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Determining the Factors Affecting Solar Energy Utilization in Saudi Housing: A Case Study in Makkah

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Abstract: This research paper examines the adoption of solar energy in residential buildings throughout Saudi Arabia, with a specific emphasis on Makkah. Despite the immense global demand for energy and growing environmental concerns, the adoption of solar energy in Saudi housing remains relatively low. While previous studies have examined the potential, feasibility, and policy support for solar energy, this research uniquely approaches the issue from the perspective of customers on a national scale. The study aims to identify the factors that influence customers' intentions to use solar energy in Saudi Arabia, contributing to the development of a sustainable circular supply chain for renewable energy. To achieve this, the research integrates the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2). An online questionnaire was distributed, garnering responses from a total of 250 participants. A regression analysis was employed to analyze the data and examine the relationships between the proposed hypotheses. The study's findings reveal that four critical factors wield significant influence over consumer behavior and their decisions regarding the adoption of solar PV technology. These factors are: Social Influence (SI), Performance Expectancy (PE), Effort Expectancy (EE), and Facilitating Conditions (FC).

Keywords: solar energy; awareness; energy sustainability; solar energy adoption; UTAUT

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1. Introduction

The global energy landscape is currently experiencing a transformative shift, driven by the urgent need to combat climate change and ensure the availability of sustainable energy sources for future generations [1]. Within this context, solar energy has emerged as a central player, offering a vast and eco-friendly alternative to conventional fossil fuels. Saudi Arabia, in particular, stands poised at the forefront of this transition due to its unique geographical advantage—abundant solar irradiance throughout the year [2]. Capitalizing on this solar potential not only holds the promise of mitigating carbon emissions, but also solidifies the nation's position as a frontrunner in the global renewable energy movement [3]. This research paper delves into the crucial task of elevating awareness about solar energy utilization within the framework of Saudi housing, with a focused exploration of the city of Makkah. The significance of Makkah as both a religious and cultural epicenter amplifies the implications of embracing sustainable energy practices within its residential landscape. While the adoption of solar energy systems brings a host of benefits, such as diminished electricity costs, a reduced reliance on finite resources, and the potential for surplus energy generation, the feasibility of these systems hinges significantly on factors such as public awareness, societal attitudes, and the establishment of an environment conducive to their implementation. Moving forward, the paper delves into an analysis of Saudi Arabia's solar energy potential, situating the nation's energy requirements within the context of its geographical attributes. Next, it proceeds to evaluate the current state of solar energy integration in the country. This investigation illuminates both the remarkable progress achieved and the challenges encountered on the journey towards its extensive adoption. Moreover, the paper embarks on an exploration of the intricate interplay of factors that exert influence over the adoption of solar energy. These factors encompass a wide spectrum, ranging from economic considerations to the prevailing attitudes within society and the policies formulated by the government. In a world becoming increasingly conscious of its environmental impact, the role of sustainable energy sources cannot be overstated. As Saudi Arabia strives to harness its solar potential and lead the transition to cleaner energy, comprehending the factors shaping this journey becomes imperative. This research paper delves into the intricate terrain of solar energy adoption within the distinctive context of Saudi housing in Makkah. The study unveils four pivotal factors that significantly influence consumer behavior and their choices concerning the adoption of solar energy. Through a comprehensive exploration of solar energy adoption, this research seeks to provide insights into the challenges and opportunities for increasing the awareness of solar energy within the Saudi housing sector.

1.1. Solar Energy Potential in Saudi Arabia

Saudi Arabia's expansive deserts receive intense solar irradiance, positioning the nation as a prime candidate for large-scale solar projects [4]. This abundant solar resource presents a transformative opportunity for the Kingdom, not only aligning with global renewable energy goals, but also offering a sustainable pathway to reshape its energy mix. Leveraging its solar abundance, Saudi Arabia holds the potential to not just power its cities and industries, but also to make substantial contributions towards global sustainability targets. The sun's radiance over its vast landscapes presents a valuable asset that can drive economic growth while curbing environmental degradation. The paper underscores the profound implications of Saudi Arabia's solar potential, emphasizing its dual role in combating carbon emissions and enhancing energy security. With ample sunlight available year round, the nation possesses a unique resource that can usher in a greener and more resilient energy future. Saudi Arabia's solar-rich terrain aligns seamlessly with the world's growing commitment to cleaner energy solutions. By harnessing its solar potential, the nation can propel itself towards meeting international climate goals, further solidifying its position as an advocate for sustainable development. Embracing solar energy is not merely a strategic move for Saudi Arabia, it is a transformative step toward reshaping the entire energy landscape. Amidst the diversification of energy sources, solar power emerges as a cornerstone for the nation's sustainable growth, offering environmental benefits and economic opportunities. However, realizing this solar potential requires a concerted transition from theoretical promises to tangible progress. This paper emphasizes the necessity of crafting comprehensive strategies, forging collaborative partnerships, and enacting supportive policies that can facilitate the transition from solar potential to impactful solar initiatives. Saudi Arabia's solar energy potential represents a beacon of promise in the journey towards sustainable energy solutions. The radiance of the sun holds the key to mitigating carbon footprints, enhancing energy independence, and fostering a cleaner world. Through its exploration of this potential, this paper adds depth to the discourse on sustainable energy transformation and underscores the pivotal role that solar energy can play in shaping Saudi Arabia's energy trajectory.

1.2. Current State of Solar Energy Utilization in Saudi Arabia

In recent years, a burgeoning interest in solar energy adoption has swept across Saudi Arabia. This surge has been invigorated by ambitious initiatives like the Saudi Vision 2030 and the National Renewable Energy Program (NREP), which underscore the government's unequivocal commitment to embedding renewable energy into the fabric of the nation [5]. However, amidst this promising progress, a set of persistent challenges cast a shadow over these advancements, encompassing crucial aspects such as the integration of renewables into existing energy systems and the sustainable performance of solar installations [6]. The vision encapsulated in the Saudi Vision 2030 and the National Renewable Energy

Program (NREP) represents a resolute stride towards a sustainable energy paradigm. These initiatives not only acknowledge the imperative of diversifying energy sources, but also spotlight the immense potential that solar energy holds within the nation's sun-drenched landscapes. The holistic approach taken in these initiatives encompasses environmental stewardship, as well as the social and economic dividends derived from transitioning to renewables. However, transitioning from intent to impactful realization involves navigating a multifaceted terrain. A primary challenge lies in seamlessly integrating renewable energy sources into the existing energy infrastructure. This entails orchestrating the coexistence of conventional and renewable energy streams through intricate technological solutions that safeguard the stability and dependability of the energy grid. Equally paramount is the consistent and reliable performance of solar installations. The effectiveness of solar systems can be influenced by diverse factors, from weather fluctuations to technological efficiencies and maintenance practices. Consequently, meticulous attention to system design, engineering precision, and diligent upkeep is imperative to ensure the sustained harnessing of solar potential and the endurance of these systems. The journey towards harnessing the full potential of solar energy in Saudi housing is not devoid of obstacles. Regulatory intricacies, financing complexities, and the need for bolstering technical capacity are among the hurdles that demand proactive resolution. Overcoming these obstacles necessitates a collaborative orchestration involving government bodies, private sector stakeholders, and research institutions. As Saudi Arabia charts its course toward a more sustainable energy landscape, it does so with a deliberate equilibrium between progress and the challenges intrinsic to transformation [2]. This trajectory mandates innovative problem solving, flexibility of policy frameworks, and a shared dedication from stakeholders spanning various sectors. In summation, the prevailing state of solar energy utilization in Saudi Arabia signifies a journey of transformation. The synergy of forward-looking government initiatives, technological ingenuity, and the tenacity to overcome obstacles steers the nation's evolution towards the comprehensive integration of renewable energy. This trajectory, with its successes, lessons, and insights, possesses the potential to illuminate a trail for other regions endeavoring to embrace a sustainable energy future.

Saudi Arabia has witnessed a substantial surge in its solar energy capacity over the past decade. In line with its commitment to diversify its energy sources and reduce its carbon emissions, the Kingdom has embarked on ambitious solar energy projects. One notable initiative is the King Abdullah City for Atomic and Renewable Energy (K.A.C.A.R.E.), which was established to oversee the development of renewable energy in Saudi Arabia [7]. As part of its National Renewable Energy Program (NREP), Saudi Arabia aims to install 27.3 GW of renewable energy capacity by 2024, with a significant portion coming from solar photovoltaic (PV) projects [8]. To achieve these objectives, Saudi Arabia has made significant strides in harnessing its abundant solar energy resources. The Kingdom's commitment to renewable energy, driven by environmental considerations and the need to diversify its energy mix, has resulted in a substantial growth in solar energy generation. One of the notable milestones in Saudi Arabia's solar energy journey was the commissioning of the Sakaka Solar Power Plant in 2019. This 300 MW photovoltaic (PV) facility, one of the largest in the Middle East at the time, marked a significant achievement in the deployment of solar energy infrastructure [9].

Moreover, Saudi Arabia benefits from its geographical location, characterized by abundant sunlight throughout the year. With some of the world's highest solar irradiance levels, the country has substantial untapped solar potential [10]. The nation's vast deserts provide ample space for solar installations, making it an ideal location for solar energy projects. The Kingdom's commitment to renewable energy aligns with its Vision 2030 plan, which aims to transform Saudi Arabia into a more diversified and sustainable economy. By harnessing its solar energy potential, Saudi Arabia seeks not only to reduce its carbon footprint, but also to create jobs, stimulate economic growth, and establish itself as a global leader in renewable energy [11].

1.3. Assessing the Possibilities of Increasing Solar Generation in Saudi Arabia

Looking ahead, Saudi Arabia's potential for increasing solar energy generation is substantial and promising. Several key factors contribute to this optimistic outlook. First, the Kingdom has set ambitious renewable energy targets through its National Renewable Energy Program (NREP), aiming to install 27.3 GW of renewable energy capacity by 2024. A significant portion of this capacity will come from solar PV projects, including both utility-scale and distributed installations [8]. Second, Saudi Arabia enjoys some of the highest solar irradiance levels in the world, with abundant sunlight year round. This makes it well-suited for large-scale solar energy generation, both in its deserts and across urban areas. Third, the Kingdom has attracted substantial investments in its renewable energy sector. The government has collaborated with international energy companies and investors to fund and develop solar projects. These partnerships are expected to drive the expansion of solar capacity [9].

Furthermore, as part of its Vision 2030 plan, Saudi Arabia aims to diversify its economy, reduce its reliance on oil, and create new job opportunities. The renewable energy sector, including solar energy, plays a pivotal role in achieving these economic diversification objectives. Lastly, advances in solar panel technologies and energy storage solutions are enhancing the efficiency and reliability of solar installations. These innovations are expected to make solar energy more accessible and cost-effective [8]. In conclusion, Saudi Arabia has witnessed a notable increase in solar energy generation capacity in recent years, driven by ambitious government initiatives and favorable geographical conditions. The Kingdom's commitment to further expanding its solar energy capacity is evident in its renewable energy targets and investments in the sector. With its abundant solar resources and strategic vision, Saudi Arabia is well-positioned to significantly increase its solar energy generation in the coming years.

The subsequent content is structured into several key sections: Section 2 examines the factors influencing solar energy adoption, and presents the conceptual framework, Section 3 outlines the materials and methods employed in the research, Section 4 reports the results, and Section 5 provides a comprehensive discussion. Finally, the paper concludes by summarizing the findings and proposing avenues for future research.

2. Literature Review and Hypothesis Formulation

2.1. Integration of IoT Technologies and Modern Energy Management Strategies

In today's evolving energy landscape, electricity retailers and distribution companies are becoming increasingly focused on promoting demand response among users [12]. This shift is facilitated through the implementation of advanced home energy management control schemes, often coupled with Internet of Things (IoT) technologies, to govern household appliances intelligently and reduce electricity bills. These technologies enable the active participation of end-users in the electricity market, giving rise to roles commonly known as "smart consumers" or "smart prosumers" [13]. A "smart consumer" primarily functions as a load, consuming electricity efficiently through IoT-enabled control systems. On the other hand, a "smart prosumer" possesses the capability to generate surplus energy using resources like photovoltaic (PV) systems or energy storage batteries. This surplus energy can be intelligently managed and, when necessary, sold back to the grid to generate revenue [14]. This paradigm shift from the traditional passive home model, where households were primarily consumers of electricity, has introduced a new level of complexity. In the past, load curves for dwellings were relatively easy to predict, as peak and valley loads typically occurred at similar hours, and there was no mechanism for selling excess energy back to the grid. However, the emergence of the prosumer environment, coupled with IoT technologies, has disrupted these predictable patterns due to the higher degree of variability introduced by energy generation and trading activities [15].

This dynamic shift towards active participation in the energy market highlights the significance of advanced home energy management systems, coupled with IoT technologies, and their role in reshaping the residential energy sector. It also underscores the need for innovative approaches to grid management and regulation to accommodate the diverse behaviors of smart consumers and prosumers, ultimately fostering a more resilient, sustainable, and responsive energy ecosystem [15]. In the contemporary drive towards sustainable energy adoption, the spotlight has shifted to Saudi housing in the vibrant city of Makkah, offering a rich landscape to investigate the determinants shaping the uptake of innovative technologies. While numerous models exist for examining the adoption of novel technologies, such as the Theory of Planned Behavior (TPB) [16], the Theory of Reasoned Action [17], and the Technology Acceptance Model (TAM) [18], each meticulously crafted to dissect the underlying factors driving adoption, the unique context of solar photovoltaic (PV) technology in Saudi Arabia calls for a tailored approach.

2.2. The Relevance of the Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) stands as a robust framework rooted in psychological theories, most notably reasoned action and planned behavior, which allows for a comprehensive exploration of technology acceptance across various innovative domains [19]. The TAM centers around two fundamental constructs: Perceived Ease of Use (PEOU), which encapsulates the degree to which individuals perceive a nascent technology as comprehensible and user-friendly, indicating the ease with which potential adopters believe they can use the technology [18]. Perceived Usefulness (PU): PU delves into the extent to which a technology augments utility for the end-user, assessing whether individuals perceive the technology as beneficial and valuable [18].

The relevance of these constructs in the context of solar PV adoption lies in the fact that consumers' perceptions of ease of use and usefulness play pivotal roles in their decision-making process.

2.3. Evolving TAM with UTAUT

While PU and PEOU contribute significantly to understanding consumer intentions, there is potential for a more nuanced model that aligns with the unique dynamics of solar PV technology adoption. To address this, we draw inspiration from the Unified Theory of Acceptance and Use of Technology (UTAUT), a vanguard model for scrutinizing the user intentions and behaviors surrounding information system adoption [19,20]. The UTAUT emerged through a synthesis of eight foundational models, encompassing theories like the Innovation Diffusion Theory (IDT), Theory of Reasoned Action (TRA), and others [21]. It has found application in diverse domains, including e-learning, e-governance, and e-banking [21–24]. However, its adaptability to the unique realm of solar PV technology adoption within Saudi housing in Makkah remains largely unexplored. The distinct attributes of this sector demand a fresh perspective, one that bridges the gap between existing models and the specific context of our study.

2.4. Factors Affecting the Use of Solar Energy in Saudi Arabia

Based on the aforementioned hypotheses, we have constructed a comprehensive conceptual framework that outlines the positive impacts of PE, EE, SI, and FC on consumers' behavioral intentions to adopt solar PV technology in Saudi housing in Makkah. This framework serves as the foundation upon which our empirical analysis is built.

- Performance Expectancy (PE): Performance Expectancy refers to a user's perception of how effective a technology or system will be in helping them to achieve their goals. It encompasses the user's expectation that using the technology will enhance their performance or make tasks easier to accomplish. Research by Davis (1989), within the context of the original Technology Acceptance Model (TAM), demonstrated that perceived usefulness, which aligns with performance expectancy, strongly influences technology acceptance [18,23]. Users are more likely to adopt technology when they perceive it as valuable and capable of improving their performance.
- Effort Expectancy (EE): Effort Expectancy is closely related to the concept of perceived ease of use. It refers to a user's expectation of how easy or difficult it will be to use the

technology. If a system is perceived as easy to use, users are more likely to adopt it. Research by Venkatesh et al. (2003), in the context of the Unified Theory of Acceptance and Use of Technology (UTAUT), introduced effort expectancy as a key factor and emphasized its significance in technology adoption [19,24]. When users anticipate that using a technology will not require excessive effort, they are more inclined to adopt it.

- Social Influence (SI): Social Influence examines the impact of peers, friends, family, or social networks on an individual's decision to adopt technology. It considers whether individuals are influenced by the opinions, recommendations, or behaviors of others in their social circles. The theory of normative social behavior (NSB) posits that social influence plays a significant role in shaping individual behaviors, including technology adoption [20]. People often turn to their social networks for guidance and validation when making decisions about adopting new technologies.
- Facilitating Conditions (FC): Facilitating Conditions relate to the availability of the necessary resources and support that users need to effectively use a technology. This includes factors such as access to training, technical support, and infrastructure. Research within the UTAUT framework has shown that facilitating conditions significantly affect technology adoption [19]. When users have the necessary resources and support available to them, this reduces barriers to adoption and enhances their likelihood of accepting the technology. These studies underscore the importance of these factors in shaping technology adoption and provide a solid foundation for our hypotheses.

2.5. Formulated Hypotheses

With this theoretical foundation in place, we have developed the following hypotheses to guide our research:

H1: *Performance Expectancy (PE) significantly influences the behavioral intention to adopt solar PV technology.*

H2: *Effort Expectancy (EE) significantly influences the behavioral intention to adopt solar PV technology.*

H3: *Social Influence (SI) significantly influences the behavioral intention to adopt solar PV technology.*

H4: *Facilitating Conditions (FC) significantly influence the behavioral intention to adopt solar PV technology.*

These hypotheses set the course for our investigation into the complex interplay of factors influencing the embrace of solar PV technology within the unique landscape of Saudi housing in Makkah. By delving into the nuances of these factors, this research endeavors to provide holistic insights that resonate both academically and practically in the pursuit of sustainable energy adoption.

3. Materials and Methods

The choice of Saudi Housing in Makkah as the study case is informed by specific factors. Firstly, Makkah's energy landscape is characterized by its reliance on conventional energy sources, necessitating a closer examination of potential shifts towards sustainable alternatives. Secondly, Makkah's significance as a spiritual hub and its global prominence makes it pertinent to explore avenues for reducing its environmental impact, aligning with broader sustainability goals.

3.1. Sampling Population and Data Collection

The study encompasses a diverse range of households within Saudi Housing in Makkah. This choice is deliberate, given the potential for significant energy consumption within this context. The data collection was executed through a self-administered questionnaire divided into two sections. The initial section gathered demographic details, including variables such as gender, age, education, and more.

3.2. Selection of Constructs and Measurement

The study's constructs were meticulously selected, aligning with prior research and encompassing both exogenous and endogenous factors critical to understanding the respondents' expectations and intentions regarding solar energy utilization in Saudi housing in Makkah. These constructs were designed to capture a comprehensive view of the factors influencing the adoption of solar PV technology.

3.2.1. Performance Expectancy (PE)

Performance Expectancy, one of the key constructs, was adapted from Davis (1989) and refers to the degree to which individuals perceive solar energy utilization as beneficial and enhancing their quality of life. To measure this construct, the respondents were presented with a set of statements related to the potential advantages of solar energy in Saudi housing in Makkah. These statements were rated on a 7-point Likert scale, ranging from 1 ("strongly disagree") to 7 ("strongly agree").

Example statements related to Performance Expectancy include:

> "Using solar energy in residential buildings in Makkah would significantly reduce my energy bills".

> "Solar energy utilization would enhance the reliability of electricity supply in my home". [20,25,26]

3.2.2. Effort Expectancy (EE)

Effort Expectancy, inspired by Venkatesh et al. [19], gauges the ease with which the respondents perceive the adoption and use of solar PV technology. In assessing this construct, the participants were presented with statements related to the perceived simplicity of adopting and using solar energy systems in their homes.

Sample statements related to Effort Expectancy encompass:

> "I think solar PV technology is an environmentally friendly technology".

> "I think solar PV technology will be beneficial in my daily life". [20,25,26]

3.2.3. Social Influence (SI)

Social Influence captures the impact of peers, family, and societal norms on the respondents' decisions regarding solar energy adoption. To measure this construct, the respondents were asked to consider statements concerning the influence of others on their intentions to adopt solar energy.

Example statements reflecting Social Influence encompass:

> "I always ask friends about their experiences using an item before deciding to buy".

> "If my friends have a good experience with solar PV technology, I am likely to be interested in buying one too". [20,25,26]

3.2.4. Facilitating Conditions (FC)

Facilitating Conditions, as per Venkatesh et al. (2003) [19], evaluate the availability of the resources, infrastructure, and support necessary for the respondents to adopt solar PV technology. To assess this construct, the respondents were presented with statements concerning the practical aspects of adopting and using solar energy systems.

Sample statements about Facilitating Conditions include:

> "I have a sufficient/usable area to install solar PV technology in my residence".

> "I have sufficient knowledge of solar PV technology". [20,25,26]

3.2.5. Behavioral Intentions (BI)

Behavioral Intentions serve as a central construct, reflecting the respondents' intentions to adopt solar PV technology in Saudi housing in Makkah. This construct was measured by asking the respondents about their willingness and plans to use solar energy systems in their residential buildings.

Example statements related to Behavioral Intentions include:

"I intend to adopt solar energy systems in my home within the next year".

"I am actively considering the installation of solar panels on my residential property". [20,25,26]

All the responses to these construct-related statements were collected using a 7-point Likert scale, allowing the participants to express their agreement or disagreement with each statement, thereby facilitating a nuanced understanding of their perceptions and intentions regarding solar energy utilization in Saudi housing in Makkah.

This carefully designed measurement approach aimed to provide comprehensive insights into the factors influencing the adoption of solar PV technology, fostering a deeper understanding of the respondents' perspectives and intentions within the unique context of Makkah's housing sector.

3.3. Sampling Methodology and Sample Size Determination

Non-probability sampling was the chosen methodology, apt for situations where complete access to the sample frame is challenging [27]. This approach is particularly suitable for achieving theoretical generalizability [28]. Thus, purposive sampling was utilized to select the sample. Given the relevance of income to pro-environmental behavior [29], middle-class residents with an income of around USD 1000 were targeted for inclusion. The sample size determination followed guidance from [30], suggesting a range from 200 to 500 for behavioral studies. Therefore, 300 questionnaires were distributed, considering that the usual response rate falls between 40% and 60% in behavioral studies. Out of these, 250 questionnaires were returned, and, after screening, approximately 221 were deemed valid. This equates to a response rate of 73.6%, in line with Mellahi and Harris' [31] findings (2016) that response rates in the subcontinent averaged around 52.68%. Demographics Profile: Table 1 portrays the demographic profiles of the respondents, encompassing factors such as gender, age, and education level.

Table 1. Demographic profiles.

Criterion	Factor	Frequency	Percentage
Gender	Female	120	54%
	Male	101	46%
Age	Between 18 and 29	166	75%
	Between 30 and 39	35	15%
	Between 40 and 49	10	4%
	Between 50 and 59	10	4%
Education level	Diploma or below	65	29%
	Bachelors	136	61%
	Postgraduate	20	9%

3.4. Multiple Regression Analysis

In our research, we used a Likert scale to quantify the factors that influence behavioral intention (BI) to adopt solar PV technology. A Likert scale is a type of psychometric scale that is used to measure people's attitudes or opinions on a particular topic. Likert scales typically use a 5-point scale, with 1 being the lowest level of agreement and 5 being the highest level of agreement.

We used a Likert scale to measure the factors that influence BI to adopt solar PV technology, because it is a relatively easy and effective way of collecting data from a large sample of people. It is also a versatile scale that can be used to measure a wide range of attitudes and opinions.

To measure the factors that influence BI to adopt solar PV technology, we developed a Likert scale questionnaire that included items that assessed each of the four factors in our conceptual framework: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC). For example, one item in the questionnaire might be: "I believe that using solar PV technology will help me save money on my energy bills". The participants would then rate their level of agreement with this statement on a scale from 1 to 5. Once we collected the data from the Likert scale questionnaire, we used a multiple regression analysis to examine the relationships between the four factors and BI to adopt solar PV technology. This will allow us to identify the factors that have the strongest influence on BI to adopt solar PV technology.

In a multiple regression analysis, the relationship between the dependent variable, Behavioral Intention (BI), and the independent variables (Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC)) can be expressed as follows:

$$BI = \beta 0 + \beta 1\ (PE) + \beta 2\ (EE) + \beta 3\ (SI) + \beta 4\ (FC) + \varepsilon$$

where:

BI: Behavioral Intention to adopt solar PV technology (dependent variable).

$\beta 0$: The intercept (constant) of the regression model.

$\beta 1$, $\beta 2$, $\beta 3$, and $\beta 4$: Coefficients representing the impact of each independent variable on BI.

PE, EE, SI, FC: independent variables (Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions).

ε: The error term representing unexplained variance in BI.

The coefficients ($\beta 1$, $\beta 2$, $\beta 3$, and $\beta 4$) indicate the strength and direction of the relationship between each independent variable and the dependent variable BI. A positive coefficient suggests that an increase in the independent variable positively influences BI, while a negative coefficient suggests a negative influence.

This formula represents the mathematical relationship used in the regression analysis to estimate how the various factors (PE, EE, SI, and FC) collectively impact individuals' Behavioral Intention to adopt solar PV technology in the context of Saudi housing in Makkah. It is important to note that β and B are related in the sense that they represent coefficients in a regression model, but they serve slightly different purposes. β standardizes the coefficients, making them comparable, while B provides the actual numerical change in the dependent variable associated with changes in the independent variables.

4. Results

To establish the validity of the proposed model constructs and ensure their reliability, reliability and validity testing methodologies were employed. The results demonstrate the validity of the instrument's items and indicate a strong consistency and reliability between them [17]. As the model encompasses one dependent variable, the hypotheses were examined using a linear regression analysis, a suitable technique for testing the model [17,18]. In Table 2, Cronbach's Alpha (α) values are presented to assess the internal consistency or reliability of the measurement scales used in the study. Cronbach's Alpha is a statistical measure that indicates how closely related a set of items on a scale are as a group. In the context of this study, it was used to evaluate the reliability of the questionnaire items related to factors influencing the adoption of solar PV technology. A high Cronbach's Alpha value suggests that the items in a scale consistently measure the same underlying construct.

Table 2. Reliability and validity testing.

Construct	Cronbach's Alpha
Effort Expectancy	0.902
Performance Expectancy	0.943
Facilitating Conditions	0.819
behavioral intention	0.868
Social Influence	0.876

4.1. Hypotheses Analysis

In this section, we present the analysis of our study, which explores the factors influencing the behavioral intention to adopt solar PV technology among residents in Saudi housing in Makkah. We employed a regression analysis to test the hypotheses outlined in Section 3. Our analysis focused on the H1, H2, H3, and H4 hypotheses.

4.2. Model Fit and Explained Variance

Our proposed regression model was constructed to assess the relationships between the independent variables (PE, EE, SI, and FC) and the dependent variable (behavioral intention to adopt solar PV technology). The model's overall fit was examined using the R-squared (R^2) value. The R^2 value of 0.502 indicates that approximately 50.2% of the variance in behavioral intention is explained by our model.

While the R^2 value may seem modest, it is important to contextualize these results within the domain of technology adoption research. Behavioral intention is influenced by a multitude of complex factors, and achieving a high R^2 in such contexts can be challenging. Despite the modest R^2, our findings provide valuable insights into the factors affecting the adoption of solar PV technology in Saudi housing in Makkah.

4.3. Factors Influencing Behavioral Intention

Table 3 shows that the regression analysis revealed the following results for the impact of each independent variable on behavioral intention:

- Performance Expectancy (PE): PE was found to have a positive and significant impact on behavioral intention ($\beta = 0.235$, $p < 0.001$). This suggests that individuals who perceive solar PV technology as enhancing their performance are more likely to express a behavioral intention to adopt it.
- Effort Expectancy (EE): EE was found to have a positive and significant impact on behavioral intention ($\beta = 0.027$, $p = 0.001$). This implies that individuals who find solar PV technology easy to use are more inclined to express a behavioral intention to adopt it.
- Social Influence (SI): SI was found to have a positive and significant impact on behavioral intention ($\beta = 0.211$, $p < 0.001$). This indicates that individuals who are influenced by their social networks and peers are more likely to express a behavioral intention to adopt solar PV technology.
- Facilitating Conditions (FC): FC was found to have a positive and significant impact on behavioral intention ($\beta = 0.143$, $p = 0.002$). This suggests that individuals who perceive favorable conditions and support for adopting solar PV technology are more likely to express a behavioral intention to adopt it.

While the R^2 value of 0.502 indicates that a substantial portion of the variance in behavioral intention is explained by our model, it is important to acknowledge that behavioral intention is a multifaceted construct influenced by various external and contextual factors. Therefore, the remaining unexplained variance highlights the complexity of the adoption decision.

Table 3. Regression model.

	Unit Coefficients		**St Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	1.063	0.186		11.064	0.000
EE	0.188	0.045	0.235	0.211	0.000
FE	0.020	0.042	0.027	0.487	0.001
SI	0.250	0.054	0.211	0.641	0.000
FC	0.253	0.053	0.143	0.370	0.002

The practical significance of our findings should not be underestimated. Even though the explained variance is moderate, the identified factors—PE, EE, SI, and FC—are meaningful in shaping individuals' intentions to adopt solar PV technology. Policymakers and stakeholders can leverage these insights to develop targeted strategies for promoting solar energy adoption in Saudi housing in Makkah. This supports existing research that underscores the significance of these factors in shaping technology adoption behaviors [32–34]. The statistical significance of our results, as indicated by low p-values, reinforces the reliability of our findings. Furthermore, the relatively large sample size enhances the robustness of our analysis.

The study's analysis of the factors influencing the behavioral intention to adopt solar PV technology in Saudi housing in Makkah revealed key insights. Firstly, individuals who perceive solar PV technology as enhancing their performance are more likely to express a behavioral intention to adopt it, emphasizing the importance of conveying its benefits. Secondly, ease of use plays a crucial role, with those finding it user-friendly being more inclined to adopt it, highlighting the significance of straightforward interfaces and installation processes. Thirdly, social influence, especially recommendations from social networks and peers, significantly affects adoption, underlining the role of social factors. Lastly, individuals who perceive favorable conditions and support for adoption are more likely to express a behavioral intention to adopt solar PV technology, suggesting the importance of creating an enabling environment. These findings recommend policy actions such as incentive programs, the promotion of user-friendly solutions, and community initiatives for enhancing adoption. For industry stakeholders, the study suggests investing in education and customer support, as well as designing user-friendly solar PV systems. By addressing these insights, stakeholders can collectively promote sustainable energy adoption and contribute to a greener future.

5. Discussion

This study delved into the complex landscape of solar PV technology adoption within the unique context of Saudi Housing in Makkah. The research unearthed four critical factors that wield significant influence over consumer behavior and their decisions regarding the adoption of solar PV technology. These factors are: Social Influence (SI), Performance Expectancy (PE), Effort Expectancy (EE), and Facilitating Conditions (FC). One of the standout findings of this study is the extraordinary impact of Social Influence (SI). It emerged as the most powerful driver of consumer behavioral intention to embrace solar PV technology. SI underscores the pivotal role of societal dynamics and interpersonal relationships in shaping technology adoption decisions. In the context of Saudi Housing in Makkah, the influence of friends, family, and social networks is particularly pronounced. Conversations, recommendations, and experiences shared within these social circles significantly sway individual attitudes and intentions. This aligns seamlessly with established research in the field, which consistently underscores the significance of these social factors [18–20]. In addition to SI, this study places a spotlight on two other fundamental factors: Performance Expectancy (PE) and Effort Expectancy (EE). PE relates to consumers' perceptions of the technology's utility, emphasizing what they believe the technology can deliver in terms of its benefits and advantages. EE, on the other hand, pertains to the perceived ease of using the technology, considering how effortless or challenging the adoption process may seem. Both of these factors play pivotal roles in shaping attitudes and intentions regarding the adoption of solar PV technology. When consumers perceive that solar PV systems offer tangible benefits such as cost savings, a reduced environmental impact, or energy independence (PE), and when they believe that using these systems will not be overly complex or burdensome (EE), they are more inclined to consider adopting them. This underscores the broader understanding that the perceived benefits and simplicity of technology significantly influence an individual's willingness to embrace it. Facilitating Conditions (FC) emerge as a factor of notable influence in this study. This underscores the importance of a conducive environment for the adoption of solar PV technology. This encompasses a range of factors, including the availability of the necessary infrastructure, access to financial resources, and supportive policies and regulations. When these facilitating conditions are present, they significantly ease the adoption process and positively affect consumer intentions. For instance, the existence of incentives, grants, and easy financing options can remove financial barriers and encourage more individuals to invest in solar PV systems. Similarly, well-crafted policies and regulations can create a regulatory framework that promotes renewable energy adoption. Therefore, the role of a favorable ecosystem, inclusive of infrastructure and access to necessary resources, cannot be overstated. Such conditions can substantially accelerate the adoption of new technologies. These findings align harmoniously with a wealth of existing research in the field of technology adoption. The influences of social networks, perceived benefits, ease of use, and the availability of supportive conditions have been widely documented. What makes this study particularly valuable is its empirical validation of these relationships within the specific context of solar PV technology adoption in Saudi Housing in Makkah. In practical terms, these insights offer valuable guidance for stakeholders interested in promoting the adoption of solar PV technology, not only in Saudi Housing in Makkah, but also in similar contexts globally. To encourage adoption, strategies should encompass more than just technology promotion. They should consider the role of social networks and influencers, emphasize the tangible benefits of solar PV systems, address concerns about complexity, and create a supportive ecosystem that facilitates adoption. By understanding and addressing these factors, policymakers, businesses, and advocacy groups can foster a more sustainable and renewable energy landscape in Saudi Arabia and beyond.

The findings of this study bring forth several noteworthy contributions to the field of solar energy adoption in the context of Saudi housing, particularly in Makkah. These contributions shed light on the unique dynamics of solar PV technology adoption and offer fresh insights into the determinants shaping the behavioral intentions of residents. Importantly, they also distinguish themselves from prior research in the following ways:

Contextual Relevance: This study is situated in the specific context of Saudi housing in Makkah, which holds its own set of socio-cultural, economic, and environmental attributes. While previous studies have examined solar energy adoption in various contexts, our focus on this region brings a nuanced perspective to the discourse.

Integration of UTAUT: By incorporating the Unified Theory of Acceptance and Use of Technology (UTAUT), this study adapts a well-established framework used extensively in various domains, such as e-learning and e-banking. However, its application in the realm of solar PV technology adoption in Saudi housing in Makkah is relatively unexplored. This adaptation provides a fresh lens through which to analyze user behavior and attitudes, enriching the existing body of literature.

Comprehensive Model: Our study incorporates multiple factors, including Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC), to predict Behavioral Intention (BI). While previous research has often focused on individual factors, our comprehensive model captures the intricate interplay of these elements, yielding a more holistic understanding of solar technology adoption.

Empirical Validation: The findings presented in this study are grounded in empirical data collected through surveys and analyzed using a regression analysis. This empirical validation strengthens the credibility of our results and contributes to the practical applicability of the model.

Implications for Policy and Practice: We underscore the practical implications of our findings for policymakers, residents, and stakeholders. The insights generated here can inform the development of targeted strategies for promoting solar energy adoption in Saudi housing in Makkah, aligning with the nation's renewable energy goals and sustainability objectives.

6. Conclusions and Policy Implications

The study's findings have profound implications for policy and practice in promoting the adoption of solar PV technology. Recognizing the pivotal role of Social Influence (SI) in influencing adoption intentions, policymakers and stakeholders can focus on cultivating positive narratives, fostering community engagement, and leveraging social networks to enhance the perceived desirability and normative value of adopting solar PV technology. Moreover, acknowledging the importance of Performance Expectancy (PE), Effort Expectancy (EE), and Facilitating Conditions (FC), efforts can be directed toward educating consumers about the tangible benefits of the technology, simplifying its usage experience, and creating a supportive ecosystem that facilitates the integration of solar PV systems. Collaborative endeavors between governments, industry players, and educational institutions can amplify the impact of these findings. Public awareness campaigns that highlight both the individual benefits and broader societal advantages of adopting solar PV technology can effectively address Performance Expectations (PE) and foster a more positive attitude toward the technology. Similarly, initiatives that streamline the adoption process and reduce perceived effort barriers can bolster Effort Expectancy (EE) and enhance consumer confidence. In conclusion, this study's comprehensive exploration of the factors influencing solar PV technology adoption unveils the critical roles of Social Influence (SI), Performance Expectancy (PE), Effort Expectancy (EE), and Facilitating Conditions (FC). By aligning with existing research and offering context-specific insights, these findings serve as a valuable guide for policymakers, industry leaders, and researchers aiming to accelerate the transition towards sustainable energy sources in Saudi Housing in Makkah and beyond.

While this study provides valuable insights, it is not without limitations. The cross-sectional nature of our data limits our ability to establish causality. Longitudinal studies could provide a deeper understanding of how these factors influence adoption over time. Additionally, there may be unaccounted for variables that influence behavioral intention. To enhance our understanding of solar PV technology adoption in Saudi housing in Makkah, future research could consider:

- Exploring additional factors that may influence behavioral intention, such as environmental consciousness and economic factors.
- Conducting qualitative research to gain deeper insights into the motivations and barriers faced by potential adopters.
- Examining the role of government policies and incentives in shaping adoption behaviors.

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