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THE ROLE AND CHALLENGES OF SOLAR ENERGY IN THE INCLUSIVE DEVELOPMENT OF TRIBAL COMMUNITIES (WITH SPECIAL REFERENCE TO SONBHADRA DISTRICT, UTTAR PRADESH)

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ABSTRACT

Research paper examines the hypothesis that India's solar energy policies, aimed at delivering clean, affordable, and accessible energy to tribal communities, are not merely a means to address electricity deficits, but are also emerging as a powerful instrument for inclusive development by positively influencing their environmental, social, economic, and educational lives. The study specifically focuses on tribal communities residing in the forested, hilly, and remote regions of Sonbhadra district in Uttar Pradesh, where access to traditional energy sources remains limited. Through a comprehensive review of literature and field surveys, the research analyzes how solar energy is enhancing the quality of life by fulfilling basic needs related to education, healthcare, communication, and livelihood among these marginalized communities. At the same time, the study critically investigates the structural, technical, and administrative challenges that hinder the effective implementation of solar energy schemes and restrict the full realization of inclusive development among these groups. Thus, this research positions solar energy not merely as a technical solution, but as a transformative social tool that advances equitable opportunity, participatory growth, and empowerment for tribal communities.

KEYWORDS: Solar Energy, Inclusive Development, Tribal Communities, Energy Justice, Social Empowerment, Sonbhadra, Renewable Energy, Rural Development, Technological Challenges.

INTRODUCTION

Tribal communities are among the most marginalized and disadvantaged populations in the country. Although efforts have been made to ensure their empowerment and protect their rights through constitutional provisions and various policy measures, these communities still remain excluded from the actual process of development in terms of access to social, economic, and basic services[1].

The concept of inclusive development emphasizes that the development process should ensure equal participation, benefit-sharing, and empowerment of all sections of society[2]. It encompasses not just economic growth, but also social justice, equal opportunities, access to education and healthcare, and cultural self-reliance[3].

Energy—particularly renewable and clean energy—is considered a critical factor for inclusive development[4]. The unavailability of energy not only affects the quality of life but also hinders access to essential services like education, healthcare, employment, communication, and safety[5]. In many remote and forested regions of India, traditional electricity grids are still absent[6], making solar energy a viable and sustainable solution. In this context, **Sonbhadra district in Uttar Pradesh emerges as a significant case study[7].** It is the only tribal-majority district in the state, and due to its hilly, forested geography, it faces several infrastructural challenges. A large portion of the population belongs to Scheduled Tribes[8], who continue to face limitations in accessing basic resources like electricity, healthcare, education, and communication.

In recent years, both the Government of India and the Government of Uttar Pradesh have made efforts to expand energy access in these regions through solar energy schemes. One such initiative is the *Pradhan Mantri Suryaghar Muft Bijli Yojana*, launched on 13 February 2024[9], aiming to provide free electricity to one crore households by 2027. Additionally, under the *PM JANMAN Scheme (Pradhan Mantri Janjati Adivasi Nyay Maha Abhiyan)*, tribal groups are being provided with solar-powered electrification of homes[10]. The *PM-KUSUM* scheme connects farmers' agricultural pumps to solar power for on-grid farming needs[11].

Over ₹75,000 crore has been allocated in subsidies and financial support to extend the scheme's benefits to as many families as possible[12].

As a result of these central and state efforts, tribal communities are gaining better access to essential services through solar energy—including improved healthcare, support for agricultural activities, domestic lighting, and a more conducive learning environment[13]. While several areas have witnessed positive outcomes, significant challenges remain—such as lack of technical awareness, maintenance of equipment, insufficient financial resources, and administrative inertia—which continue to limit the long-term sustainability and inclusive impact of solar energy[14].

This research seeks to analyze the socio-economic impact of solar energy on tribal communities, to what extent it has facilitated inclusive development, and what key barriers are hindering its effectiveness[15]. The study, through literature review, policy documents, and field surveys, attempts a multi-dimensional understanding of solar energy's role. It also offers recommendations on how these schemes can be made more impactful and inclusive.

A foundational reference in this discourse is the study by *Sharma[16] (2017)* titled *"The Role of Renewable Energy in Rural Development"*, which establishes that solar energy is a compelling option for regions without grid access, such as tribal and remote villages. It enables access to services like education, healthcare, communication, and irrigation—thus paving the way for holistic socio-economic development.

This idea is further expanded by *Tripathi and Mishra[17] (2019)*, who examined the impact of solar energy on tribal communities in Eastern Uttar Pradesh. Their findings reveal that solar energy has led to increased female education, enhanced women's self-reliance, and improved agricultural productivity. In the same vein, *Joshi and Kumari[18] (2020)* explored the influence of solar energy on rural women's lives. According to their study, especially solar streetlights have contributed significantly to women's safety, social participation, and active presence in community life.

Both studies suggest that solar energy plays a substantial role in gender empowerment and social inclusion. However, alongside these positive aspects, structural and behavioral challenges persist. *Yadav[19] (2023)* has clearly outlined these challenges, noting that a lack of

technical awareness, maintenance difficulties, and limited financial resources undermine the long-term utility and effectiveness of solar energy.

Similarly, a government report by *MNRE*[20] *(2020)* highlights that despite a rise in solar energy coverage in remote areas of Uttar Pradesh due to governmental schemes, the impact remains uneven due to geographical disparities, administrative inertia, and poor local-level planning.

A consolidated analysis of all the above studies underscores that solar energy, particularly in rural and tribal contexts, is a powerful and promising medium. It can bring transformative change in areas like education, health, women empowerment, and social participation. However, the sustainability and scale of this transformation depend on how effectively we can strengthen policy implementation, local participation, training, and social infrastructure.

Theoretical Framework

This study is grounded in the principles of *inclusive development*, *energy justice*, *sustainable development*, and *human-centered development*. Inclusive development emphasizes the active participation of marginalized communities and ensures equal opportunities for all. Energy justice seeks to guarantee access to clean and affordable energy for everyone. Sustainable development focuses on fulfilling long-term needs while maintaining environmental balance in energy usage. The human-centered approach considers improvements in education, health, and standard of living as the core of development. In light of these principles, this research analyzes the potential and challenges of inclusive development of tribal communities through the use of solar energy.

Objectives of the Study

The primary objective of this study is to conduct a comprehensive assessment of the potential, impact, and challenges of inclusive development among tribal communities through solar energy. Under this central aim, the following specific objectives are proposed:

1. To analyze how solar energy is contributing to the inclusive development of tribal communities, particularly in terms of access to education, healthcare, livelihood, and basic services.
2. To examine the direct and indirect effects of solar energy availability on the social, economic, cultural, and environmental aspects of tribal life.
3. To identify the key challenges associated with the use of solar energy.

Study Area and Sample Selection

The study was conducted in *Sonbhadra*, the second-largest district of Uttar Pradesh in terms of area and a tribal-dominated region. Located in the southeastern part of the state, the district has a total population of approximately 1,862,559, out of which 385,018 individuals belong to Scheduled Tribes—accounting for around 20.67% of the population. This district is unique in its geographic, social, and environmental features, with most tribal communities residing in remote, forested, and hilly regions that are significantly isolated from urban and market areas.

Several tribal groups inhabit Sonbhadra, including: **Uraon, Dhangar, Chero, Gond, Panika, Kharwar, Agariya, Baiga, Kol, and Pathari**. Administratively, the district is divided into ten development blocks: *Robertsganj, Ghorawal, Chatra, Nagwa, Chopan, Babhani, Myorpur, Dudhi, Karma,* and *Kon*.

Since the objective of the study is to evaluate the relationship between solar energy and the inclusive development of tribal communities, along with the practical challenges involved, the respondents were selected from all these development blocks.

Sampling Methodology

In the sample selection process, only those tribal households were included that are beneficiaries of solar energy schemes and are actively using solar energy. Given that most tribal communities in Sonbhadra live in difficult-to-reach hilly, forested, and poorly connected areas, *Snowball Sampling Method* was employed. Through this technique, one beneficiary household led to the identification of others, allowing a gradual and network-based expansion of the sample.

Sample Size

To ensure representation, a total of **200 tribal beneficiary households** were selected across all ten development blocks of Sonbhadra district. This sample size was intended to facilitate a comprehensive, comparative, and balanced evaluation of the impact of solar energy among tribal communities.

Table: 1 Block-wise Selection of Sample (Beneficiary Tribal Communities in Sonbhadra District)

S. No.	Block	Oraon (1)	Dhangar (2)	Chero (3)	Gond (4)	Panika (5)	Kharwar (6)	Agariya (7)	Baiga (8)	Kol (9)	Pathari (10)	Total
1	Kon	11	10	7	-	-	-	-	-	-	-	28

2	Robertsganj	-	-	-	13	5	-	-	-	-	-	18
3	Babhani	-	-	-	19	-	5	10	-	-	-	34
4	Chatra	-	-	-	16	-	6	-	-	-	-	22
5	Ghorawal	-	-	-	-	-	7	-	18	8	-	33
6	Karma	-	-	-	-	-	5	-	-	-	-	5
7	Nagwa	-	-	6	-	-	-	-	-	-	-	6
8	Dudhi	-	-	-	17	7	-	-	-	-	8	32
9	Chopan	-	-	-	12	-	-	-	-	-	-	12
10	Myorpur	-	-	-	10	-	-	-	-	-	-	10
	Total	**11**	**10**	**13**	**87**	**12**	**23**	**10**	**18**	**8**	**8**	**200**

Source – Primary Data

Table Number– 1 clearly indicates that a total of **87 beneficiaries** were selected from the **Gond tribe**, accounting for **43.5%** of the total sample. This indicates that the Gond community has been the **most significantly impacted** by solar energy initiatives.The **highest number of beneficiaries** were selected from the **Babhani (34)**, **Ghorawal (33)**, and **Dudhi (32)** blocks, suggesting that these areas have relatively **greater access to solar energy projects**. In the **Kon block**, the **Oraon, Dhangar, and Chero** communities are predominantly represented, with a total of **28 beneficiaries**, indicating a concentration of these tribes in this region. In **Ghorawal block**, a significant number of **Baiga (18)** and **Kol (8)** tribe members were selected, which reflects a **localized concentration** of these communities in the area. The **Agariya tribe** is represented by **10 individuals**, all selected exclusively from **Babhani**, while the **Pathari tribe** (8 beneficiaries) was selected solely from **Dudhi block**. This points to the **spatial concentration** of these particular tribal groups.**Karma and Myorpur blocks** had a **very limited number of selections** (5 and 10 beneficiaries, respectively), which may indicate either **limited availability** of solar energy projects or **lower population density** of tribal communities in these areas.

Table : 2 Total number of beneficiaries from each tribal community across all blocks in Sonbhadra.

Tribal Community	**Total Beneficiaries**	**Percentage (%)**
Gond	87	43.5%
Kharwar	23	11.5%
Baiga	18	9%
Panika	12	6%

Tribal Community	Total Beneficiaries	Percentage (%)
Chero	13	6.5%
Oraon	11	5.5%
Dhangar	10	5%
Agariya	10	5%
Kol	8	4%
Pathari	8	4%
Total	**200**	**100%**

Source – Primary Data

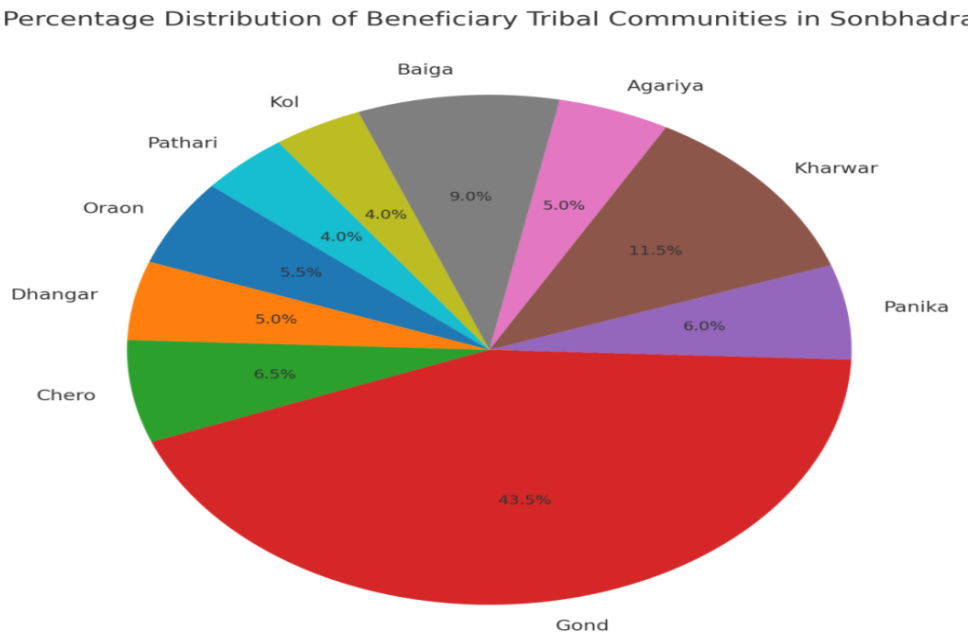


Fig. 1: In this diagram it has seen that, the Gond community (43.5%) **received the highest share of benefits, indicating their stronger administrative access and greater geographical participation. Communities like** Kharwar (11.5%)**,** Baiga (9%)**, and** Chero (6.5%) **received a moderate level of benefits. Communities such as** Oraon, Dhangar, Panika, and Agariya **had around** 5% participation**, reflecting limited impact.The** Kol and Pathari communities (less than 4%) **received minimal benefits, highlighting their continued exclusion from such schemes.Out of a total of** 200 beneficiaries**, the** distribution remains uneven**, indicating that solar energy schemes have not reached all communities equally.**

Table Number 3: Type of Solar Panels Used Among Tribal Communities Question: What type of solar energy panel do you use?

S. No.	Tribal Community	Solar Rooftop (Frequency)	Solar Water Pump (Frequency)	Both (Frequency)	Others (Frequency)	Total
1.	Oraon	9 (4.5%)	2 (1%)	–	–	11
2.	Dhangar	10 (5%)	–	–	–	10
3.	Chero	13 (6.5%)	–	–	–	13
4.	Gond	39 (19.5%)	42 (21%)	6 (3%)	–	87
5.	Panika	9 (4.5%)	3 (1.5%)	–	–	12
6.	Kharwar	12 (6%)	7 (3.5%)	4 (2%)	–	23
7.	Agariya	10 (5%)	–	–	–	10
8.	Baiga	17 (8.5%)	1 (0.5%)	–	–	18
9.	Kol	8 (4%)	–	–	–	8
10.	Pathari	8 (4%)	–	–	–	8
	Total	**135 (67.5%)**	**55 (27.5%)**	**10 (5%)**	–	**200 (100%)**

Source – Primary Data

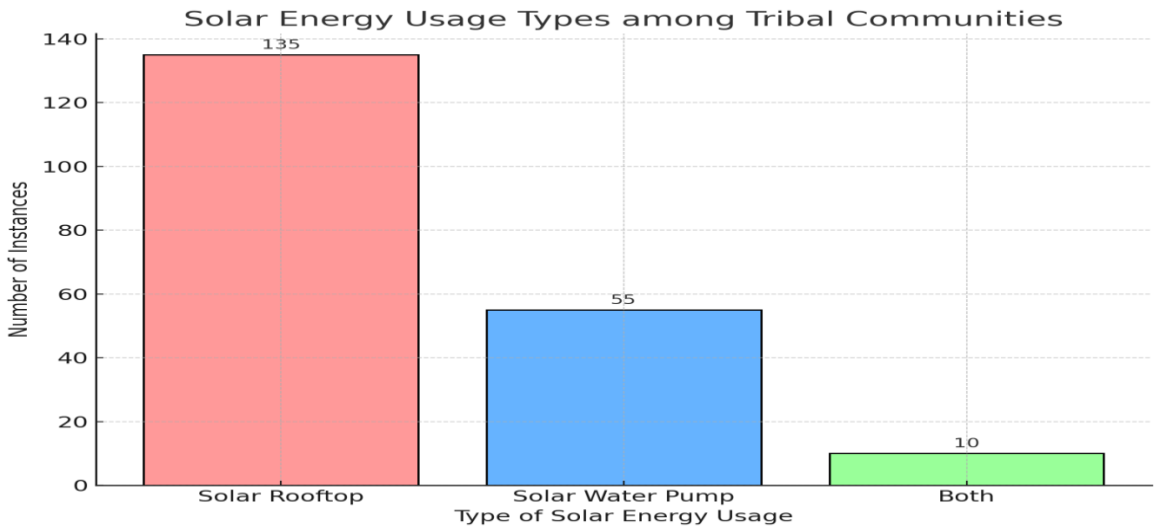


Table Number– 3 clearly indicates that out of 100% respondents, 135 (67.5%) use solar rooftop systems**,** 55 (27.5%) use solar water pumps, while 5% of the respondents use both types of solar panels**.**From a comparative perspective, the Gond tribe ranks the highest**,** with **39 (**19.5%) using solar rooftops**, 42** (21%) using solar water pumps, and 6(3%) using both types**.**Thus**,** this table presents a comparative statistical overview of the use of solar energy panels among tribal communities based on the type of usage.

Table No. 4 In which activities do you use solar energy?

S. No.	Purpose of Use	Frequency	Percentage
1.	Residential Use (Drinking water and other domestic purposes)	147	73.5%
2.	Agricultural Use	39	19.5%
3.	Both of the above	14	7%
4.	Industrial Use	00	0%
5.	All / Other Uses	00	0%
	Total	**200**	**100%**

Source – Primary Data

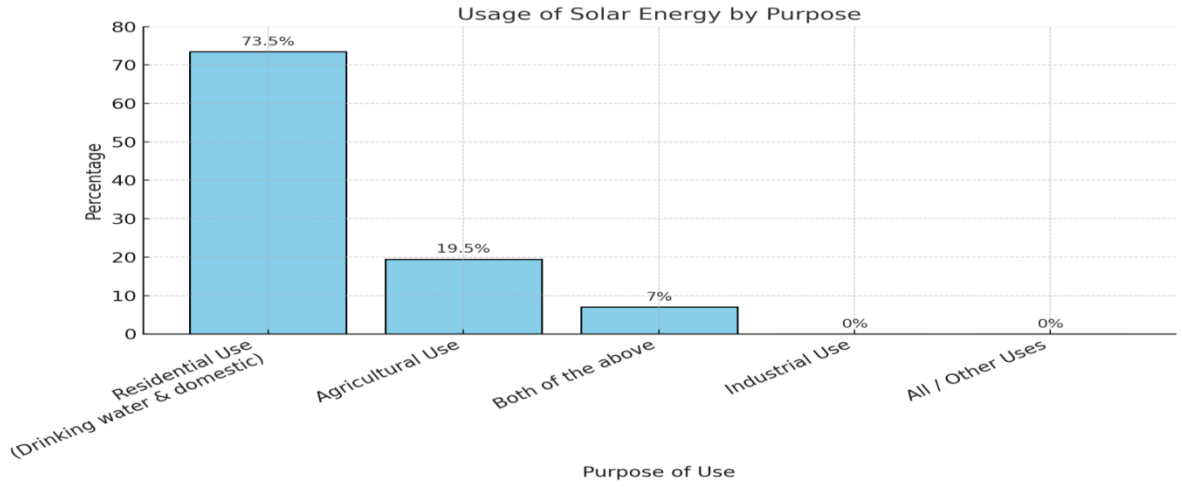
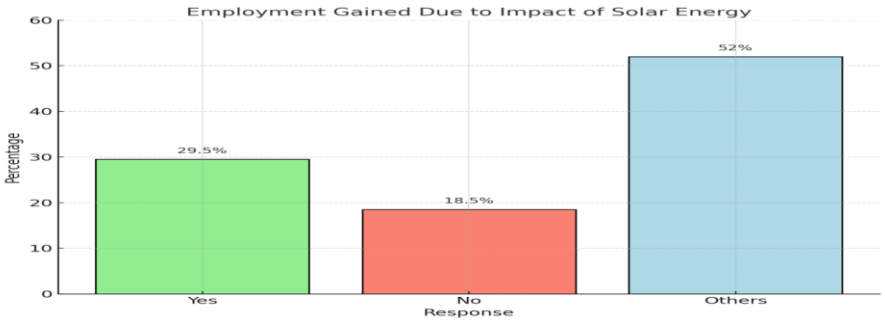


Table Number– 4 clearly indicates that out of the total 100% respondents, 73.5% use solar energy exclusively for domestic purposes. 19.5% of the respondents use solar energy for agricultural purposes, while 7% use it for both domestic and agricultural activities. The table shows that in tribal areas, the use of solar energy is still largely confined to household purposes. Although there is potential for its use in the agricultural sector, its application remains limited. Moreover, the percentage of solar energy usage at the industrial level among tribal communities is zero.

Table No. 5 Question: Have you gained any kind of employment as a result of the impact of solar energy?

S. No.	Response	Frequency	Percentage
1.	Yes	59	29.5%
2.	No	37	18.5%
3.	Others	104	52%
	Total	**200**	**100%**

Source – Primary Data



Responses – (3) Others – *"It only lights a bulb, how can that lead to employment?", "We just use it for drinking water," or "If it had higher capacity, we might have considered employment opportunities."*

Table Number– 5 clearly indicates that 29.5% of the respondents acknowledged that they gained employment due to the impact of solar energy. This is a positive sign indicating that solar energy is proving helpful in livelihood generation. However, 18.5% of the respondents explicitly stated that they did not gain any employment. A significant 52% chose the "Others" option. The table indicates that nearly one-third of the respondents affirm employment generation due to solar energy, which is an encouraging trend. However, the high percentage in the "Others" category (52%) suggests that people have different perspectives or uncertainties regarding the relationship between solar energy and employment.

Table No. 6 Question: Is your income increasing due to solar energy?

S. No.	Response	Frequency	Percentage
1.	Yes	49	24.5%
2.	No	127	63.5%
3.	Others	24	12%
	Total	**200**	**100%**

Source – Primary Data

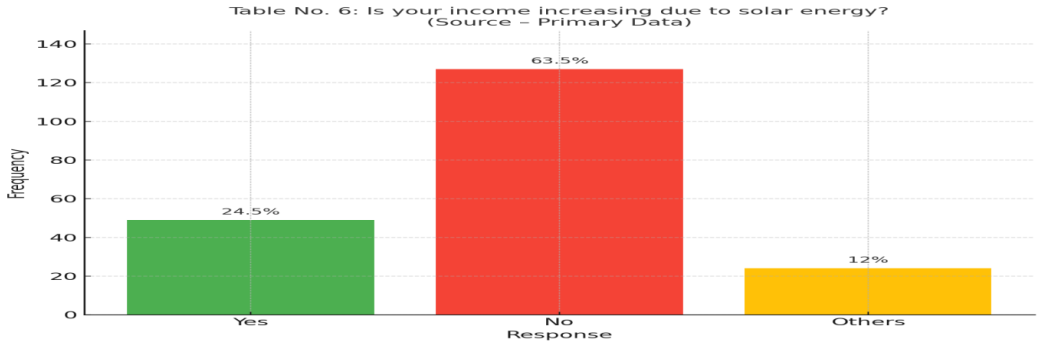


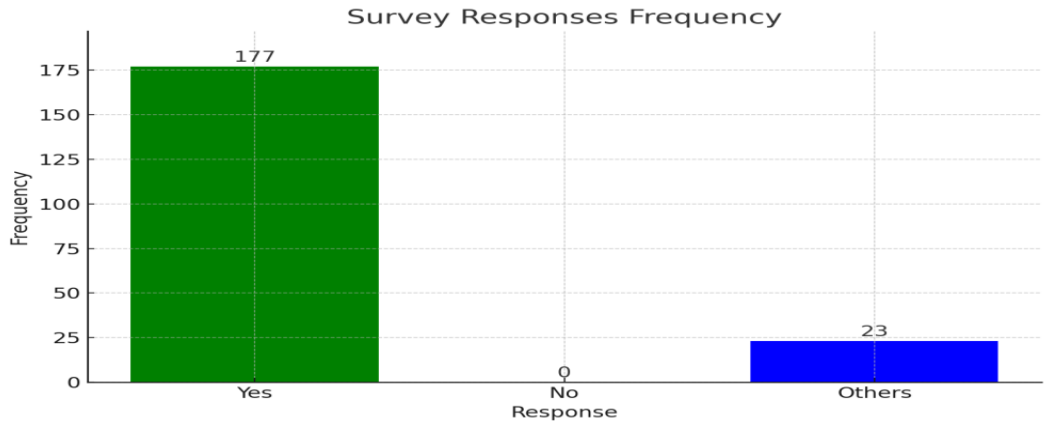
Table Number–6 clearly indicates that out of 200 respondents, only 24.5% believed that solar energy has increased their income. In contrast, 63.5% of respondents stated that solar energy has not led to any increase in their income, while 12% gave uncertain or ambiguous responses. Based on these facts, it becomes evident that the use of solar energy is still largely limited to household activities rather than economic pursuits.

Although access to solar energy is expanding, its economic benefits have not yet effectively reached the majority of people. Unless it is linked with employment and entrepreneurship, it will remain merely a supportive service rather than a tool for economic development.

Table No. 7 Question: Has solar energy positively impacted your standard of living or improved your living conditions?

S. No.	Response	Frequency	Percentage
1.	Yes	177	88.5%
2.	No	00	00.0%
3.	Others	23	11.5%
	Total	**200**	**100%**

Source – Primary Data



Responses –

Serial No. *(1): The impact of solar energy on quality of life has been highly positive. It has provided people with lighting at night, access to drinking water, and a cleaner living environment.*

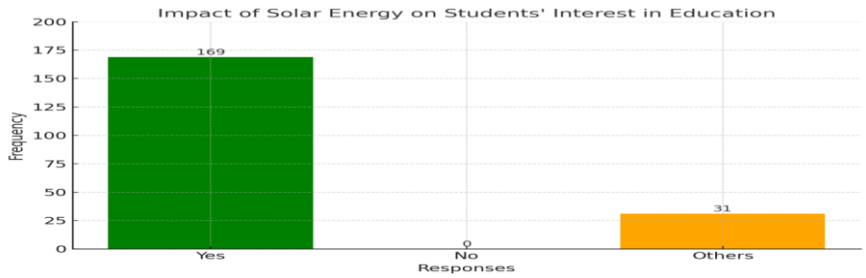
(3): Only the light bulb works, and water supply is functional, which makes household chores easier. However, if other electronic appliances could also run, it would be even better.

Table Number– 7 clearly indicates that out of a total of 200 respondents, **88.5%** believe that solar energy has brought positive changes in their lives. In contrast, **11.5%** chose the 'Others' option, indicating mixed experiences. **None of the respondents gave a negative response ('No')**, meaning that no one believes solar energy has failed to improve their life.The findings clearly suggest that solar energy has played a significant role in enhancing the living standards of tribal communities.

Table Number – 8 Question: Has the impact of solar energy increased interest in education among your children or the students in the community?

S. No.	Response	Frequency	Percentage
1.	Yes	169	84.5%
2.	No	00	00.0%
3.	Others	31	15.5%
	Total	**200**	**100%**

Source – Primary



Responses **–**

(S. No. (1): *Due to the availability of light at night, studying has become possible. Facilities such as online learning and device charging, along with energy availability at home and school, have improved the learning experience.*

S. No. (3): *Although the system is not of high capacity and poses some difficulties, it is still appreciated. Earlier, it was hard to work or move around the village at night due to darkness, but now it's much easier.)*

Analysis –

Table Number–8 clearly indicates that **84.5%** of the respondents believe that the availability of solar energy has increased children's interest in education. **0%** of respondents reported any negative impact — a strong indicator of positive social change. **15.5%** of the respondents fall under the "Others" category, suggesting they have different experiences. Based on the

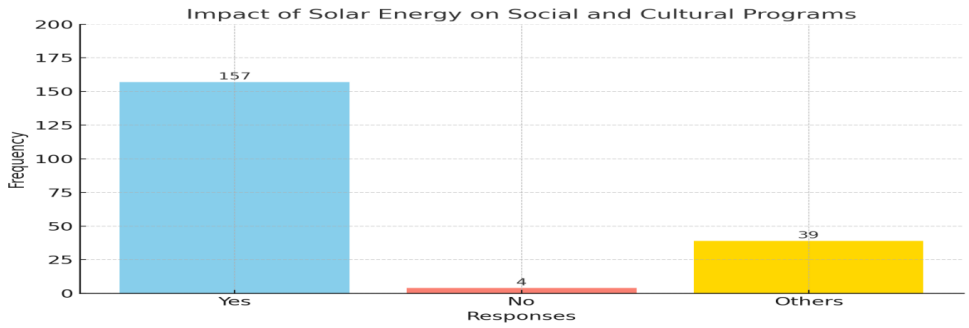
responses, it is evident that solar energy has helped create a supportive environment for education, especially enabling night-time study. No respondent stated that solar energy had a negative effect on education, which indicates that solar energy is emerging as an **undisputedly positive and transformative force**. It is not just a source of energy but is becoming a **means of educational empowerment**, particularly benefiting rural and tribal children by providing a **positive and sustainable learning environment**.

In the future, if solar energy is formally integrated into educational planning, it can further enhance **student retention, academic performance, and motivation**.

Table Number – 9 Question: Has solar energy helped improve your social and cultural programs?.

S. No.	Response	Frequency	Percentage
1.	Yes	157	78.5%
2.	No	04	2.0%
3.	Others	39	19.5%
	Total	**200**	**100%**

Source – Primary



Responses –

(S. No. (3) Others: For large night-time programs, the lighting provided by it is not sufficient. Where the bulb is working, it is fine, but for other areas, generator arrangements have to be made.)

Analysis –

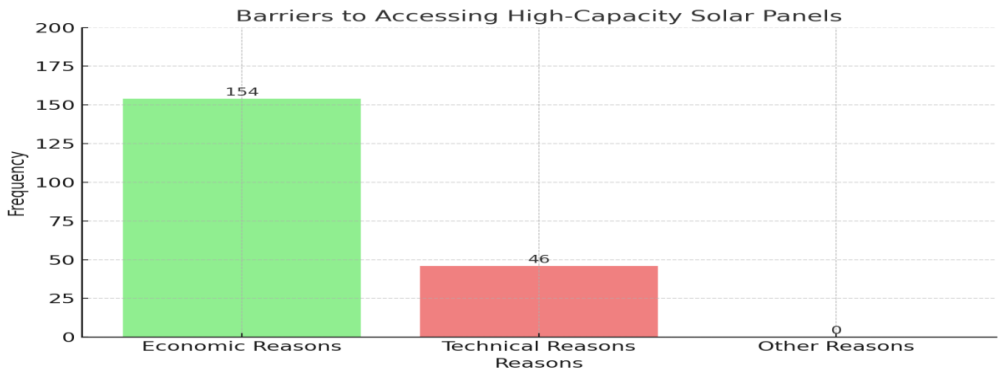
Table Number–9 clearly indicates that **78.5%** of the total respondents believe that solar energy has made their social and cultural events more organized, safe, and impactful. This makes it clear that solar energy is not limited to domestic use only, but has also become a means of community development. Only **2%** of respondents believe that solar energy has not

made any significant contribution, while **19.5%** of respondents have chosen the "Others" category.

Table Number – 10 In your opinion, what are the reasons other tribal communities or individuals are unable or unwilling to benefit from higher-capacity solar energy panels?

S. No.	Reason	Frequency	Percentage
1.	Due to economic reasons	154	77.0%
2.	Due to technical reasons	46	23.0%
3.	Due to other reasons	00	00.0%
	Total	**200**	**100%**

Source – Primary



Analysis –

Table Number–10 clearly indicates that 77% of respondents believe that people are unable to benefit from solar panels due to economic reasons. 23% of respondents think that technical reasons are the barrier. No respondent mentioned any other reasons, which clearly indicates that the issue is primarily centered around economic and technical factors.

DISCUSSION

According to the survey, 67.5% of households are using solar energy mainly for basic lighting, while 73.5% of users consider it effective for household purposes like drinking water, bulbs, and fans. However, the use of solar energy for agricultural purposes remains limited (19.5%), indicating that its multi-dimensional application is still in its early stages.

Social and Educational Impact

Solar energy has contributed positively to social transformation in tribal communities. 88.5% of respondents believe it has improved their quality of life, and 84.5% agree that it has increased children's interest in education. Additionally, 78.5% of participants acknowledged

that it has helped improve social and cultural events. These figures indicate that solar energy has not only ensured energy supply but also strengthened social empowerment and cultural consciousness.

Economic Perspective

Although the social benefits are evident, the economic impact appears mixed. Only 24.5% of respondents believe it has contributed to income generation, whereas 63.5% disagree. This may be due to the limited use of solar energy in livelihood-based activities such as agriculture, small industries, or self-employment.

Barriers and Challenges

Table Number – 10 reveals that 77% of respondents cited economic reasons and 23% cited technical reasons as the main obstacles preventing wider adoption of solar energy. This indicates that unless these two primary barriers are addressed by the government and social institutions, the reach of solar energy will remain limited.

Solar energy has emerged as a ray of hope in tribal communities. It is not only enabling social and educational transformation but also improving the quality of life through clean and sustainable energy. However, greater efforts are needed to realize its economic potential and broader utility. The following interventions are recommended:

1. Financial Support: Subsidies and affordable loans to reduce the cost of solar panels.
2. Technical Training: Awareness and operational training at the village level.
3. Expanded Usage: Integrating solar energy into agriculture, irrigation, and rural enterprises.

If implemented in a planned manner, solar energy can transform both the direction and condition of tribal life—not just as an energy source, but as a catalyst for sustainable development, self-reliance, and social progress.

CONCLUSION AND SUGGESTIONS

Based on the data collected from the survey, it is clear that solar energy has positively influenced multiple aspects of life in tribal communities—particularly domestic life, education, social activities, and overall quality of life.

By ensuring access to lighting, drinking water pumps, and operation of household appliances, solar energy has provided a reliable and sustainable solution. Most respondents described

solar energy as convenient, clean, and useful, with its role in education being especially significant—showing improved interest and consistency in children's studies.
In social and cultural events, its benefit is also visible. Lighting arrangements and device availability have made night-time programs more organized and safer, enhancing community participation and cohesion.

However, the economic results are mixed. While some reported an increase in income, the majority indicated that they have not yet realized direct economic benefits from solar energy. Two major obstacles were identified:

1. *Economic constraints (77%)*
2. *Lack of technical knowledge (23%)*

Due to these barriers, many families are unable to use higher-capacity solar equipment, even though the need and interest exist. This leads to the conclusion that solar energy holds immense potential to empower rural and tribal lives, but to fully realize this, action must be taken on the following points:

KEY FINDINGS

1. Solar energy has improved quality of life, especially in education and household usage.
2. Direct economic benefits are limited and need support through policies and training.
3. Social and cultural life has become more active and self-reliant.
4. Economic and technical barriers are the main hindrances to full success.
5. Through government and institutional efforts, solar energy can be integrated into livelihood, agriculture, and micro-enterprises to expand its benefits.
6. Solar technology will be truly effective for rural and tribal communities only when it is adopted not just as a product but as a community-oriented solution. For this, governments, NGOs, and private institutions must collaborate to offer financial aid, easy credit, and local-level training.

Solar energy is not just an alternative energy source for tribal areas—it is becoming a medium of social transformation, educational advancement, and community empowerment. If aligned properly with policy, training, and resource support, this technology can become a foundation for sustainable and inclusive rural development. Therefore, the result of hypothesis testing in this study is positive.

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