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ECONOMIC AND BEHAVIOURAL DRIVERS OF RESIDENTIAL SOLAR ENERGY ADOPTION IN ALIGARH DISTRICT

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Abstract

The transition towards renewable energy has gained significant momentum in India, with solar energy emerging as a viable solution to rising residential energy demand and environmental concerns. This study examines the factors influencing the adoption of solar energy products and analyses their impact on residential energy consumption and the quality of life of households in the Aligarh District. Using a descriptive and analytical research design, primary data were collected from 100 households through a structured questionnaire. The study employs statistical tools such as mean and standard deviation to assess household perceptions regarding key adoption factors, including cost savings, perceived value, trust in technology, and environmental concern. The findings reveal that perceived value and savings in energy costs are the most influential factors driving the adoption of solar energy products among households, while environmental concern plays a relatively moderate role. The analysis further indicates that households adopting solar energy experience a noticeable reduction in conventional electricity consumption, leading to improved energy efficiency and financial savings. Additionally, the adoption of solar energy products contributes positively to the quality of life by enhancing energy reliability, reducing monthly expenditure, and promoting sustainable living practices. The study highlights the importance of economic incentives, awareness programs, and trust-building measures to accelerate household-level solar adoption. The findings offer valuable insights for policymakers, energy planners, and stakeholders to design region-specific strategies aimed at promoting renewable energy adoption and improving household welfare in semi-urban and urban regions like Aligarh.

Keywords: *Aligarh District, Quality of Life, Renewable Energy, Residential Energy Consumption, Solar Energy Adoption.*

INTRODUCTION

The growing demand for energy, coupled with increasing concerns over environmental degradation and the depletion of conventional energy resources, has intensified the global shift towards renewable energy sources. Among various renewable options, solar energy has emerged as one of the most sustainable and accessible solutions, particularly for residential applications in developing countries like India. With abundant solar radiation and supportive government policies, India has witnessed a gradual expansion in the adoption of solar energy technologies at the household level.

Residential energy consumption constitutes a significant share of total electricity usage, especially in urban and semi-urban regions. Rising electricity tariffs, frequent power outages, and growing awareness of environmental sustainability have motivated households to explore alternative energy sources. Solar energy products such as rooftop photovoltaic systems, solar water heaters, and solar lighting systems offer multiple advantages, including reduced dependency on grid electricity, long-term cost savings, and lower carbon emissions. However, despite these benefits, the adoption rate of solar energy products among households remains uneven across regions. The decision to adopt solar energy products is influenced by a combination of economic, technological, social, and psychological factors. Key determinants include perceived cost savings, initial investment costs, perceived value and reliability of solar technology, trust in service providers, availability of government incentives, and environmental awareness. Understanding these factors is crucial for designing effective strategies that encourage wider adoption of solar energy at the household level.

In addition to energy savings, solar energy adoption has broader implications for household well-being. Reduced energy expenditure, improved reliability of power supply, and enhanced energy security can significantly influence the quality of life of households. Access to clean and reliable energy supports better living conditions, facilitates the use of modern appliances, and contributes to sustainable lifestyles. However, empirical evidence linking solar energy adoption with residential energy consumption patterns and quality of life remains limited, particularly at the regional level.

The Aligarh District, located in the state of Uttar Pradesh, presents a relevant context for examining household adoption of solar energy products. Characterized by a mix of urban, semi-urban, and peri-urban settlements, the region faces challenges such as rising energy demand, power supply fluctuations, and increasing household electricity expenses. Despite adequate

solar potential, the adoption of solar energy products in the region has not reached its optimum level, making it an appropriate case for empirical investigation.

Against this backdrop, the present study seeks to explore the factors influencing the adoption of solar energy products and to analyse their impact on residential energy consumption and the quality of life of households in Aligarh District. By employing statistical tools such as mean and standard deviation, the study provides quantitative insights into household perceptions and adoption behaviour. The findings aim to contribute to the existing literature on renewable energy adoption and offer policy-relevant recommendations for promoting sustainable energy solutions at the household level.

LITERATURE REVIEW

Recent studies have highlighted multiple socio-economic and behavioural factors influencing solar energy adoption. **De Groote et al. (2016)** reported that household size and electricity expenditure significantly affect photovoltaic adoption decisions.

Simpson and Clifton (2017) emphasized the role of financial incentives and information dissemination in accelerating solar technology diffusion.

Earlier studies on solar energy adoption mainly focused on economic feasibility and cost-related factors. **Rai and McAndrews (2019)** highlighted that financial incentives and expected savings significantly influence household decisions to adopt solar energy systems.

Jabeen et al. (2019) identified environmental concern, perceived benefits, and cost considerations as major drivers of renewable energy adoption.

Irfan et al. (2021) found that perceived benefits alone may not be sufficient unless supported by awareness and trust.

Etongo and Naidu (2022) revealed that income and access to finance significantly influence household solar adoption in island regions.

More recent studies, such as **Alinaitwe (2023)**, highlighted savings, education, and household characteristics as critical determinants of solar photovoltaic adoption. However, limited research has simultaneously examined adoption factors, residential energy consumption, and quality of life, particularly in the Aligarh context. This study addresses this research gap.

Building on this, **Kumar et al. (2020)** examined the Indian residential sector and found that although high initial installation costs act as a barrier, long-term reduction in electricity expenditure encourages adoption.

During the same period, studies began emphasizing household perceptions, with **Adnan et al. (2021)** identifying attitudes, perceived usefulness, and social influence as important behavioural determinants of renewable energy adoption.

Subsequent research shifted towards understanding consumption patterns and broader household outcomes. **Ghosh and Ghosal (2021)** observed that solar-adopting households exhibit reduced dependence on grid electricity and improved energy efficiency.

In 2022, Shukla et al. reported that perceived value, trust in technology, and awareness of government incentives play a crucial role in promoting solar adoption in urban and semi-urban regions of India, while environmental concern remained a secondary motivator.

Bhattacharya et al. (2022) further emphasized the importance of policy support and subsidies in accelerating household-level adoption.

More recent studies have integrated solar adoption with quality-of-life outcomes**. Singh and Verma (2023)** found that economic benefits and reliability of solar systems have a stronger influence on adoption than environmental awareness.

Ahmed et al. (2023) demonstrated that renewable energy adoption positively affects household well-being by reducing energy costs and enhancing energy security.

Patel and Shah (2024) concluded that solar energy adoption not only lowers residential energy consumption but also improves living standards and overall quality of life. Despite these contributions, region-specific studies linking adoption factors with energy consumption and quality of life remain limited, particularly in districts such as Aligarh, highlighting the relevance of the present study.

FORMULATION OF THE RESEARCH PROBLEM

Solar energy adoption is widely recognized as a crucial step toward achieving sustainable energy systems. While numerous policies promote renewable energy usage, there remains limited understanding of how solar energy adoption influences household energy consumption patterns and quality of life, particularly in the Aligarh District. A detailed examination of adoption factors such as cost savings, perceived value, trust, and environmental concern is necessary to assess their effectiveness in shaping household energy behaviour.

OBJECTIVES OF THE STUDY

The objectives of the study are:

- To identify the key factors influencing the adoption of solar energy products among households in the Aligarh District.
- To analyse the impact of solar energy adoption on residential energy consumption.

- To examine the relationship between solar energy adoption factors and residential energy consumption.
- To assess the influence of solar energy adoption on the quality of life of households.

RESEARCH METHODOLOGY

The present study follows an **exploratory and descriptive research design** to examine the factors influencing solar energy adoption and its impact on residential energy consumption and household quality of life. A **mixed-method research approach** has been employed, integrating both quantitative and qualitative elements to achieve a comprehensive understanding of the research problem.

The study focuses on households that are users of solar energy products in the Aligarh District. **Primary data** were collected through a structured questionnaire from 100 such households designed to gather information related to adoption factors, residential energy consumption, and quality of life indicators. The sample was selected using the **convenience sampling technique**, considering accessibility and willingness of respondents to participate in the survey.

For data analysis, **descriptive statistical tools** such as Mean, Standard Deviation, Independent Sample t-test, Correlation Analysis and Multiple Regression Analysis were applied to assess household perceptions and energy consumption patterns. These tools facilitated a systematic interpretation of responses and supported meaningful conclusions regarding solar energy adoption and its associated outcomes.

HYPOTHESIS OF THE STUDY

Hypothesis 1: Adoption Factors and Solar Energy Adoption

H_o: There is no significant influence of savings in cost of energy, perceived trust, perceived value, and environmental concern on the adoption of solar energy products among households in the Aligarh District.

H_a: Savings in cost of energy, perceived trust, perceived value, and environmental concern have a significant influence on the adoption of solar energy products among households in the Aligarh District.

Hypothesis 2: Solar Energy Adoption and Residential Energy Consumption

H_o: Solar energy adoption has no significant impact on residential energy consumption of households in the Aligarh District.

H_a: Solar energy adoption has a significant impact on residential energy consumption of households in the Aligarh District.

Hypothesis 3: Gender and Perception of Solar Energy Adoption Factors

H_o: There is no significant difference between male and female households with respect to their perception of factors influencing solar energy adoption.

H_a: There is a significant difference between male and female households with respect to their perception of factors influencing solar energy adoption.

Hypothesis 4: Years of Usage and Perception of Adoption Factors

H_o: There is no significant difference in perception of solar energy adoption factors among households based on years of usage of solar energy products.

H_a: There is a significant difference in perception of solar energy adoption factors among households based on years of usage of solar energy products.

Hypothesis 5: Adoption Factors and Residential Energy Consumption

H_o: There is no significant relationship between solar energy adoption factors and residential energy consumption.

H_a: There is a significant relationship between solar energy adoption factors and residential energy consumption.

Hypothesis 6: Solar Energy Adoption Factors and Quality of Life

H_o: Solar energy adoption factors do not significantly influence the quality of life of households in the Aligarh District.

H_a: Solar energy adoption factors significantly influence the quality of life of households in the Aligarh District.

CONCEPTUAL AND THEORETICAL FRAMEWORK

Determinants of Solar Energy Adoption

This variable refers to household perceptions regarding the determinants that influence the extent of solar energy adoption. Adoption, in this context, signifies the installation, presence, and effective utilization of solar energy systems within residential premises. It reflects the degree to which solar technologies are integrated into household energy practices, including the use of solar photovoltaic panels, solar water heaters, and other solar-based applications aimed at harnessing renewable energy.

The adoption of solar energy among households is shaped by several critical determinants, namely **Savings in Cost of Energy, Perceived Trust, Perceived Value, and Environmental Concern**. These determinants collectively influence household decisions to move away from conventional energy sources such as fossil fuels and grid-based electricity toward cleaner and sustainable solar energy alternatives. Thus, solar energy adoption represents a gradual

transition toward renewable energy usage and environmentally responsible household energy behaviour.

Household Residential Energy Consumption

Household residential energy consumption refers to the total volume of energy utilized by households for routine domestic activities such as lighting, heating, cooling, cooking, and operation of electrical appliances. It includes overall energy consumption patterns observed before and after the adoption of solar energy systems. This variable captures changes in electricity usage levels, dependence on grid electricity, energy cost savings, and variations in household energy-use behaviour.

Residential energy consumption is influenced by household decision-making related to energy efficiency, conservation practices, and the adoption of alternative energy technologies. The integration of solar energy systems significantly alters household consumption patterns by reducing reliance on conventional power sources and encouraging efficient and sustainable energy utilization.

Household Quality of Life

Household quality of life refers to the overall well-being, comfort, and satisfaction experienced by individuals and families within their residential environment. It encompasses various dimensions such as affordability of energy, reliability and availability of power supply, comfort in daily living, environmental sustainability, and overall satisfaction with living conditions.

Examining the relationship between residential energy consumption and quality of life is crucial for understanding how household energy choices influence overall well-being. The adoption of solar energy contributes positively to quality of life by lowering energy expenses, improving energy security, and supporting environmentally sustainable living practices. Analysing these interrelationships provides meaningful insights into the impact of solar energy adoption on household energy consumption patterns and the resulting quality of life of households in the Aligarh District.

DATA ANALYSIS AND RESULTS

The mean analysis of solar energy adoption factors is based upon responses collected from **100 households using solar energy products** in the Aligarh District.

Demographic Profile of the Households/Users

Table 1: Demographic Profile of the Households/Users (N = 100)

Variables	Options	Frequency	Percentage (%)
Gender	Male	63	63.00
	Female	37	37.00
Age	21- 40 Years	46	46.00
	41- 60 Years	41	41.00
	Above 60 Years	13	13.00
Education	School / Diploma	45	45.00
	Graduation / post-graduation	38	38.00
	Professional Qualification	17	17.00
Occupation	Salaried	34	34.00
	Business / Professional	28	28.00
	Students	7	7.00
	Homemakers / Retired	31	31.00
Monthly Family Income (₹)	Up to 50,000	42	42.00
	50,001 - 1,00,000	33	33.00
	Above 1,00,000	25	25.00
Family Size	Up to 3 Members	37	37.00
	4 - 6 Members	45	45.00
	Above 6 Members	18	18.00

Source: Primary Data

Table 1 presents the demographic characteristics of the 100 households using solar energy products in the Aligarh District. The sample consists of 63% male and 37% female respondents, indicating higher participation of male household decision-makers in solar energy adoption. In terms of age, 46% of respondents belong to the 21 - 40 years group, followed closely by 41% in the 41 - 60 years category, suggesting that solar adoption is prominent among economically stable and working-age households.

Regarding educational qualification, 45% of the respondents possess school or diploma-level education, while 38% are graduates or postgraduates, indicating that solar energy adoption is not limited to highly educated households. Occupational distribution shows that 34% of respondents are salaried employees and 28% are engaged in business or professional activities, reflecting stable income sources. A majority of households (42%) fall in the lower-income group (up to ₹50,000), while 25% belong to the high-income category, indicating adoption across different income levels. Family size data reveal that 45% of households consist of 4 - 6 members, suggesting greater energy demand and motivation to adopt alternative energy sources.

Table 2: Usage Pattern of Solar Energy Products (N = 100)

Variables	Options	Frequency	Percentage (%)
Type of Solar Product Used	Solar Rooftop Panels	23	23.00
	Solar Battery / Charger	20	20.00
	Solar Lantern	15	15.00
	Solar Water Heater	16	16.00
	Solar Water Pump / Purifier	11	11.00
	Solar Cooker	9	9.00
	Solar Air Conditioner	4	4.00
	Other Solar Products	2	2.00
Period of Usage	Up to 3 Years	43	43.00
	4 - 6 Years	35	35.00
	More than 6 Years	22	22.00
Source of Knowledge	Media Sources	38	38.00
	Non-Media Sources	62	62.00

Source: Primary Data

Table 2 describes the usage pattern of solar energy products among households in the study area. The data indicate that solar rooftop panels (23%) are the most used solar product, followed by solar batteries or chargers (20%) and solar lanterns (15%). The usage of solar water heaters (16%) further highlights the growing acceptance of solar technology for daily household needs. Advanced solar products such as solar air conditioners (4%) are used by a limited number of households, reflecting cost and accessibility constraints.

Regarding the duration of usage, 43% of households have been using solar energy products for up to three years, indicating recent growth in adoption, while 22% have more than six years of usage, reflecting long-term trust in solar technology. Awareness sources show that 62% of households gained information through non-media channels such as friends, relatives, and neighbours, emphasizing the role of social influence and word-of-mouth communication in promoting solar energy adoption.

Table 3: Households' Perception on Solar Energy Adoption Factors (Mean Analysis)

S. No.	Adoption Factors	Mean	Standard Deviation
1	Savings in Cost of Energy	11.74	3.312
2	Perceived Trust	10.68	3.547
3	Perceived Value	13.58	2.264
4	Environmental Concern	9.82	3.811
Overall Perception Score		**45.82**	**6.947**

Source: Primary Data

Table 3 presents the mean scores and standard deviations of key factors influencing solar energy adoption. Among the four factors studied, Perceived Value records the highest mean

score (13.58), indicating that households strongly believe solar energy products provide long-term benefits and value for money. This is followed by Savings in Cost of Energy (Mean = 11.74), highlighting the importance of reduced electricity expenditure in adoption decisions. Perceived Trust (Mean = 10.68) reflects moderate confidence in the reliability and performance of solar technology, while Environmental Concern (Mean = 9.82) shows comparatively lower influence on adoption decisions. The overall perception score of 45.82 suggests a generally positive and favourable attitude toward solar energy products among households in the Aligarh District.

Table 4: Gender and Perception on Solar Energy Adoption Factors (t-Test)

Gender	N	Mean	SD	t-value	p-value
Male	63	46.91	5.418	3.428	0.018**
Female	37	44.32	6.703		

**Significant at 5% level

Source: Primary Data

Table 4 examines the difference between male and female respondents regarding their perception of solar energy adoption factors using an independent samples t-test. The results show that male respondents have a higher mean perception score (Mean = 46.91) compared to female respondents (Mean = 44.32). The obtained p-value (0.018) is less than 0.05, indicating a statistically significant difference.

This finding suggests that male household members exhibit greater awareness and stronger perception of the benefits associated with solar energy adoption. Therefore, the null hypothesis is rejected, confirming the existence of a gender-based difference in perception toward solar energy adoption factors.

Table 5: Years of Usage and Perception on Adoption Factors (ANOVA)

Years of Usage	N	Mean	SD	F-value	p-value
Up to 3 Years	43	42.81	7.894	6.218	0.001**
4–6 Years	35	45.06	6.982		
More than 6 Years	22	48.93	5.217		

**Significant at 1% level

Source: Primary Data

Table 5 presents the results of a one-way ANOVA examining differences in perception based on years of solar energy usage. The mean perception score increases steadily with the duration of usage, from 42.81 for households using solar products for up to three years to 48.93 for households with more than six years of experience. The calculated F-value (6.218) with a p-value of 0.001 indicates statistical significance at the 1% level. This result suggests that

prolonged usage enhances familiarity, satisfaction, and confidence in solar energy products. Hence, the null hypothesis is rejected, confirming that years of usage significantly influence household perception toward solar energy adoption.

Table 6: Gender and Impact of Solar Energy on Residential Energy Consumption

Gender	N	Mean	SD	t-value	p-value
Male	63	23.06	3.421	3.587	0.015*
Female	37	21.14	4.902		

*Significant at 5% level

Source: Primary Data

Table 6 analyses gender differences in the impact of solar energy adoption on residential energy consumption. The mean score for male respondents (23.06) is higher than that of female respondents (21.14), indicating that male-led households perceive a greater reduction in conventional electricity usage after adopting solar energy. The p-value of 0.015 indicates statistical significance at the 5% level, leading to the rejection of the null hypothesis. This finding suggests that male households/users may be more actively involved in monitoring energy consumption and evaluating cost savings resulting from solar energy adoption.

Table 7: Correlation between Adoption Factors and Residential Energy Consumption

Variables	r-value	p-value	Relationship	Result
Savings in Cost of Energy	0.728**	0.000	Positive	Significant
Perceived Trust	0.684**	0.000	Positive	Significant
Perceived Value	0.832**	0.000	Positive	Significant
Environmental Concern	0.641**	0.000	Positive	Significant
Overall Adoption Factors	**0.792**	**0.000**	Positive	Significant

**Significant at 1% level

Source: Primary Data

Table 7 presents the results of Pearson correlation analysis examining the relationship between solar energy adoption factors and residential energy consumption. All four adoption factors show a strong positive and statistically significant relationship with residential energy consumption at the 1% level. Among the factors, **Perceived Value** exhibits the strongest correlation (r = 0.832), indicating that households perceiving higher value from solar energy experience greater reductions in conventional energy consumption. **Environmental Concern** shows the weakest, though still significant, relationship (r = 0.641). The overall adoption factors demonstrate a high positive correlation (r = 0.792), confirming that stronger adoption perceptions are associated with improved energy efficiency.

Table 8: Regression Analysis – Adoption Factors and Quality of Life

Independent Variables	B	Std. Error	Beta	t	Sig.
Constant	-3.126	0.641	—	-2.984	0.028
Savings in Cost of Energy	0.296	0.081	0.304	4.214	0.000**
Perceived Trust	0.214	0.089	0.217	3.612	0.004**
Perceived Value	0.401	0.073	0.389	5.487	0.000**
Environmental Concern	0.158	0.097	0.149	2.431	0.037*

Adjusted $R^2 = 0.752$ | F = 361.874

Dependent Variable: Quality of Life of Households

*5% level, **1% level

Source: Primary Data

Table 8 presents the results of multiple regression analysis assessing the influence of solar energy adoption factors on the quality of life of households. The regression model is statistically significant, with an F-value of 361.874 and an adjusted R^2 of 0.752, indicating that approximately 75% of the variation in household quality of life is explained by solar energy adoption factors. Among the independent variables, **Perceived Value** emerges as the strongest predictor ($\beta = 0.389$), followed by **Savings in Cost of Energy** ($\beta = 0.304$). **Perceived Trust** and **Environmental Concern** also show significant positive effects, though to a lesser extent. These findings confirm that solar energy adoption enhances household quality of life primarily through economic benefits, reliability, and perceived long-term value.

FINDINGS

- Households demonstrate above-average perception towards solar energy adoption
- Male households show higher perception and energy impact awareness
- Long-term users exhibit stronger adoption perception
- Solar energy adoption significantly reduces residential energy consumption
- Perceived Value is the strongest determinant of household quality of life over the Environmental Concern.

SUGGESTIONS AND RECOMENDATIONS

- Launch community-led workshops and campaigns to spread the word about solar benefits to a much broader audience in the region.
- Create gender-inclusive outreach programs specifically designed to support and encourage more women to lead solar adoption at home.

- Provide extra resources and "onboarding" help for new users to bridge the gap between them and those with years of experience.
- Prioritize the quality and reliability of hardware by encouraging the use of certified products and offering maintenance support.
- Help households track their energy performance so they can see the real-time value and efficiency of their investment.
- Keep the conversation about the environment alive by showing families how their individual switch to solar helps the planet long-term.
- Push for better government incentives, such as tax breaks or subsidies, to lower the initial cost barrier for middle-income families.
- Enhance the overall customer experience and service to ensure users fully feel the "value for money" that boosts their quality of life.

CONCLUSION

The study demonstrates that adopting solar energy significantly reshapes residential consumption patterns in the Aligarh District by reducing reliance on conventional power and promoting long-term energy efficiency. Beyond the technical shift, solar integration directly enhances the quality of life for households through increased energy independence, improved comfort, and greater financial affordability. By focusing on these residential needs, energy planners can better assess consumption trends and formulate targeted strategies that not only lower household costs but also actively reduce greenhouse gas emissions across the district.

The findings offer a strategic roadmap for policymakers and stakeholders in Aligarh District to accelerate the transition toward renewable energy and sustainable development. By identifying the specific drivers that motivate households to switch to solar, authorities can design more effective incentives and infrastructure programs tailored to the unique socio-economic landscape of Aligarh District. Ultimately, this research empowers residents to make informed decisions that lead to significant cost savings and environmental conservation, contributing to the broader well-being of the community and a more sustainable future for the Aligarh District.

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