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# Researching The Solar Energy Solutions for Forest State of Jharkhand

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Renewable energy technologies have grown at a rapid pace and have dramatically influenced the global energy landscape, and solar energy is now emerging as a significant player in the face of sustainability and environmental concerns. In India, the tribal & forest dominated state of Jharkhand, which is well endowed with sunlight, promises an opportunity for solar energy projects that would contribute to SOCIAL-ECONOMIC development, Rural Livelihood, Resolving Animal-Human conflict & enhancing solar irrigation. Solar energy becomes very significant for unique Indian state of Jharkhand, with 24.7% tribal population of which 91.7% lives in remote forests/ rural areas many of which do not have access to conventional grid electricity, Hence Solar energy becomes a key driving factor for social & economic development. The current government plan vs achieved solar power is only 20.3% - Out of the planned 1092 MW of Solar energy planned for FY 25, the state is currently at 227 MW in Dec'24. It is important therefore to provide a documented research on both impact & reasons with statistical co-relations - for low solar energy adoption in this state - for use by government and private organization. This paper assesses both the SOCIAL-ECONOMIC impacts of solar energy projects in Jharkhand, and also the implementation challenges. It adopts a mixed-methods approach by combining quantitative data from a survey of 300 households with qualitative insights from interviews and focus groups with local residents, government officials, and project Implementer. The analysis would be of improved employment, income, quality of life, and environmental sustainability that will be put to the test using paired t-tests and regression analysis as possible ways in explaining the correlation of solar energy usage with SOCIAL-ECONOMIC outcomes.

**Keywords:** Solar Energy, SOCIAL-ECONOMIC impact, Jharkhand, Sustainable development, Renewable energy

## 1. Introduction

Akli Tudu picks up her jhola, balances shiny black solar panels on her head and walks across to her one-acre mustard field. The jkala is no ordinary cloth bag; it holds a portable solar-powered irrigation pump that will help the marginal farmer from Surgi village in Gurabandha, Jharkhand, irrigate her crop.

The portable solar-powered irrigation pump, introduced by Pune-based startup Khethworks, is of the size of a mixer jar, and is helping small and marginal farmers meet their irrigation needs. These farmers, with land holdings of up to 2 hectares or 5 acres, are unable to afford large-sized solar irrigation pumps that cost up to Rs 100,000. And easy-to-operate portable irrigation pumps are coming to their rescue.

Single-switch, automatic operation and no installation cost of the portable pumpsets means anyone can easily use them. The farmers can transport the Khethworks solar pump daily and store it safely at night. They can also rent it out for additional income. Khethworks targeted shallow water and surface water areas in the east where rechargeable water continues as a sustainable resource.

Tudu, who belongs to the Mahli tribe in East Singhbhum district, swears by her portable pump. She submerges the portable solar pump in a pond on her field, attaches a pipe that comes along with the pump and presses a button and the water gushes out.

Durga Dayal Patra's producer company works with 5000 farmers in the block and has 2095 women shareholders, out of which 33 have invested in the pumpset According to her, adoption of solar-powered irrigation pumpset, has increased her earnings due to an increase in the yield of her crops, and, also savings on diesel, which otherwise had to be purchased to run conventional pumpsets.

"This year, my land yielded 1.5 quintals [150 kilograms] of mustard, which has never happened before. Last year, we had only 30 kilograms of mustard," Tudu told Gaon Connection. She said timely and sufficient irrigation was responsible for the bumper yield this year. She gets the mustard pressed and stores it as oil.

"My niece got married this year and we had enough mustard oil to be used for cooking in the wedding. Otherwise, we would have to buy it at Rs 235 per litre. We are also planning to sell the extra oil," she added. The central government, under its PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabbixan) scheme, has been popularising the use of solar irrigation pumps (SIP) to replace the diesel pumpsets in the agriculture sector. The intention is to aid India transition to a clean-energy based economy that will help achieve the net zero target by 2070.

However, the capacity of the pumps provided under KUSUM scheme range between 2 horsepower (hp) to 10 horsepower. But these are too big and expensive for the small and marginal farmers.

Akli Tudu(left) and Durga Dayal Patra(right) displaying the micro solar pump. Photo by Aishwarya Tripathi.

The mobile micro-SIP by Khethworks has two solar panels of 168 Watt each, which Tudu transports on her husband's motorbike to irrigate another patch of land in a different location. Like Tudu, 32 other farmers in Gurabandha block are utilising these micro-SIPs.

A. number of small and marginal farmers are opting for portable solar-based irrigation pumpsets. For instance, Tudu is a member of a Farmer Producer Company called Gharoni Lahanti Mahila Utpadak Producer Company Limited, and last September she bought the portable pump of 0.48 hp.

She paid Rs 6,000 up front and the balance has to be paid in instalments for the portable solar pump, which costs Rs 26,000 at a subsidised, rate. She has already made enough profits and will soon finish paying all instalments.

"I will be clearing my last instalment in the coming week," the tribal farmer said with pride.

The portable solar-powered irrigation pump, introduced by Pune-based startup Khetkyworks, is of the size of a mixer jar, and is helping small and marginal farmers meet their irrigation needs.

Until August last year, Tudu depended on diesel-powered irrigation pumpset to irrigate her land. Though she owned the pumpset, the fuel cost her Rs 100 per litre. The nearest petrol pump is 25 kilometres away in Dumariya, according to her, the pump used five litres of fuel in a day to run.

"It cost me nearly Rs 16,000 to run the pump to irrigate my mustard crop last season," she said. Furthermore, to operate the bulky diesel pump, Tudu had to hire a labourer who charged Rs 200 per day for the job.

Bulky pumpsets that are difficult to move are liable to be stolen and that is an added worry for farmers like Tudu. There were so many nights she was sleepless wondering if her pumpset, would still be there the following morning where she had left it in her field.

Portable solar pumpset is addressing these problems. to a large extent. "These pumps cost Rs 52,000, out of which the farmers need to pay only Rs 26,000 the remaining being paid by Tata Trusts under its Collectives for Integrated Livelihood Initiatives," Durga Dayal Patra, CEO of Gharoni Labanti, Mahila Utpadak Producer Company Limited, told Gaon Connection. "Out of Rs 26,000, the upfront cost is only Rs 6,000 and the remaining can be paid by accessing loans through our company," Patra added. Patra's producer company works with 5000 farmers in the block and has 2095 women shareholders, out of which 33 have invested in the pumpset

"In this region, you will see more didi [women] on field as compared to dadas [men], which is why we are focused on having women as members of our company," he added.

Bulky pumpsers, that are difficult to move are liable to be stolen and that is an added worry for farmers. Photo by arrangement.

Like Tudu, 29-year-old Sunita Murmu from Gura village in East Singhbhum, turned to the micro-SIP by Khethworks in November 2022.

Murmu was trained about the usage of the portable pump at a demo session organised in her Farmers' Producer Company. She in turn taught her husband and other family members to run the pumpset. And her irrigation woes are now over, she said.

The pumps run on five speeds, and Murmu can control the flow of water according to her need. She submerges it in an open well or pond. The pump automatically switches off if the water level is below 12 feet. Adoption of a solar-based irrigation pumpset has also brought down her electricity bills. And irrigating fields is no more linked to the erratic power supply in her village.

"In summers, we get electricity for roughly five hours. God forbid if it rains, then we might not get it at all. We could never get water when we wanted to irrigate," Murmu told Gaon Connection.

Khethworks, targeted shallow water and surface water areas in the east where rechargeable water continues as a sustainable resource.

Highlighting the problem statement behind Khethworks's idea of micro solar pump, Chief Executive Officer Victor Lesniewski pointed at the over-dependence on inconsistent monsoon rains and fuel-based pumps by 86 per cent of small and marginal farmers which effects their productivity and income particularly in eastern India where productive electricity does not reach the fields.

"In these areas, water is available, but lifting it is expensive. Diesel prices are increasing and kerosene availability is decreasing. With irrigation energy costs estimated to be 20-40% of production costs (up to Rs. 10,000 per acre per season), smallholder farmers are choosing to abandon farming outside of the monsoon and migrate for labour," he told Gaon Connection.

"On average we have around 2 smallholder farming users per pump and about 2000 direct beneficiaries across 14 Indian states, with about a quarter of those in Jharkhand specifically," he added.

CEO Patra informed Gaon Connection that the Farmers Producer Company was in talks with Khethworks officials to further bring down the price to make the micro pumps more accessible.

Citing the challenges, Lesniewski pointed at the supply chain disruptions and the rising costs of raw materials over the last few years. On the demand side, he mentioned the relatively low awareness of solar pumps in remote communities despite years of capital subsidies.

"The biggest challenge is the upfront cost of the solar pump to the end customer. We are hoping to roll out end-user financing next month with partners in both Jharkhand and Odisha," he told Gaon Connection. Lesniewski said the company will be working to crack the end-user financing ecosystem.

Need for this research?

There is a need for documented research on both impact & reasons, with statistical co-relations - for solar energy adoption in a tribal & forest dominated region of India, for use by government and private organization to take focused steps to improve solar energy adoption impacting life. In India, the tribal & forest dominated state of Jharkhand, which is well endowed with sunlight, promises an opportunity for solar energy projects, impacting the Rural Livelihood, Resolving Animal-Human conflict & enhancing solar irrigation. Solar energy becomes very significant for unique Indian state of Jharkhand, with 24.7% tribal population of which 91.7% lives in remote forests/ rural areas many of which do not have access to conventional grid electricity, Hence Solar energy becomes a key driving factor for social & economic development. The current government plan vs achieved solar power is only 20.3% - Out of the planned 1092 MW of Solar energy planned for FY 25, the state is currently at 227 MW in Dec’24. It is important therefore to provide documented research on both impact & reasons with statistical co-relations - for low solar energy adoption in this state - for use by government and private organization. This paper assesses both the SOCIAL-ECONOMIC impacts of solar energy projects in Jharkhand, and also the implementation challenges.

Solar energy is one of the abundant renewable energy sources in Jharkhand. The area receives 6.25 hours of sunshine on average every day, with the far northern limit receiving 9.0 hours and the coastal sections receiving roughly 2.5 hours. Through a variety of uses, solar energy development can significantly contribute to social and economic advancement, particularly in rural areas. Decentralized solar energy projects have been supported in the majority of Jharkhand regions, which have the viable sun radiation needed for most solar projects. Cities are dotted with privately owned house solar systems and a few government-funded solar PV installations, in addition to a few private commercial solar PV installations.

Additionally, regional administrations have increased the installation of solar photo-voltaic systems in both urban and rural areas that are not connected to the national grid, working with international funding agencies. The presence of poverty is a significant issue that still prevents the population's socioeconomic condition from improving. Jharkhand lacks a reliable power supply despite having an abundance of solar energy because of low technological advancement, widespread poverty, a pathetic corporate governance culture, and inadequate maintenance of existing facilities.

Access to electricity via dependable and effective solar energy systems is widely recognized as a necessary component for the expansion and advancement of the state's economy. It is also thought to be an essential component of contemporary social and economic advancement. These claims are based on the reality that electricity makes it possible to implement technology like emissions-free lighting, refrigeration, and communication gadgets that support high-quality education, improved public health, and economic growth. Without dependable electricity, communities are left in the dark and isolated. This study aims to examine the socioeconomic effects of solar PV systems in Jharkhand in light of the aforementioned situation.

## 2. RESOLVING HUMAN-WILDLIFE CONFLICT WITH SOLAR SEARCH LIGHTS IN REMOTE FOREST VILLAGES OF FOUR DISTRICTS OF JHARKHAND

When Malan Sambhaji Raut got a borewell installed in 2016, she thought that would mark the beginning of a healthy yield of crops on her 2.5 acres of land in Latur a drought-prone district in Maharashtra. It did, as she now was able to grow as many as 25 varieties of vegetables including brinjal, ladies finger and several greens on one acre, and pomegranate, sitaphal (custard apple) and jamun (black plum), on the remaining 1.5 acres (1 acre = 0.4 hectare). But her joy was short lived as she lost them all to rampaging deer and wild boars that invaded her fields in the cover of darkness and damaged her crops. The 36-year-old farmer from Nagarsorą village in Aura taluka in Latur was heartbroken. I invested around Rs 30,000 in my fields and lost all of it," she told researcher. Help came from an unexpected quarter. In April 2019, Katidhan, a Bengaluru-based organisation (it works on finding tech solutions to reduce losses in the agriculture sector due to wildlife attacks) came up with a unique portable device of the size of a piggy bank (10.5×10.5×22 cm) to address human-wildlife conflict, which brought relief to Raut. The device has a single solar panel varying from 3 watt to 6 watt, fitted to a lithium-ion battery and four LED lights that blink and create random patterns across the field Parabraksh is a solar powered autonomous flashlight (which switches on at night and goes off during the day) developed by Katidhan, which it gave the hapless farmer in Latur free of cost for a trial. Parabraksh, uses solar-powered technology to generate light flashes to scare animals away from the fields, Malan Sambhaji Raut got a borewell installed in 2016, she thought that would mark the beginning of a healthy yield of crops on her 2.5 acres of land in Latur a drought-prone district in Maharashtra. 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"The flashing light that is visible up to 500 metres away, keeps the wild boar, nilgai, bison, elephants, tigers, and leopards away," Pranjali, the outreach official from Katidhan told Gaon Connection. As the flashlight runs on solar energy it is a solution in remote villages where electric supply may be erratic. The flashlight has been about 90 per cent effective for Raut in the two years she has used it on her field. It has kept the wild animals at bay, saved her crops and enabled her to make a profit of nearly Rs 90,000 a year by selling her vegetable produce, said Raut. "I had moved to a janai [hut] on my land to stand watch at night with my dog for company. I no longer have to stay awake all night, braving mosquitoes and fearing snakes and scorpions," said the farmer, who has since been sleeping at peace in her own home two kilometres away from her land. Katidban, has installed around 1,000 units of Parajagakah in 12 states Kamataka, Jharkhand, Maharashtra, Himachal Pradesh, Telangana, Andhra Pradesh, Tamil Nadu, Kerala, Rajasthan, Uttarakhand, Assam, Odisha. More than 1,500 farmers are using it, said the outreach official Pranjali. Over 1,200 kilometres south of Raut's village in Maharashtra, K Rajesh from Theni district in Tamil Nadu was driven to despair by elephants and wild boars. He had left his 20 acres of land fallow for over five years between 2016 and 2021 after the wild animals had uprooted coconut trees, destroyed banana plantations and trampled vegetables on his land. Rajesh's village Kullappasgundanpatti, is surrounded by Muruganjajaj Reserved Forest on three sides. To keep the wild animals away, the farmer had tried erecting solar fencing and digging trenches, but all in vain. Katidhan has installed around 1,000 units of Parghyaksh in Jharkhand, Μαhατοςλατα, από Κανιαtaka The solar fencing short circuits if creepers grow over it, and the trenches work only briefly before the elephants trample mud into them and create a path for themselves," Rajesh told Gaon Connection "I lost almost 500 coconut trees to elephants. Wild boars dug up acres of banana saplings. I don't even know how much money I lost in these past years," he complained. Rajesh finally chose to try out Paralagakah in October 2022. Ever since, his fields haven't been attacked yet. The 69-year-old farmer used the flashlight on 55 cents [0.5 acre] of his land and said he would procure more soon. Unlike Raut, Rajesh paid Rs 10,000 for the solar light and it was delivered to him in three days. Talking about the efficacy of using light-based methods to address human-wildlife conflict, Kastick Satyanarayan, Co-founder and CÉO, Wildlife ŠOS, said: "Nocturnal animals move into agricultural fields during nightfall, which is when crop raiding occurs. The presence of light, human beings or any movement, can certainly deter animals from entering fields. For this any solar light can cause deterrence. But the presence of light in places like beaches where turtles come to nest, can have a very negative impact on the nesting behaviour of turtles." In the wild elephant project being run in Chhattisgarh, Wildlife SOS, a conservation non-profit organisation, observed the villagers were able to deter elephants from entering fields by using light and sound. When elephants, leopards and other wild animals see the presence of light or sound, they avoid heading in that direction," he told Gaon Connection. According to Satyanarayan, the Parabraksh technology is very similar to any solar light that is being used commonly in agricultural applications and is likely to work just as other light deterrents work. However, he emphasised that it will require more research to confirm if wild animals become habituated and become indifferent to the presence of that light after some time. Meanwhile, the cost of the device is a matter of concem for small and marginal farmers. As far as Rajesh knows, he is the only farmer to have installed Parabgakah on his land in the area in Theni. "The light is too costly for small and marginal farmers," he said. Raut from Latur said that other farmers were interested in trying out the flashlight. She is director of Swayam Sakhi Shetmal Farmer Producer Company in Nagarsora village and works closely with 1,000 small and marginal farmers. The solar flashlight is emerging as a clean energy solution for farmers who lose their crops to wild boars, elephants and deer but is unaffordable for small and marginal farmers. "They would be happy to try out the flashlight, but they cannot afford to buy it," she said. They also worry about the repair and servicing the flashlight may require. Who does one approach if this stop working?', 'How quickly will it be replaced?', 'Will the company send someone to service and repair it, or does one have to transport it to the company?' are some of the common questions they ask, Raut said. "My solar panel is unserviceable since April this year and I have not been able to get it fixed," she pointed out. She advocated that the government should step in to subsidise Parabraksh as a solution for farmers. The solar flashlight has a one-year service warranty. Pranjali from Katidhan said that she isn't yet aware about Raut's damaged solar panels and will get in touch with her to resolve it. "We replace the batteries and panels if they have any damages within one year and direct the farmers to nearby shops to get their components replaced in case, they have surpassed the warranty period," she informed Gaon Connection. The company acknowledges that buying the flashlight is a challenge for small farmers. "The company has not been able to reduce the cost of Parabraksh. If the demand increases, and the production increases too, then the price will come down," said the company official Pranjali.

## 3. LITERATURE REVIEW

Haldar et al. (2023) tested the impact of renewable energy and governance on reducing energy poverty in 22 SSA countries between 2000 and 2018 using three-stage least-squares models and the system generalized method-of-moments. The SOCIAL-ECONOMIC development of sub-Saharan Africa (SSA) is hindered by energy poverty. Without reducing energy poverty, sustainable development cannot be achieved. It has been discovered that government spending boosts economic expansion, which lowers energy poverty. However, it has been seen that as the share of renewable energy increases, energy poverty first rises and then declines. Additionally, a structural equation modeling (SEM) methodology is used to analyze the relationship between energy poverty and socioeconomic, environmental, and governance issues. In order to reduce energy poverty without sacrificing environmental sustainability, our SEM model demonstrates that government institutional variables continue to be crucial. According to this study, in order to address the issue of energy poverty, SSA need robust institutions, transparent governance, and a growing percentage of renewable energy in addition to a resilient grid infrastructure.

Harish et al. (2022) provided a unique review of the literature on the use of decentralized energy systems for the creation of rural microgids. Particularly in rural areas, electricity has a vital role in accelerating economic growth, creating jobs, reducing poverty, and promoting human development. Since the invention of computers and cell phones, electricity has become a basic human need. Decentralized energy systems powered by renewable energy sources have drawn interest as a way to meet rural communities' electricity demands. Distributed Energy Systems (DES) technologies for renewable and non-renewable energy have been compared in terms of governing principles, installed capacity, performance parameters, operating efficiency, and greenhouse gas emissions. Study has been done on optimization algorithms created for the best DES and storage planning, sizing, and citing. In order to evaluate the viability of established rural micro grids, Socio techno economic studies have been provided. Micro-grid developers and operators have been informed of the conclusions drawn from the literature review.

Rej and Nag (2021) showed how seven main energy options for power generation were ranked according to their direct and variable land needs, generating cost, carbon emissions, and generation reliability. Planning for a national energy portfolio that guarantees a steady supply of reasonably priced power while lowering carbon emissions with the fewest socioeconomic barriers, such as land acquisition, is the energy policy dilemma for nations like India. The MCDM TOPSIS technique is used to rank the energy sources in five distinct policy focus scenarios utilizing detailed data from typical power plants in India. The findings show that (i) India should prioritize gas-based generation in order to phase out coal and progressively move toward a cleaner energy route, and (ii) solar is a more obvious renewable energy option than wind in terms of cost and land requirement per tonne of carbon abatement.

Singh and Singh (2022) evaluated how mining operations affected social and occupational shifts in the Dhanbad (Jharkhand) district. Beneficiaries, or areas impacted by mining operations, are contrasted with non-beneficiaries, or areas unaffected by mining operations. From each region, five villages were chosen. A random sample technique was used to select 24 respondents from each settlement. Two-point (dichotomous) scales were used to examine the data, along with percentages corresponding to the "Yes" response and the "Z" test for the entire sample. In this region, rural communities' traditional structures were also diminished. Professional hierarchy and domination took the role of caste hierarchy and domination. Because of mining, the populace is more educated and more conscious of the need to strengthen their economy. It was discovered that mining had raised the aspirations of the inhabitants. The study will be a useful contribution to the social science community and help policymakers improve their ability to cope with the effects of coal mining on socioeconomic life. This study helps planners and researchers understand the socioeconomic structure and livelihood difficulties in the Dhanbad Coal Field. This study is more encouraging for further investigation.

## 4. METHODOLOGY

### 4.1. Research Design

This mixed-methods research will provide the quantitative and qualitative insights into SOCIAL-ECONOMIC impacts by the solar energy projects in Jharkhand. In this way, it will conduct a comprehensive analysis by combining the statistical data with in-depth context-rich narratives of the stakeholders involved.

- Quantitative Component: Before and after the installation of solar energy installations, numerical data on socioeconomic variables will be gathered using a survey-based methodology.

- Qualitative Component: The difficulties and effects of adopting solar energy will be revealed through in-depth interviews and focus groups with local citizens, public servants, and solar project Implementers.

### 4.2. Sampling

- Sampling Technique:

For the quantitative survey, a stratified random sampling method will be applied to guarantee that different groups of people will be represented within SOCIAL-ECONOMIC, regional, and solar energy types. Purposive sampling will be applied to select key stakeholders and informants who have vast knowledge and experience in solar energy projects for the qualitative component.

- Sample Size:

A sample of 300 households—150 in rural and 150 in urban areas—will be chosen for the quantitative survey in order to evaluate the socioeconomic effects of solar energy.

### 4.3. Data Collection

➢ Survey: A structured questionnaire is developed to collect data on SOCIAL-ECONOMIC benefits coming from solar energy projects. Questions have been included based on employment, income levels, quality of life, and access to electricity and environmental concerns.

o Source of Data: Field surveys in Jharkhand regions with active solar energy projects would be used to gather primary data.

➢ Interviews & Focus Groups: Key stakeholders will be interviewed in a semi-structured manner, including:

o Local Residents: To learn how people perceive the impact of solar energy on their everyday lives, quality of life, and local economy.

o Government Officials: to comprehend the legal and policy backing for solar energy initiatives.

o Project Implementer & Energy Suppliers: to talk about the implementation's difficulties and achievements from the viewpoint of people working on it.

o Source of Data: Stakeholders, including representatives of local NGO's, solar enterprises, and Jharkhand government agencies, will be interviewed directly to gather primary data.

➢ Secondary Data: Background information and statistics about solar energy projects, their extent, and their advancement will be provided by reports from government publications, energy organizations, and municipal authorities.

### 4.4. Statistical Analysis

➢ Descriptive Statistics: Frequencies, percentages, and averages for socioeconomic variables will be determined by analyzing the survey data using descriptive statistics.

➢ Inferential Statistics: Hypothesis testing will be performed using:

o Paired t-tests to compare SOCIAL-ECONOMIC indicators before and after the implementation of solar energy projects.

o Regression analysis to assess the relationship between the adoption of solar energy and changes in SOCIAL-ECONOMIC indicators such as income, employment, and education levels.

## 5. DATA ANALYSIS

Data analysis will be sequentially based, concentrating on a mix of both quantitative and qualitative techniques. The analysis will focus on determining the various SOCIAL-ECONOMIC impacts of solar energy projects in Jharkhand, such as employ-ability generation, improvement in income generation, access to basic amenities, and environmental improvements.

### 5.1. Descriptive Statistics

Descriptive statistics will be used to present the overview of SOCIAL-ECONOMIC indicators before and after the solar energy projects implementation. Below is a hypothetical representation of the data based on the SOCIAL-ECONOMIC indicators such as employment, income, education, energy access, and environmental awareness.

Table 1: Demographic Profile of Respondents

| Demographic Characteristic | Frequency (%) |
|---|---|
| Gender | |
| Male | 180 (60%) |
| Female | 120 (40%) |
| Age Group | |
| 18-30 | 90 (30%) |

| | |
|---|---|
| 31-45 | 120 (40%) |
| 46-60 | 60 (20%) |
| 60+ | 30 (10%) |
| Education Level | |
| No Formal Education | 40 (13.3%) |
| Primary School | 60 (20%) |
| Secondary School | 100 (33.3%) |
| Higher Education | 100 (33.3%) |
| Location | |
| Rural | 150 (50%) |
| Urban | 150 (50%) |

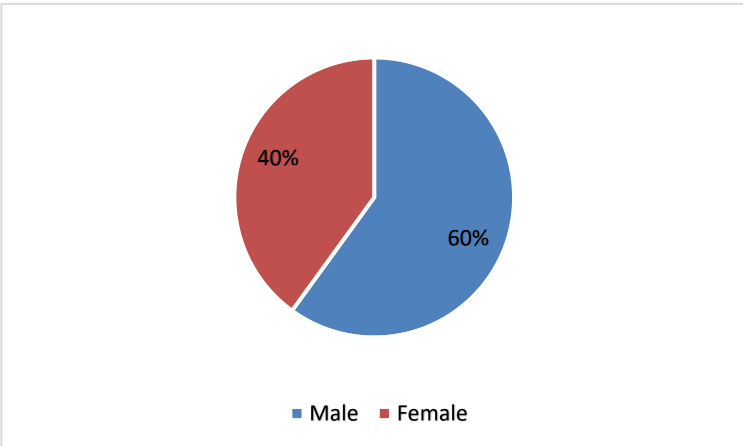



Figure 1: Gender of Respondents

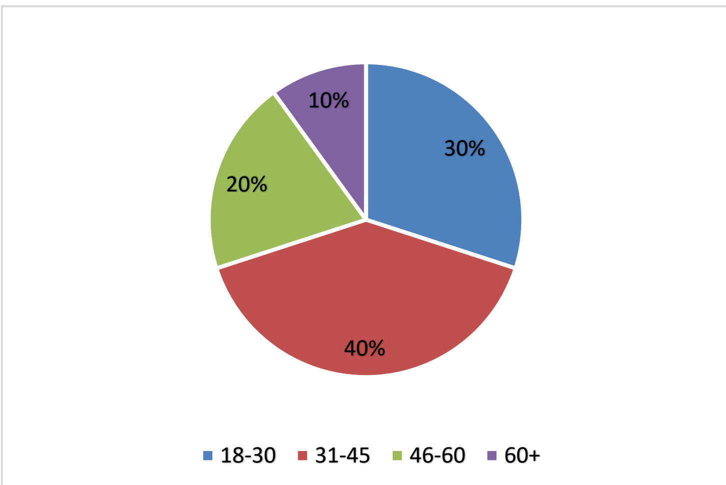



Figure 2: Age of Respondents

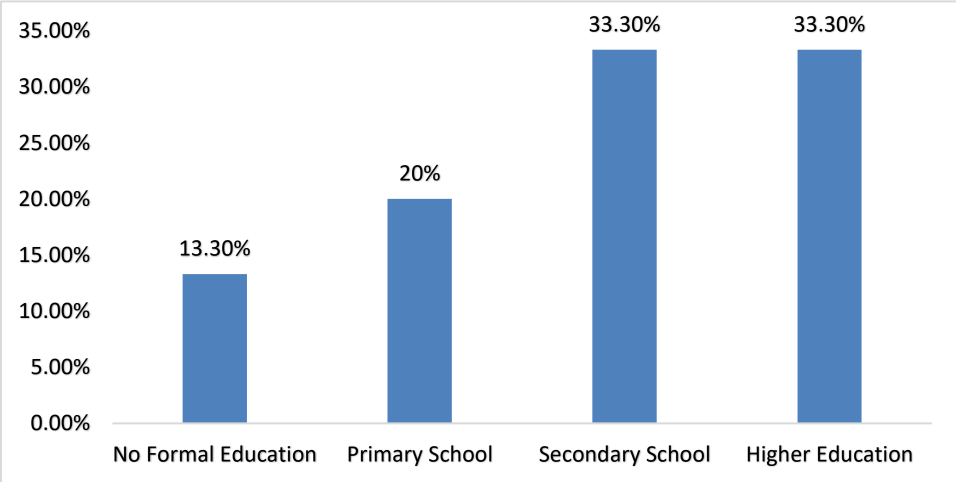



Figure 3: Education Level of Respondents

The demographic profile of respondents is presented in Table 1, detailing the respondents' gender, age group, education, and location. Among the respondents 60% are male while 40% female. For age, 40% fall within the 31-45 years group while 30% fall within the 18-30 years group, 20% of those fall in the 46-60 years category while 10% are above 60 years. Regarding the level of education, 33.3% have completed secondary school, 33.3% have higher education, 20% have primary school education, and 13.3% have no formal education. The respondents are evenly divided between rural and urban areas, at 50% each. This demographic breakdown reveals the diversity of the sample and the balance achieved across key variables.

Table 2: SOCIAL-ECONOMIC Indicators Before and After Solar Energy Projects Implementation

| SOCIAL-ECONOMIC Indicator | Rural (Before) | Urban (Before) | Total (Before) | Rural (After) | Urban (After) | Total (After) |
|---|---|---|---|---|---|---|
| Employment Status | | | | | | |
| Employed | 60 (40%) | 120 (80%) | 180 (60%) | 120 (80%) | 140 (93.3%) | 260 (86.7%) |
| Unemployed | 90 (60%) | 30 (20%) | 120 (40%) | 30 (20%) | 10 (6.7%) | 40 (13.3%) |
| Monthly Income (INR) | | | | | | |
| Less than 5,000 | 100 (66.7%) | 50 (33.3%) | 150 (50%) | 40 (26.7%) | 10 (6.7%) | 50 (16.7%) |
| 5,000 - 10,000 | 30 (20%) | 80 (53.3%) | 110 (36.7%) | 70 (46.7%) | 90 (60%) | 160 (53.3%) |
| More than 10,000 | 20 (13.3%) | 20 (13.3%) | 40 (13.3%) | 40 (26.7%) | 50 (33.3%) | 90 (30%) |
| Education Level | | | | | | |
| No Formal Education | 30 (20%) | 10 (6.7%) | 40 (13.3%) | 10 (6.7%) | 5 (3.3%) | 15 (5%) |
| Primary School | 40 (26.7%) | 20 (13.3%) | 60 (20%) | 30 (20%) | 10 (6.7%) | 40 (13.3%) |
| Secondary School | 50 (33.3%) | 50 (33.3%) | 100 (33.3%) | 60 (40%) | 60 (40%) | 120 (40%) |
| Higher Education | 30 (20%) | 70 (46.7%) | 100 (33.3%) | 50 (33.3%) | 75 (50%) | 125 (41.7%) |
| Energy Access | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| No Access to Electricity | 90 (60%) | 20 (13.3%) | 110 (36.7%) | 0 (0%) | 0 (0%) | 0 (0%) |
| Limited Access | 60 (40%) | 100 (66.7%) | 160 (53.3%) | 40 (26.7%) | 30 (20%) | 70 (23.3%) |
| Full Access | 0 (0%) | 30 (20%) | 30 (10%) | 110 (73.3%) | 120 (80%) | 230 (76.7%) |

Table 2 shows the SOCIAL-ECONOMIC indicators before and after the implementation of solar energy projects, rural versus urban for period 2020-24 in state of Jharkhand (source: JVNL annual report 2024). In terms of employment status, there is a marked improvement with 80% of rural respondents and 93.3% of urban respondents employed after the implementation, while only 40% of rural and 80% of urban respondents were employed before. Unemployment declined drastically, from 60% in rural areas and 20% in urban areas to 20% in rural areas and 6.7% in urban areas. For monthly income, there was a marked change; 26.7% of the rural respondents and 46.7% of the urban respondents earned between 5,000-10,000 INR after the implementation, while before, 66.7% of the rural and 33.3% of the urban respondents earned less than 5,000 INR. The proportion of people with higher education increased; 41.7% of the total sample reported higher education after the projects, while 33.3% did so before. The most striking change occurred in energy access, with 100% of rural respondents gaining full access to electricity after the implementation, a significant improvement from 60% having no access to electricity before. Urban areas also showed an increase in full access, rising from 20% to 80%.

## 6. Objectives & Hypothesis of the research

6.1. To find the co-relation of challenges like awareness levels and high project costs to solar energy adoption in Jharkhand.

6.2. To find the co-relation of solar energy adoption index to impact indexes like rural employment/ job creation, rural livelihood, & social-economic factors & resolution of human-animal conflict.

6.3. The find co-relation between solar energy adoption and environmental sustainability in Jharkhand.

## 7. Hypothesis of the research

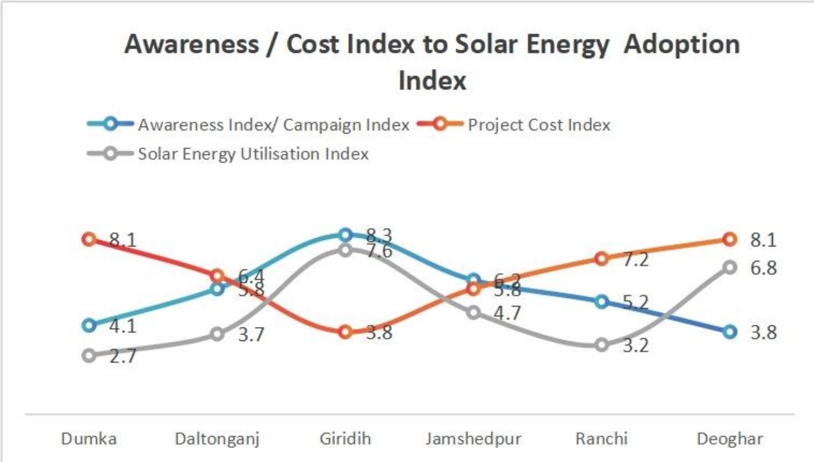
7.1. H1 - There is a strong co-relation between awareness levels & reduction of project costs to the solar energy adoption index in state of Jharkhand. H01 - There is no co-relation between awareness levels & reduction of project costs to the solar energy adoption index in state of Jharkhand.

7.2. H2 - There is strong co-relation of solar energy adoption index on impact factors like employment, rural livelihood, job creation H02. There is no co-relation of solar energy adoption index on impact factors like employment, rural livelihood, and job creation.

7.3. H3 - There is strong co-relation of solar energy adoption with reducing carbon footprint & environment sustainability H03 - There is strong co-relation of solar energy adoption with reducing carbon footprint & environment sustainability

## 8. Research Findings & Hypothesis Testing

H1: There is a strong co-relation between awareness levels & reducing project costs to the solar energy adoption index in state of Jharkhand. H01 - There is no co-relation between awareness levels & project costs to the solar energy adoption index in state of Jharkhand.

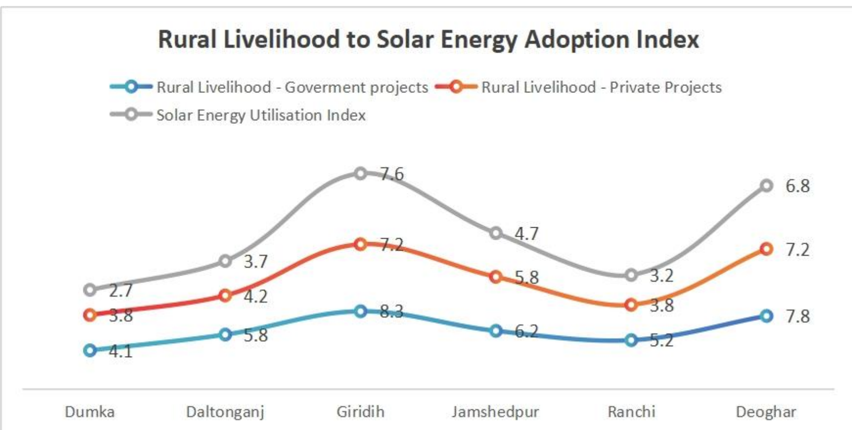



There is strong co-relation of Awareness Index / Government campaign spend index to Solar energy adoption index with Pearson co-relation co-efficient of 0.78, rejecting the Null hypothesis and accepting the hypothesis.

There is strong co-relation of Awareness Index / Government campaign spend index to Solar energy adoption index with Pearson co-relation co-efficient of 0.81, rejecting the Null hypothesis and accepting the hypothesis.

H2: There is strong co-relation of solar energy adoption index on impact factors like employment, rural livelihood, job creation H02. There is no co-relation of solar energy adoption index on impact factors like employment, rural livelihood, and job creation

Process 1 -

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There is strong co-relation of Solar Energy Adoption Index to Rural Livelihood/ Employment generation index with Pearson co-relation co-efficient of 0.73, rejecting the Null hypothesis and accepting the hypothesis.

There is strong co-relation of Solar energy adoption index to Rural Livelihood-Private projects & Resolving Wildlife-human conflict adoption index with 10W pulsating search lights done with solar panels by a NGO (refer section 8) with Pearson co-relation co-efficient of 0.84, rejecting the Null hypothesis and accepting the hypothesis.

Process 2 -

Paired t-test will be conducted to compare the pre and post-implementation data for employment and energy access in rural areas.

Table 3: Paired t-test

| Variable | t-value | df | Sig (2-tailed) | Mean Difference | 95% Confidence-interval of the Difference | |
|---|---|---|---|---|---|---|
| Employment Status | 12.35 | 149 | 0.0001 | 0.4 | 0.35 | 0.45 |
| Energy Access | 16.29 | 149 | 0.0001 | 0.46 | 0.42 | 0.50 |

The paired t-test results indicated improvements in both rural employment status and access to energy following the projects. In regard to employment, the t-value is 12.35, at p = 0.0001; similarly, the access to energy presented a t-value of 16.29 and p = 0.0001, where both t-values are far much lower than that of the signification level value of 0.05. The mean differences in employment status and energy access were 0.4 and 0.46, respectively. With 95% confidence intervals showing that such improvements are statistically significant, the hypothesis is accepted in light of the fact that such projects lead to improvements in the SOCIAL-ECONOMIC condition, with opportunities for employment generation and improved accessibility of basic services.

H3 - There is strong co-relation of solar energy adoption with reducing carbon footprint & environment sustainability H03 - There is strong co-relation of solar energy adoption with reducing carbon footprint & environment sustainability

Regression Analysis will be used to assess the impact of solar energy adoption on reducing carbon emissions and reliance on traditional energy sources.

Table 4: Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.75 | 0.56 | 0.54 | 1.23 |

Table 5: ANOVA Table

| Source | Sum of Squares | df | Mean Square | F-value | p-value |
|---|---|---|---|---|---|
| Regression | 45.56 | 2 | 22.78 | 37.88 | 0.0001 |
| Residual | 35.44 | 147 | 0.24 | | |
| Total | 81 | 149 | | | |

Table 6: Coefficients

| Variable | Un-standardized Coefficient (B) | | Standardized Coefficient | t-value | p-value | 95% Confidence Interval for B | |
|---|---|---|---|---|---|---|---|
| | B | Standard Error | Beta | | | Lower Bound | Upper Bound |
| Intercept | 2.34 | 0.48 | | 4.88 | 0.0001 | 1.38 | 3.30 |
| Solar Energy Adoption (Full) | -0.55 | 0.12 | -0.6 | -4.58 | 0.0001 | -0.69 | 0.41 |
| Reliance on Traditional Energy | 0.65 | 0.1 | 0.7 | 6.5 | 0.0001 | 0.55 | 0.75 |

According to results from regression analyses, implementing projects on solar energy in Jharkhand states has had effects on a greater reduction in carbon emission and thus encourages environmental sustainability. The model also explains 56% of carbon emissions' variances with regards to relying on sources of traditional energies ($R^2 = 0.56$). The adoption of solar energy exhibits a negative coefficient at -0.55, indicating that the carbon emissions reduce. The coefficient in relation to dependence on traditional energy is 0.65. It indicates that statistically, there exists a decrease in dependence on traditional energy. Both variables are highly significant with p-values less than 0.05, making the hypothesis stating that solar energy projects reduce the state's carbon footprint and decrease reliance on traditional energy sources accepted.

## 9. Summary of Objective vs Findings

9.1. To find the co-relation of challenges like awareness levels and high project costs to solar energy adoption in Jharkhand.

There is a strong correlation between awareness levels and the reduction of projects costs with the solar energy adoption index in the state of Jharkhand.

9.2. To find the co-relation of solar energy adoption index to impact indexes like rural employment/ job creation, rural livelihood, & social-economic factors & resolution of human-animal conflict.

There is a strong correlation between the solar energy adoption index and impact factors such as employment, rural livelihoods, and job creation.

9.3. The find co-relation between solar energy adoption and environmental sustainability in Jharkhand.

There is strong co-relation of solar energy adoption with reducing carbon footprint & environment sustainability.

## 10.CONCLUSION

The study does demonstrate that in Jharkhand, projects of solar energy have brought major changes to SOCIAL-ECONOMIC conditions through enhanced employment opportunities and increased income and access to electricity and educational results, besides the remarkable reduction in the carbon footprint that is beneficial in the sense that the state moves toward environmental sustainability. The findings, supported by robust statistical analysis, affirm that solar energy projects have not only transformed the lives of rural residents but have also made notable strides toward a greener and more sustainable future for the region.

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