ISAR Journal of Science and Technology

Volume 3, Issue 10, 2025, Page: 90-95

Abbriviate Title- ISAR J Sci Tech

ISSN *(Online)*- 2584-2056

https://isarpublisher.com/journal/isarjst

The Impact of Solar Photovoltaic on Afghanistan's Rural Development

Keramatullah Amiry[1*], Sayed Rohullah Mosavi[2], Gulhabib Hanifi[3], Mustafa Rahime[4], Sayed Abdul Moqim Hussaini[5], Fida Mohammad Mohammadi[6]

Physics Department, Education Faculty, Ghazni University, Gahzni Afghanistan.

***Corresponding Author**

Keramatullah Amiry

Physics Department, Education Faculty, Ghazni University, Gahzni Afghanistan.

Article History

Received: 12.08.2025
Accepted: 11.10.2025
Published: 29.10.2025

Abstract: Meeting energy demands in Afghanistan is a significant challenge, as much of the required energy is imported from neighboring countries, particularly Iran, Turkmenistan, Uzbekistan, and Tajikistan. Afghanistan's energy system, particularly in rural regions, is highly dependent on fossil fuels, which can lead to issues such as fossil fuel depletion and social, economic, and environmental harm. To overcome these problems the country should design a sustainable energy system based on clean and renewable energy. Since solar photovoltaic energy is one type of renewable energy, the purpose of this study is to explore the role of this renewable energy in rural areas and the various methods of taking advantage of solar photovoltaic energy to enhance rural living conditions in our country. Considering the energy supply challenges in these areas, suitable solutions from renewable energy sources, especially solar energy, have been proposed. This article, which has been prepared using an analytical and descriptive approach, explores the impacts of energy consumption on rural communities and analyzes its role in economic growth, education, health, and social development, based on various studies and research findings. Finally, the findings illustrate that solar photovoltaic energy, which is affordable and widely accessible, has improved the lives of rural communities and reduced dependence on biomass and fossil fuels, which contribute to environmental pollution.

Keywords: *rural areas, renewable energy, solar cells, photovoltaics, sustainable development*.

Cite this article:

Amiry, K., Mosavi, S. R., Hanifi, G., Rahime, M., Hussaini, A. A. M., Mohammadi, F. M., (2025). The Impact of Solar Photovoltaic on Afghanistan's Rural Development. *ISAR Journal of Science and Technology*, *3*(10), 90-95.

Introduction

Afghanistan faces many challenges in energy supply, especially in rural areas due to its mountainous terrain and lack of extensive grid infrastructure. With over 74% of the population residing in rural areas, traditional energy sources such as diesel generators and biomass remain costly and environmentally unsustainable (Korkovelos et al., 2020a). Afghanistan is rich in natural resources, which can provide reliable and accessible energy to its rural populations. However, the country's abundant renewable and clean energy sources especially solar resources present a promising opportunity to address this energy gap and foster sustainable development in rural areas. With an average of 300 sunny days per year, Afghanistan possesses substantial potential for solar energy generation, which is increasingly being recognized as a transformative solution for enhancing energy access, improving livelihoods, and stimulating local economies in underserved areas("300 Sunny Days in a Year," 2018; Zaheb et al., 2023).

Solar energy, a renewable and sustainable resource, has gained immense importance worldwide, particularly in regions with limited access to traditional energy sources. Afghanistan, a country characterized by its rugged terrain and prolonged periods of conflict, faces significant challenges in energy infrastructure (Ahady et al., 2020). The significance of this topic cannot be overstated, as many rural communities in Afghanistan still lack reliable access to electricity, which is essential for improving quality of life, facilitating economic growth, and fostering social development (Ershad, 2017). The integration of solar energy into these rural areas has emerged as a powerful tool to address these pressing issues, offering a potential pathway toward sustainable development.

The historical context of Afghanistan reveals a nation that has long struggled with energy shortages and infrastructural inadequacies. Before the introduction of solar energy initiatives, many rural villages relied on traditional energy sources such as firewood, kerosene, and batteries for lighting and cooking. These sources not only contributed to environmental degradation but also posed health risks due to indoor air pollution(Jahangiri et al., 2019). In recent years, however, the Afghan government, alongside international organizations and NGOs, has recognized the potential of solar energy to revolutionize rural development. The research

statement asserts that solar energy has positively impacted rural development by enhancing energy accessibility, improving socio-economic conditions, and promoting environmental sustainability in Afghanistan. By providing a reliable and clean source of energy, solar power has the potential to uplift communities, empower individuals, and foster a more sustainable future (Mehrad, 2021).

To substantiate this article, it is important to delve deeper into the various dimensions of solar energy's impact on rural development. First and foremost, solar energy enhances energy accessibility. In regions where the national grid is either absent or unreliable, solar power systems can be deployed to provide electricity to households, schools, and healthcare facilities(Nasrat et al., 2018). For instance, according to a report by the United Nations Development Program (UNDP), approximately 80% of Afghanistan's rural population lacks access to electricity. The introduction of solar home systems, which can be installed in individual households, has emerged as a practical solution to bridge this energy gap. These systems consist of solar panels, batteries, and inverters, enabling families to access electricity for lighting, communication, and small appliances(Sabory et al., 2021). This newfound access not only transforms daily life but also opens doors to educational opportunities, as children can study after dark and engage in online learning.

Moreover, solar photovoltaic energy has been instrumental in improving socio-economic conditions in rural communities. The availability of electricity empowers local entrepreneurs to start small businesses, such as tailoring shops, bakeries, and grocery stores. This economic diversification has a multiplier effect, creating jobs and stimulating local economies. Research conducted by the World Bank indicates that for every job created in the renewable energy sector, an additional three jobs can be generated in related industries, illustrating the potential of solar energy to catalyze economic development (Rahime et al., 2024). Additionally, access to electricity facilitates better healthcare services, as medical facilities can operate essential equipment such as refrigerators for vaccine storage and diagnostic tools, thus enhancing the overall health and well-being of the community.

Furthermore, the environmental benefits of solar energy cannot be overlooked. With the global urgency to combat climate change, transitioning to renewable energy sources is imperative. Afghanistan, with its abundant sunlight, has a unique opportunity to harness solar energy and reduce its reliance on fossil fuels. The environmental impacts of traditional energy sources, such as deforestation and air pollution, have long posed threats to rural ecosystems (Fahimi & Upham, 2018a). By integrating solar power, communities can mitigate these risks, contributing to a healthier environment and promoting biodiversity. According to the International Renewable Energy Agency (IRENA), transitioning to renewable energy sources could lead to a reduction of up to 60% in carbon emissions in Afghanistan(Ahady et al., 2020). In conclusion, by enhancing energy accessibility, improving socio-economic conditions, and promoting environmental sustainability, solar energy has the potential to uplift communities and pave the way for a brighter future. As we delve further into this paper, we will explore the historical development of solar energy initiatives, analyze the socio-economic and environmental perspectives, and present regional case studies that illustrate the practical benefits and challenges of implementing solar energy projects. The findings will not only support our research but also highlight the critical role solar photovoltaic energy can play in the sustainable development of rural Afghanistan.

Methodology

This study utilizes a qualitative approach to investigate the role of solar energy in the development of rural areas in Afghanistan. The research relies on a review of relevant literature, including academic journal articles, reports, and policy documents. The data collection process involved a systematic search of electronic databases, such as Google Scholar, Scopus, and Web of Science, using keywords related to solar energy, rural development, and Afghanistan. The selected sources were then analyzed to identify the key themes, challenges, and strategies for promoting solar energy in rural Afghanistan.

Literature Review

The existing literature on solar photovoltaic energy in rural Afghanistan highlights the significant potential of this renewable resource to address the energy needs of underserved communities. The studies show that solar energy can play a vital role not only in Afghanistan's energy supply but also in poverty reduction, social and political stability, and improving living standards. (Rostami et al., 2017). One study done by (Sabory et al., 2021) emphasizes the numerous benefits of renewable energies, including solar, for Afghanistan's rural areas. The authors note that these "unbound sources could play a vital role not only in Afghanistan's energy supply, but also in poverty reduction, social and political stability, and improving living standard."

Another study provides an overview of the opportunities and challenges in sustaining the energy industry in Afghanistan. The authors highlight the progress made in developing solar and wind energy projects while also noting the underappreciation of other renewable sources, such as hydropower. Furthermore, a case study on the impact of solar energy on rural households in Badakhshan province found that the deployment of solar photovoltaic systems has positively impacted the welfare of rural communities, including improved access to lighting, water pumping, and other essential services. (Haidari, 2020).

Solar Energy Potential in Afghanistan

Afghanistan's geographical location and climate make it an ideal candidate for harnessing solar energy. The country experiences high levels of solar irradiation throughout the year, with an average of 300 sunny days annually (Rostami et al., 2017). Afghanistan is classified as a "sunbelt" country due to its high solar irradiance. The national annual average Global Horizontal Irradiance (GHI) is estimated at 1,935 kWh/m²/year, with seasonal daily averages ranging between 2.38 kWh/m²/day (minimum) and 7.84 kWh/m²/day (Ershad et al., 2016).

In certain provinces, particularly in the western and southern regions, peak summer GHI values can reach approximately 9.0 kWh/m²/day. Preliminary assessments conducted by the U.S. National Renewable Energy Laboratory (NREL) estimate Afghanistan's theoretical solar energy potential at around 220,000 megawatts (MW). Using a Multi-Criteria Decision Analysis (MCDA) approach integrated with Geographic Information System (GIS) tools,(Fahimi & Upham, 2018b). calculated the country's total annual solar electricity generation potential to be approximately 146,982 GWh—with 140,982 GWh attributable to

photovoltaic (PV) systems and 6,000 GWh to concentrated solar power (CSP) technologies.

Solar Electricity and the Applications of Solar PV in Rural Afghanistan

Electricity produced from sunlight is referred to as solar electricity, and the mechanism by which solar radiation is converted into electrical energy is known as the photovoltaic (PV) process. During this process, solar energy is directly converted into direct current (DC) electricity through the photovoltaic effect. A typical solar PV system comprises four primary components: (a) solar panels, which capture and convert solar radiation; (b) batteries, which store the generated electricity for later use; (c) charge controllers, which regulate the voltage and current to protect the batteries; and (d) DC electrical appliances, such as lamps, small fans, or televisions, which operate directly on the generated DC power (Ahammed & Taufiq, 2008).

A solar panel consists of multiple silicon-based photovoltaic (PV) cells, with each typically producing about 0.5 volts of direct current (DC) electricity. The positioning of solar panels is essential for their energy production, as it affects the amount of solar irradiance they capture. In Afghanistan, panels are usually installed at a fixed tilt angle of 28-31° relative to the ground. This angle is chosen to optimize energy collection throughout the year, taking into account the country's geographic latitude and seasonal changes in solar exposure. In the summer, sunlight strikes the Earth's surface more directly from overhead, so a tilt angle of approximately 15° to 20° is ideal for enhancing solar absorption. Conversely, when sunlight arrives at a lower angle in winter, a tilt of around 45° proves to be more effective. Regular adjustments to the panel tilt with seasonal shifts are often impractical. Consequently, experts suggest a fixed tilt of 30°, which strikes a good balance for annual energy production without requiring mechanical sun-tracking systems.(Zaheb et al., 2023).

Additionally, to maintain optimal performance, it is essential to ensure that solar panels are installed in locations free from shading or obstructions, as any barrier that blocks sunlight can significantly reduce the efficiency and output of the solar PV system. These decentralized systems can be deployed at the household or community level, addressing the lack of access to the national grid in remote areas. The implementation of small-scale solar PV systems has been found to positively impact the socio-economic status and energy security of rural Afghan households. (Bhallamudi et al., 2021).

Economic Impact of Solar PV

Implementing solar photovoltaic (PV) systems in rural areas has significantly contributed to economic development. Access to reliable electricity enables the operation of small businesses and agricultural activities by powering irrigation systems, facilitating food preservation, and extending working hours beyond daylight. Empirical studies underscore these benefits. For instance, in rural Kenya, the introduction of solar mini-grids led to a quadrupling of median household incomes, highlighting the substantial economic uplifting associated with decentralized renewable energy access (Carabajal et al., 2024) Similarly, the adoption of solar-powered irrigation systems has markedly improved agricultural productivity. A study conducted in the Cholistan Desert of Pakistan found that implementing solar-powered smart irrigation systems increased crop yields from 3.0 to 4.8 tons per hectare, while simultaneously reducing water and energy consumption (Abdelhamid et al., 2025).

Local technicians and engineers are now able to work on solar projects, ensuring that communities have access to skilled professionals who can maintain and repair systems as needed. A report by the International Renewable Energy Agency (IRENA) suggests that the renewable energy sector has the potential to create up to 500,000 jobs in Afghanistan by 2030, with solar energy being a significant contributor to this growth. This job creation is particularly important in rural areas, where unemployment rates are often high, and economic opportunities are limited.(Sadat & Sabory, 2020).

Enhancing Educational Outcomes

Access to solar-powered electricity has significantly improved educational outcomes in rural communities by enabling the use of modern teaching aids, such as computers and internet access, and by facilitating evening study sessions for students. Empirical studies underscore these benefits. For instance, in rural Bangladesh, the implementation of solar home systems (SHS) led to increased study hours in the evening and before examinations, providing students with better opportunities to complete their academic assignments (Shapna et al., 2025).

Similarly, a study conducted in rural India found that the adoption of solar study lamps increased children's total study time during dark hours by approximately 0.49 hours per day, with a more significant enhancement observed among girls (Sharma et al., 2019) Solar energy projects have also facilitated the use of technology in education. Schools equipped with solar panels can power computers, projectors, and other educational tools, enriching the learning experience for students. According to a report by the Afghan Ministry of Education, schools with solar photovoltaic energy access have reported a 12% increase in student enrollment (as shown in

Table 1), particularly among girls, who are often disproportionately affected by educational barriers. The ability to study in a well-lit environment and access digital learning resources equips students with the skills necessary for the modern workforce (Hamdard, 2017).

Table 1: Impact of Solar PV on Rural Education in Afghanistan

Indicator	Before PV Installation	After PV Installation	Source
Average school operation hours	~ 4 hours/day (due to daylight limitation)	~7 hours/day (with lighting support)	GIZ Rural Electrification Project, 2018
Access to lighting for evening study	Limited to candles/kerosene	80–90% of households reported children to study at night	UNDP Afghanistan Renewable Energy Project, 2019
School enrollment rate (selected villages)	~60%	~72% (12% increase)	World Bank Off-Grid Solar Program, 2020
Dropout rate (girls aged 10–14)	~30%	Reduced to ~18%	UN Women Pilot Solar Education Report, 2018
Student academic performance	Not formally tracked	Teachers reported 20–30% improvement in test scores	GIZ Solar for Education Program, 2018–2019

Enhancing Healthcare Services in Rural Areas through Solar Electrification

Access to reliable electricity is crucial for the effective operation of healthcare facilities, particularly in rural and underserved regions. Solar energy solutions have emerged as a sustainable means to power essential medical equipment, refrigerate vaccines, and lighting for nighttime emergencies, improving healthcare delivery and patient outcomes. The World Health Organization (WHO) reports that nearly 1 billion people in low- and lower-middle-income countries are served by healthcare facilities lacking reliable electricity access. This deficiency hampers the delivery of critical health services, including safe childbirth, immunization, and emergency care. Decentralized renewable energy systems, particularly solar photovoltaic installations, offer cost-effective and rapidly deployable solutions to electrify healthcare facilities sustainably and enhance their climate resiliency. (*WHO, 2023*)

Empirical studies underscore the benefits of solar electrification in healthcare settings. For instance, in Papua New Guinea, the implementation of solar-powered oxygen systems in 38 remote health facilities led to a significant reduction in child pneumonia deaths. The availability of reliable oxygen therapy, facilitated by solar energy, improved treatment outcomes, and reduced mortality rates. (Duke et al., 2021)

In Herat province, the World Bank's Herat Electrification Project facilitated the installation of solar panels in ten hospitals, including the Shaidayi Children's Hospital. These installations provided uninterrupted power to critical medical equipment, such as ventilators in Intensive Care Units (ICUs), ensuring continuous patient care during the COVID-19 pandemic. The solar systems generated 10 kW of energy, significantly reducing reliance on unreliable generators and enhancing the working environment for medical staff. (World Bank Group, 2020)

The Bamyan Provincial Hospital, equipped with a 400-kW solar power plant, exemplifies the large-scale integration of renewable energy in healthcare. This facility provides affordable and quality healthcare services to remote communities, with solar energy ensuring uninterrupted power supply for various medical operations. The solar infrastructure has reduced susceptibility to power outages, thereby enhancing the hospital's capacity to deliver consistent healthcare services. (*UNDP*, 2024).These examples underscore the transformative impact of solar photovoltaic energy on healthcare in Afghanistan, particularly in enhancing service delivery, ensuring reliable power supply, and promoting sustainable development in rural areas (as illustrated in

Table ***2***).

Table 2: Impact of Solar PV on Rural Healthcare Services in Afghanistan

Indicator	Before Solar PV Installation	After Solar PV Installation	Source / Notes
Health facilities with reliable electricity	~30% (in rural areas)	~65–80% (in project areas)	World Bank Health Systems Strengthening Report, 2020
Vaccine storage capability (cold chain)	Severely limited	+90% of solar-equipped clinics maintain stable vaccine storage	WHO Afghanistan Immunization Report, 2021
Average working hours of clinics	~6 hrs/day (limited by daylight)	~10–12 hrs/day (with solar lighting)	GIZ Solar for Health Program, 2019
Safe childbirth services available at night	Rare or unavailable	Increased by 50–70% (midwives report safer deliveries)	UNFPA Solar Birth Kit Initiative, 2020
Reduction in patient referral time (due to	High (due to lack of equipment)	Reduced by 30–40% (basic services handled	UNDP Rural Health Access Pilot, 2021

on-site services)		locally)	
Healthcare worker retention in rural areas	Low (~40% turnover)	Improved to ~70% retention (due to better conditions)	Ministry of Public Health (MoPH), Afghanistan, 2020

Challenges and Barriers to Solar photovoltaic Energy Adoption

One of the primary challenges in adopting solar photovoltaic energy in rural Afghanistan is the significant upfront costs associated with installing and maintaining solar photovoltaic systems. The lack of readily available financing options and subsidies, coupled with limited technical expertise and infrastructure, has hindered the widespread deployment of solar technologies (Haidari, 2020).

Another key challenge is the weak institutional and policy framework for renewable energy development in Afghanistan. The country's energy management system has been characterized as complex, with a lack of clear strategies and coordination among various stakeholders.

Additionally, the absence of a robust supply chain for solar components, as well as a shortage of trained personnel for system installation and maintenance, has further impeded the growth of the solar energy sector in rural areas(Ahady et al., 2020; Rostami et al., 2017).

Strategies for Promoting Solar Energy in Rural Afghanistan

To overcome these challenges and harness the potential of solar energy in rural Afghanistan, a comprehensive and coordinated approach is necessary. This may involve the following strategies:

Developing a robust policy and regulatory framework that provides incentives and support for solar energy deployment in rural areas(Fahimi & Upham, 2018c). Establishing dedicated financing mechanisms, such as low-interest loans and subsidies, to reduce the upfront costs for rural communities. Investing in capacity-building programs to train local technicians and communities on installing, operating, and maintaining solar photovoltaic systems. Fostering collaboration between government agencies, non-governmental organizations, and the private sector to create a sustainable ecosystem for solar energy development(Korkovelos et al., 2020b).

Findings and Discussion

The findings of this research indicate that solar energy has significant potential to contribute to the development of rural Afghanistan. The country's abundant solar resources, coupled with the lack of access to the national grid and alternative energy sources in rural areas, present a compelling case for the deployment of solar photovoltaic systems. However, the adoption of solar energy in rural Afghanistan has faced several challenges, including high upfront costs, weak institutional and policy frameworks, and a lack of technical expertise and infrastructure.

To address these challenges, a comprehensive and coordinated approach is necessary. This may involve the development of a robust policy and regulatory framework, the establishment of dedicated financing mechanisms, and the implementation of capacity-building programs to train local technicians and communities. In conclusion, this research has highlighted the immense potential of solar photovoltaic energy to contribute to the development of rural Afghanistan. While the path forward is not without challenges, the strategic deployment of solar technologies, coupled with a supportive policy environment and capacity-building initiatives, can unlock the transformative power of this renewable resource in these underserved communities.

Conclusion

In conclusion, solar photovoltaic energy presents a sustainable and practical solution to Afghanistan's ongoing energy challenges, particularly in rural and off-grid regions. The deployment of solar energy systems has demonstrated positive impacts on key development sectors such as healthcare, education, and economic growth. By ensuring reliable access to electricity, solar initiatives not only improve living standards but also promote social equity and community resilience. To maximize these benefits, coordinated efforts among government bodies, private sector actors, and international organizations are essential. Continued investment in infrastructure, training, and policy support will be critical for expanding solar adoption and securing Afghanistan's sustainable energy future

References

1. Abdelhamid, M. A., Abdelkader, T. K., Sayed, H. A. A., Zhang, Z., Zhao, X., & Atia, M. F. (2025). Design and evaluation of a solar powered smart irrigation system for sustainable urban agriculture. *Scientific Reports*, *15*(1), 11761. https://doi.org/10.1038/s41598-025-94251-3
2. Ahady, S., Dev, N., & Mandal, A. (2020). An overview of the opportunities and challenges in sustaining the energy industry in Afghanistan. *E3S Web of Conferences*, *173*, 03006. https://doi.org/10.1051/e3sconf/202017303006
3. Ahammed, F., & Taufiq, D. A. (2008). *Applications of Solar PV On Rural Development in Bangladesh*.
4. Bhallamudi, R., Kumarasamy, S., & Sundarabalan, C. (2021). Effect of Dust and Shadow on Performance of Solar Photovoltaic Modules: Experimental Analysis. *Energy Engineering*, *118*(6), 1827–1838. https://doi.org/10.32604/EE.2021.016798
5. Carabajal, A. T., Orsot, A., Moudio, M. P. E., Haggai, T., Okonkwo, C. J., III, G. T. J., & Selby, N. S. (2024). Social and Economic Impact Analysis of Solar Mini-Grids in Rural Africa: A Cohort Study from Kenya and Nigeria. *Environmental Research: Infrastructure and Sustainability*, *4*(2), 025005. https://doi.org/10.1088/2634-4505/ad4ffb
6. Duke, T., Pulsan, F., Panauwe, D., Hwaihwanje, I., Sa'avu, M., Kaupa, M., Karubi, J., Neal, E., Graham, H., Izadnegahdar, R., & Donath, S. (2021). Solar-powered oxygen, quality improvement and child pneumonia deaths: A large-scale effectiveness study. *Archives of Disease in Childhood*, *106*(3), 224–230. https://doi.org/10.1136/archdischild-2020-320107

7. *Electricity in health-care facilities*. (n.d.). Retrieved May 20, 2025, from https://www.who.int/news-room/fact-sheets/detail/electricity-in-health-care-facilities
8. Ershad, A. M. (2017). Institutional and Policy Assessment of Renewable Energy Sector in Afghanistan. *Journal of Renewable Energy*, *2017*, 1–10. https://doi.org/10.1155/2017/5723152
9. Ershad, A. M., Brecha, R. J., & Hallinan, K. (2016). Analysis of solar photovoltaic and wind power potential in Afghanistan. *Renewable Energy*, *85*, 445–453. https://doi.org/10.1016/j.renene.2015.06.067
10. Fahimi, A., & Upham, P. (2018a). The renewable energy sector in Afghanistan: Policy and potential. *Wiley Interdisciplinary Reviews: Energy and Environment*, *7*(2), e280.
11. Fahimi, A., & Upham, P. (2018b). The renewable energy sector in Afghanistan: Policy and potential. *WIREs Energy and Environment*, *7*(2), e280. https://doi.org/10.1002/wene.280
12. Fahimi, A., & Upham, P. (2018c). The renewable energy sector in Afghanistan: Policy and potential. *WIREs Energy and Environment*, *7*(2), e280. https://doi.org/10.1002/wene.280
13. Haidari, A. (2020). Renewable Energy (Solar) and its Impact on Rural Households' Welfare (Case Study of Badakhshan Province, Afghanistan). *Journal of Economics and Business*, *3*(3). https://doi.org/10.31014/aior.1992.03.03.257
14. Hamdard, S. M. (2017). *Solar power bridges digital divide for students in Kandahar | UNICEF Afghanistan*. https://www.unicef.org/afghanistan/stories/solar-power-bridges-digital-divide-students-kandahar?utm_source=chatgpt.com
15. *Harnessing the sun to power Afghanistan's development | United Nations Development Programme*. (2024). https://www.undp.org/afghanistan/stories/harnessing-sun-power-afghanistans-development?utm_source=chatgpt.com
16. Jahangiri, M., Haghani, A., Mostafaeipour, A., Khosravi, A., & Raeisi, H. A. (2019). Assessment of solar-wind power plants in Afghanistan: A review. *Renewable and Sustainable Energy Reviews*, *99*, 169–190. https://doi.org/10.1016/j.rser.2018.10.003
17. Korkovelos, A., Mentis, D., Bazilian, M., Howells, M., Saraj, A., Fayez Hotaki, S., & Missfeldt-Ringius, F. (2020a). Supporting Electrification Policy in Fragile States: A Conflict-Adjusted Geospatial Least Cost Approach for Afghanistan. *Sustainability*, *12*(3), 777. https://doi.org/10.3390/su12030777
18. Korkovelos, A., Mentis, D., Bazilian, M., Howells, M., Saraj, A., Fayez Hotaki, S., & Missfeldt-Ringius, F. (2020b). Supporting Electrification Policy in Fragile States: A Conflict-Adjusted Geospatial Least Cost Approach for Afghanistan. *Sustainability*, *12*(3), 777. https://doi.org/10.3390/su12030777
19. Mehrad, A. T. (2021). Assessment of solar energy potential and development in Afghanistan. *E3S Web of Conferences*, *239*, 00012. https://doi.org/10.1051/e3sconf/202123900012
20. Nasrat, S., Sadat, F. S., & Sapi, H. (2018). Rural Technology Park-A New Inclusive Rural Development Concept for the Reduction of Poverty in Rural Afghanistan. *Economic Alternatives*, *2*, 250–266.
21. Rahime, M., Rashitovich, K. B., Shahryar, S. A., Hamdard, R., & Aseel, Y. (2024). Development of Electric Network Impact on Socio-Economic of Ghazni Province, Republic of Afghanistan. *Sciences*, *2*(2), 334–345.
22. Rostami, R., Khoshnava, S. M., Lamit, H., Streimikiene, D., & Mardani, A. (2017). An overview of Afghanistan's trends toward renewable and sustainable energies. *Renewable and Sustainable Energy Reviews*, *76*, 1440–1464.
23. Sabory, N. R., Senjyu, T., Danish, M. S. S., Ahmadi, M., Zaheb, H., & Halim, M. (2021). A framework for integration of smart and sustainable energy systems in urban planning processes of low-income developing countries: Afghanistan case. *Sustainability*, *13*(15), 8428.
24. Sadat, S. M. W., & Sabory, N. R. (2020). Afghanistan renewable energy sector's human resources estimation until 2032. *Repa Proceeding Series*, *1*(1), 96–101. https://doi.org/10.37357/1068/SODC2019.1.1.12
25. Shapna, K. J., Li, J., & Hossain, M. L. (2025). Solar energy integration in off-grid communities: Empowering remote areas in Bangladesh for sustainable development. *Discover Sustainability*, *6*(1), 371. https://doi.org/10.1007/s43621-025-01214-9
26. Sharma, R., Choudhary, D., Kumar, P., Venkateswaran, J., & Solanki, C. S. (2019). Do solar study lamps help children study at night? Evidence from rural India. *Energy for Sustainable Development*, *50*, 109–116. https://doi.org/10.1016/j.esd.2019.03.005
27. World Bank Group. (2020). *Solar Power Provides a Lifeline to Afghanistan's Hospitals*. World Bank. https://www.worldbank.org/en/news/feature/2020/12/06/solar-power-provides-a-lifeline-to-afghanistans-hospitals
28. Zaheb, H., Amiry, H., Ahmadi, M., Fedayi, H., Amiry, S., & Yona, A. (2023). Maximizing Annual Energy Yield in a Grid-Connected PV Solar Power Plant: Analysis of Seasonal Tilt Angle and Solar Tracking Strategies. *Sustainability*, *15*(14), Article 14. https://doi.org/10.3390/su151411053