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Solar Energy and Smart Village Development in Selected Areas of North Karnataka

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Abstract: The concept of sustainable rural development has gained significant attention in recent years, particularly in developing countries like India. Smart villages aim to enhance the quality of rural life through improved infrastructure, renewable energy integration, digital services, and efficient governance. Among renewable sources, solar energy plays a crucial role due to its availability, environmental benefits, and suitability for decentralized applications. This study examines the role of solar energy in the development of smart villages, focusing on awareness levels, applications, benefits, and challenges. Primary data were collected using a structured questionnaire, and statistical analysis was carried out using the chi-square test. The findings indicate a positive perception of solar energy among rural respondents and highlight its potential as a backbone for smart village development. The main aim of the article is to present the concept of a smart village as an instrument for the implementation of public tasks in rural areas. The theoretical basis of the smart village concept is the basic point of reference. The implementation of the assumptions of the smart village concept in Poland gives municipalities the possibility of an innovative approach to the implementation of local public services. The authors demonstrated that there is no universal model for each unit. A smart village will implement solutions tailored to economic, social, cultural, and natural conditions.

Keywords: *Solar Energy, Smart Village, Renewable Energy, Rural Development, Sustainability.*

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I. INTRODUCTION

Energy is a key factor in rural development. Many villages still face challenges such as irregular power supply, dependence on fossil fuels, and lack of modern facilities. The Smart Village concept provides a holistic approach to rural development by integrating renewable energy, digital services, smart governance, and community participation. Solar energy is an ideal solution for villages due to its availability, eco-friendliness, and suitability for decentralized power generation.

The smart village concept also emphasizes the role of the so-called smart regional specializations. Recognition and appreciation of the role of knowledge and innovation represents a breakthrough in relation to the existing, traditional perception of the directions of rural development. The traditional approach viewed rural areas as areas with a dominant agricultural function, and the development concepts that exist to date admittedly drew attention to the need to switch from mono-functionality towards multifunctional ity; however, never before has the need to launch the so-called intelligent development mechanism been so strongly emphasised. This was probably partly due to the fact that the previous approaches treated innovation as a technological phenomenon specific to urban centers, which are saturated with the companies' activities, as well as research and educational institutions. At present, pro-innovative activity is more broadly under stood as supporting new social solutions based on collective action (social capital) and the promotion of modern production and service concepts implemented in small and local markets.

As indicated earlier, the smart village takes certain inspirations from the smart city concept that has already been put into practice. Initially, the smart city concept was associated only with the use of information technologies This was a result of the challenges that were emerging at the time, which related to technological progress, the knowledge-based economy, innovative equipment and environmental pressures The support of international institutions was also of significance At present, the smart city concept is considered more broadly and is included in the three dimensions of urban research: the digital city, the knowledge city, and the green city Research carried out in recent years has produced other terms, such as the resilient

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city and sustainable city This demonstrates the extension of the smart city concept into different areas of the city.

Rural areas are often considered to be lagging in development. Frequently, their outermost location, as well as the insufficient level of development in transport infrastructure, prevent them from fully participating in this progress. In the other side this placement create chance becoming the location of significant investments and economic activity The limited sectoral structure of the economy and high dependence on external consumers are also some of the problems in these areas. In order to increase their level of coherence with more developed areas, actions have been taken to strengthen their development potential through new opportunities provided by innovation, new smart digi tal technologies, and institutional changes [56–58]. Another issue for a large portion of rural areas are unfavorable demographic phenomena, such as ageing and migration, especially of young people, which, in the longer term, leads to the depopulation of these areas.

➢ *Research Objective*

The aim of this study is to analyze the role of solar energy in the development of smart villages and to understand how renewable energy can contribute to sustainable and self-reliant rural development.

II. LITERATURE REVIEW

India's rural electrification journey has moved from a limited, agriculture-focused approach to a broader vision of inclusive development. In the early Five-Year Plans, electricity was treated mainly as a tool for irrigation and agro-industries, leaving millions of households without access (Swain, 2016). The Electricity Act later reframed power as both an economic driver and a social necessity, expanding priorities toward rural communities. Ritu Chandra et al. (2019) emphasize that electricity, alongside education, is essential for reducing rural poverty where nearly 80 percent of India's poor reside and for achieving equitable growth through schemes like the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), which align with the Sustainable Development Goals. Vasant Surdev (2017) underscores electricity's role as a cornerstone of infrastructure and welfare, noting that while the sector was state-controlled until the early 1990s, post-liberalization reforms opened it to private participation, followed by initiatives such as UDAY and DDUGJY to improve efficiency in generation, transmission, and distribution. More recently, Smart Village programs like Sansad Adarsh Gram Yojana (SAGY) and the Shyama Prasad Mukherji Rurban Mission (SPMRM) reflect a shift toward holistic rural transformation, integrating reliable electricity, renewable energy, digital literacy, and modern infrastructure to bridge rural–urban disparities and promote sustainable growth.

Several studies highlight the importance of renewable energy in rural development. Solar energy has been identified as a cost-effective and sustainable solution for decentralized power generation in villages. Previous research emphasizes that smart villages integrating solar energy improve education, healthcare, agriculture, and governance. These studies form the theoretical foundation for the present research.

➢ *Objectives of the Present Study*

To analyze the solar energy potential and its role in rural development in North Karnataka.

➢ *Hypotheses*

- Null Hypothesis 1: There is no Significant Association between Educational Qualification and Belief that Solar Energy Reduces Dependence on Traditional Electricity
- Null Hypothesis 2: There is no Significant Association between Educational Qualification and Willingness to Invest in Solar Systems.
- Null Hypothesis 3: There is no Significant Association between Educational Qualification and Belief that Solar Energy is a Sustainable Solution for Rural Areas

III. METHODOLOGY

➢ *Sample of the Present Study:*

145 respondents from various districts of north Karnataka through simple random sampling technique by employing survey method.

➢ *Problem Statement*

Despite various rural development schemes, many villages continue to face issues such as unreliable electricity supply, high energy costs, and environmental pollution. Conventional energy sources are limited and not sustainable. There is a need to explore solar energy as a reliable and eco-friendly solution to support smart village development. Hence Solar Energy and Smart Village Development in Selected Areas of North Karnataka.

➢ *Scope of the Study*

The scope of the study includes a conceptual and descriptive analysis of solar energy applications in smart villages. The study focuses on awareness, benefits, and challenges related to solar energy adoption in rural areas. The present work is limited to primary data collected through questionnaires and secondary data from published sources.

➢ *Research Methodology*

The present study adopts a descriptive research design suitable for both primary and secondary data were used. Primary data were collected through a structured questionnaire administered to rural respondents. Secondary data were obtained from peer-reviewed journals, government publications, reports of the Ministry of New and Renewable Energy (MNRE), and international agencies. The study follows a descriptive research design. Primary data were collected using a structured questionnaire administered to village respondents. Secondary data were collected from journals, government reports, and official websites.

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➢ *Data Collection Tool*

The questionnaire consisted of questions related to awareness of solar energy, perception of smart villages, benefits of solar energy, and challenges in implementation. Responses were measured using a five-point Likert scale. Statistical analysis was carried out using descriptive statistics and Chi-test.

IV. DATA ANALYSIS AND RESULTS

Table 1 Awareness, Interest, and Adoption Potential of Solar Energy

Indicator	Yes (%)	No (%)
Awareness of solar energy systems	78.5	21.5
Interest in installing solar systems	78.5	16.7
Belief that solar energy reduces dependence on grid electricity	81.9	18.1
Willingness to invest if subsidies are provided	70.1	29.9
Solar energy seen as future rural solution	77.8	22.2

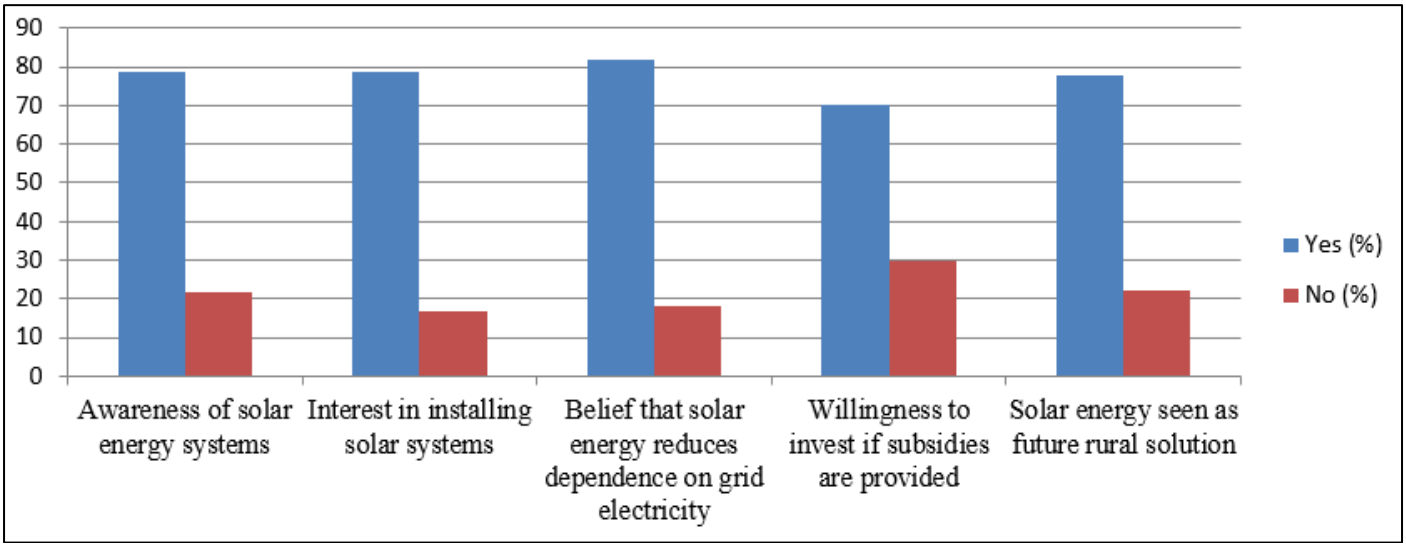

Fig 1 Awareness, Interest, and Adoption Potential of Solar Energy

Table 2 Association Between Educational Qualification and Belief that Solar Energy Reduces Dependence on Traditional Electricity (N = 144)

Education	Yes	No	Total	df	χ^2	p-value
Illiterate	24 (82.8%)	5 (17.2%)	29 (100%)			
Higher Secondary	21 (80.8%)	5 (19.2%)	26 (100%)			
PUC	24 (75.0%)	8 (25.0%)	32 (100%)			
Graduation and Above	49 (86.0%)	8 (14.0%)	57 (100%)	**3**	**1.703**	**0.636**
Total	118	26	144			

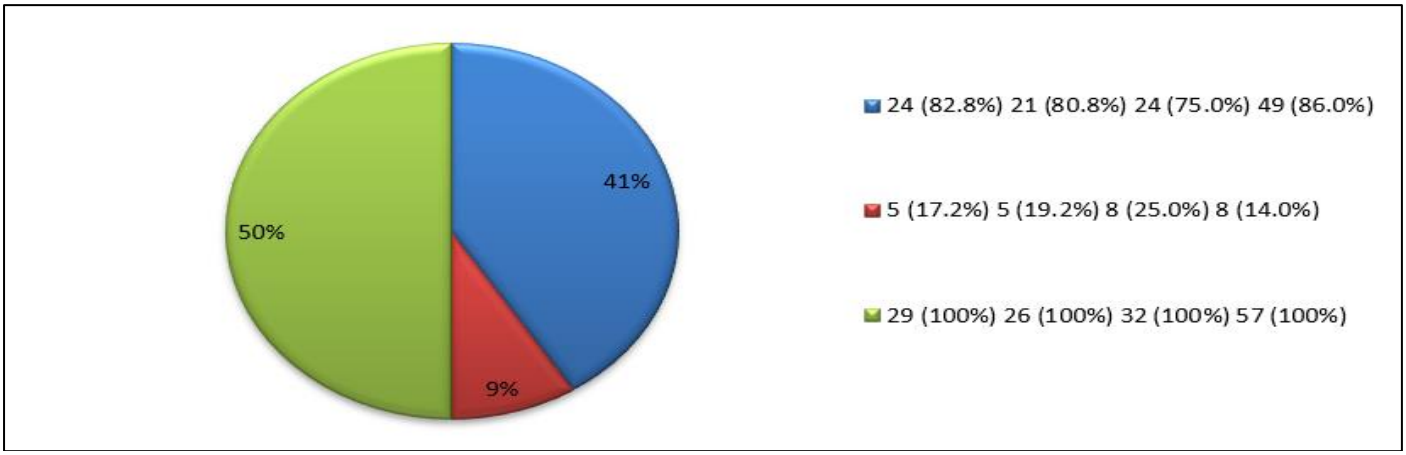

Fig 2 Association Between Educational Qualification and Belief that Solar Energy Reduces Dependence on Traditional Electricity (N = 144)

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Table 3 Association Between Educational Qualification and Willingness to Invest in Solar Systems if Subsidies are Provided (N = 144)

Education	Yes	No	Total	df	χ^2	p-value
Illiterate	24 (82.8%)	5 (17.2%)	29 (100%)			
Higher Secondary	18 (69.2%)	8 (30.8%)	26 (100%)			
PUC	22 (68.8%)	10 (31.2%)	32 (100%)			
Graduation and Above	37 (64.9%)	20 (35.1%)	57 (100%)	**3**	**2.988**	**0.393**
Total	101	43	144			

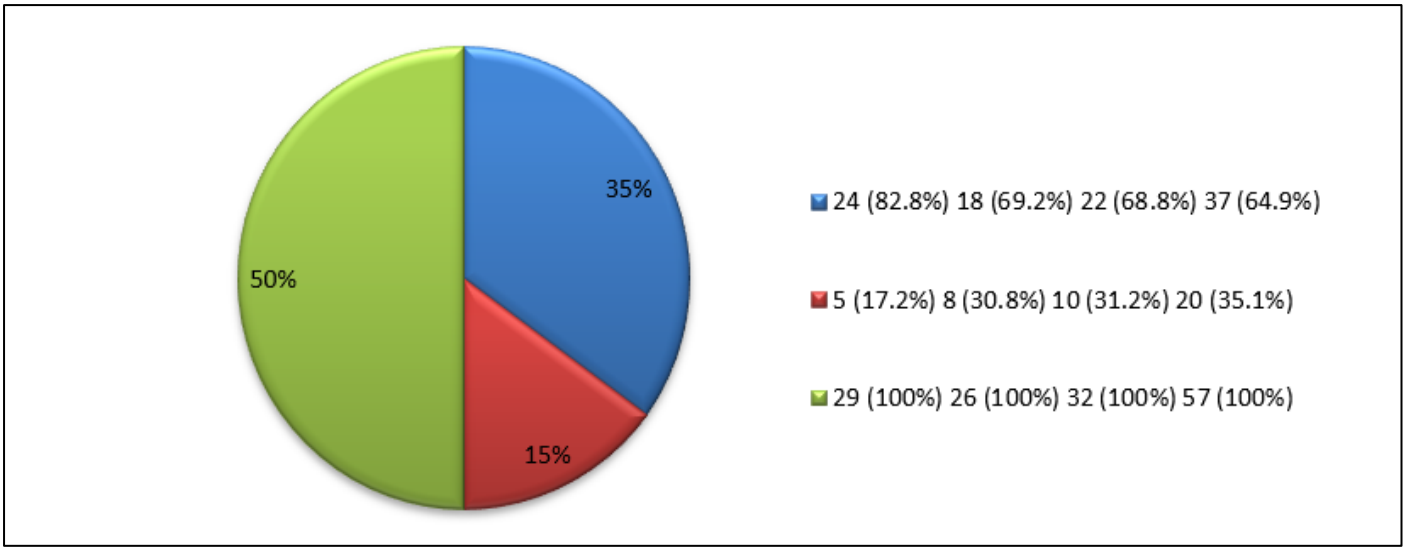

Fig 3 Association Between Educational Qualification and Willingness to Invest in Solar Systems if Subsidies are Provided (N = 144)

Table 4 Association Between Educational Qualification and Belief that Solar Energy is a Sustainable Solution for Rural Areas (N = 144)

Education	Yes	No	Total	df	χ^2	p-value
Illiterate	19 (65.5%)	10 (34.5%)	29 (100%)			
Higher Secondary	18 (69.2%)	8 (30.8%)	26 (100%)			
PUC	20 (62.5%)	12 (37.5%)	32 (100%)			
Graduation and Above	40 (70.2%)	17 (29.8%)	57 (100%)	**3**	**0.635**	**0.888**
Total	97	47	144			

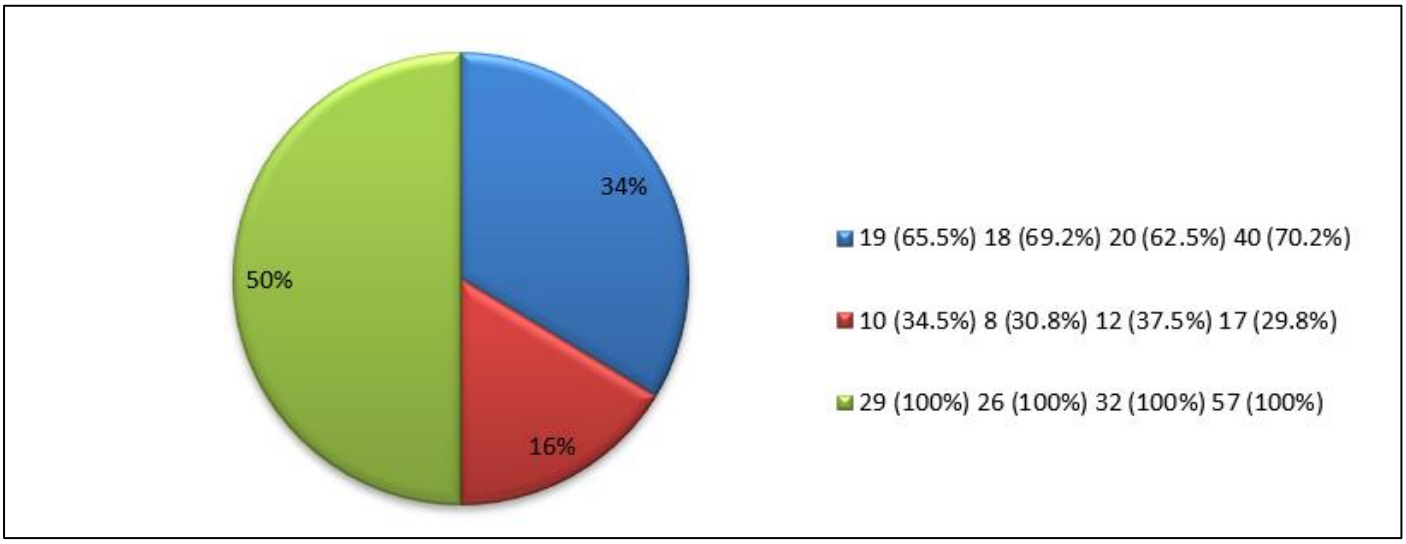

Fig 4 Association Between Educational Qualification and Belief that Solar Energy is a Sustainable Solution for Rural Areas (N = 144)

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V. FINDINGS

- A high level of awareness and interest in solar energy is evident among villagers. The strong willingness to invest when subsidies are available highlights financial barriers rather than motivational constraints. The findings clearly establish solar energy as a viable and acceptable rural development solution in North Karnataka.
- The Chi-square test indicates no statistically significant association between educational qualification and the belief that solar energy can reduce dependence on traditional electricity ($\chi^2 = 1.703$, df = 3, p = 0.636). This suggests that positive perceptions regarding the role of solar energy in reducing reliance on conventional electricity sources are consistent across all educational levels.
- The Chi-square analysis indicates no statistically significant association between educational qualification and willingness to invest in solar systems when subsidies are provided ($\chi^2 = 2.988$, df = 3, p = 0.393). This suggests that financial willingness to adopt solar energy, given subsidy support, is relatively uniform across all educational categories.
- The Chi-square test indicates no statistically significant association between educational qualification and the belief that solar energy is a sustainable solution for rural areas ($\chi^2 = 0.635$, df = 3, p = 0.888). This suggests that perceptions regarding the sustainability of solar energy are consistent across all educational levels.

VI. DISCUSSION AND CONCLUSION

The findings indicate a positive perception of solar energy and smart village initiatives among respondents. Uniform awareness levels suggest that awareness programs and government initiatives have been effective. However, high installation costs and maintenance issues were identified as major challenges. Financial assistance and technical training are necessary for wider adoption. The study concludes that solar energy plays a vital role in the successful implementation of the smart village concept. High awareness levels and positive perceptions among respondents indicate readiness for solar-based rural transformation. Despite challenges such as initial installation costs and maintenance issues, solar energy offers long-term economic and environmental benefits. Policy support, financial incentives, and technical training can further enhance adoption. Solar energy–based smart villages can serve as sustainable models for inclusive rural development in India.

VII. IMPLICATIONS OF THE STUDY

The findings of this study are useful for policymakers, rural development agencies, and researchers. The study provides insights into community awareness and acceptance of solar energy, which can help in designing effective rural energy policies and smart village programs. The study concludes that solar energy is a vital component for smart village development. Solar-based smart villages promote sustainable development, reduce environmental impact, and improve rural quality of life. With proper policy support, financial aid, and community participation, solar energy can significantly contribute to rural transformation.

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