World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

A study on adaption of rooftop solar system in Gujarat: Opportunities and challenges

Suman Ramapati [1,*] and Shipra Gupta [2]

[1] *Department of Business and Management, Institute of Advanced Research, Gandhinagar (382426), Gujarat, India.*
[2] *GB Shah College for BBA & BCA, Affiliated with Gujarat Technological University, Ahmedabad, Gujarat, India.*

World Journal of Advanced Research and Reviews, 2024, 24(03), 1731-1738

Publication history: Received on 05 November 2024; revised on 16 December 2024; accepted on 18 December 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.3.3827

Abstract

The current research paper examines the adaptation of the rooftop solar system in Gujarat and mainly pays attention to its opportunities and challenges. The main focus of this paper is to create an enabling environment that encourages investment, promotes awareness, and ensures the long-term sustainability of rooftop solar initiatives. Despite having the 6th largest land area and the 9th largest population, Gujarat is a crucial player in the world energy market and is frequently disregarded. Here, the government is committed to helping customers find cost-effective installations, and more than 20k MW of clean power are currently operational. The data has been considered from Patan and Mehsana districts of Gujarat, 400 participants from 20 villages participated in the current study. For data examination, the study has various sorts of variables; capital set-up cost is taken as a dependent variable while maintenance, subsidies, available space, and awareness are considered independent variables. The study is driven with the help of Karl Pearson's Correlation Method and Durbin's Autocorrelation Model to check the relationship among the selected variables. The study revealed a perfect correlation with the worth (1.0) and in the alignment of the result, Durbin's Model (1.727) also found a positive autocorrelation among the selected dependent and independent variables. Gujarat has made significant strides in promoting rooftop solar systems through a variety of government initiatives, opening doors for financial savings, energy independence, and environmental benefits. Resolving these issues and encouraging broader use across the state would need sustained efforts to increase awareness, better financial choices, and technology advancements.

Keywords: Rooftop Solar System; Renewable energy; Patan and Mehsana Districts; Karl Pearson's Correlation; Durbin's Autocorrelation

1. Introduction

Energy from renewable sources is currently being rapidly consumed throughout the world. India is also emerging as a world leader in producing renewable energy.

Through the time of 2022, the nation's government hopes to have built 175 GW of energy from renewable sources, as part of its initiatives to advance environmentally friendly growth. Part of it is that rooftop solar system aims have been established at 100 GW. Gujarat is one of the leading states in India for the adoption of solar energy. The government of Gujarat has introduced a Solar Power Policy for the development of Solar Projects, including Rooftop Solar Installations. The policy offers various incentives and Subsidies to encourage the use of solar energy by individuals, companies, and industry.

* Corresponding author: Suman Ramapati.

Source: https://www.saurenergy.com/solar-energy-news/rooftop-solar-gujarat-maha-added-highest-capacity-in-7-months

Figure 1 Rooftop Solar: Gujarat, Maha Added Highest Capacities

The GEDA (Gujarat Energy Development Agency) plays an active role in the implementation of rooftop solar projects. They help in planning and executing solar rooftop projects. Various industries and commercial establishments are adopting rooftop solar energy to meet their power needs and reduce their expenses. The economic advantages of solar energy for large consumers are driving this trend. The government should encourage lending to the rooftop solar industry. At present, banks don't provide loans specifically for rooftop solar. Loans are only available when the proposed solar rooftop is offered as collateral for the property (News Bureau, March 02, 2021).

Energy is a fundamental factor in the advancement of any nation. It is essential for the functioning of industries and households, as well as for the enhancement of productivity. Goal No.7 of the United Nations Sustainable Development Goal (SDG) guarantees all individuals access to affordable, dependable, and sustainable energy. The UN recognizes that this objective is a necessary condition for the attainment of other SDGs such as poverty, reduction, industrialization, and the mitigation of climate change (United Nations, 2020). About ten years ago, the primary obstacle to the adoption of solar power was its commercialization, as direct costs were higher than those of fossil fuels. However, this has now been significantly lessened due to a substantial decrease in production costs, which have reportedly resulted in the cancellation of a few coal-based projects (Bloomberg, 2017). Furthermore, in an auction held in 2020, the solar power tariff reached a record-low of Rs. 2.36 per unit (Rs.2, 00,000), significantly lower than that of many coal-related projects (Bhaskar, 2020).

Renewable energy is becoming increasingly popular as an alternative to fossil fuels because of pollution, global warming, and ozone depletion caused by the greenhouse effect (Shukla, et al.2016) [12]. Utilizing clean technologies, solar energy is an efficient renewable energy source for large-scale energy production and a wide range of applications in buildings, crop drying, greenhouse heating and lighting, heating and cooling, remote energy supply, water pumping, and a variety of other macro and micro applications (Devabhaktuni, V. and et. al.2013) [1].

The level of energy consumed per capita is a key determinant of a nation's development. Accessibility and affordability of energy have a significant impact on the lifestyle and standard of living of any nation. Conversely, a country's industrial and economic development may be hindered by a lack of energy (Mirza, U. K., et al., 2007) [8]. Micropower systems are composed of electrical and thermal loads as well as any combination of PV, wind turbines, small hydroelectricity, biomass, power generation, micro turbine, fuel cells, reciprocating motor generators, batteries, or hydrogen storage. Analyzing and designing a micro power system can be difficult due to the numerous design options available and the lack of clarity in key parameters such as load size and future fuel cost. Furthermore, renewable energy sources add to the complexity of the system due to the potential for intermittent, seasonal, or non-availability of the output (Rocha, M. D. and et. al.) [10].

India's National Solar Mission (NSM) was launched in 2020 to generate 100 Gigawatt (GW) of solar energy by 2022. This was to be achieved through the installation of utility-scale systems, with the latter segment accounting for 60 GW of the total capacity and the latter 40. In August 2022, the Government of India updated the Nationally Determined Contribution (NDC) to this objective, aiming to achieve a 50% reduction in carbon emissions by 2030. Solar energy is a

key component of this national target, and can be divided into two categories based on scale and location: utility-scale and rooftop solar (Kristoff, M.M. 2022) [7].

2. Literature review

Kar, S. K., et al. (2016)[5] conducted their research on solar energy market developments in India as their thought aligned to a range of existing energy resources and lessen India's carbon emissions, solar energy has been highlighted to be among the most significant sources of renewable energy. The article investigates the nations' economic principles around renewable power as well as its possibilities, consumer preferences, infrastructure expansions, current output, and part industrial sectors. The continuity and emergency operations facilities, governmental and legislative changes, productivity improvement, initial financial commitment, absence of innovative funding sources, perceived expertise, and adoption are all key hurdles that the solar sector must overcome. The problems may be overcome, as suggested by the experts, if crucial power actions are taken, such as generating an environment that attracts investors, providing finance accessible, building transportation and supply equipment, expanding skill sets, and growing the local part of the industrial sector. India will be able to attain its goal of an industrial revolution with renewable power appreciation to such forward-thinking measures.

Shyam, B. & Kanakasabapathy, P. (2017) [14] stated India is a developing country that is rapidly becoming a leader in the use of renewable energy sources. The energy sector is playing an increasingly important role in the country's energy and economic security. The government is providing financial, institutional, and educational support to the sector, and the renewable energy policy and strategies are essential for its growth. India has a large amount of renewable energy, including solar and wind which is dispersed geographically. Researchers examined the historical evolution and current state of renewable energy use in India, as well as the policy framework, renewable energy capacity, and the contribution of renewable energy to the energy mix. Additionally, the paper looked at the potential challenges associated with the integration of renewable energy sources and the state of the smart grid in India.

The Indian energy crisis can be alleviated through the use of reliable renewable energy sources such as solar power with minimal negative environmental impacts. Several PV projects have been approved based on rooftop models and land-based solar parks to address energy security issues. India's strategy of increasing the installation of solar plants has resulted in a large-scale expansion of its renewable energy market. In their work, they discussed the current approaches, notable accomplishments, and the potential solar energy scenario in India. Additionally, various technological solutions, research, education, and outreach activities are discussed to promote the deployment of solar power. These supportive policies include tax incentives, attractive tariff plans, and economic incentives that promote the sustainability of the nation (Khare Saxena, A. and et. al. 2020) [6].

Kabir, E., and et.al. (2018), stated that renewable sources have become widely recognized around the world. Billions of dollars are currently being spent to achieve this and several more are planned to follow shortly to overcome the current barriers in the solar industry. The off-grid solar industry remains largely untapped. Researchers should also focus on making solar more competitive with traditional and alternative energy sources. To sum up, scientists have identified solar energy innovation as one of the largest potential sources of clean energy to meet global energy needs, regardless of some constraints. Sharma, N.K., and et.al, (2012) [11] commented that India has a severe power deficiency and needs massive expansions to meet the needs of its fast-developing economy. Sun-based energy can increase energy security, broaden supply, decrease import dependence, and improve fuel cost unpredictability, making it a significant investment for the country's energy security and economy. Developed states have the potential to create limitless and clean wellsprings of energy through photovoltaic power systems, which can encourage home-grown modern development and provide a safe power supply for modern technology.

A comprehensive layout of an independent rooftop solar PV system that provides continuous electricity to a hostel facility was detailed by Shukla, A. K., et al. (2016) [13]. The methodical procedure for ascertaining every element of the Self-Contained Rooftop Photovoltaic System and evaluating its efficiency using simulation software is explained. Additionally, they offer a thorough cost analysis that accounts for both the roof-mounted solar PV mechanism's setup and ongoing maintenance. Both ecological benefits and the cost of PV generation are highlighted. It is also important to consider the difficulties that come with using cells or other forms of storage when analyzing independently solar power projects that include electricity storage. When building and managing an off-grid solar PV system in the future, it provides helpful reference material.

The important topic of climate change was examined by Parmar, B. J., & Patel, C. R. (2020) [9], who also emphasized the crucial role that renewable technologies—particularly photovoltaic (PV) systems—play in reducing the negative effects of greenhouse gas emissions. They emphasized the worldwide necessity to combat climate change by switching to

renewable energy sources, as described by the Intergovernmental Panel on Climate Change. The utilization of renewable technology, especially photovoltaic (PV) systems, has been proposed as a significant solution to the pressing problem of climate change. The paper addressed the future of India as an around-the-world participant in the renewable sector, in addition to the research's results on popular attitudes toward solar rooftop installations. The primary findings were good opinions concerning solar energy's autonomy skepticism on its influence on the value of real estate, and moderate views on its economic feasibility and accessibility to the marketplace. Despite these worries, respondents firmly believe that solar systems are environmentally beneficial. The study emphasized the need for focused marketing campaigns to close the knowledge gap and supported government-run programs like exhibits to encourage the educated use of solar solutions. Overall, their research provided helpful information for everyone in the field of clean energy and suggested areas for development in public understanding and opinion.

In 2020, Dutta, A., and Das, S. [2] investigated stakeholder views on solar energy implementation, with a focus on the Jammu and Kashmir area, which includes Jammu, the Kashmir Valley, and Ladakh. They especially looked at non-grid solar rooftop systems. The study used a mixed-method approach to gradually collect responses from a subset of stakeholders. The research results demonstrated variations in perspectives between locals and authorities, highlighting the necessity of developing policies with subtlety. The research identified financial and non-financial elements that drive solar system choice of investments and highlighted the regional effects on various populations.

The research advocated for customized policies that balance economic, social, and environmental issues, highlighting the significance of taking into account many viewpoints in promoting sustainable solar energy adoption in the area. These are only a few of the difficulties that were addressed.

3. Research methodology

Research methodology refers to the systematic process followed by researchers to design, conduct, analyze, and interpret research studies. It provides a framework for collecting, organizing, and analyzing data to answer research questions or test hypotheses. A well-defined research methodology is crucial for ensuring the validity and reliability of research findings.

- **OBJECTIVE:** To study the possible opportunities and challenges faced by Patan and Mehsana district villagers in adopting rooftop solar systems in Gujarat state.
- **HYPOTHESIS:**
  - H0: There is a positive relationship between maintenance and capital set-up costs in the adoption of rooftop solar systems in Gujarat.
  - H0: There is a positive correlation between subsidies from govt. And capital set-up costs in the adoption of rooftop solar systems in Gujarat.
  - H0: There are favorable responses to space availability and awareness of capital set-up costs.
- **Research design:** Descriptive Research
- **Research types:** The present study adopts a mixed-method research approach (both quantitative as well as qualitative).
- **Sampling techniques:** Members are considered based on convenience or judgments.
- **Data collection methods:** Based on a survey/ questionnaire, data has been gathered through structured questions.
- **Data presentation and interpretation:** Data has been represented using tables, charts, graphs, and narrative reports with the help of Microsoft Excel and SPSS software.

3.1. Data analysis

The present study has surveyed 400 people from 20 villages in the Patan and Mehsana districts of Gujarat. A survey questionnaire was distributed among the villages to collect the required information. The study considered the following variables; cost of set-up capital as a dependent variable and maintenance, subsidies, available space, and awareness as independent variables.

Before executing panel data regression, the study went through some pre-testing like a reliability test to examine internal consistency among the attributes, a normality test by One-Sample Kolmogorov-Smirnov Test, and finally applied multicollinearity test by Karl Pearson’s correlation and autocorrelation by Durbin Watson’s model to check the relationship among the variables.

3.2. Reliability Statistics

Table 1 Reliability test

Reliability Statistics	
Cronbach's Alpha	No. of Items
0.848	5

Source: SPSS Output

Cronbach's alpha measure is used to test the internal inconsistency or reliability of a set of survey scales. It measures the level of harmony on a standardized scale i.e. 0 to 1. While higher values always specify the higher approval among the items. Most of the authors suggested that a score of Cronbach's Alpha is more than 0.7 acceptable while the present study has a value of 0.848 which indicates good internal consistency among the number of items.

3.3. One-Sample Kolmogorov-Smirnov Test

Table 2 One-Sample Kolmogorov-Smirnov Test

One-Sample Kolmogorov-Smirnov Test						
Particulars		**Capital Set Up Cost**	**Maintenance**	**Subsidies**	**Available space**	**Awareness**
N		**5**	**5**	**5**	**5**	**5**
Normal Parameters [a, b]	Mean	80.00	80.00	80.00	80.00	80.00
	Std. Deviation	47.329	40.688	35.164	14.560	49.985
Test Statistic		0.183	0.207	0.190	0.332	0.255
Asymp. Sig. (2-tailed)		0.200	0.200	0.200	0.076	0.200
a. Test distribution is Normal.						
b. Calculated from data.						
c. This is a lower bound of the true significance.						

Source: SPSS Output

In statistics, the One-Sample Kolmogorov-Smirnov test is a nonparametric test that is applied to check whether a sample is distributed equally or not. Hence, the KS test was applied to check whether the dependent variable is normally distributed or not. The KS test is isolated into the criteria of acceptance and rejection. If the study has calculated the value of the KS test is less than the critical value (table value), the null hypothesis is the alliance of acceptance while the higher value of the KS test represents the rejection of the null hypothesis. From the above table, we can observe that the significance value of capital set-up cost is 0.200 which is higher than the critical value (0.05) which means rejecting the null hypothesis and the dependent variable is not normally distributed.

3.4. Karl Pearson's Correlation

Table 3 Karl Pearson's Correlation

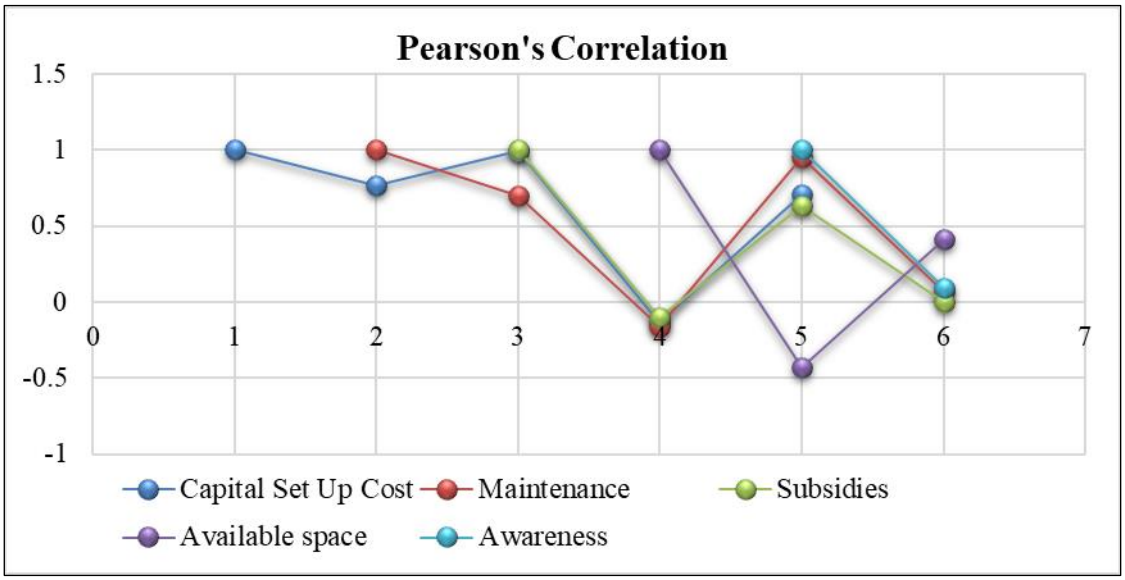
Correlations						
	Variables	**Capital Set Up Cost**	**Maintenance**	**Subsidies**	**Available space**	**Awareness**
Pearson Correlation	Capital Set Up Cost	1	0.767	0.994	-0.134	0.705
	Maintenance	0.767	1	0.698	-0.162	0.952
	Subsidies	0.994	0.698	1	-0.1	0.628
	Available space	-0.134	-0.162	-0.1	1	-0.434
	Awareness	0.705	0.952	0.628	-0.434	1
Sig. (1-tailed)	Capital Set Up Cost		0.065	0	0.415	0.092

Source: Researchers' Computation

Regression Model,

Capital Set Up Cost = β0 + β1 (Maintenance) + β2 (Subsidies) + β3 (Available space) + β4 (Awareness) + ε

The correlation coefficient is a statistical measure used to quantify the strength of linear association between two variables. Its value always lies between -1 to +1. The correlation matrix defines if the study has a correlation value -1 means there is a negative relationship while +1 represents the positive relationship among the variables. From the above table, it can be seen that there is a higher relationship between capital set-up cost and subsidies (0.994), maintenance, and awareness (0.952) which shows the presence of multicollinearity issues. The matrix also revealed a negative association between the available space with the capital set-up cost, maintenance, subsidies, awareness, etc.



Source: Researchers' computation

Figure 2 Karl Pearson's Correlation

3.5. Autocorrelation by Durbin Watson

Table 4 Autocorrelation by Durbin Watson

Model Summary [b]										
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin - Watson**
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**	
1	**1.00a**	**1.00**			**1.000**		**4**	**0**		**1.727**
a. Predictors: (Constant), Awareness, Available space, Subsidies, Maintenance										
b. Dependent Variable: Capital Set-Up Cost										

Source: SPSS Output

The value of correlation (R=1.00) represents the perfect relationship between a dependent variable and all the predictors while R^2 gives the estimated strength relationship of the variables in the regression model.

Durbin Model is also known as sequential or consecutive correlation in residuals during the regression assessment which is used to examine the autocorrelation.

$$d = \frac{\sum_{t=2}^{T}(e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^2}$$

The nature of autocorrelation can be positive or negative. Its values always assume between 0 and 4. A value of 2.0 indicates there is no autocorrelation, a value below 2.0 of DW shows positive autocorrelation while a value higher than 2.0 shows a negative autocorrelation among the variables. From the above table, we can observe that Durbin's Model indicates a positive autocorrelation (1.727) which lies near 2 to 4.

4. Result and discussion

The result and discussion section is a critical component of a research paper. The section presents and interprets the findings of the study.

- This study surveyed total no. of 400 people from 20 selected villages of Patan and Mehsana districts in Gujarat State.
- Based on the stated variables; cost of set-up capital as a dependent variable and maintenance, subsidies, available space, and awareness as independent variables, a list of questions was designed and distributed among the participants.
- Before the execution of any method for data analysis, the study has gone through pre-testing i.e. One-Sample Kolmogorov-Smirnov Test, and finally applied multicollinearity test by Karl Pearson's correlation and autocorrelation by Durbin Watson's model to check the relationship among the variables.
- The study also checked the reliability and validity of the data via Cronbach's alpha.
- As per table 5.2, it can be observed that the significance value of capital set-up cost is 0.200 which is higher than the critical value (0.05) which means rejecting the null hypothesis and the dependent variable is not normally distributed.
- Table 5.3 shows that there is a higher relationship between capital set-up cost and subsidies (0.994), maintenance, and awareness (0.952) which shows the presence of multicollinearity issues. While, it found a negative association between the available space with the capital set-up cost, maintenance, subsidies, awareness, etc.
- Durbin's Model also indicates a positive autocorrelation (1.727) which lies near 2 to 4.
- The successful adoption of rooftop solar systems in Gujarat depends on addressing these challenges through coordinated efforts from the government, private sector, and local communities.

5. Conclusion

Gujarat, a state in India, has made significant strides in renewable energy, and rooftop solar can play a crucial role in the state's energy transition. Rooftop solar systems in Gujarat: What do you need to know about rooftop solar systems in Gujarat? What do you need to know? What do you need to do? How to overcome challenges? How to take advantage of opportunities? How to create a resilient, sustainable solar ecosystem in Gujarat as Gujarat moves towards a cleaner, more energy-efficient future, a well-coordinated and strategic approach to rooftop solar energy will help unlock its full potential. The study tried to examine the adaptation of the rooftop solar system in Gujarat and mainly pays attention to the opportunities and challenges. The study applied the Karl Pearson Correlation Method and Durbin's Autocorrelation Model to check the relationship among the selected variables. Lastly, it contributed to a perfect correlation between selected dependent and independent variables while Durbin's Model also indicated a positive autocorrelation among the selected dependent and independent variables.

Lastly, the successful adoption of rooftop solar systems in Gujarat will depend on addressing these challenges through coordinated efforts from the government, private sector, and local communities. It's essential to create an enabling environment that encourages investment, promotes awareness, and ensures the long-term sustainability of rooftop solar initiatives.

Compliance with ethical standards

Acknowledgments

I am grateful for the insightful criticism provided by our reviewers, which has greatly raised the caliber of this work.

Disclosure of conflict of interest

I declare that there are no conflicts of interest regarding the publication of this research article.

References

[1] Devabhaktuni, V., Alam, M., Depuru, S. S. S. R., Green II, R. C., Nims, D., & Near, C. (2013). Solar energy: Trends and enabling technologies. *Renewable and Sustainable Energy Reviews*, *19*, 555-564.

[2] Dutta, A., & Das, S. (2020). Adoption of grid-connected solar rooftop systems in the state of Jammu and Kashmir: A stakeholder analysis. *Energy Policy*, *140*, 111382.

[3] Finance, B. N. E. (2017). Accelerating India's Clean Energy Transition: The future of rooftop PV and other distributed energy markets in India. *Retrieved September 16*, 2018.

[4] Kabir, E., Kumar, P., Kumar, S., Adelodun, A. A., & Kim, K. H. (2018). Solar energy: Potential and prospects. *Renewable and Sustainable Energy Reviews*, *82*, 894-900.

[5] Kar, S. K., Sharma, A., & Roy, B. (2016). Solar energy market developments in India. *Renewable and sustainable energy reviews*, *62*, 121-133.

[6] Khare Saxena, A., Saxena, S., & Sudhakar, K. (2020). Solar energy policy of India: An overview. *CSEE Journal of Power and Energy Systems*.

[7] Kristoff, M. M. (2022). Indian Residential Rooftops: A Vast Trove of Solar Energy Potential-Resurgent Demand and Strong Supply-Side.

[8] Mirza, U. K., Ahmad, N., Majeed, T., & Harijan, K. (2007). Wind energy development in Pakistan. *Renewable and Sustainable Energy Reviews*, *11*(9), 2179-2190.

[9] Parmar, B. J., & Patel, C. R. (2020). A Study on Perception for solar rooftop electricity generation system.

[10] Rocha, M. D., Landa Noronha, G., & Paula Cardoso, A. Feasibility study for Hybrid Electric Generating with Wind-Diesel and Grid Resources.

[11] Sharma, N. K., Tiwari, P. K., & Sood, Y. R. (2012). Solar energy in India: Strategies, policies, perspectives, and future potential. *Renewable and sustainable energy reviews*, *16*(1), 933-941.

[12] Shukla, A. K., et al. (2016). Design, simulation, and economic analysis of standalone rooftop solar PV system in India. *Solar Energy*, *136*, 437-449.

[13] Shukla, A. K., Sudhakar, K., & Baredar, P. (2016). Simulation and performance analysis of 110 kW grid-connected photovoltaic system for residential building in India: A comparative analysis of various PV technology. *Energy Reports*, *2*, 82-88.

[14] Shyam, B., & Kanakasabapathy, P. (2017, December). Renewable energy utilization in India—policies, opportunities and challenges. In *2017 International Conference on Technological Advancements in Power and Energy (TAP Energy)* (pp. 1-6). IEEE.

[15] United Nations. Department of Economic and Social Affairs. (2022). *The Sustainable Development Goals: Report 2022*. UN.