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Access to Sustainable Energy Off-Grid Options for Rural Areas

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Abstract: Energy is widely acknowledged as one of the most important resources for both human and economic progress. There is a significant reciprocal relationship between economic growth and energy use. Energy resources in rural and isolated locations are under significant strain due to the massive growth in demand from the commercial, industrial, residential, and agricultural sectors. Through Niti Aayog and other ministries, India has implemented a number of policies and plans to generate sustainable energy for rural areas. However, in order to achieve sustainability, additional holistic refining is needed. Utilizing renewable energy sources can be viewed as an excellent way to bridge the supply and demand gap in rural areas. In order to create an integrated policy structure in a thorough way, it has been hypothesized that strong descriptive policy aspects for the Rural Renewable Energy System in the Indian context must be identified. This would concretize the key descriptive policy aspects while also reducing complexity to a greater degree.

Keywords: Living conditions; Productivity; Progress; Rural communities; The globalized world; and the Sustainable Development Goals.

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I. Introduction

Around the world, energy is regarded as one of the most important components for human and economic growth. Economic development and energy usage are strongly correlated. Even while energy is the foundation of economic expansion, economic growth has been perceived as requiring energy since an expanding economy, with its increased global competitiveness, depends more on the availability of safe, affordable, and environmentally friendly energy sources. Energy consumption has skyrocketed in the commercial, industrial, residential, and agricultural sectors (Bose et al., 2021). It has put a great deal of strain on the nation's resources. The country's resources must be used as efficiently as possible due to the rising pollution levels and environmental problems brought on by energy use. Therefore, achieving self-sufficiency necessitates appropriate energy planning. An appropriate plan to maximize its use requires an up-to-date and integrated database of the production and consumption of various energy sources, including coal, crude petroleum, natural gas, and electricity. An extensive energy database will enable tracking of power production from several sources, its use across industries, and an assessment of the environmental impact. India's energy reserves have been under tremendous strain due to its significant and ongoing economic growth. The 2006 Integrated Energy Policy Report (Mulugetta et al., 2019), which outlines several policy ideas for the expansion of the energy industry, is a long-term energy policy aspect. India's characteristic geographical and geological conditions provide it the advantage of having access to a variety of energy supplies. The country's energy resources have grown at a rate of 4.58% for coal, -1.87% for lignite, -0.60% for crude oil, and 5.51% for natural gas between 2019 and 20 compared to 2018 and 19. In addition to other relevant factors like environmental challenges, pressure on land, land and soil degradation, declining forest resources, declining per capita forest and agricultural land, food grain availability, habitat destruction, declining biodiversity, water scarcity, global warming, water pollution, and climate change with changing consumption patterns, a nation's population size and growth have a significant impact on energy demand, economic development, and health sector needs (Babalola et al., 2022).

II. Review of Literature

Singh brought up concerns about RPO, feeding tariffs, and rules governing the purchase of renewable energy from small producers. According to Pandey et al., 722 businesses have registered for solar investment to develop a solar energy plant with a capacity of 16900 MW, making Rajasthan a popular state in India for investment in various solar energy projects. The primary argument put up is that Rajasthan was able to draw in investors by establishing an investment-friendly government that promoted policies, built support infrastructure, facilitated transactions, and practiced good governance. Solar cookers were introduced and markets were investigated to meet the needs for smokeless alternative cooking (Aberilla et al., 2020).

The importance of "finance" requirements for RE production in India was underlined by Liming & Huang. They separated the financial systems into several categories, such as those that deal with public stock exchanges, private sector financing, venture capital, subsidies, commercial and savings and loan financing, government financing, and international financing. The Indian government established various RE research centers, like IREDA Limited, and individual ministries, such MNRE, to address the need for renewable energy by providing financing for research, project creation, and project implementation.

A fictitious study was carried out by Chourey and Kandpal to investigate the feasibility of solar lamps in rural regions. They talked about ways to finance product marketing through government subsidies, build solar lantern charging stations, and create jobs for people while encouraging rural entrepreneurship. Between 27.1% and 28.3% of all Indians living in rural areas are thought to be Rao et al. suggested energy microfinance for rural residents below the poverty line (BPL) using an intangible framework. Forster considered the direct distribution model while researching the efficiency of solar consumption in urban India (Bhattacharyya & Palit, 2021).

According to Roger, the innovation adoption cycle should continue by focusing on financially favorable consumers initially. However, the government targeted underprivileged populations rather than early adopters based on their profiles, which led to a market failure. In a similar vein, Peter et al. used Rogger's diffusion-of-innovation model in their empirical research to determine the elements that promote the adoption of solar photovoltaics (PV). Additionally, Pohekar and Ramachandran examined solar cooker fuel selections for agricultural strategies. The Multi-Criteria Decision Support (MCDS) system was utilized in the study to model the options (Chauhan & Saini, 2015).

For related problems, Pohekar & Ramchandaran also applied the multi-attribute utility theory. Because of their maintenance problems, solar cookers were the least popular among consumers.

Household preferences for mini-grid home lighting systems (HLS) and standalone solar photovoltaic (SPV) systems were investigated by Bhandari et al. In his study, Maradin, D. listed some of the disadvantages of RE systems, including their non-continuity and unpredictability, high reliance on weather, poor capacity to generate electricity, low energy efficiency, and rigidity in admitting renewable electricity in the power system.

2.1. Objective of the Study

The RECENT project's goals for the isolated and sparsely populated areas were to:

- Increase the adoption of energy-efficient and renewable energy solutions in public infrastructure and dwellings.
- To identify regional or local issues and potential technological and financial fixes.
- To create environmental and energy asset management systems that are sustainable.
- To boost new technology transfer and innovation.
- To share information in order to raise public awareness.
- To engage stakeholders in cooperative monitoring and assessment efforts throughout the project.

III. Materials and Methods

There are project-specific definitions for terms used in the RECENT project. Any group of people inside the NPA program area who gained something from the pilot, whether directly or indirectly, was considered a community. Pilots were the actual technological solutions or implementations used to construct the community's public infrastructure. The majority of the towns under study were small, isolated, and dealing with issues related to public infrastructure (such as conflicting demands for land and water use) as well as the effects of climate change. Some places, like the University of Oulu (UOulu), were not distant; yet, their northern location and underutilized resources presented difficulties. Through the development of small-scale solutions and the creation of synergy amongst vital public assets, RECENT assisted the towns under study in becoming more energy independent. Every community had a pilot or many pilots, totaling 25 over 5 areas, and all of them had multiple assets working in tandem. Synergistic solutions included energy recovery from wastewater, co-digestion of bio-waste, garden waste, and/or wastewater sludge, land-use of generated digestate, producing transportation biofuel from wastes, and harvesting solar and wind energy, among other region-specific technologies (Mandelli, 2015).

Protecting the environment is essential for people to live effective lives and accomplish their goals, both personal and professional. When the atmosphere is suitable, people can live their lives effectively and complete all of their jobs and activities in the right way. In order to raise knowledge of geographical sustainability, people must comprehend how to satisfy their current wants without sacrificing those of future generations. In this situation, the people must be enlightening about the manner in which they interact with the surroundings. People must come up with the steps that are required to protect the ecosystem. People should only use the resources that are necessary. Natural resource exploitation ought to be avoided. Preserving human people, plants, and animals is the focus of biological sustainability. It's called the ability to persevere. It is important to design the environment and surrounds so that they allow (Bhattacharyya, 2013).

Preserving human people, plants, and animals is the focus of biological sustainability. It is referred to the capacity to endure. Environmental circumstances and surroundings should be designed to allow people to use resources efficiently in order to increase productivity and profitability. People are able to comprehend how biological systems continue to be varied and fruitful over time It alludes to the potential for long-term human well-being, which depends on protecting the environment and its resources. Individuals gain the ability to be sustained through biological sustainability. Their knowledge of all the elements required to improve living conditions must be up to date.

Sociocultural disintegration is thought to have only one underlying cause: ecological deterioration. All communities and regions are urged to prioritize environmental sustainability. It is imperative that people, especially those from rural and tribal communities, raise awareness about environmental preservation. Maintaining a clean environment and getting rid of pollution in the air, water, land, and noise is one of the most crucial things. because a large portion of their daily routine activities rely on the natural ambient conditions. Deterioration of resources has resulted in significant risks to life-sustaining systems and security conflicts. Both in times of peace and conflict, environmental security is a part of it. The two main pillars of environmental security are the environmental factors that lead to or contribute to potentially violent conflicts, as well as the consequences of environmental degradation on the public health system, the overall political economy, and individual life.

IV. Statistical Measures

Making a connection between development and prevailing social standards is known as social sustainability. People live in a world where social and economic developments occur in a way that is fitting. People would oppose or resist any effort that violates current societal ideals or that aims to achieve social sustainability. This raises the question of how to establish the social boundaries that need to be adhered to in order to attain sustainability. Religions, rituals, and traditions serve as the foundation for societal norms.

People must follow norms, values, morality, and ethics in order to build positive connections and good terms with others if they are to achieve societal sustainability. Determining, quantifying, and assessing social boundaries is challenging. Laws and social boundaries cannot be used to codify social sustainability. If this type of growth is to be realized, action and respect for all governments are necessary at the regional and global levels.

Table 1: Descriptive Statistics

	N	Minimum	Maximum	Mean
	Statistic	Statistic	Statistic	Statistic
Learning and knowledge sharing	1035	1.33	5.00	3.8006
Monitoring and evaluation	1035	1.20	5.00	3.8216
Community engagement and participation	1035	1.45	4.82	3.8156
Financial management and planning	1035	1.50	4.88	3.7920
Human resources and training	1035	1.45	4.80	3.8075
Organizational structures and management	1035	1.00	5.00	3.4206
Institutional capacity and governance	1035	2.00	5.00	4.0444
Climate change and environmental policies	1035	1.50	5.00	4.2406
Energy access and equity policies	1035	1.78	4.89	3.9019

The norms, values, habits, and traditions are referred to as culture. In every community—rural, urban, and tribal—these factors have an impact on people's lives. Cultural sustainability is the sustainability that makes it possible to recognize how much cultural characteristics impact people's lives.

Table 2: ANOVA Table

	Sum of Squares	df	Mean Square	F	Sig.
What are the opportunities for integrating off-grid energy solutions with sustainable land use practices and ecosystem conservation in rural areas?	5.477	1	5.477	8.255	.004
	685.389	1033	.663		
	690.866	1034			
How can off-grid energy solutions contribute to climate change mitigation and adaptation efforts in rural areas?	1.880	1	1.880	3.054	.081
	635.955	1033	.616		
	637.835	1034			
What are the environmental impacts of off-grid energy solutions in rural areas, and how can they be mitigated?	3.396	1	3.396	5.759	.017
	609.151	1033	.590		
	612.547	1034			
What are the implications of off-grid energy solutions for rural areas on national energy policies and grid expansion plans?	1.120	1	1.120	1.948	.163
	593.677	1033	.575		
	594.797	1034			
How can governments and international organizations incentivize private sector investment in off-grid energy solutions for rural areas?	2.733	1	2.733	4.886	.027
	577.760	1033	.559		
	580.493	1034			
What policy and regulatory frameworks are needed to support the development and deployment of off-grid energy solutions in rural areas?	6.846	2	3.423	5.164	.006
	684.020	1032	.663		
	690.866	1034			
3. What role can community-based energy initiatives play in promoting sustainable energy access in rural areas?	5.620	2	2.810	4.587	.010
	632.215	1032	.613		
	637.835	1034			
How can off-grid energy solutions be made affordable and accessible to low-income households in rural areas?	3.631	2	1.816	3.077	.047
	608.916	1032	.590		
	612.547	1034			
What are the socioeconomic benefits of accessing sustainable energy in rural areas, and how can they be measured?	2.406	2	1.203	2.096	.123
	592.391	1032	.574		
	594.797	1034			
What are the challenges and opportunities for integrating off-grid energy	1.799	2	.900	1.604	.202

systems with existing grid infrastructure?	578.694	1032	.561		
	580.493	1034			
How can energy storage systems be optimized for off-grid applications in rural areas?	39.071	5	7.814	12.337	.000
	651.795	1029	.633		
	690.866	1034			
What are the most suitable off-grid energy technologies (e.g., solar, wind, hydro) for rural areas, considering factors like resource availability and energy demand?	41.213	5	8.243	14.216	.000
	596.622	1029	.580		
	637.835	1034			
What are the implications of off-grid energy solutions for rural areas on global environmental goals and agreements?	44.795	5	8.959	16.238	.000
	567.752	1029	.552		
	612.547	1034			
How can off-grid energy solutions be integrated with climate change mitigation and adaptation efforts in rural areas?	30.593	5	6.119	11.159	.000
	564.203	1029	.548		
	594.797	1034			
What are the opportunities for using off-grid energy solutions to promote ecosystem conservation and sustainable land use practices in rural areas?	38.482	5	7.696	14.612	.000
	542.011	1029	.527		
	580.493	1034			
How can off-grid energy solutions be designed to minimize environmental impacts and promote sustainable development in rural areas?	14.602	5	2.920	5.470	.000
	549.403	1029	.534		
	564.005	1034			

Everyday activities, the performance of various tasks and responsibilities, participation in social, cultural, political, economic, and religious activities, interpersonal contact, and so forth are all impacted by cultural traits. People from various cultural backgrounds must collaborate and communicate with one another in both educational and professional settings. Therefore, it is essential that they develop good perspectives and accept diverse cultures. As people raise awareness about embracing different cultures, they must ensure that everyone has equal rights and opportunities and refrain from discriminating against one another based on any of the following: caste, creed, race, religion, gender, ethnicity, age, educational background, occupation, and socioeconomic background.

V. Conclusion

The recent project's objectives were to boost public awareness and social well-being, implement renewable energy solutions, improve energy efficiency, and make better use of idle assets, mostly in rural and sparsely inhabited villages. Based on the findings, implementing these pilots would offer competitive social, economic, and environmental benefits while also promoting community sustainability. Solar photovoltaic energy generation appeared to be a more alluring option for the new towns in the NPA region, despite its northern latitude. Even in the far north, it can be considered a workable solution with storage and an intelligent control system. On the down side, the NPA region's solar systems' profitability is being hampered by a lack of appropriate market incentives. Despite significant investments in wind farms, the NPA region still has a lot of untapped wind potential. In order to provide benefits to the community in which these pilots operate, good partnership with local communities is a crucial component of wind projects. Additional research, technology development, and support are required for space heating methods. Energy efficiency is a fairly simple answer; pilots can pay for itself in as little as one to two years and require only relatively modest initial investment. In sustainable energy projects, economics is just one factor to take into account; the community and its social and environmental advantages must also be acknowledged. One of the most significant takeaways from the previous experiments is that support networks are essential, particularly for tiny, rural areas. Significant differences in the legal and institutional framework of various countries and even regions must be taken into consideration when planning sustainable solutions, even though the majority of the pilot solutions in recent years are such that they can be replicated in the entire NPA region and other areas. Additionally, pilots with environmental service synergies were the focus of the project.

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