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Exploring The Factors Influencing The Adoption Of Solar Energy Products And Their Impact On Residential Energy Consumption And Quality Of Life Of Households With Reference To Puducherry Region

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Abstract:

The adoption of solar energy in residential settings has gained significant attention as a sustainable and renewable energy solution. Understanding the factors that influence the adoption of solar energy and their impact on residential energy consumption and quality of life is essential for promoting sustainable development and improving the overall well-being of households. This research aims to explore the factors that influence the adoption of solar energy among households of the Puducherry region and examine the subsequent effects on energy consumption patterns and quality of life.

This study adopts an approach that is both exploratory and descriptive in nature. It utilizes a mixed research methodology, incorporating both qualitative and quantitative methods. The study focuses on the Users (households) population of Solar Energy Products. The sample for the study was selected through convenience sampling, and primary data was gathered using a structured questionnaire administered to 160 households who are adopting Solar Energy Products in Puducherry region. After the data collection by using a pre-planned questionnaire, descriptive and inferential statistical analysis are carried out to analyze the data. Percentage & Mean Analysis, Independent Sample "t" Test, One-way ANOVA, Correlation and Multiple Regression are employed to test the hypotheses and analyze the data.

The study found that Households/users' perception of the Solar Energy Adoption factors is above the average level which indicates the appreciable adoption level on solar energy products in the study area. The study also revealed that male households have perceived more on the Solar Energy Product Adoption factors and Residential Energy Consumption than their counter-part. Solar Energy Product Adoption Factors have positive and high and also significant relationship with Residential Energy Consumption of households. The study indicated that out of four adoption factors, 'Perceived Value' contributes more and 'Environmental Concern' contributes lesser in predicting Quality of Life of households than others. The findings and suggestions of this research can have significant implications for policymakers, energy planners, and households in Puducherry region. This study contributes to the broader goals of sustainable development, environmental conservation, and the well-being of individuals and communities in the study region.

Key Words: Solar Energy Adoption, Residential Energy Consumption, Quality of Life, Savings in Cost of Energy, Perceived Value, Perceived Trust, Environmental Concern.

1. Introduction

The adoption of solar energy in residential settings has gained significant attention as a sustainable and renewable energy solution. Understanding the factors that influence the adoption of solar energy and their impact on residential energy consumption and quality of life is essential for promoting sustainable development and improving the overall well-being of households. This research aims to explore the factors that influence the adoption of solar energy among households of Puducherry region, and examine the subsequent effects on energy consumption patterns and quality of life.

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Formulation Of Research Problem

The adoption of solar energy has emerged as a significant sustainable energy solution worldwide. The adoption of solar energy systems contributes to sustainable development by reducing greenhouse gas emissions and mitigating climate change. However, in the specific context of Puducherry region, there is a need to understand the relationship between the adoption of solar energy and its impact on residential energy consumption and the quality of life of households. Despite the increasing promotion of solar energy adoption, there is a lack of comprehensive knowledge about how the adoption of solar energy systems influences households' energy consumption patterns and their overall quality of life in the study area. Understanding the impact on energy consumption will help to evaluate the effectiveness of solar energy systems in reducing households' reliance on conventional energy sources and promoting energy efficiency.

Puducherry region provides an ideal context for this study due to its high solar potential, increasing interest in renewable energy, and the need to reduce dependence on fossil fuels. By investigating the factors influencing solar energy adoption, such as cost-effectiveness, government policies, environmental awareness, and technological advancements, the research seeks to contribute to the knowledge base on sustainable energy adoption in residential areas. Understanding these factors is crucial for designing effective strategies to promote and encourage the widespread adoption of solar energy in the Puducherry region.

Study Objectives

The following are the objectives of the study:

- ❖ To identify and analyse the factors that influencing the adoption of Solar Energy Products in Puducherry region.
- ❖ To analyse the impact of adoption of Solar Energy Products on the Residential Energy Consumption in Puducherry region.
- ❖ To identify and assess relationship between Solar Energy Product Adoption Factors and Residential Energy Consumption in Puducherry region.
- ❖ To examine the impact of adoption of Solar Energy Products on the Quality of Life of households in Puducherry region.

2. Literature Review

De Groote et al. (2016) conducted a study in Flanders to explore the factors influencing the adoption of photovoltaic systems. Their findings revealed that larger households are more likely to adopt solar PV due to their higher proportion of income spent on electricity. Conversely, smaller households tend to have lower adoption rates. Simpson and Clifton (2017) utilized diffusion theory to investigate the adoption of solar photovoltaic panels in homes in Western Australia. Their survey highlighted the impact of incentives on adoption rates. The study emphasized the importance of adequate education to comprehend the cost parameters and benefits of solar technology. Furthermore, it revealed that the majority of adopters installed these panels primarily for financial reasons.

Jabeen et al. (2019) analysed the factors influencing consumers' intention to use renewable power generation technology. Their study identified environmental concern, environmental knowledge, awareness, perceived behavioural control, subjective norms, relative advantage, and cost as the major factors influencing the utilization of solar energy. Irfan et al. (2021) evaluated the perception of self-effectiveness, awareness, environmental concern, perception of neighbour participation, beliefs about cost and benefits in relation to the adoption of solar energy solutions in Pakistan. Their findings suggested that perceived benefits of using renewable energy solutions did not significantly influence the intention to adopt renewable energies.

Etongo and Naidu (2022) conducted a study on Mahe Island, Seychelles, to understand the factors affecting the adoption of solar PV systems. Their research employed logistic regression and descriptive statistics to analyse the driving factors behind household decisions. The results indicated that access to credit and monthly household income significantly influenced the adoption of solar PV systems, while variables such as gender, age, education of household heads, and family size were not significant. Motivational drivers for the 60 households that had adopted solar PV systems included cost-saving, energy security, environmentally friendly perceptions, and access to loans. Bouaguel and Alsulimani (2022) examined the factors influencing the perception and

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attitudes of people in Saudi society towards the adoption of new solar technologies. Their study utilized the Technology Acceptance Model (TAM) and found that constructs such as perceived usefulness, perceived ease of use, relative advantages, environmental awareness, and cost of solar photovoltaic systems significantly impacted attitudes towards the adoption of solar energy for residential use.

Zulu, Sam, et al. (2022) explored the factors influencing households' intention to adopt solar energy solutions in Zambia using the theory of planned behaviour (TPB). Their survey, conducted among adult household members contributing to the household's income, yielded 961 respondents. The results, analysed through structural equation modelling, demonstrated that attitude, trust, benefits, and subjective norms influence the intention to adopt solar energy solutions. Trust and benefits also indirectly influence the intention through attitude. Alinaitwe (2023) investigated the factors influencing the adoption and use of solar photovoltaic technologies in Uganda. By analysing the Probit model and Multivariate Probit model, the study identified savings, income, education, age of household head, and household size as the major drivers for the usage of solar PVs in Uganda.

There is no previous research that examines the factors that influencing the adoption of Solar Energy Products and their impact on residential energy consumption and quality of life of consumers in general and households of Puducherry region in particular. Hence, this research was undertaken to fill this research gap and present the valuable insights for the producers and marketers of Solar Energy Products, helping them develop effective strategies and enhance the households/users' adoption for the same.

3. Theoretical Framework
Factors That Influencing The Adoption Of Solar Energy

This variable represents the households/users' perception on the factors that influencing the level of adoption of solar energy among households. It includes the presence of solar panels, extent of solar energy utilization, and overall integration of solar energy systems in residential settings. It involves the installation and operation of solar panels, solar water heaters, or other solar-based systems to harness renewable energy from the sun. The factors that influencing the level of adoption of solar energy among households are Savings in Cost of Energy, Perceived Trust, Perceived Value and Environmental Concern. The adoption of solar energy signifies a transition from traditional energy sources, such as fossil fuels, to a cleaner and more sustainable alternative.

Residential Energy Consumption

Residential energy consumption refers to the amount of energy used by households in their day-to-day activities, including electricity, heating, cooling, and other energy-related services. This consumption encompasses the overall energy consumption patterns of households, both before and after solar energy adoption. It includes electricity consumption, reliance on the grid, energy savings, and shifts in energy usage patterns. It is influenced by the choices made by individuals and households regarding energy use, conservation practices, and the adoption of energy-efficient technologies.

Quality Of Life Of Households

Quality of life of households encompasses various aspects of well-being, satisfaction, and comfort experienced by individuals and families in their living environment. It includes factors such as comfort levels, affordability of energy, environmental impact, and overall satisfaction with the residential living conditions.

Understanding the relationship between residential energy consumption and quality of life is essential for assessing the impact of energy usage on households' well-being and identifying strategies to improve energy efficiency, affordability, and overall living standards. By analyzing these factors, researchers can provide insights into how the adoption of solar energy influences residential energy consumption patterns and subsequently affects the quality of life of households of Puducherry region.

Methodology Adopted

This study adopts an approach that is both exploratory and descriptive in nature. It utilizes a mixed research methodology, incorporating both qualitative and quantitative methods. The study focuses on the Users (households) population of Solar Energy Products. The sample for the study was selected through convenience

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sampling, and primary data was gathered using a structured questionnaire administered to 160 households who are adopting Solar Energy Products in Puducherry region.

The researcher employed a combination of descriptive and inferential statistical techniques to analyze the collected data. Statistical tools like Mean Analysis, Independent Sample 't' test, One-way ANOVA, Correlation Analysis and Multiple Regression Analysis are utilized to analyse the perception on the factors that influencing the adoption of Solar Energy Products and their impact on Residential Energy Consumption and Quality of Life of households in Puducherry region.

3. Data Analysis and Results

Demographic Profile Of The Households/Users

Table 1: Demographic Profile Of The Households/Users

VARIABLES	OPTIONS	FREQUENCIES	(%)
Gender	Male	93	58.13
	Female	67	41.87
Age	21 – 40 Years	84	52.50
	41 – 60 Years	60	37.50
	Above 60 Years	16	10.00
Level of Education	School / Diploma	63	39.38
	Graduation (UG/PG) Professional	77	48.12
	Qualification	20	12.50
Occupation	Salaried job	66	41.25
	Business / Professional	30	18.75
	Students	18	11.25
	Home-makers/Retired	46	28.75
Monthly Family Income (RS)	Up-to 50,000 Rs	52	32.50
	50,001 – 10,0000 RS	76	47.50
	Above 100,000 RS	32	20.00
Size of Family	Up-to 3 Members	73	45.63
	4 – 6 Members	52	32.50
	Above 6 Members	35	21.87

 Source: Primary Data

From the Demographic Profile of the households table 1, it is inferred that male households/users (58.13%) are more than female households/users (41.87%). 52.50% of them belong to the Age group of 21-40 Years. Most of the households/users (48.12%) are Graduates (UG/PG). 41.25% of them are Salaried persons and 47.50% of the households belong to the monthly family income category of 10,001 – 20,000 RS. In terms of size of family of the households/users, 45.63% of them have up-to 3 members in their family.

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Table 2 : Usage Pattern Of Solar Energy Products

VARIABLES	OPTIONS	FREQUENCIES	(%)
Type of Solar Energy Product used	Solar Rooftop Panels for electricity usage	48	30.00
	Solar Battery/Charger	22	13.75
	Solar Lantern	14	8.75
	Solar Water Heater	30	18.75
	Solar Water Pumps/Purifier	15	9.38
	Solar Cooker	13	8.12
	Solar Air Conditioners	10	6.25
	Other Solar Energy Products	8	5.00
Period of using Solar Energy Products	Up-to 3 Years	53	33.13
	4 – 6 Years	76	47.50
	More than 6 Years	31	19.37
Knowledge about Solar Energy Products	Media Sources	71	44.38
	Non-Media Sources	89	55.62

Source: Primary Data

The table 2 provides the information about the Usage pattern of Solar Energy Products in Puducherry region. It is inferred from the table that 30% of the households/users are using Solar Rooftop Panels for electricity usage followed by Solar Water Heater (18.75%), Solar Battery/Charger (13.75%), etc. 47.50% of the households are using Solar Energy Products for 4 – 6 Years and 55.62% of the households came to know about the Solar Energy Products through Non-Media Sources (Own Knowledge, Friends/Colleagues, etc.).

Households' Perception On The Factors That Influencing The Adoption Of Solar Energy Products – Mean Analysis

In order to identify Households/Users' perception on the factors that influencing the Adoption of Solar Energy Products, 12 Questions relating to the four factors i.e., Savings in Cost of Energy, Perceived Trust, Perceived Value and Environmental Concern (3 Questions/variables for each) are inquired from the households through the structured questionnaire and the results are as follows.

Table 3: Households' Perception On The Factors That Influencing
The Adoption Of Solar Energy Products
Descriptive Statistics

S. No.	SOLAR ENERGY ADOPTION FACTORS	N	Mean	SD
1.	Savings in Cost of Energy	160	12.63	2.884
2.	Perceived Trust	160	11.35	3.113
3.	Perceived Value	160	13.05	2.547
4.	Environmental Concern	160	10.84	3.465
	HOUSEHOLDS' PERCEPTION ON THE SOLAR ENERGY ADOPTION FACTORS	**160**	**47.87**	**6.326**

Source: Primary Data

From the above table 3, it is found that households/users have more perception on 'Perceived Value' (M = 13.05) factor and have lesser perception on 'Environmental Concern' factor (M = 10.84) when compared with other factors relating to the Adoption of Solar Energy Products. From the above table, it is also inferred that the households/users on the various factors that influencing the Adoption of Solar Energy Products are above the

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average level since all mean values of the variables are above 10 (two-third or 66.67%) out of 15. The mean value of the Overall households/users' Perception on the factors that influencing the Adoption of Solar Energy Products is 47.87 (79.78%) which is above 79%.

H$_0$: There is no significant difference between the Male and Female households/users with respect to the households/users' Perception on the Factors that influencing the adoption of Solar Energy Products.

An independent-samples t-test was conducted to compare the difference between the Male and Female households/users with respect to the households/users' Perception on the Factors that influencing the adoption of Solar Energy Products.

Table 4: Gender – Perception On The Solar Energy Adoption Factors

VARIABLE	GENDER						t - value	p – value
	MALE			FEMALE				
	N	Mean	SD	N	Mean	SD		
PERCEPTION ON THE SOLAR ENERGY ADOPTION FACTORS	93	48.32	5.223	67	46.33	6.314	3.154	0.027*

Source: Primary Data
(*5% Level of Significance)

As the P Value (0.027) is lesser than Sig. Value at 5%, the Null Hypothesis is rejected. Based on the Mean score of Households/Users' Perception on the Solar Energy Product Adoption Factors, it inferred that the mean score of the Male users (M = 48.32) is more than Female Users (M = 46.33) of Solar Energy Products. Thus, a significant difference exists between the Male and Female Users with respect to the Perception on the Factors that influencing the adoption of Solar Energy Products.

H$_0$: There is no significant difference among the Years of Using Solar Energy Products by the households/users with respect to the Perception on the Factors that influencing the adoption of Solar Energy Products.

A one-way between-groups analysis of variance (ANOVA) was conducted to explore the significant difference among the Years of Using Solar Energy Products by the households/users with respect to the Perception on the Factors that influencing the adoption of Solar Energy Products.

Table 5: Years Of Usage – Perception On The Solar Energy Adoption Factors

VARIABLE	YEARS OF USAGE			F – value	p – value
	Up-to 3 Years (53)	4 – 6 Years (76)	More than 6 Years (31)		
PERCEPTION ON THE SOLAR ENERGY ADOPTION FACTORS	43.44	45.30	48.57	5.694	0.000**
	7.553	6.774	5.635		

Source: Primary Data (No. of Households/Users are shown in brackets)
(1% Level of Significance)**

As the _P_ value (0.000) is lesser than Sig. Value (0.01) in the Perception on the Factors that influencing the adoption of Solar Energy Products Score, the Null Hypothesis is rejected. Apart from reaching statistical significance, the actual difference in the mean score among the 'Years of Usage groups is also considerable (M =

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43.44 to 48.57). The Mean score of the Perception on the Factors that influencing the adoption of Solar Energy Products is higher (M = 48.57) in case of the households who are using Solar Energy Products for more than 6 years than others.

This indicates that the households who are using Solar Energy Products for more than 6 years have more perception on the factors that influencing Adoption of Solar Energy Products than others. Hence, there is significant difference among the Years of Using Solar Energy Products by the households with respect to Perception on the Factors that influencing the adoption of Solar Energy Products.

Impact Of Solar Energy Products On Residential Energy Consumption

H_0: **There is no significant difference between the Male and Female households/users with respect to the Impact of the adoption of Solar Energy Products on the Residential Energy Consumption.**

An independent-samples t-test was conducted to compare the difference between the Male and Female households/users with respect to the Impact of the adoption of Solar Energy Products on the Residential Energy Consumption.

Table 6: Gender – Impact Of Solar Energy Products On
Residential Energy Consumption

VARIABLE	GENDER						t - value	p – value
	MALE			FEMALE				
	N	Mean	SD	N	Mean	SD		
IMPACT OF SOLAR ENERGY PRODUCTS ON RESIDENTIAL ENERGY CONSUMPTION	93	22.58	3.596	67	21.39	4.684	3.113	0.021*

Source: Primary Data
(*5% Level of Significance)

As the P Value (0.021) is lesser than Sig. Value at 5%, the Null Hypothesis is rejected. Based on the Mean score of Residential Energy Consumption due to the adoption of Solar Energy Products, it inferred that the mean score of the Male households/users (M = 22.58) is more than the mean score of the Female households/users (M = 21.39). Thus, a significant difference exists between the Male and Female households/users with respect to the Impact of the adoption of Solar Energy Products on the Residential Energy Consumption.

Relationship Between Solar Energy Product Adoption Factors And Residential Energy Consumption

H_0: **There is no significant relationship between the Solar Energy Adoption Factors and Residential Energy Consumption of households.**

A Pearson product-moment correlation was run to determine the relationship between the Solar Energy Adoption Factors and Residential Energy Consumption of households.

Table 7: Relationship Between Solar Energy Product Adoption Factors And Residential Energy Consumption

VARIABLE	N	'r' VALUE	P - VALUE	RELATIONSHIP	REMARKS SIGNIFICANT	RESULT
Savings in Cost of Energy	160	0.743**	0.000	Positive	Significant	REJECTED
Perceived Trust	160	0.702**	0.000	Positive	Significant	REJECTED
Perceived Value	160	0.816**	0.000	Positive	Significant	REJECTED
Environmental Concern	160	0.667**	0.000	Positive	Significant	REJECTED
SOLAR ENERGY PRODUCT ADOPTION FACTORS AND RESIDENTIAL ENERGY CONSUMPTION	160	0.803**	0.000	Positive	Significant	REJECTED

(Source: Primary Data) **. Correlation is significant at the 0.01 level (2-tailed).

As the P value (0.000) is lesser than Sig. Value (0.01) in all the above relationships, the Null Hypotheses are rejected. There are high positive and significant correlations between the variables. Out of four factors, 'Perceived Value' (r = 0.816) has more relationship with Residential Energy Consumption and 'Environmental Concern' (r = 0.667) has lesser relationship with Residential Energy Consumption of households than others. Overall, Solar Energy Product Adoption Factors have positive and high and also significant relationship (r = 0.803) with Residential Energy Consumption of households.

Impact Of Adoption Of Solar Energy Products On The Quality Of Life Of Households

Multiple Regression Analysis

Multiple Regression was conducted to determine the best linear combination of the Solar Energy Product Adoption Factors (Independent Variables) to predict Quality of Life (Dependent Variable) of households.

Table 8: Solar Energy Product Adoption Factors - Quality Of Life Of Households
REGRESSION COEFFICIENT

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.654	.584		-2.754	.032
	Savings in Cost of Energy	.318	.074	.321	4.774	.000**
	Perceived Trust	.233	.082	.229	3.995	.006**
	Perceived Value	**.374**	**.070**	**.367**	**5.361**	**.000**
	Environmental Concern	.172	.091	.168	2.763	.029*

Dependent Variable: QUALITY OF LIFE OF HOUSEHOLDS

The combination of all the four independent variables i.e., Solar Energy Product Adoption Factors, significantly predicts the dependent variable i.e., Quality of Life of households, $F_{(4, 155)} = 403.236$, *p values are* lesser than .001 and 0.005 (Sig. Value 2-tailed) and Adjusted R Square is 0.769 or 77% which is large effect according to Cohen.

Out of four independent variables relating to the Solar Energy Product Adoption Factors, "Perceived Value" (0.367) is the strongest influencing factor in predicting the dependent variable i.e., Quality of Life of

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households. From the unstandardized coefficient, it is found that the one unit increase in "Perceived Value" factor would increase the Quality of Life of households by 0.374 units. Savings in Cost of Energy (0.321), Perceived Trust (0.229) and Environmental Concern (0.168) also influence the Quality of Life of households significantly but lesser than "Perceived Value" factor.

4. Summary Of Findings

The study found that Households/users' perception on the Solar Energy Adoption factors is above the average level which indicates the appreciable adoption level on solar energy products in the study area. The study also revealed that male households have perceived more on the Solar Energy Product Adoption factors and Residential Energy Consumption than their counter-part. The households who are using Solar Energy Products for more than 6 years have more perception on the factors that influencing Adoption of Solar Energy Products than others. Solar Energy Product Adoption Factors have positive and high and also significant relationship with Residential Energy Consumption of households. The study indicated that out of four adoption factors, 'Perceived Value' contributes more and 'Environmental Concern' contributes lesser in predicting Quality of Life of households than others.

5. Suggestions And Recommendations

Despite the favorable perception, it is essential to continue educating households in the Puducherry region about the benefits of solar energy adoption. This can be done through community workshops, informational campaigns, and outreach programs to increase awareness among a wider audience. Recognizing that male households have shown higher perception levels, it's important to design gender-inclusive programs that target female households as well. Specialized outreach and support initiatives can be developed to encourage their participation in solar energy adoption. Households with more than 6 years of experience have shown greater perception of adoption factors. It is recommended to consider providing support and resources to new users to help them overcome initial barriers and ensure they maximize the benefits of solar energy over time.

Given the significant relationship between solar energy product adoption factors and residential energy consumption, focus on ensuring the quality and reliability of solar energy products. The study suggested to encourage the use of certified products and offer assistance with maintenance and performance monitoring. Although 'Environmental Concern' was found to be a lesser predictor of quality of life, it's still an essential factor. Promoting the environmental benefits of solar energy to enhance its appeal and highlighting how individual actions contribute to environmental conservation and sustainability. The government may consider introducing or expanding incentive programs to further encourage solar energy adoption. This could include financial incentives, tax breaks, or subsidies, making the initial investment more appealing to a wider audience. Since 'Perceived Value' was a significant predictor of quality of life, focus on enhancing the perceived value of solar energy products. This can be achieved through improved customer service, product enhancements, and ensuring that users understand the full range of benefits.

6. Conclusion

The study revealed that solar energy adoption has a significant impact on residential energy consumption patterns. It demonstrated the potential for reduced reliance on conventional energy sources, energy conservation, and the promotion of energy efficiency through solar energy adoption. Moreover, the study highlighted the positive implications of solar energy adoption for the quality of life of households. It emphasized the potential for enhanced energy affordability, improved comfort levels, environmental responsibility, energy independence, and community engagement. Understanding residential energy consumption is essential for energy planning, efficiency programs, and policy development. It allows for the assessment of energy needs, identification of consumption patterns, evaluation of energy efficiency measures, and formulation of strategies to promote sustainable energy use, reduce greenhouse gas emissions, and lower energy costs for households.

The findings of this research can have significant implications for policymakers, energy planners, and households in Puducherry region. This study contributes to the broader goals of sustainable development, environmental conservation, and the well-being of individuals and communities in the study region. By uncovering the key factors influencing solar energy adoption, policymakers can develop targeted strategies and

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incentives to promote its use in residential areas. Energy planners can use the insights to design effective programs for integrating solar energy into the existing energy infrastructure. Furthermore, households can make informed decisions regarding solar energy adoption based on the identified factors, contributing to reduced energy consumption, cost savings, and enhanced quality of life and achieving a more sustainable future.

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