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Harnessing the Sun for Rural Transformation: India's Path to Sustainable Development

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ABSTRACT
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INTRODUCTION

The Economic Survey 2022-2023 places significant emphasis on rural development. The survey highlights the fact that 65 per cent (2021 data) of the country's population lives in rural areas. Around 47 per cent of the population depends on agriculture for their livelihood. As a result, it becomes necessary to provide the rural population with the essentials that promote the overall economic development of the nation. One of the basic necessities that results in socio -economic development is the availability of Electricity. It has become crucial for the day- to -day activities of human life, and to the dismay, the rural population is deprived of this.

Recently, there has been a growing concern towards green and sustainable energy. The government is now focusing on combining developmental activities with eco-friendly initiatives to ensure sustainable growth.This has resulted in harnessing renewable sources of energy, mainly wind, solar and other alternatives.

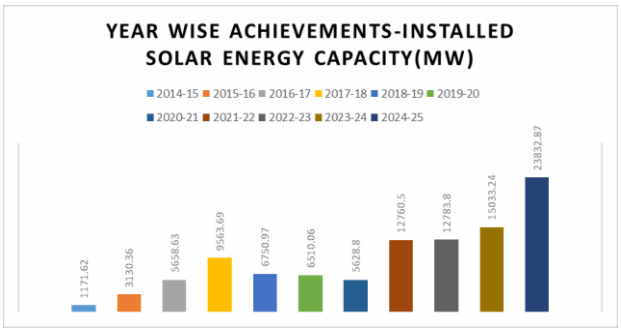
Significant progress can be found in the country's transition to clean energy. Today India boasts of a triple increase in the renewable energy capacity from 76.37 GW to 233.99 GW. This rapid growth includes a 4000 per cent increase in solar power capacity as per July 2025 records. The Ministry of New & Renewable Energy (MNRE) is actively working to meet the COP26 goal of achieving 500

GW of non-fossil fuel capacity by 2030.

Solar energy, being clean, renewable, and increasingly cost-effective, has appeared as a practical substitute to traditional electricity sources in rural regions. The adoption of solar-based electrification not only supports national commitments to sustainable development goals (SDGs) but also provides cheap access to energy, reduces reliance on fossil fuels, and minimizes environmental deprivation. Beyond meeting basic household needs, electrification fosters fisca l opportunities, empowers communities, and enhances the overall standard of living.

The focus of the study is to understand how electrification can bring about positive changes in the lives of a community through social empowerment. Apart from the impact of the electrification this paper particularly aims at studying the impact of solar energy as a means of sustainable development through community empowerment.

The case study of The Mahadev Koli solar electrification project stands as an example of how a sustainable goals and developmental goals can be achieved simultaneously through government initiatives collaborated with private institutions.



Source-https://mnre.gov.in/en/year-wise-achievement/[1]

1.Review of literature

Rural electricity through renewable energy and socio - economic development are the two broad concepts that have been tried to converge in the following paper. Several literature reviews are done in order to understand how these topics overlap each other. Based on the literature survey, it is grouped under the following themes.

[1]https://mnre.gov.in/en/physical-progress/**2.1 Rural electrification for socio-economic development through renewable sources** Bhattacharyya (2013) asserts that rural electrification through renewable sources such as solar energy will be a game changer in socio-economic development. Such transformation is apparent in Mahadev Hindu Koli village in the increased education prospects for children and ability of women to participate more actively in economic activities. This project supports long-term development in nurturing a more equitable and sustainable environment.

Elavarasan (2019) argue that energy access is foundational for economic development and poverty alleviation in rural areas. By encouraging entrepreneurial ventures and improving the agricultural productivity through better storage facilities, and by creating new job opportunities linked to system maintenance and management, solar energy has empowered the farmers. To assess how this green energy has acted as a catalyst for growth and development,the researchers of this study have used Mahadev Koli Village as an example.

In the past decade, India has taken many steps to enhance the adoption of solar energy in rural areas. To improve access to electricity in rural areas, the government has implemented various strategies to build the renewable energy capacity (Pathania et al.,2017). To further enhance the adoption of solar energy, it has become imperative to understand the key drivers and barriers to such adoption. This approach will provide us with insights to develop strategies that will increase the uptake of this sustainable technology in the rural regions (Kapoor &Diwedi, 2019).

2.2 Impact of Public-Private Collaboration

The teamwork between Bosch, known for high-tech innovation and Gram Oorja, with a deep sense of community development, illustrates how corporate and grassroots establishments can result in a beautiful symphony of Public-Private Collaboration. Such collaboration has played a fantastic role in creating scalable and sustainable solutions that can be simulated across various regions.

Various product attributes,including compatibility, complexity, observability and trialability, need to be analysed to embrace the solar panels (Menon & Sujatha, 2021).The territorial distribution of the solar energy subsidies in the rural areas has been examined by the private investment and the Government bodies before their rollout.

This encompasses the analysis of the dynamics of public intervention and distributive politics in the given context (Girard & Sareen, 2024). Long-term benefits for societies from rural electrification

also include increased income and improvements in education for girls as the adoption of solar energy transforms community development.

Government support and the emergence of off-grid solar markets for low-income households have been associated with the growing adoption of solar energy technologies in rural India. Nevertheless, further growth is constrained by challenges such as policy inefficiencies and the need for reconceptualization of approaches. While solar energy adoption can significantly boost rural economies, create jobs, and improve living standards, it also raises environmental concerns, such as deforestation and land acquisition issues associated with large-scale solar projects (Swarooprani,

2023).

2.3 Solar energy and sustainable development

Pachauri et al. (2013) note that local community engagement and ownership are necessary elements of sustainable energy development projects. Engaging Mahadev Koli villagers in the process, further providing them with skills in terms of maintenance of systems promotes autonomy and ensures benefits reaped from electrification do not dissipate in a very short period of time.

There is recognition that solar energy is one of the viable renewable energy sources since it is readily available and could easily address issues relating to the environment resulting from traditional sources of energy (Babatunde, 2019).

The utilisation of solar energy is consistent with the concept of sustainable development, since it is cheap in terms of energy that may improve the living conditions, especially among the poor and in t developing countries (Azevêdo et al., 2020). In addition, solar energy systems can provide both economic and environmental benefits, which make it a good solution for regions looking to meet energy needs while preserving the environment (Devabhaktuni et al., 2012).

3.Research methodology

This paper is qualitative research based on the secondary sources of data like the government websites, published articles and e-journals. The data also includes a case study derived from secondary sources from the beneficiaries.

3.1 Objectives of the Study

1. Understanding the role of solar energy in rural development by highlighting how solar energy can address energy access challenges in underserved economies.

Evaluate the benefits of solar electrification on the socio-economic and environmental sustainability.

3. Explore the importance of Private-Public collaboration in implementing renewable energy projects.

4. Identify the challenges in solar electrification concerning money availability and other infrastructural issues.

5. Provide insights in terms of scaling up strategies that ensure long-term sustenance.

4.Context of the Case

4.1 Impact and Challenges: of Solar electrification in Rural India: An Indian Perspective on

Sustainable Development

Access to electricity is still a concern in rural India. Solar electrification is proving to be a crucial determinant for rural energy access. With its attributes of abundance and low environmental impact, solar power has become a contributor to revitalising these rural areas. They play a pivotal role in filling the gap for rural energy access and thus help in attaining the milestone of rural development.

4.2 Solar Power Capacity and Government Efforts

According to the November 2024 data, the installed solar power capacity has reached up to 94.17

GW, accounting for approximately 20%of the total renewable energy capacity in India.From 2014 to 2024, solar energy grew at a breakneck pace, from 2.65 GW in 2014 to 94.17 GW, with a compound annual growth rate (CAGR) of more than 40% (MNRE, 2024). The government's thrust on solar electrification has been led by schemes such as the Pradhan Mantri Kisan Urja Suraksha evamUtthaanMahabhiyan (PM-KUSUM), which aims to deploy 30.8 GW of solar capacity through decentralized systems such as solar pumps and mini-grids. By 2023, more than 1.4 million solar pumps had been installed, reducing farmers' dependence on diesel-powered irrigation and contributing to increased agricultural productivity (MNRE, 2023).

4.3 Progress and Regional Disparities of Grid Electricity

Significant growth, **regional** disparities remain in rural electrification. A survey conducted in 2019 showed that only 65% of the rural enterprises had access to grid electricity. Grid electric ity is the electricity that is produced in the centralised power plants and distributed to homes, industries and business through an interconnected network of transmission lines and distribution systems. While places like Uttar Pradesh and Bihar were less than 60% of the mark (NSSO,

2019), states like Odisha and Rajasthan had more than 90% grid access. It is the regional disparity, which has made it imperative that interventions and investments are targeted for the least-served regions to ensure a balanced access to energy.

4.4 Decentralized Solar Solutions

Decentralized solar solutions, such as solar home systems and mini-grids, have shown to be effective in filling the gaps in energy access. According to IREDA (2021), a study showed that the solar microgrids ensure reliable electricity supply to more than 300,000 households in remote areas. This increases the study hours of children and reduces dependence on non-renewable energy sources like kerosene[2].

In addition, the solar-powered irrigation pumps have helped the rural farmers save about 2 million litres of diesel per year, saving costs and emitting less in the environment as well (MNRE, 2023).

4.5 Cost and Environmental Savings

The economic impact of solar electrification in rural India has been immense. Solar projects have already generated more than 1 million direct and indirect jobs, starting from the manufacturing and installation of solar equipment to operating and maintaining the systems[3]. According to a 2021

World Bank report, rural electrification through solar could annually add $4 billion to the Indian economy by raising agricultural productivity, enhancing rural livelihoods, and supporting local industries (World Bank, 2021)

On the environmental front, India's solar energy initiatives have played a significant role in reducing greenhouse gas emissions. By displacing fossil fuels, particularly diesel generators and coal-based electricity, solar projects have contributed to a reduction of approximately 35 million tons of CO_2 emissions annually (CERC, 2023). These emissions reductions are vital in addressing

India's climate goals and moving toward a more sustainable energy future.

[2]https://solarvillageproject.org/2025/01/10/bringing-solar-power-to-rural-india-fighting-climate-change-and-energy-poverty/

[3]https://economictimes.indiatimes.com/industry/renewables/renewables-created-nearly-1-million- jobs-in-2022-in-india-report/articleshow/104188637.cms?from=mdr&utm_source=chatgpt.com

Source:mnre.gov.in[4]

4.6 Challenges and the Way Forward

Although some headway has been made, problems such as high up-front costs, limited financial access, and insufficient infrastructure continue to inhibit the solar electrification system. NITI Aayog released a report in 2022,stating that 30 percent of the rural households only have intermittent power supply, and around 10 million homes are yet to see the light of electrification. The rural areas in India is still be strengthened through proper electrification. The challenges call for a stronger policy framework, increased private-public partnerships and increased funding to improve the level of adoption of solar energy in these pockets.

4.7India's Renewable Energy Landscape: Key States Driving the Transition in October 2024 - An Overview

India has witnessed fantastic progress in renewable energy development. According to the statistics stated in Renewable Energy Watch, the total renewable energy capacity has reached

203,215.27 MW as of October 2024. This is about 45 per cent of the total power capacity in the country, which stands at 454,452.18MW (Renewable Energy watch, 2024).

The following table presents the analytical overview of leading states, and their contributions. These are relevant insights for understanding the national picture of renewable energy, especially for case study research on solar energy, as well as other comprehensive clean

energy transitions.

Table 1: Renewable Energy installation pattern in different states

State	Total Capacity (MW)	Wind (MW)	Solar (MW)	Large Hydro (MW)	Biopower (MW)
Rajasthan	30,309.86	5,195.82	24,553.13	0.00	0.00
Gujarat	29,814.36	12,314.48	15,305.26	0.00	0.00
Tamil Nadu	23,799.59	11,128.84	9,324.05	0.00	0.00
Karnataka	22,538.34	6,724.36	8,930.10	0.00	0.00
Maharashtra	19,765.28	5,216.38	8,133.57	0.00	0.00
Himachal Pradesh	11,422.22	0.00	0.00	10,281.02	0.00
Andhra Pradesh	11,095.24	4,096.65	4,650.89	0.00	0.00
Madhya Pradesh	9,586.63	2,844.29	4,248.69	0.00	0.00
Telangana	7,688.34	128.10	4,842.10	0.00	0.00
Uttar Pradesh	6,103.07	0.00	3,286.98	0.00	2,265.39

5. Case Example: The Future of the Forty

The Mahadev Hindu Koli tribes, living in scattered villages, had continuously experienced difficulties related to power shortage. The 40 members of this close-knit family had used lamps for kerosene and wood for lighting purposes. These sources of energy as they emitted smoke and toxic fumes that made respiratory problems worse not only posed health risks but also restricted the community's productivity after sunset. Children were not able to study for long time after sunset because of no lighting and even other activities which is related to earning for human livelihood were stopped because of no power and no lighting facility.

Mr. Ramesh Thangavelu along with his colleague from Bosch company has taken a required step to change the darkness situation and tried to give free power system through sunlight i.e,solar energy. Their goal was intentional and objective, to electrify the village with renewable energy systemsBosch Energy and Building Solutions, known for its solar energy provider in association with Gram Oorja, who was the representative of that particular village has taken tremendous transformational step by converting black village into bright village installed a 9.3-kilowatt photovoltaic solar energy system.

The aim of the providing solar power was to ensure sustainable and green power system as well as affordable energy system to that particular small village. All 40 homes got the electricity finally which was very secured and it’s a clean source of energy throughout the lifetime. The life of forty has been turned progressively in one fine day with the brightness of light with the help of Bosch energy systems.The kids could now have a better education system, households were safe, and small

shops were able to work with little more time to earn more and take care of livelihood in better way.

The project shows the integeration of renewable energy system through sustainable electrification into rural communities from the point of view of SDG 12 on responsible consumption and production, Narula et al. (2012) suggest that the application of solar energy in rural India increases life span of people over there and will lead to better lifestyle because of reduction in carbon footprint. Carbon emissions are reduced by the village's solar energy system, setting an example for environmentally responsible energy consumption.

Solar energy adoption offers numerous advantages in rural India, including enhanced electrification, improved living conditions, and rural transformation. Despite this, achieving 100% rural electrification faces technical, social, and financial challenges. Solar microgrids have demonstrated significant benefits in rural households by providing improved energy access, better time allocation for women, increased study time for students, and enhanced indoor air quality illustrating the positive impact of solar energy adoption (Chakravarty & Roy, 2021).

6. Conclusion

The Mahadev Koli solar electrification project stands as a testimony to the transformative power of renewable energy in rural India. It shows how access to clean energy can be a catalyst for socio - economic development, improve living standards, and contribute to environmental sustainability. This initiative is not just a case of technological shift but it addresses a more fundamental issue like socio economic independence, poverty reduction and environmental stewardship. It also illustrates the importance of the various SDGs namely the SDG 7 and 12 that revolves around clean and affordable energy and responsible consumption and Production One of the key learning's of this case is that technology alone cannot lead to sustainable success; it is the joint participation of the community and the government that makes these new solutions to the problems a success. The success was being ensured not only by Bosch energy and the mediator Gram Oorja but because of the Koli communities' ready acceptance of required change.

The limitation of these study also includes that this transformation will not reflect the complete picture of the socio-economic situation of other dark villages which doesn't have power so far. The short-term focus is also limiting when it comes to the long-term viability of the solar energy systems, particularly with regard to the governance, maintenance and community ownership. Hence the future scope for this research will be to concentrate on other regional studies through longitudinal method. For practitioners the case gives the outline about how the rural community can get developed with different facilities especially with basic infrastructural facilities wherein the balanced growth can be ensured.

In conclusion through the solar electrification project, there is a acknowledgement from forty people towards fulfilling the need of the hour,.i.e ,Rural Electrification. Offering the major required lighting facility is the first step for any rural development. Its outcome provides valuable takeaways to practitioners, policymakers and researchers who are working hard to make the universe brighter with renewable power. The case of Mahadev Koli tribes are the classic example of the fact that India has the potential to achieve the best results and can rise the rural community people with sustainable renewable energy systems...

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