced carbon emissions and improved air quality, are calculated to underline the positive impact of renewable energy adoption. [6]. This highlights the significant potential for renewable energy in Azerbaijan Overall, Azerbaijan has shown significant progress in promoting renewable energy sources, creating regulatory frameworks, and establishing support mechanisms for renewable energy projects.

According to the Azerbaijan Ministry of Energy, renewable energy sources in Azerbaijan have huge potential, with a potential capacity of 27,000 MW, including wind, solar, bioenergy and hydro power [5]. The total electricity generation capacity in the country is 7542.2 MW, and the capacity of power plants based on renewable energy sources, including bio-energy and geothermal energy, is 1304.5 MW, which is 17.3% of the total capacity [6]. It is important to note that the country is heavily dependent on the oil and gas industry, which provides about 90% of its export revenues and finances about 60% of the government budget.

It is crucial to emphasize that the country's economic stability is intricately intertwined with its commitment to the oil and gas sector. This sector plays a huge role, contributing 90% of the country's export revenues, thus serving as the cornerstone of its financial foundation. Moreover, this industry accounts for about 60% of the government budget, exemplifying its important role in maintaining essential public services and development initiatives [9]. Beyond its economic implications, the importance of the oil and gas industry resonates deeply with the country's energy landscape. An overwhelming 98% of primary energy consumption comes from these limited resources, emphasizing their indispensable

role in feeding various sectors of the economy [7]. In particular, this extensive dependency extends to the power generation sector, where oil and natural gas together account for more than 90% of the country's electricity production [7].

Azerbaijan has significant potential for renewable energy development, including strong solar and wind resources, as well as prospects for biomass, geothermal, and hydropower [7]. In fact, due to its climatic conditions and location, Azerbaijan has greater potential for renewable power generation than the rest of the region, with higher insolation values and comparable conditions to neighboring countries in the South Caucasus [9]. In particular, the country has been found to have excellent conditions for solar photovoltaic (PV) energy, with around 70 countries boasting average daily output that exceeds 4.5-kilowatt hours per installed kilowatt of capacity (kWh) - enough to boil around 25 liters of water [7]. It is worth noting that in total, 93% of the global population lives in countries that have an average daily solar PV potential between 3.0 and 5.0 kWh [10]. Despite the country's potential, practical deployment of renewable energy resources in Azerbaijan has been limited so far. Nonetheless, the country's long-term ambitions suggest that there is interest in developing these resources further [7].

According to Global Wind Atlas data, the average wind speed in Azerbaijan is between 4-6 meters per second. The wind speed in this country is considered to be medium to high and it is suitable for wind farms to be established in areas with this wind potential. These regions, including the Absheron Peninsula, the Caspian coast and the mountainous regions of the Greater Caucasus, have good wind resources. Despite this potential, wind energy is currently underdeveloped in Azerbaijan, and there are only a few wind farms in operation. According to the International Renewable Energy Agency (IRENA), the installed wind power capacity in Azerbaijan was only 28 MW at the end of 2020, which is a relatively small generation compared to the country's total electricity generation capacity [6]. Generally, the country has a technical offshore wind resource of around 157 GW – over 20 times the country’s current installed energy capacity [14]. The capacity for harnessing renewable energy sources, recognized for both their economic viability and technical feasibility, is projected to reach an impressive 27,000 MW. This substantial potential encompasses a diverse range of sources, with a significant portion amounting to 3,000 MW specifically attributed to wind energy. This optimistic outlook not only underscores the tangible benefits of transitioning towards sustainable energy alternatives but also highlights the substantial strides that can be made in reducing carbon emissions and fostering a cleaner and more resilient energy landscape [6], [13].

A country that embraces sustainable energy solutions, Azerbaijan uses various types of renewable energy sources to power its future. Among them, hydroelectric plants, wind farms, solar installations and biomass plants stand as beacons of innovation and progress.

In the field of hydropower, Azerbaijan has a network of 12 large and 7 small hydropower plants. By skillfully using limited water resources, Azerbaijan has made its way towards energy self-sufficiency and environmental responsibility. Entering the field of wind energy, Azerbaijan has installed 6 wind farms that beautify its landscapes. Then, with 10 solar power plants, the country's PV panels turn sunlight into an endless source of power, reducing the country's carbon footprint while lighting the way toward cleaner and more sustainable energy production.

Azerbaijan, which includes organic substances in the renewable energy matrix, has also mastered the potential of biomass energy. Through the establishment of 3 biomass power plants, the country effectively converts waste into a valuable resource. As a result, the years 2008-2018 saw a significant increase in renewable energy infrastructure, with a total installed capacity of 420 MW across all sources [14].

Guided by an ambitious vision, the government of Azerbaijan has set itself an ambitious goal: to increase the share of renewable energy sources in its total electricity production by an impressive 30% by 2030. This firm commitment reflects a comprehensive strategy. In addition, Azerbaijan plans to achieve renewable energy goals in the following ways:

- Attracting foreign investments to the renewable energy sector.
- Providing tax incentives for renewable energy projects.
- Development of a legal framework for the development of renewable energy.
- Promotion of public-private partnerships in the renewable energy sector.
- Increasing the use of renewable energy sources in the transport sector, etc.

The main goal is to reduce the country's dependence on traditional fossil fuels, strengthen energy security, reduce greenhouse gas emissions, and foster a cleaner and more prosperous future for future generations.

The power generation potential of the rivers in Azerbaijan is estimated at 40 billion kilowatts per hour, and the feasible potential is 16 billion kilowatts per hour. Additionally, small-scale hydropower has significant developmental potential in Azerbaijan, particularly in the lower reaches of the Kura River, the Aras River, and other rivers flowing into the Caspian Sea [11]. Azerbaijan has not fully utilized its renewable energy resources, including hydropower. Currently, according to the International Renewable Energy Agency (IRENA) data, hydropower accounted for 15% of Azerbaijan's renewable energy capacity in 2021, with a total capacity of 1,152 MW [7], [11].

Azerbaijan has a high potential for renewable energy sources, including geothermal. According to the International Energy Agency (IEA), Azerbaijan has a geothermal energy potential of up to 800 MW [7]. Initial studies indicate that there are 11 geothermal zones available in Azerbaijan that hold water of 30 °C to 100 °C that can generate either electrical or heat energy, depending on the type of thermal water [6], [7].

IV. Discussion

This article provides an overview of the links between renewable energy development and ecosystem services. These advantages are included below:

- Renewable energy sources like solar, wind, hydro, and biomass aim to provide sustainable energy while reducing environmental impacts compared to fossil fuels. However, the development of these energy sources can still impact ecosystem services in various ways.
- Ecosystem services refer to the benefits that humans gain from natural ecosystems, such as water purification, erosion control, habitat provision, and aesthetic value. Renewable energy development may enhance, reduce or modify these ecosystem services in the areas where facilities are built.
- The impacts of renewable energy on ecosystem services depend on several factors, including the type of technology, siting and design of facilities, as well as the sensitivity and value of ecosystem services in a given location. Geographical factors such as topography, climate, and land cover also play a role.
- A geographical perspective is useful for identifying locations where renewable energy and ecosystem services can co-exist sustainably. Mapping the distribution of both energy sources and ecosystem services can enable careful planning to maximize benefits and minimize trade-offs.
- Further research is needed to improve our understanding of the relationship between renewable energy and ecosystem services. Sustainable practices that conserve ecosystem services should be integrated into energy planning and policymaking.
- A balance is needed between mitigating climate change through renewable energy and protecting the ecosystem services that are vital for supporting human well-being. Geographers can contribute to finding this balance through evidence-based assessments of trade-offs and co-benefits at different spatial scales.

Renewable energy has many advantages, but it also has some disadvantages. One of the biggest disadvantages of renewable energy is that it is unreliable. While fossil fuels are available in demand, renewable technologies depend on the weather and other factors to run. In the current scenario, it is notable that the establishment of most renewable energy generators entails substantial initial costs. This financial aspect often serves as a significant barrier to their widespread adoption, as the upfront investment required for technologies like solar panels and wind turbines can be considerably higher compared to traditional energy infrastructure. However, it is important to recognize that ongoing advancements in technology, coupled with increasing economies of scale, are gradually working to reduce these setup expenses over time. As research and innovation progress, we can anticipate a trajectory towards more cost-effective and accessible renewable energy solutions.

Furthermore, the inherent reliance on certain renewable sources, such as wind turbines and solar cells, on prevailing weather conditions introduces an element of variability that distinguishes them from the more consistent output of conventional power sources. This intermittency factor can indeed impact the reliability of renewable energy systems, posing challenges in meeting the continuous and stable energy demands of modern societies. Cloud cover, low wind speeds, and nighttime hours can temporarily limit the output of solar and wind installations, potentially necessitating supplementary energy sources or robust energy storage solutions to bridge these gaps effectively [12]. However, renewable energy is still a promising alternative to fossil fuels and has many benefits for the environment and human health.

V. Conclusion

Renewable energy, including sources such as solar, wind, geothermal, hydroelectric, and biomass, has the potential to provide substantial benefits for the climate, public health, and the economy. Compared to fossil fuels such as coal, oil, and natural gas, renewable energy sources have a lower impact on the environment by most measures, including air and water pollution, land use, and greenhouse gas emissions. Azerbaijan's renewable energy sources are hydropower, wind, solar, and biomass power plants. Together, these generated 1.48 billion kilowatt-hours (kWh) of energy in 2018, comprising almost 9% of the total production of 17.2 billion kWh. Azerbaijan has 12 big and 7 small hydroelectric plants. It also has 6 wind, 10 solar, and 6 biomass power plants constructed from 2018 to 2020, which are expected to have an installed capacity of 420 MW [6]. These benefits of renewable energy in terms of mitigating climate change and promoting sustainability make it a worthwhile investment for the future. However, it is important to ensure that these projects are developed continuously to minimize their impact on the environment and the ecosystem services it provides.

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