Vol. XVII & Issue No. 03 March - 2024
INDUSTRIAL ENGINEERING JOURNAL

SOCIO-ECONOMIC ANALYSIS AFTER SOLAR ENERGY-BASED ELECTRIFICATION OF A REMOTE VILLAGE IN NORTHEAST INDIA: A MODEL FOR RURAL INDIA

Chandrajita Chakraborty
final year student of Master of Science (Renewable Energy and Environment)
School of Engineering and Technology, IGNOU, New Delhi.
Email: chandrajitachak@gmail.com

Shweta Tripathi
Assistant Professor, Mechanical Engineering at SOET, IGNOU, New Delhi.
Email: shweta.tripathi@ignou.ac.in

Ashish Agarwal
Professor, Mechanical Engineering at School of Engineering &
Technology Indira Gandhi National Open University New Delhi India.
Email : ashisha@ignou.ac.in

Shashank Srivastava
Assistant Professor, Mechanical Engineering at School of Engineering and Technology, IGNOU, New Delhi
Email: ssrivastav@ignou.ac.in

N.Venkateshwarlu
Professor, Mechanical Engineering, School of Engineering and Technology, IGNOU, New Delhi.
Email : nvenkateshwarlu2008@ignou.ac.in

Abstract

Countries across the world are alarmed and holding talks on ways to transition to a renewable energy source, becoming the leader in the energy sector. From big industries to agriculture purposes, renewable energy sources are emerging as a need of the hour. Focusing on renewable energy sources have emerged as a solution to providing energy to remote areas where conventional form of energy failed to assist. This study was conducted on a small village of Tripura which experienced electricity for the first time when a 2kW power output micro-grid solar power plant was installed in this area. An open-ended survey method was used to gather information from the villagers on the socio-economic changes that followed after the installation of the solar plant. A remarkable change was seen in the livelihood of villagers which was credited to the solar energy plant that was now used for all major energy-requiring purposes like water heating, occupational purposes, and illumination. It increased quality of life and satisfaction of the people. This solar project provided electricity to a remote village, enhancing its socio-economic structure and market access. It uplifts UN-SDG goals and serves as a model for similar locations needing renewable energy intervention.

Keywords: Socio-economic, Solar Energy, Rural Electrification, Sustainable Development

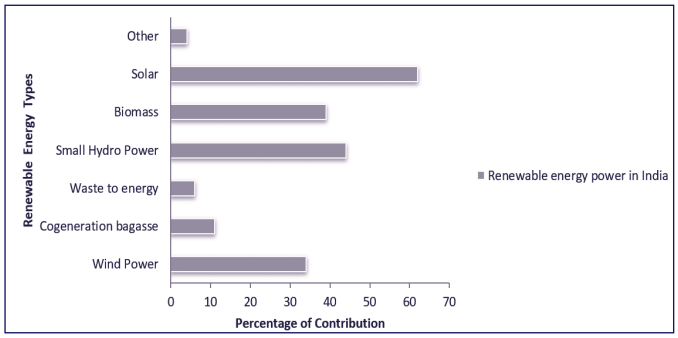
1. INTRODUCTION:

The use of renewable energy is being seen as the most powerful weapon to combat climate change all over the world. When we look from the Indian perspective, India has its own commitments to battle climate change and reach net zero emissions by 2070. It also aims to cater to fifty percent energy demand of one of the most populous countries of the world through renewable energy sources by 2030 (Birol & Kant, 2022).

The Council on Energy, Environment, and Water was surveyed in 2019 to check the availability of residential energy as claimed Under Pradhan Mantri Saubhagya Scheme and concluded with a few key findings. One of them was that 2.43 percent of Indian households remain unelectrified (Agrawal et al., 2020). This is unfortunate and at the same time a golden opportunity to provide these households with electricity through renewable sources. At present, it's no more an alternative, rather, a need to balance the supply and demand of adequate energy resources by using renewable alternatives (OECD, 2012). Utilizing renewable energy like wind energy, PVs, and small-scale hydropower can be an economically viable option for electrification when compared to existing grid expansion (Nouni et al., 2018). Countries have come forward to support better energy policies which resulted in increased use of Solar panels and wind generation by 275 TWh, setting a new record (IEA, 2023). Two points can be attributed to the above report, first that there was an increase in the emission of CO_2 due to reliance on non-renewable sources of energy and a particular shift to coal from gas due to the global energy crisis. Secondly, this increased emission was compensated due to shifting towards renewable sources of energy in the wake of climate change. The reliability of solar panels and wind generation makes it evident that the upcoming era is of clean energy.

In its present form, solar energy is one of the most reliable cosmopolitan sources of renewable energy (Mekhilef et al., 2013). The contribution of renewable energy sources in India (Kalita et al., 2019) are shown in Figure:1. The start of the decade saw a small market and high prices for the same, but over the years demand for solar energy increased, the market grew and new technologies helped in reducing the cost, specifically in geographically sunnier regions. The increase in reliability over renewable sources of energy ensures that it plays an active role in the production of electricity in large parts of the world (WEF, 2020). At an individual level, however, it has been seen that the outlook toward these sources can help lower household energy costs which can benefit rural areas (Zywiolek et al., 2022).

Figure 1. Contribution of Various Renewable Energy Sources in India



The Parties to the United Nations Framework Convention on Climate Change held its 27th Conference in Egypt. It was aimed at finding ways not to cross the red line that takes the planet over a 1.50 temperature rise. The key themes revolved around climate change, and renewable energy and were one of the major themes of discussion (UN, 2022). The report also emphasized how fossil fuels act as the largest contributor to global climate change by emitting 75% of greenhouse gas emissions and accounting for 90% of all carbon dioxide emissions. The key science to deal with this is to invest in alternative sources of energy that are clean, accessible, affordable, sustainable, and reliable. Encouraging eco-friendly policies and investments, and other monetary instruments like taxes levied for environmental interest can also increase economic input into improving this sector (Li et al., 2022).

India since independence has worked to evolve as the world's third largest producer of renewable energy, with forty percent of its installed electricity capacity from non-fossil sources such as hydropower, solar energy, and nuclear energy. India's installed solar capacity is 48.55 GW (MNRE, 2023). The nation has a geographical benefit due to its position in a tropical area, where it receives a tremendous amount of solar energy equal to 3000 hours of sunshine annually (Singh et al., 2016). This advantage needs to be exploited by emphasizing policies that aim to instill self-reliance with respect to several solar applications such as solar batteries, panels, and inverters (Gagal, 2022).

The North Eastern region of India ranks lowest in the country in terms of per capita energy consumption, this is because of remoteness, climatic conditions, and less industrialization (Kalita et al., 2019). There are attempts to make the North East region the sustainable powerhouse of India, with hydropower, bio-energy, and solar projects majorly in Assam, Manipur, and Mizoram. Nevertheless, the region remains unexplored with respect to the tremendous potential of 62,000 MW in solar energy and 56,480 MW in hydroelectricity. (NEEPCO, 2022).

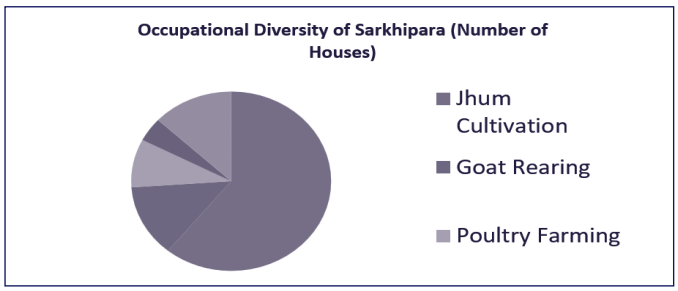
For the purpose of filling the energy deficiency in this region and making it India's leader in solar energy, new and innovative methods are being implicated like solar rooftops. It has been one of the brilliant solutions to develop self-sustainability and a vital step towards a green future for the country. The Ministry of New Renewable Energy brings a scheme under Viability Gap Funding focused on increasing solar rooftop capacity by 2700 MW. The Ministry Of New Renewable Energy is already in action and has sanctioned projects for the purpose of uplifting capacities of storage in North East region and it is estimated that by 2026 energy storage will be cheaper by 50% to 70% as there are attempts to advance the battery technology (Krishna, 2022).

All the efforts made to date are yet not enough and it is evident that NorthEastern India is still dependent on biomass fuels and the situation remains the same through remote villages. 90% of energy attribution, here, is coordinated towards cooking and space warming followed by 70% towards another domestic purpose (Palit, 2003). Quoting North Eastern Council, GoI according to its report NEC is working on projects to benefit all 7 NE states. These include two schemes, wherein under Renewable Resources Energy initiative has been taken for providing Gap funding to RRE. This includes small hydropower, solar, and wind energy projects. Under these projects, un-electrified rural populations have & will be benefiting by availing electricity to fulfill their day-to-day requirements (NEC, 2023).

Information Regarding Study Site: Sarkhipara, the study site is a remote hamlet in the Dhalai district of Tripura. Situated at a latitude of 23.74719° and a longitude of 91.742866°, the area comes under Nunachhara R.F and is at a distance of 68 km from the state capital of Agartala. The state receives average annual solar radiation of 4.64 kWh/m^2/day (Bhattacharjee et al., 2018). The basic source of income source is variable with Jhum Cultivation as a major one. The village has lived a scarce life, due to dense vegetation and lack of proper roads, resources, and modern infrastructure.

The site experiences hot and humid summers from April to November when the temperature might scale to 35 degrees Celsius. It experiences monsoon downpours in July. Winter starts in November and goes till March. Sarkipara is inhabited by people of Reang tribes and overall there are 14 families in this hamlet. Reangs are one of the nineteen scheduled tribes inhabiting Tripura, but only this tribe has been identified as a Primitive Tribal Group (PTG). The major occupation of the locals is Jhum cultivation, goat rearing, MGNREGA, creating traditional attires, and home gardening (Figure: 2). The lack of modern amenities and clean energy resources before 2021 failed the area and is the reason behind its remoteness and other connected socioeconomic constraints they faced.

Figure 2. Occupational Diversity in Study Site



Why Solar-Powered Microgrid Plant?

Solar Powered Microgrids prove to be more sustainable and ensure energy access to remote areas not connected to conventional energy sources. Microgrids prove to be a more reliable source in such areas avoiding any power outrage and disruption. Communities like those of Sarkhipara earlier used fossil fuels like kerosene for basic energy needs like cooking, lighting, and operating home appliances. Solar Powered Microgrids create adequate energy for such small and remote communities that can't thrive on conventional and harmful energy sources.

Details of the Solar PV Power Plant in the Study Site: The micro-grid solar power plant installed in Sarkhipara has a capacity of 2kWp. The plant type is of ground mount type with a module number of 6 consisting of 2 modules in a series. The solar panels have been grounded using steel beams, making adjustments easy. The number of strings used is three and a battery of capacity 48V/400 Ah is used along with it. The solar panels are tilted and fixed at an angle of 22^0 to catch maximum solar radiation. Mounting is made of mild steel with hot dip galvanized finishing to resist environmental erosion that could probably have lowered the life expectancy of the solar plant.

2. METHODOLOGY

The entire study is based on an open-ended flexible survey that was conducted within a span of six months. During this period, the villagers were asked previously framed questions in the first two sessions and the latter two sessions were kept open so that additional information can also be gained. The data collected was then thoroughly analyzed and interpreted mathematically to give an overview of the socioeconomic comparison before and after setting up the solar plant.

3. RESULTS AND DISCUSSION

Economic Conditions

Energy Expenditures: Before the solar plant came into existence in the study site, the people of this village were completely dependent on Kerosene for various household uses such as water heating and illuminating their houses at night in case of emergency. Before the solar plant was installed, the average monthly kerosene consumption by the family was between 1.5 and 3 liters. A reasonable and favorable downfall of 45.42% in lamp fuel utilization (Figure 3) with the month-to-month energy costs dropping from 367.5-612.5 INR to 183.75-367.5 INR (Figure 4) reducing monthly energy costs by 45.416 percent was calculated from the data obtained. The reduced energy costs and increased income are within an even range which can act as a positive loop for an increase in the uses of renewable energy sources (Uzar 2020).

Figure 3. Usage of Kerosene Before and After Setting up the Solar Power Plant

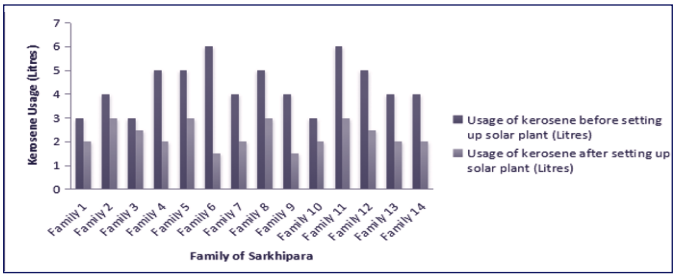
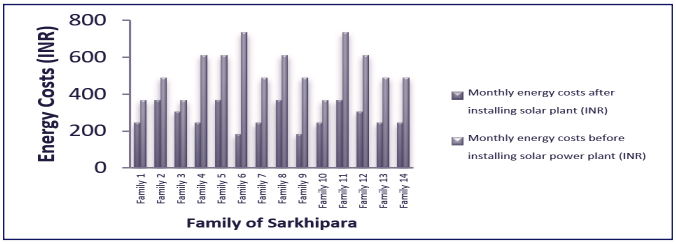


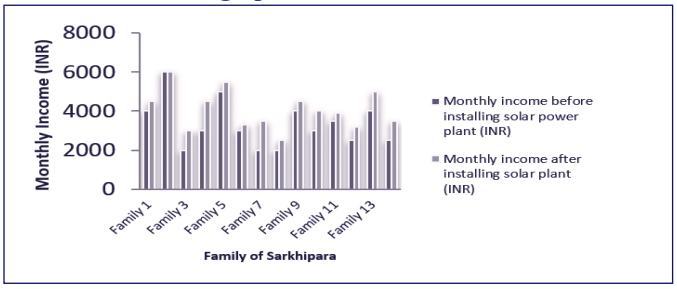
Figure 4. Monthly Energy Costs Spent Per Family Before and After Setting up the Solar Power Plant



Health Expenditures: From the survey it was also found out that their healthcare expenditure reduced by 35%. It has been proven that breathing kerosene vapor for a significant period of time may result in feeling nauseous, increased blood pressure, and irritation in the eyes along with many other physical symptoms (Granie et al., 2020). As they started using cleaner energy source for illumination, the symptoms that were seen in these people gradually subsided, and with it, their frequent visits to healthcare facilities. With electrification of this site, the healthcare is also bound to improve with a proper planning of the energy policies in relation to the developments in this sector (Dholakia, 2018).

Work Output and Income: The solar plant has made work hours preferable longer with more sources of illumination. It gives them the liberty to choose to work at night according to their demands. As a result, the work output has increased along with a 27.34% gain in monthly income as shown in Figure 5**,** giving them more financial returns. This kind of micro-scale generation indicates their gradual overcoming of energy poverty in the near future as they keep on utilizing solar power for electricity (Judson and Zirakbash, 2022).

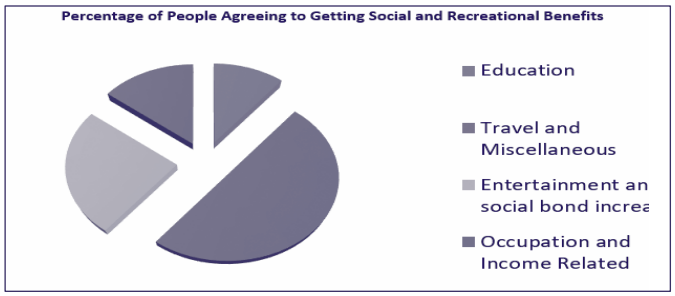
Figure 5. Monthly Income of Families Before and After Setting up the Solar Power Plant



The established solar panel also opened the internet for people as they have access to electronic devices, which has the potential to improve the market for them, create economic opportunities, enhance productivity, and connect them to the outer world (Salahuddin and Alam). Through the strategic and targeted use of public funding, for instance, successful nations have also found a way to strike a balance between the necessity of maintaining affordable consumer prices and the objective of ensuring the financial viability of electricity providers (The World Bank, 2018).

Social and Recreational Benefits: The people of Sarkhipara earlier had to restrict their activities after night due to the lingering darkness, fear of wild animals, and lack of visibility. Figure: 6 shows that, after installing the micro-grid solar power plant, the situation changed with 21.43% of the people getting education-related benefits as the children can study at night. 28.57% of people got occupational benefits with a rise in overall income, as mentioned earlier, and 50% of residents have accepted enjoying recreational activities after sunset by celebrating traditional Reang tribe's festivals with more vigor and liveliness. All of the 14 families, i.e 100% of the families have reported to feeling an ease of traveling at night and performing other miscellaneous outdoor activities. It is clear that the morning-oriented lifestyle of Sarkhipara gradually shifted partially after sunset, making it equally night-oriented. Similar findings were seen while studying the relationship between household lifestyle and electricity in Japan (Ozawa, 2016).

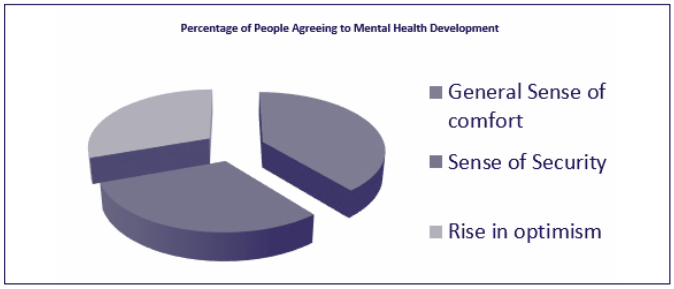
Figure 6. Social and Recreational Benefits After Setting up the Solar Power Plant.



Health Conditions: Like many other households which lacked electrification, Sarkipara also relied on kerosene oil to fulfill its need for energy, but it has been proven that daily and continuous use of kerosene oil poses a threat to health such as the threat of respiratory poisoning (Lam et al., 2012,). Breathing the fumes of kerosene or its contact with the skin depending on intensity and time of exposure can cause severe effects and may lead to coma, cause a lack of muscle control, and severe lung problems (PHE, 2016). Now that people have a defined awareness due to the usage of solar energy, evident advancement can be seen in the health benefits. According to the data analysis of Sarkhipara, 85.71% of people claimed to have felt an improvement in their physical symptoms as shown in Figure 7. Not only in terms of it, but also as far as the mental health benefits of people of the site are concerned, 64.28% of people reported feeling a sense of comfort, 50% felt more secure 50% of the total number of families also felt a rise in optimism as shown in Figure 8. A very healthy and optimistic change is visible in the area which is in tandem with studies conducted in other areas, after electrification. The positive effects are even more visible as earlier this area was lagging in terms of its electricity services (Nasrudin et al., 2022).

Figure 7. Improvement in physical symptoms after setting up the solar power plant.

Figure 8. Mental health improvements in people after setting up the solar power plant.



4. CONCLUSION

India is a developing country and its demand for energy is growing every year by 3% due to industrialization and urbanization (Kala, 2022). The government of India being a pioneer in sustainable energy sources aims to deal with growing energy demand with the help of sustainable sources. India has been leading to deliver electricity to remote areas through solar power plants, rooftop plants, and microgrid solar plants, where conventional methods aren't able to reach them efficiently (Fuchet, 2022). The study and analysis of a remote northeastern village with respect to the socio-economic changes brought about by micro-grid solar power have proved the feasibility of such projects in unelectrified areas of India. Such models stand strong focusing on the basic human right to provide everyone with electricity irrespective of their establishment in remote and rural areas (Banerjee, 2021). This model is just not about providing electricity to remote areas but also a model of how through a decentralized process and transition can be made towards cleaner and renewable sources of energy.

REFERENCES

1. *Agrawal, S., Mani, S., Jain, A., & Ganesan, K. (2020). State of electricity access in India. Insights from the India Residential Energy Survey.*
2. *Banerjee, S. (2021, October 25). Energy : is it a part of human rights. iPleaders. Retrieved May 12, 2023, from https://blog.ipleaders.in/energy-is-it-a-part-of-human-rights/*
3. *Bhattacharjee, S., Chakraborty, S., Thakur, B. N., & Ali, M. S. (2018). Modelling, optimization and cost analysis of grid connected solar-battery system for Tripura University Campus. Int J Adv Sci Res Manag, 3(9), 23-31.*
4. *Birol, F., & Kant, A. (2022). India's clean energy transition is rapidly underway, benefiting the entire world.*
5. *CO_2 Emissions in 2022 - Analysis. (2023, March). IEA. Retrieved May 9, 2023, from https://www.iea.org/reports/co2-emissions-in-2022*

6. COP27: Delivering for people and the planet | United Nations. (2022, November 20). the United Nations. Retrieved May 9, 2023, from https://www.un.org/en/climatechange/cop27
7. Dholakia, H. H. (2018). Solar powered healthcare in developing countries. Nature Energy, 3(9), 705-707.
8. Fuchet, A. (2022, June 15). Access to Energy: Empowering India's Rural Communities. Schneider Electric Blog. Retrieved May 12, 2023, from https://blog.se.com/sustainability/2022/06/15/access-to-energy-empowering-indias-rural-communities/
9. Gagal, V. (2022, December 10). Future of solar energy expansion in India. Times of India. https://timesofindia.indiatimes.com/blogs/voices/future-of-solar-energy-expansion-in-india/
10. Granie, P., Kadavy, P., Mooney, S., Padilla, J., & Phillips, R. (2020). Sustainable Energy for Rural Uganda.
11. Judson, E., & Zirakbash, F. (2022). Investigating the potential of solar energy for low-income communities in Australia to reduce hardship, debt and inequality. Energy Research & Social Science, 84, 102386.
12. Kala, R. R. (2022, October 27). India's energy demand to be highest globally during 2021-2030: IEA. The Hindu Business Line. https://www.thehindubusinessline.com/news/indias-energy-demand-to-be-highest-globally-during-2021-2030-iea/article66061339.ece
13. Kalita, P., Das, S., Das, D., Borgohain, P., Dewan, A., & Banik, R. K. (2019). Feasibility study of installation of MW level grid connected solar photovoltaic power plant for northeastern region of India. S?dhan?, 44(9), 1-24.
14. Karmakar, R. (2022, August 20). From darkness to solar powered light. The Hindu.
15. Krishna, G. (2022, November 10). Renewable Energy in the North East. Invest India. Retrieved May 11, 2023, from https://www.investindia.gov.in/team-india-blogs/renewable-energy-north-east
16. Lam, N. L., Smith, K. R., Gauthier, A., & Bates, M. N. (2012). Kerosene: a review of household uses and their hazards in low-and middle-income countries. Journal of Toxicology and Environmental Health, Part B, 15(6), 396-432.
17. Li, Z., Kuo, T. H., Siao-Yun, W., & Vinh, L. T. (2022). Role of green finance, volatility and risk in promoting the investments in Renewable Energy Resources in the post-covid-19. Resources Policy, 76, 102563.
18. Mekhilef, S., Faramarzi, S. Z., Saidur, R., & Salam, Z. (2013). The application of solar technologies for sustainable development of agricultural sector. Renewable and sustainable energy reviews, 18, 583-594.
19. Nasrudin, R. A., Quarina, Q., & Dartanto, T. (2022). Revisiting the Energy-Happiness Paradox: A Quasi-Experimental Evidence of Electricity Access in Indonesia. Journal of Happiness Studies, 23(7), 3549-3576.
20. Nouni, M. R., Mullick, S. C., & Kandpal, T. C. (2008). Providing electricity access to remote areas in India: An approach towards identifying potential areas for decentralized electricity supply. Renewable and Sustainable Energy Reviews, 12(5), 1187-1220.
21. OECD. (2012). Linking renewable energy to rural development.
22. Ozawa, A., Furusato, R., & Yoshida, Y. (2016). Determining the relationship between a household's lifestyle and its electricity consumption in Japan by analyzing measured electric load profiles. Energy and Buildings, 119, 200-210.
23. Palit, D. (2003, October). Renewable energy in north east India; issues and prospects. In International Conference on Energy and Environmental Technologies for Sustainable Development (pp. 85-93).
24. PHE Centre for Radiation, Chemical and Environmental Hazards. (2016, October). Compendium of Chemical Hazards. GOV.UK. Retrieved May 12, 2023, from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/561056/kerosene_general_information.pdf
25. POWER POTENTIAL IN THE NORTH EASTERN REGION | North Eastern Electric Power Corporaton Limited. (2022, January 19). NEEPCO. Retrieved May 11, 2023, from https://neepco.co.in/power-generation/power-potential
26. Power and Renewable Resources of Energy. (2023, March 10). North Eastern Council. Retrieved May 11, 2023, from https://necouncil.gov.in/nec-project-sector/power-and-renewable-resources-energyReport from Ministry of New and Renewable Energy. (2023, September 9). Renewable Energy in India. PIB. Retrieved May 9 2023 from https://pib.gov.in/FeaturesDeatils.aspx?NoteId=151141&ModuleId%20=%202
27. Salahuddin, M., & Alam, K. (2016). Information and Communication Technology, electricity consumption and economic growth in OECD countries: A panel data analysis. International Journal of Electrical Power & Energy Systems, 76, 185-193.
28. Shukla, H. (2021, September 14). Tripura to Set Up Solar Microgrids in 23 Villages. Mercom India. Retrieved May 11, 2023, from https://www.mercomindia.com/tripura-set-up-solar-microgrids-23-villages
29. Singh, B. R., & Singh, O. (2016). Future scope of solar energy in India. SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology, 8(01), 20-25.
30. Solar Power Lights up 11 Remote Tripura State Rifle Camps. (2023, April 20). Saur Energy International. Retrieved May 11, 2023, from https://www.saurenergy.com/solar-energy-news/solar-power-lights-up-11-remote-tripura-state-rifle-camps
31. The World Bank. (2018, April 18). Access to Energy is at the Heart of Development. World Bank. Retrieved May 12, 2023, from https://www.worldbank.org/en/news/feature/2018/04/18/access-energy-sustainable-development-goal-7
32. Uzar, U. (2020). Is income inequality a driver for renewable energy consumption?. Journal of Cleaner Production, 255, 120287.
33. Why the future looks bright for solar energy. (2020, January 16). The World Economic Forum. Retrieved May 9, 2023, from https://www.weforum.org/agenda/2020/01/the-future-looks-bright-for-solar-energy/
34. Zywiolek, J., Rosak-Szyrocka, J., Khan, M. A., & Sharif, A. (2022). Trust in renewable energy as part of energy-saving knowledge. Energies, 15(4), 1566.