6th Intercontinental Geoinformation Days

igd.mersin.edu.tr

Using GIS to identify and assess renewable energy sources

Imamverdiyev Nijat Sohrab

Institute of Geography, Ministry of Science and Education of Azerbaijan

Keywords
Renewable energy
Energy assessment
GIS
Energy mapping
Energy resources

Abstract

This article describes the use of Geographic Information Systems (GIS) in identifying and assessing alternative energy sources. GIS is a powerful tool that can be used to analyze various factors, such as geography, climate, and land use, to identify the most suitable locations for renewable energy projects. This paper provides an overview of the different types of alternative energy sources and their potential for energy production. The use of GIS in mapping and analyzing solar, wind, hydroelectric, geothermal, biomass, and tidal energy resources are discussed, along with case studies and examples of successful projects. The paper first presents an overview of GIS technology and its application in energy assessment. The material also highlights the importance of stakeholder engagement and community involvement in the planning and development of alternative energy projects. Also, it demonstrates the potential of GIS in promoting the transition to a more sustainable and renewable energy future. Finally, the paper highlights the benefits of using GIS for energy analysis, including its ability to provide accurate and detailed information about the potential of different energy sources in a specific location. Overall, in this article aims to demonstrate the importance of GIS technology in promoting the adoption of alternative energy sources and contributing to a more sustainable energy future.

1. Introduction

GIS (Geographic Information System) is a powerful tool that can be used to identify and assess alternative energy sources. GIS is enabling new energy production by identifying sites of maximum energy potential and optimized economic development while minimizing environmental impact. GIS can be used to explore renewable energy resources using remote sensing and GIS (Avtar et al. 2019). The renewable energy technical potential of a technology is its achievable energy generation given system performance, and topographic, environmental, and land-use constraints. The benefit of assessing technical potential is that it establishes an upper-boundary estimate of development potential (Lopez et al. 2012). It can help identify areas with high potential for developing renewable energy sources (RES), and regions with restrictions on their exploitation, such as environmentally or culturally sensitive areas (Jordao, 2010).

GIS can save time and money when determining where and how renewable energy sources should be exploited and used (Jordao, 2010). It can also help monitor fluctuations over time, evaluate the feasibility of proposed projects and predict their effects on the environment (Resch et al. 2014).

Furthermore, one example of a successful renewable energy project that used GIS is the Cape Wind Project in Massachusetts, USA. The Cape Wind Project is a proposed offshore wind farm that aims to generate up to 468 MW of electricity, enough to power more than 200,000 homes. To determine the best location for the wind farm, the developers used GIS to analyze various factors such as wind speed, ocean depth, and proximity to shore. They collected data from various sources such as weather stations, buoys, and remote sensing, to create a wind resource map of the area (Kimmell and Stalenhoef, 2011). They also used GIS to analyze the seabed to identify areas with suitable soil conditions for anchoring the turbines. Besides, GIS is enabling new energy production by identifying sites of maximum energy potential and optimized economic development while minimizing environmental impact (Lopez et al. 2012).

2. Material and method

Geographic Information Systems (GIS) were used to identify and assess renewable energy sources by

* **Corresponding Author**

*(imamverdiyev.nicat@gmail.com) ORCID ID 0000-0002-5573-0209

Cite this study

Sohrab, I. N. (2023). Using GIS to identify and assess renewable energy sources. Intercontinental Geoinformation Days (IGD), 6, 24-27, Baku, Azerbaijan

combining spatial data on various factors, such as land use, topography, climate, and existing infrastructure. It was taken the following steps for this:

Data collection: Gather data on topography, climate, land use, etc. Data integration: Integrate the different types of data into a GIS software such as ArcGIS or QGIS. Analysis: Performed spatial analysis to identify areas that are suitable for renewable energy sources, such as wind, solar, hydro, and geothermal. Mapping: Created maps showing the potential locations for renewable energy sources based on the analysis. Evaluation: The potential of each renewable energy source and comparing them to one another. Implementation: Determination of the most viable renewable energy source based on the evaluation.

There are several software options that can be used for renewable energy analysis. Here are a few of the most used: ArcGIS, QGIS, GRASS GIS, Wind Navigator and PVsyst. These GIS software options are used by renewable energy developers to identify and assess renewable energy sources, analyze the potential for energy production, and make decisions about renewable energy projects.

3. Results

GIS maps allow users to assess the potential for renewable energy sources in particular areas based on criteria such as wind speed, solar irradiance, and topography. For instance, to identify suitable sites for wind turbines, GIS tools can generate maps of wind speed and direction along with data from remote sensors based on topography. The same methods are used to identify suitable areas for solar panel installation.

One example of the use of GIS in renewable energy planning is the Renewable Energy Zones (REZ) Toolkit, which provides a step-by-step process for identifying and designating renewable energy zones (Lee and Roberts, 2018). This toolkit includes steps for process design, candidate zone selection, transmission options development, final transmission plan designation, and transmission system upgrade. GIS is used extensively in this process for renewable energy resource assessment, candidate zone identification, and transmission system design.

Another study applies the Analytic Hierarchy Process (AHP) and develops a systematic approach and decision support system to assess energy alternatives and help municipalities select the most suitable alternatives (Budak et al. 2019). This methodology involves integrating experts' input and data analytics and helps decision-makers form long-term strategies for renewable energy development.

This study was investigated by applying spatial analysis in GIS. GIS spatial analyses offer an effective method for identifying and assessing renewable energy sources, providing a comprehensive understanding of the potential for renewable energy in a given area. GIS (Geographic Information System) technology can be utilized to identify and assess renewable energy sources (Maclaurin et al. 2019). Spatial analysis is a crucial tool within GIS that allows users to combine and analyze data from various sources, helping to answer complex spatial questions (Ramachandra and Shruthi, 2007). This analysis calculates renewable energy capacity, generation, and cost based on geospatial intersection with grid infrastructure and land-use characteristics.

It is determined that the spatial analysis mapping method in Azerbaijan has a significant untapped potential for renewable energy sources (IEA, 2020). The potential of renewable energy sources, which are economically viable and technically feasible, is estimated at 27 000 MW, including 3 000 MW of wind energy, 23 000 MW of solar energy, 380 MW of bio-energy potential, and 520 MW of mountain rivers (The Ministry… 2022). Azerbaijan's renewable energy potential is estimated to be at around 27,000 megawatts, the largest share of which belongs to solar energy (23,000 megawatts) (Jafarova 2019). According to a report by the International Renewable Energy Agency (IRENA), Azerbaijan has the potential to generate over 27,000 megawatts of wind and solar power combined. This is a significant figure, considering that Azerbaijan's current electricity demand is around 7,000 megawatts. In recent years, Azerbaijan has made significant strides in renewable energy development, including the construction of some wind and solar power plants across the country. One such example is the Gobustan Wind Farm, which has a capacity of 50 megawatts and produces enough electricity to power around 35,000 homes. Generally, Azerbaijan has excellent solar power potential. The country has an estimated technical potential of around 23,000 MW for solar energy generation and receives 2,400 to 3,200 sunshine hours annually with an estimated solar intensity of 1,500 kWh/m^2 to 2,000 kWh/m^2 (The Ministry… 2022). Additionally, Azerbaijan has significant prospects for renewable energy development, including solar energy. The country has excellent solar resources and is considered to be a suitable area for solar energy potential. Therefore, it can be inferred that Azerbaijan is a suitable location for the deployment of solar energy infrastructure.

Azerbaijan has immense potential for offshore wind power, with a technical offshore wind resource of around 157GW - over 20 times the country's current installed energy capacity. Current wind farms are mainly located in the regions of Absheron, Khizi, and Gobustan, but other regions of Azerbaijan also have the potential based on wind power density (Jafarova, 2019).

In addition, in 2019, Azerbaijan adopted a law on renewable energy which aims to increase the share of renewable energy in the country's energy mix to 30% by 2030. The government has also implemented several incentives to attract investment in the sector, including tax breaks for renewable energy projects and a feed-in tariff system for electricity generated from renewable sources. Currently, the largest renewable energy project in Azerbaijan is the 200 MW wind farm in the Caspian Sea, which is expected to be completed in 2022. The country also has several solar power projects in the pipeline, including a 240 MW solar power plant in the Gobustan region. In addition to wind and solar power, Azerbaijan has the potential for geothermal and biomass energy. The government has installed some energy stations in the country. Here are a few examples (The Ministry, 2022):

1. Gobustan Wind Farm: This 52 MW wind farm, located in the Gobustan region, was commissioned in 2019 and is currently the largest wind farm in Azerbaijan. The project was developed by the state-owned company Azerenerji and is expected to generate around 200 GWh of electricity per year.

2. Solar power plant in Pirallahi: This 10 MW solar power plant, located on the Pirallahi Island in the Caspian Sea, was commissioned in 2019. The project was developed by the Norwegian company Scatec Solar and is expected to generate around 16 GWh of electricity per year.

3. Geothermal power plant in Nakhchivan: This 8 MW geothermal power plant, located in the Nakhchivan Autonomous Republic, was commissioned in 2018. The project was developed by the Turkish company MB Holding and is expected to generate around 60 GWh of electricity per year.

4. Baku White City Solar Power Plant: This 1 MW solar power plant, located in the Baku White City development, was commissioned in 2018. The project was developed by the German company Solarwatt and is expected to generate around 1.2 GWh of electricity per year.

The government of Azerbaijan has set ambitious targets for the development of renewable energy in the country. The primary target is to increase the share of renewable energy in the country's energy mix to 30% by 2030. This target is part of the country's broader efforts to reduce its dependence on fossil fuels and diversify its energy sources. In addition to the 30% target, the government has set a number of specific targets for different types of renewable energy. For example, the goal is to install 420 MW of wind power capacity and 650 MW of solar power capacity by 2025. The government has also set a target of 440 MW of geothermal power capacity by 2030. To achieve these targets, the government has implemented a range of incentives and support measures for renewable energy projects, including feed-in tariffs, tax breaks, and simplified permitting processes (Jafarova, 2019).

4. Discussion

While Azerbaijan has the potential to become a leader in renewable energy, there are several challenges that must be addressed to achieve this goal. Some of the main challenges facing the renewable energy sector in Azerbaijan include:

1. Lack of investment: Despite the incentives offered by the government, investment in renewable energy projects in Azerbaijan remains relatively low. This is partly due to the country's dependence on natural gas exports, which has traditionally been the main source of revenue for the government and the economy.

2. Limited infrastructure: Azerbaijan's renewable energy sector is still in its early stages, and there is limited infrastructure in place to support it. This includes a lack of transmission lines and interconnectors to connect renewable energy sources to the national grid.

3. Regulatory barriers: The regulatory framework for renewable energy in Azerbaijan is still developing, and there are several barriers to entry for investors. These include bureaucratic procedures, complex permitting processes, and a lack of transparency in decision-making.

4. Technical issues: Azerbaijan's climate and terrain can make it difficult to develop certain types of renewable energy, particularly wind power. There are also technical challenges associated with integrating intermittent energy sources like wind and solar into the grid.

5. Public awareness: There is still a lack of public awareness and understanding of renewable energy in Azerbaijan, which can make it difficult to build support for the sector and attract investment.

Overall, addressing these challenges will be critical to the development of Azerbaijan's renewable energy sector and the achievement of its ambitious targets for renewable energy deployment. Thus, Azerbaijan's renewable energy potential is largely untapped, with practical deployment limited compared to the scale of available resources and long-term ambitions (IEA, 2020).

To promote the development of renewable energy in the country, Azerbaijan passed the "Law on Renewable Energy" in May 2021, which established a regulatory framework for renewables and support mechanisms for renewable energy projects. This law aims to promote the use of renewable energy sources in the production of electricity, reduce greenhouse gas emissions, and increase energy efficiency.

The government of Azerbaijan has also taken other measures to promote renewable energy, such as setting a target to increase the share of renewable energy in the country's electricity mix to 30% by 2030 [3]. The country has also participated in international renewable energy initiatives, such as the International Renewable Energy Agency (IRENA) and the European Union's Eastern Partnership initiative, to share knowledge and best practices and to attract investment in the renewable energy sector (IEA, 2020).

5. Conclusion

GIS-based spatial analyses are an important aspect of renewable energy research, enabling researchers to make informed decisions about energy planning and production. GIS is an important tool for conducting spatial analyses related to renewable energy research. This technology enables researchers to produce maps, analyses, models, applications, and visualizations that inform energy planning and production. It was determined that Azerbaijan has significant potential for renewable energy development, with excellent solar and wind resources and significant prospects for biomass, geothermal, and hydropower. As of 2020, the country had installed 12 large and 7 small hydroelectric plants, 6 wind, 10 solar, and 6 biomass power plants, with an installed capacity of 420 megawatts (MW.

Moreover, it is noted that Azerbaijan has a high potential for renewable energy sources, with an estimated 27,000 MW of economically viable and technically feasible potential, including 3,000 MW of wind energy, 23,000 MW of solar energy, 380 MW of bioenergy potential, and 520 MW of mountain rivers. In

2019, the total renewable energy supply in Azerbaijan was around 66%, out of which hydropower, wind, solar, and biomass power plants were the main sources of renewable energy. Azerbaijan has 12 big and 7 small hydroelectric plants, and 6 wind, 10 solar, and 6 biomass power plants that were constructed from 2018 to 2020, which are expected to have an installed capacity of 420 MW.

Acknowledgement

Acknowledgements of support for the Ministry of Energy of the Republic of Azerbaijan are welcome.

References

Avtar, Sahu, Aggarwal, Chakraborty, Kharrazi, Yunus, Dou, et al. (2019). Exploring Renewable Energy Resources Using Remote Sensing and GIS—A Review. Resources, 8(3), 149. MDPI AG. Retrieved from http://dx.doi.org/10.3390/resources8030149

Budak, G., Chen, X., Celik, S., & Ozturk, B. (2019). A systematic approach for assessment of renewable energy using analytic hierarchy process. Energy, Sustainability and Society, 9, 1-14.

IEA (2020), Azerbaijan energy profile, IEA, Paris https://www.iea.org/reports/azerbaijan-energy-profile, License: CC BY 4.0

Jafarova, E. (2019). Renewable Energy Renews Azerbaijan's Energy Strategy. The Georgetown Journal of International Affairs, NW Washington, D.C. 20057.

Jordao, Ticiano Costa. (2010). GIS and renewable energy sources. GIM International, 24.

Kimmell, K., & Stalenhoef, D. S. (2011). The cape wind offshore wind energy project: a case study of the difficult transition to renewable energy. Golden Gate U. Envtl. LJ, 5, 197.

Lee, N., & Roberts, B. J. (2018). Technical Potential Assessment for the Renewable Energy Zone (REZ) Process: A GIS-Based Approach (No. NREL/TP-7A40-71004). National Renewable Energy Lab. (NREL), Golden, CO (United States).

Lopez, A., Roberts, B., Heimiller, D., Blair, N., & Porro, G. (2012). Us renewable energy technical potentials. a gis-based analysis (No. NREL/TP-6A20-51946). National Renewable Energy Lab. (NREL), Golden, CO (United States).

Maclaurin, G., Grue, N., Lopez, A., Heimiller, D., Rossol, M., Buster, G., & Williams, T. (2019). The renewable energy potential (rev) model: a geospatial platform for technical potential and supply curve modeling (No. NREL/TP-6A20-73067). National Renewable Energy Lab. (NREL), Golden, CO (United States).

Ramachandra, T. V., & Shruthi, B. V. (2007). Spatial mapping of renewable energy potential. Renewable and sustainable energy reviews, 11(7), 1460-1480.

Resch, B., Sagl, G., Törnros, T., Bachmaier, A., Eggers, J. B., Herkel, S., ... & Gündra, H. (2014). GIS-based planning and modeling for renewable energy: Challenges and future research avenues. ISPRS International Journal of Geo-Information, 3(2), 662-692.

The Ministry of Energy of the Republic of Azerbaijan: The Use of Renewable Energy Resources in Azerbaijan [Electronic resource] / Aprel 24, 2022. URL: The Use of Renewable Energy Resources in Azerbaijan |Ministry of Energy of Azerbaijan (minenergy.gov.az).