

Article

Understanding the Factors Influencing Consumers' Intention toward Shifting to Solar Energy Technology for Residential Use in Saudi Arabia Using the Technology Acceptance Model

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Abstract: Over the last few years, the Kingdom of Saudi Arabia has taken significant steps in adopting clean and sustainable energy coming from renewable energy sources. The adoption of solar energy in residential use was one of the main projects in the 2030 Saudi vision of preserving nature reserves, with sustainability as a key pillar. The Saudi government has granted individuals the right to install solar photovoltaic systems in their homes and has taken many steps to encourage this initiative. However, despite all these efforts to bring solar energy into homes, few applications have been received. Therefore, it is important to examine the various factors that influence Saudi society's perceptions and attitudes toward the acceptance or rejection of new solar technologies. The Technology Acceptance Model is one of the best technology acceptance frameworks. The model examines intentions and attitudes to adopt new technologies based on two constructs: perceived usefulness and perceived ease of use. In this study, we extend the Technology Acceptance Model by adding new constructs: relative advantages, environmental awareness, and cost of solar photovoltaic systems. These factors were examined by analyzing the intentions of 492 male and female respondents. Data were collected through online surveys. The findings of the study indicated that all the Technology Acceptance Model constructs significantly impact the attitude toward the adoption of solar energy in residential use. These results recommend that the Saudi government should focus on increasing Saudi environment awareness, reconsidering solar PV costs, and putting more emphasis on the relative advantages of solar PV in residential use.

Keywords: sustainability; data analytic; technology acceptance model



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1. Introduction

Energy has an important place in our lives, and we are constantly surrounded by it. We need energy for countless reasons, and it is essential for making everything happen in our daily lives [1]. Despite the fundamental role of all energy sources in our lives, most of us tend to take the industrial-scale energy benefits for granted. We are basically ignorant about the huge investment of capital and resources and human forces required to deliver the needed energy in every aspect of our global economy. Because we need energy, we much more ignore the warnings put forward by environmentalists that our use of energy is a problem urgently in need of a solution.

According to [2], all nonrenewable energy sources have several effects to the environment and the ecological balance of the globe. Fossil fuels are liquid, gas, or rock-like resources that are transformed to generate energy sources. They also can cause substantial damage, such as CO₂ emissions, water pollution by chemicals components, global warming pollution, etc. [3]. In addition to all the environmental issues, existing nonrenewable energy materials are insufficient to maintain the basic needs of humans. According to [1,4], if available assets do not rise, and demand remains stable at 2019 levels, it will take about 48 years to exhaust those assets. Hence, shifting toward renewable energy use has become a global trend.

The development and growth of many countries in the world and in particular the Gulf Cooperation Council countries is based on the revenues derived from oil and natural gas exports. This holds true for the Kingdom of Saudi Arabia (KSA). Energy in KSA includes the production, consumption, and export of oil and natural gas as well as power generation. KSA is an oil-rich country and the world's leading oil producer and exporter with 17.2% of the world's proven oil reserves in 2022 [5]. Oil accounts for 90% of the country's exports and nearly 75% of government revenue with a production of 12 million barrels per day in 2017 and about 10,714,000 Barrels per day in July 2022 [6,7]. The oil industry accounts for approximately 42% of KSA's GDP, while the private sector accounts for 40% [8]. In recent decades, KSA has experienced rapid growth in the construction industry in its pursuit of development and modernization. The residential sector is the largest energy consumer in the country, accounting for more than 53% of the country's total energy, accounting for 296 billion kWh, with an annual growth rate of approximately 8% [9,10]. Electricity demand in the household sector is expected to more than double by 2025 [10]. In principle, KSA's current fossil fuel-based production methods have no short-term problems in meeting growing energy demands. However, policymakers and scientists increasingly recognize that economic development based on nonrenewable resources is not sustainable in the long run [11]. This situation requires a fundamental change in energy consumption patterns for sustainable development in the building sector [10].

In the past few years, the Kingdom has taken significant steps to adopt innovative solutions such as clean and sustainable energy coming from renewable energy sources. The Saudi Vision 2030 envisages concrete plans, both in the implementation and planning stages, where the Kingdom will continue to improve the standard of living of its society by investing in the latest technologies to achieve sustainable urban development and protect the environment. First, we need to understand what sustainability is and its impact on the environment. Ecological sustainability means it does not harm the environment. It just means that we need energy balance first. Sustainability thus means "a development sufficient to meet current needs without compromising the ability of future generations to meet their own needs" [12]. Solar energy embodies this definition of sustainability, considering that solar energy can be used indefinitely without affecting its future availability. One of the most sustainable things about solar energy is that the sun has an infinite source of energy that is guaranteed to last for centuries [13]. Solar power is everywhere, and as long as the sun shines, we can always benefit from producing sustainable and clean energy. The sustainable introduction of solar energy is safer for humans and will reduce the impact of two of the biggest environmental problems, the greenhouse effect and global warming [13]. Solar technology is evolving and gradually becoming more economically sustainable. With these advancements, the hope is that it will be cheaper than non-renewable energy and that solar energy will be sustainable for all. Over the years, solar technology has developed into a mature industry. With the growing importance of solar technology, more people will be able to work in the industry in the coming years. Solar panel investments and research aim to further improve the sustainability of solar panels and solar technology. As this technology continues to improve, more people will gain access to it, and the increased efficiency will make it a more viable solution for large-scale applications [14].

The Kingdom is blessed with privileged geographic location and climate, making renewable economically achievable [3]. Solar energy is seen as a promising alternative energy source, and the Kingdom has a significant potential to produce solar power [15]. This potential comes from the fact that the Kingdom is located within the global solar belt, a topographical area between 35 degrees north and 35 degrees south, and generally characterized by high solar radiation [15]. According to [16], the solar irradiation of this area is one of the largest worldwide, with a daily average of global horizontal irradiation (GHI) ranging from 5700 Wh/m² to 6700 Wh/m². The significant solar reserve potential in addition to the decreasing cost of photovoltaic (PV) components are the main factors encouraging the use of solar energy in the Kingdom [15]. The country's focus thus far has been on large-scale projects overlooking the application of PV in buildings. This is an area

that needs attention. In addition to developing large-scale PV projects, KSA also needs to exploit its small-scale generation potential, especially through the building sector [11].

Hence, the Kingdom has put a lot of effort in many national programs within the 2030 Saudi Vision. Since July 2018, the Saudi government gave the right to individuals to install and use small-scale residential PV systems in their homes and connect them to the public grid in order to restrain the surging electricity consumption in the residential sector [15]. The governor of the Water and Electricity Regulatory Authority (WERA) confirmed that the cost of residential solar PV systems ranges from at least SR 80,000 for a duplex apartment of 200 to 250 square meters to SR 200,000 for a medium-sized villa that covers an area of 400–1000 square meters [17]. Solar systems generate energy by converting sunlight into electricity and benefit from sunlight by installing rooftop solar PV arrays. A solar system consists of four basic components: PV panels that capture sunlight and convert it to direct current, a support structure that forms the base of the solar panel, an inverter that converts direct current to alternating current to accommodate most devices, and a bi-directional measurement of the quantity of imported and exported energy [18]. Solar system costs include solar panels, inverters, mounting structures, cables, and installation. Contractor costs vary based on several factors including equipment quality, location, etc. The system is designed to serve consumers. At the same time, WERA asked the company to pass on this energy to the public grid to benefit from consumer surplus. The WERA Governor noted that the system covers some electricity usage because it reduces electricity bills. He also noted that the authorities will protect the rights of consumers and meet their needs [19].

Despite all these efforts for the adoption of solar energy in residential use, the acceptance of society remains a point to address. In fact, investing in solar energy-based technology requires a more significant social component; individuals within the community should be willing to pay for the services [20,21]. Hence, studying social acceptance for using solar energy-based technology is a key for its successful adoption. Many researchers have studied the challenges of the current energy system in KSA and the transition toward a sustainable and clean energy situation [3,22,23]. These studies mainly focus on reviewing the current status and future prospects or comparing the types of renewable energy technologies in KSA [24]. However, there is a lack of existing research studies that address the social perspective on the acceptance of using solar energy technology for residential use in KSA. Hence, in this study, we shed light on the different elements influencing the perception of Saudi society and their attitudes toward the acceptance or rejection of using solar energy based new technologies.

Numerous theoretical models have been proposed to study the public acceptance of new technology. One of the most widely used is the Technology Acceptance Model (TAM) [22]. TAM aims to predict and study the behavioral intentions of individuals to use technology [25]. This model was proposed from the perspective of behavioral science, integrating expectation theory and self-efficacy theory [26]. TAM originated from the combination of the theory of reasoned action (TRA) and the theory of planned behavior (TPB), which are two comprehensive theories of behavior extended by the TAM. TAM divides the factors affecting individual behavioral attitudes toward the adoption of new technology into two variables: (1) perceived usefulness and (2) perceived ease of use. A few additional factors could be added to study the acceptance of solar energy in the Kingdom, such as the costs and environmental awareness [1]. The unified theory of acceptance and use of technology (UTAUT) [27], Diffusion of Innovation (DOI) theory and TPB [28] could be also used, among other theories, to construct a framework investigating the factors affecting consumers' adoption and intention to use solar energy in residential use in KSA. According to [28], the DOI theory includes five significant innovation features: relative advantage, compatibility, complexity, trialability and observability. Relative advantage is considered as one of the best predictors of the adoption of an innovation. It is defined as the degree to which an innovation is perceived as better than the idea it replaces [28,29].

In this research, we empirically investigate the determinants of the intention to use solar energy technology in KSA. Hence, we first attempt to quantitatively summarize the results of empirical studies in the field of residential PV use in KSA. Then, we extend TAM

by adding new constructs: relative advantages, environmental awareness, and cost of solar PV systems, providing a fundamental analytical structure for future studies. These factors were examined by analyzing the intentions of 492 male and female respondents. Data were collected through online surveys. The different hypotheses were tested and validated using construct reliability, convergent validity, and a discriminant validity test. The driver of this research was the lack of information on public perception of renewable energy in KSA. This study will serve as a guide for policy-makers and investors on the public willingness to adopt renewable energy sources for residential use.

2. Literature Review and Conceptual Framework

2.1. Technology Acceptance Model

According to [30], TAM could be used as a theoretic model for information. TAM anticipates the acceptance of new technologies by studying the principal factors influencing the behaviors of a specific group of users. The user acceptance of new technologies has become a research subject, and many studies have successfully extended the application of TAM in any kind of new technologies related to different fields. The TAM is one of the most widely used theories to study user acceptance of technology. Given its robustness, many rigorous models have been applied to expanding TAM to explain the user acceptance of new technologies. Among these studies, some were proposed in the context of advances in digital technology in education [31–33]. Tao et al in [32] proposed a longitudinal acceptance model for e-learning by combining TAM with Task-Technology Fit (TTF). The proposed model examines the main factors influencing students' acceptance and continuation of e-learning in a mandatory setting. TAM was also used in the field of financial sustainable development. Recent research presented by [34] discussed the importance of digital transformation in financially sustainable development. The authors investigated the consumers' continuance usage intention toward e-payment using TAM and the perceived seriousness of the health belief model (HBM). This study examines whether security and perceived seriousness mediate the intent to continue using electronic payments through perceived usefulness and e-WOM. The acceptance of e-Shopping was also the subject of a study completed by [35]. In this study, important factors in purchasing were identified such as perceived ease of use, perceived usefulness perceived awareness of security, and personal informativeness. The results show that the identified factors by TAM are positively influencing consumer intentions and attitudes toward online purchasing. TAM was also used in the transportation field, where a study proposed by [36] investigated residents' intention on e-bike sharing usage, which is a new rapidly growing mode of transport in China. The study combined TAM and TPB models with policy support constructs. In addition to the previously cited research, TAM has been adopted to study the perception of users of various new concepts such as online food ordering [37], advanced electric vehicle technology [38], etc. In this study, we investigate the principal factors influencing users' perceptions on renewable energy technologies for sustainable development, with a particular emphasis on solar energy and PV. The literature also contained some studies extending TAM in this context [1,3,39,40]. In [39], the authors focused on the driving factors of PV installation intention. They combined TAM with the elements of policy scenarios and analyzed the main policy driving factors of residents' installation intention. [40] explored the consumer attitude toward building-attached PV equipment using a revised TAM.

2.2. Hypothesis

In this study, other than the traditional TAM dimensions of perceived usefulness, perceived ease of use, and attitude toward using solar PV in consumers' residences, three additional variables are included—namely cost, environmental awareness, and relative advantages—to explore consumers' intention of using the PV systems. Thus, the model proposed by this study aims to find out: the effects of TAM on solar PV cost, consumers' environmental awareness, and the relative advantages of solar PV as the third latent variable.

2.2.1. Perceived Ease of Use, Perceived Usefulness and Attitude

TAM was initially developed by Davis in an effort to determine whether and why people would embrace new systems [25]. The Theory of Reasoned Action (TRA) and the TPB model serve as the model's foundations. The TRA model makes the assumption that the person makes a decision or takes an action rationally. Additionally, it is used to forecast how people will behave based on their current opinions and behavioral intentions. As a result, the theory is frequently employed to examine the connection between intentions and actual behavior. Behavior intention, which is made up of attitude and subjective norms, is what the model uses to forecast actual behavior. Additionally, behavior intention is used to gauge a person's level of intentionality for a given action. Attitude toward behavior refers to how people behave objectively while experiencing either positive or negative emotions [40]. The person's attitude is the main factor influencing his intention to use that technology [41]. The goal of TAM is to forecast and clarify user acceptance of novel technological solutions. The behavioral components of the TRA model and the TPB model's attitude measures are replaced by and combined into the TAM model. Perceived usefulness and perceived ease of use are the two main components of the TAM model.

According to [1], TAM shows that a person's attitude toward the use of new technology is mainly influenced by his view about the perceived usefulness and the perceived ease of use of that technology. Perceived usefulness is defined as the degree to which a consumer believes that using new technology or a system would improve his performance in performing a particular job [26]. Perceived ease of use, on the other hand, was defined as the degree to which a person believes that using a particular system would be free of effort [26], meaning that this new technology is easy to understand, operate and maintain. According to [29], in the case of using new technology based on renewable energy such as solar energy, the perceived ease of use is affected by consumers' opinions about installation, frequent usage, maintenance, and the recycling of new technology. In fact, the ease of use of new technology based on renewable energy can be ensured by understanding the living standards of the potential consumers, and it can be one of the major factors influencing the acceptance or rejection of solar energy implementation in households. The following hypotheses were developed from the original version of TAM

Hypothesis 1 (H1). *Attitude has a significant positive effect on the intention to use solar energy technology for residential use in KSA.*

Hypothesis 2 (H2). *Perceived ease of use has a significant positive effect on the attitude toward the use of solar energy technology for residential use in KSA.*

Hypothesis 3 (H3). *Perceived usefulness has a significant positive effect on the attitude toward the use of solar energy technology for residential use in KSA.*

2.2.2. Costs of Solar Energy

Based on the context, TAM may be extended in many directions by adding new constructs that may explain more appropriately the user acceptance of the proposed technology [42]. The costs of solar energy are an important construct to investigate. According to [29], in order to switch to alternative energy technologies, a user has to study its cost. Consumer behavior will be affected by how they perceive the costs and costs must fall within the consumer's perception of an acceptable range in order to purchase the new technology. Thus, the attitude toward utilizing and making purchases is undoubtedly influenced by solar PV costs. In fact, renewable technologies such as solar PV may have a higher initial cost; however, they can be cheaper than conventional solutions, because investment costs are usually reduced for a long time [43].

According to [43], there are two kinds of energy costs: (1) initial costs related to the investment and (2) energy costs, which are running costs. Solar PV has an initial cost for installation but no energy cost. Maintenance costs also exist but are usually a minor proportion of the other costs. The cost factor is very important and may negatively

influence the user's attitude toward the use of solar energy in their residences. Based upon the preceding research, the following hypothesis was developed from the extension of TAM.

Hypothesis 4 (H4). *Costs of solar panel has a negative effect on the attitude toward the use of solar energy technology for residential use in KSA.*

2.2.3. Environmental Awareness

As was previously noted, two of the major environmental issues are global warming and greenhouse gases. A rise in temperature brought on by an excess of greenhouse gases will melt the polar ice caps, result in the extinction of numerous species, and trigger other disasters. According to the Environmental Protection Agency, the use and production of energy account for the majority of global greenhouse gas emissions. This indicates that people should consume less energy, which may help slow down the rate of global warming. Every action matters, and every amount of climate change mitigation matters when dealing with a problem as big as the climate crisis. Decisions made by individuals and institutions frequently have ramifications; they motivate and influence other people and organizations, redefine what is "normal", and ultimately result in political change. According to [1,44], the deterioration of environmental quality has gradually increased user awareness of green and environmentally friendly technology. KSA is attempting to establish a balance between economic development and environmental development in light of the horrific tragedy that could occur in the future. The establishment of national initiatives under the 2030 Saudi Vision shows that the government is beginning to take environmental awareness seriously. Consumer awareness of green products is referred to as environmental awareness. Numerous academics have studied this topic, and some of them have looked at consumer preferences for connected goods or services [45]. Additionally, a number of researchers have looked at the connection between consumer behavior, green energy use, and environmental consciousness [46].

An individual's propensity to purchase and use products is referred to as their "green buying intention" [47]. Wu et al. [48] confirmed that environmental concerns have a positive relationship with people's intentions toward new technology. In fact, when environmental sensitivity increases, consumers' behavior changes toward the environment, and they might be willing to pay more [49] and will have a more positive attitude toward usage. Customers' increased trust in solar PV equipment influences their decision to buy green products, increasing consumer knowledge of green marketing [50]. Hence, environmentally conscious consumers are more willing to use environmentally friendly energy [1]. Additionally, there is an increasing consumer market awareness of environmental protection; therefore, this may have an impact on how consumers behave while making purchases [40].

In this context, we think that the relationship between environmental awareness and the attitude to adopt solar energy in residential use is worth examining; hence, the hypothesis was formed below from the extension of TAM:

Hypothesis 5 (H5). *Environmental awareness has a significant positive effect on the attitude toward the use of solar energy technology for residential use in KSA.*

2.2.4. Relative Advantages

Due to its long-term cost-effectiveness and ability to reduce electricity-related expenditures, residential solar PV systems provide a number of advantages over conventional electricity systems. Overall, they fulfill a more important purpose by preserving resources that are on the verge of extinction and contributing to environmental preservation by upholding a greener environment. Previous research on TAM and TPB has shown that the relative advantages of new technologies are indirectly associated with consumers' intention to employ the technology [29,51,52]. In fact, a person's interest in buying a new product depends on how they perceive it in terms of some of the innovation's features, such as the relative advantages of the product. If a person finds a product to have a higher relative

advantage over competing products in terms of performance, benefits of the product, trialability and compatibility with their interests, etc., then they are more likely to adopt the new product [53].

Rogers' theory of innovation diffusion has been used in many research studies related to the adaptation of solar PV systems. Simpson and Clifton [54] proposed a survey carried out in Western Australia using the innovation of diffusion theory that revealed that the availability of incentives had an impact on the adoption of solar photovoltaic panels in homes. About 85% of respondents said that sufficient education is necessary to grasp the cost parameters and benefits of solar technology, and the majority of adopters have installed these panels for financial reasons. By using historical evidence concerning the unique characteristics of family enterprises, ref. [55] conducted a study in micro families in Italy using Rogers' theory of innovation diffusion and offered a case study that describes the elements influencing the intention to use solar panels.

As defined previously, the relative advantage is considered one of the best predictors of the adoption of an innovation. It is defined as the degree to which an innovation is perceived as better than the idea it replaces [28,29].

According to [52], the user's perception of the potential relative advantage has a big influence on the attitude toward new technology. In fact, the greater the perceived relative advantage of an innovation, the higher its rate of adoption [51]. We can quantify the relative advantage based on many criteria such as economic terms, social prestige factors, convenience, and satisfaction [51]. Then, a potential consumer is recommended to adopt solar PV in his residence due to its beneficial outcomes to the consumer. The more potential consumers perceived that residential solar PV technology is better than the usual sources of electricity and energy, the more likely they are to adopt solar PV in their construction homes. Hence, the following hypothesis is proposed:

Hypothesis 6 (H6). *Relative advantage has a significant positive effect on the attitude toward the use of solar energy technology for residential use in KSA.*

Figure 1 presents the different hypotheses proposed in this study.

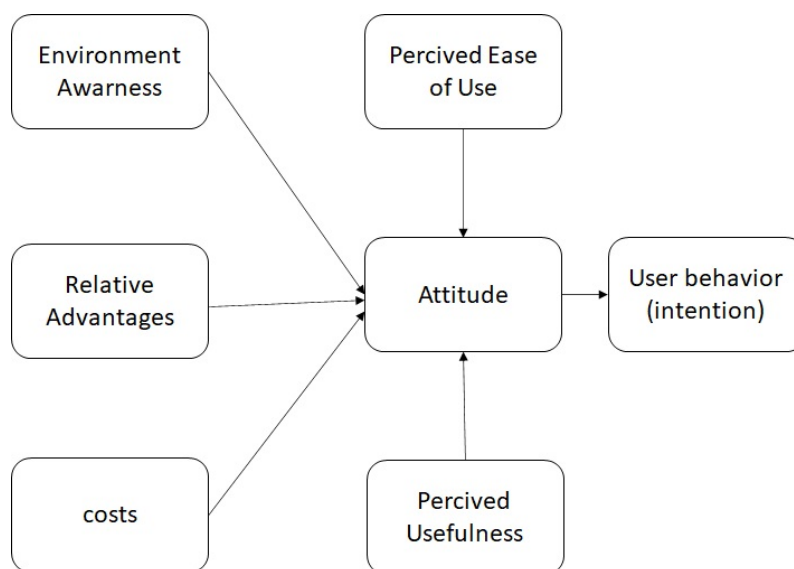


Figure 1. Conceptual framework: the proposed extended TAM model.

3. Materials and Methods

This study uses a convenience non-probability sampling method. The data used in this study were limited to the public housing sector in the Jeddah area. In this case, the online survey was chosen because it appealed to a wider audience. Online surveys were created via Google Forms with the option of limiting the response to one for each respondent. This

option was used on the Google Form settings menu in order to ensure the independency of data by stopping respondents from answering the survey twice. Online surveys are preferred over face-to-face surveys, as respondents are often willing to take the time to complete the survey, which the face-to-face method may compel them to do, especially when it takes a long time to complete the survey. The survey was distributed between 1 November 2021 and 15 February 2022 by 492 respondents via multiple online channels of the University of Jeddah, including email, WhatsApp and Twitter. In this type of survey, younger age groups contribute more than other age groups because they tend to connect more online than other age groups [56]. As a result, the majority of respondents were under the age of 40, which is also the number one demographic for smartphone usage globally.

The survey included two parts. The first part included questions about the participants' sociodemographic data (see Table 1 for more details). The second part of the survey included questions for the study model's variables (see Table 2 for more details). Five-point Likert-type scales (1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree and 5 = Strongly Agree) were used to record participants' responses. For each variable, we adapted measures from [28,57].

The majority of participants in this study were Saudi citizens (94%). Participants were of different genders; Table 1 shows that 52% were male and 48% were female; 38% were married, 59% were single and the remainder of participants marked 'other'. Table 1 shows that the majority of participants had the lowest yearly income of 1000–10,000 Saudi riyal (56%) and the least number of participants had a yearly income of 40,000–50,000 Saudi riyal (4%); the remainder of the participants are divided as follows: (17%) with a yearly income above 50,000, (11%) with 20,001–30,000 yearly income, (7%) with 10,001–20,000 and (5%) with 30,001–40,000. Participants from different age groups were engaged in this study. We notice from Table 1 that the majority of participants were aged 18–25 (71%), (10%) are aged 34–41 or 42–49, (7%) are 26–33 years old, and the reminder are 50 and above. Students represent the majority of participants (53%) followed by public sector employees (20%), where self-employed were the lowest participants (1%). The accommodation type is one of the key factors of this study. Table 1 shows that mostly, participants lived in villas (43%). Those who live in apartments represent (40%) of the participants, and (17%) lived in other types of accommodations. Most of the participants in this study (71%) own their accommodation, while (24%) live in rented accommodation. The remainder of participant (5%) have other statuses.

The construct "perceived usefulness" was determined by means of five factors ($C1_{F1}$, $C1_{F2}$, $C1_{F3}$, $C1_{F4}$, $C1_{F5}$). The construct "perceived ease of use" was determined by means of four factors ($C2_{F1}$, $C2_{F2}$, $C2_{F3}$, $C4_{F4}$). The construct "costs" was determined by means of three factors ($C3_{F1}$, $C3_{F2}$, $C3_{F3}$). The construct "environment awareness" was determined by means of three factors ($C4_{F1}$, $C4_{F2}$, $C4_{F3}$). The construct "relative advantages" was determined by means of three factors ($C5_{F1}$, $C5_{F2}$, $C5_{F3}$) and the two constructs "attitude" and "intention" were determined respectively by two factors each ($C6_{F1}$, $C6_{F2}$), ($C7_{F1}$, $C7_{F2}$) (see Table 2 for more details).

Table 1. Sociodemographic characteristics.

Attributes	Modalities	Number of Respondents
Gender	Female	234
	Male	258
Nationality	Saudi	462
	Non Saudi	30
Age	18–25	348
	26–33	12
	34–41	48
	42–49	36
	50 and above	48

Table 1. *Cont.*

Attributes	Modalities	Number of Respondents
Occupation	Unemployed	78
	Student	257
	Self-employed	6
	Public sector employee	96
	Private sector employee	17
	other	35
Marital Status	Married	186
	Single	287
	Other	12
Yearly Income(in Saudi Riyal)	1000–10,000	276
	10,001–20,000	36
	20,001–30,000	54
	30,001–40,000	24
	40,001–50,000	18
	Above 50,000	84
Accommodation Type	Apartment	192
	Villa	209
	Other	84
Accommodation Ownership	Owner	342
	Rental	114
	Other	23

Table 2. Factors description for the study model's variables.

Variables	Factors	Factors Definition
Perceived usefulness	C1 _{F1}	Using a solar PV in my residence would increase the quality of my life.
	C1 _{F2}	Using a solar PV in my residence would be useful for me.
	C1 _{F3}	Using a solar PV in my residence would be beneficial for me.
	C1 _{F4}	Using a solar PV in my residence would be convenient for me.
	C1 _{F5}	I would consider a solar PV a useful means for generating energy.
Perceived ease of use	C2 _{F1}	I believe a solar PV would be easy for me to use.
	C2 _{F2}	I believe learning to operate a solar PV would be easy for me.
	C2 _{F3}	I believe the operation of a solar PV would be clear and understandable for me.
	C2 _{F4}	I believe a solar PV would be well-suited to carry out my daily need in energy.
Costs	C3 _{F1}	The installation cost of a solar PV in my residence seems high to me.
	C3 _{F2}	The running cost of a solar PV in my residence seems reasonable to me.
	C3 _{F3}	If the cost of energy is equal to solar and conventional energy, I will choose solar energy.

Table 2. *Cont.*

Variables	Factors	Factors Definition
Environment awareness	C4 _{F1}	I am aware of the environmental risks resulting from the use of conventional energy sources.
	C4 _{F2}	I am aware that by using solar PV in my house, this may reduce greenhouse gas emission.
	C4 _{F3}	I am aware that solar panels add less heat to the atmosphere and reduce global warming.
Relative advantages	C5 _{F1}	Limitless power from the sun is an advantage of using solar PV.
	C5 _{F2}	Environmental friendliness is an advantage of using solar PV.
	C5 _{F3}	Solar power technology is expected to be developed constantly in the future.
Attitude	C6 _{F1}	I like the idea of using solar PV in my residence.
	C6 _{F2}	I have a desire to use solar PV in my residence.
Intention	C7 _{F1}	If I had a solar PV available, I would favor using it rather than a conventional energy sources.
	C7 _{F2}	I will recommend others to use solar PV in their residences.

4. Data Analysis and Results Discussion

In order to test the reliability of our constructs, we use the Cronbach's alpha measure. Cronbach's alpha is an estimator that is used to assess the reliability, or internal consistency, of a set of test factors or questions [58]. The reliability of the set of questions refers to the extent to which it is a consistent representation of a particular concept or construct. As a reliability index, Cronbach's alpha coefficient ranges between 0 and 1, although negative values can be obtained if the average inter-item covariance is negative [58]. In case all the scale factors are not correlated or share no covariance, then the Cronbach's alpha coefficient is equal to 0. On the other hand, if all the factors have high covariances, then the coefficient will approach 1. The higher the alpha coefficient, the more the factors have shared covariance and measure the same underlying concept. According to [59], Cronbach's alpha coefficient values above 0.7 are generally acceptable. Table 3 summarizes the commonly accepted rule for describing internal consistency using Cronbach's alpha coefficient as presented by [60].

Table 3. Cronbach's Alpha Score Levels.

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.7 \leq \alpha < 0.9$	Good
$0.6 \leq \alpha < 0.7$	Acceptable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Table 4 shows our Cronbach's test statistic results for each construct. We can see that our Cronbach's test statistic score is above 0.7 for our six constructs. This is generally accepted as a meaning that the reliability of our sub-scale scores is good (see Table 3). If we look in depth at the standard alpha for each construct, we notice that the perceived usefulness achieved the highest score of alpha coefficient with a score of 0.92, meaning that its reliability is excellent. However, if we are approaching 1, it may be possible that our measurement items or questions are becoming increasingly redundant. Hence, to dismiss the hypothesis of redundancy, we study in detail Cronbach's alpha if measurement items are deleted; more details are further given in Table 5. For the perceived ease of use, relative advantages, attitude, and intention, all scores are fairly similar, ranging around 0.82 to 0.88.

The results in Table 5 tell us the impact on the Cronbach's test statistic value of removing different items. If all the items are measuring the same concept, we would expect them to be correlated. Any items that have consistently low correlations across the board may need to be removed from the questionnaire to make it more reliable. Ideally, the average inter-item correlation for a set of items should be above 0.3. An average $r = 0.3$ indicates that the item may not belong on the scale. An average r above 0.3 suggests that while the items are reasonably homogeneous, they do contain sufficiently unique variance.

The column average r in Table 5 displays for each of the items the correlation between a given Task Value item and the sum score of the other two items. For example, the correlation between perceived usefulness item $C1_{F1}$ and the sum of items $C1_{F2}$, $C1_{F3}$, $C1_{F4}$ and $C1_{F5}$ is $r = 0.70$, meaning that there is a strong, positive correlation between the scores on the one item $C1_{F1}$ and the combined score of the other four items. The results in Table 5 show that for all items, the average inter-item correlation is above 0.3. Hence, we can conclude that all items can belong to the scale.

Table 4. Key statistics for the study constructs.

Attributes	Factors	Mean (M)	Standard Deviation (SD)	Cronbach's Alpha
Perceived usefulness (M = 3.649; SD = 1.293)	$C1_{F1}$	3.658	1.263	0.92
	$C1_{F2}$	3.8	1.240	
	$C1_{F3}$	3.555	1.343	
	$C1_{F4}$	3.555	1.325	
	$C1_{F5}$	3.679	1.295	
Perceived ease of use (M = 3.493; SD = 1.203)	$C2_{F1}$	3.337	1.225	0.86
	$C2_{F2}$	3.432	1.247	
	$C2_{F3}$	3.625	1.134	
	$C2_{F4}$	3.580	1.206	
Costs (M = 3.415; SD = 1.281)	$C3_{F1}$	3.395	1.255	0.73
	$C3_{F2}$	3.296	1.301	
	$C3_{F3}$	3.555	1.287	
Relative Advantages (M = 3.684; SD = 1.253)	$C4_{F1}$	3.629	1.282	0.84
	$C4_{F2}$	3.837	1.157	
	$C4_{F3}$	3.587	1.321	
Environment awareness (M = 3.641; SD = 1.299)	$C5_{F1}$	3.555	1.268	0.83
	$C5_{F2}$	3.592	1.332	
	$C5_{F3}$	3.777	1.297	
Attitude (M = 3.672; SD = 1.241)	$C6_{F1}$	3.641	1.271	0.82
	$C6_{F2}$	3.703	1.212	
Intention (M = 3.693; SD = 1.240)	$C7_{F1}$	3.725	1.215	0.88
	$C7_{F2}$	3.662	1.265	

We are more interested in the fourth column in Table 5. This column presents for each question of the questionnaire the obtained Cronbach's alpha if the question is removed. This column presents valuable information for determining which questions in the questionnaire contribute to the total alpha and which do not. For our first construct, perceived usefulness, our original alpha = 0.92. We can see from Table 5 that if we remove any of the questions ($C1_{F1}$, $C1_{F2}$, $C1_{F3}$, $C1_{F4}$), the overall raw alpha will drop from 0.92 to 0.9 or 0.88. Since the raw alpha for the first constructs will decrease with the removal of the later questions, we can conclude that those questions appear to be useful and contribute to the overall reliability of perceived usefulness. Question $C1_{F5}$, however, is less certain. An alpha score in this case would remain stable at 0.92 even if this question is deleted. However, this question cannot be removed, and we should instead retain all five questions because the alpha does not change when deleting this question, and the more important question $C1_{F5}$ still correlates very well with the composite score from the other questions.

For the second construct, perceived ease of use, our original alpha = 0.86; if we remove any of the individual questions, then our alpha value will decrease. Hence, for this second construct, our four questions would have the biggest decline on alpha, suggesting that these four questions are crucial in our attempt to measure the perceived usefulness. The same conclusions were achieved for the following constructs: the relative advantages, environment awareness, attitude and intention; removing any of the individual questions will decrease the alpha value. From Table 5, we notice that removing question C3_{F2} will increase the alpha score from 0.73 to 0.75, meaning that the running cost of a solar PV is not the biggest influence when measuring the perceived cost.

Table 5. Cronbach's Alpha Test Results If Item Deleted.

Attributes	Factors	average _r	raw-alpha	std.alpha
Perceived usefulness	C1 _{F1}	0.70	0.90	0.90
	C1 _{F2}	0.68	0.90	0.90
	C1 _{F3}	0.65	0.88	0.88
	C1 _{F4}	0.70	0.90	0.90
	C1 _{F5}	0.75	0.92	0.92
Perceived ease of use	C2 _{F1}	5.5	0.84	0.85
	C2 _{F2}	4.6	0.82	0.82
	C2 _{F3}	3.8	0.79	0.79
	C2 _{F4}	5.1	0.84	0.84
Costs	C3 _{F1}	0.49	0.66	0.66
	C3 _{F2}	0.60	0.75	0.75
	C2 _{F3}	0.32	0.49	0.49
Relative advantages	C4 _{F1}	0.66	0.79	0.80
	C4 _{F2}	0.75	0.85	0.85
	C4 _{F3}	0.50	0.67	0.67
Environment awareness	C5 _{F1}	0.61	0.76	0.76
	C5 _{F2}	0.66	0.80	0.80
	C5 _{F3}	0.58	0.73	0.73
Attitude	C6 _{F1}	0.69	0.73	0.69
	C6 _{F2}	0.69	0.66	0.69
Intention	C7 _{F1}	0.78	0.81	0.78
	C7 _{F2}	0.78	0.75	0.78

average_r: the average inter-item correlation; raw-alpha: alpha based upon the covariances; std.alpha: the standardized alpha based upon the correlations.

According to [61], using only the Cronbach's alpha coefficient is not sufficient to give a clear judgment about the examined scale construct validity. Hence, it is more appropriate to use a composite reliability measure to study the internal consistency of the questions on the scale. Convergent, discriminant, and nomo-logical validity tests can be used in this context. Hence, in addition to Cronbach's alpha coefficient, we also use the ρ_A coefficient [62]. Table 6 shows that both the composite reliability and ρ_A are above 0.7, confirming the accuracy of our results. Table 6 also shows that the Average Variance Extracted (AVE) for all constructs is greater than 0.5, meaning that all items pass the convergent validity test. Discriminant validity is also represented in Table 7. According to [1], when measuring the discriminant validity, the square root of the average variance extracted for each construct should be superior to its highest correlation with any other construct. Hence, we can confirm that the discriminant validity is also obtained.

Table 6. Construct reliability and validity.

	Cronbach's Alpha	ρ_A	Composite Reliability	Average Variance Extracted (AVE)
Relative advantages	0.840	0.849	0.899	0.748
Perceived usefulness	0.920	0.926	0.939	0.755
Perceived ease of use	0.860	0.862	0.905	0.704
Intention	0.880	0.872	0.937	0.882
Environment awareness	0.830	0.854	0.897	0.744
Costs	0.730	0.748	0.847	0.650
Attitude	0.820	0.820	0.917	0.847

Table 7. Discriminant validity.

	Attitude	Costs	Environment Awareness	Intention	Perceived Ease of Use	Perceived Usefulness	Relative Advantages
Attitude	0.920						
Costs	0.651	0.806					
Environment awareness	0.824	0.684	0.863				
Intention	0.750	0.704	0.713	0.939			
Perceived ease of use	0.774	0.748	0.765	0.729	0.839		
Perceived usefulness	0.783	0.685	0.757	0.785	0.775	0.869	
Relative advantages	0.758	0.631	0.791	0.664	0.758	0.718	0.865

In order to deeply study the hidden relations between constructs, we build a structural model using Smart PLS software (see Figure 2 for more details). Our structural model is composed of five exogenous variables and two endogenous variables.

The values of the coefficient of determination R^2 and the path coefficients β are shown in Figure 2. The R^2 coefficient (also called coefficient of determination and represented by the value in the dependent variables in the structural model) reflects how much all exogenous variables grouped together are influencing the dependent variable. For example, the perceived usefulness, cost, relative advantages, environment awareness and perceived ease of use are causing 76% of the variance of the attitude toward the use of renewable energies in residential use in KSA. The attitude construct is causing 56.3% of the variation of the intention toward shifting to solar energy technology for residential use in KSA. The path coefficients are basically like linear regression weights. Path coefficients are usually used in the structural model to study the causal link between the exogenous and endogenous variables. The path coefficients generated by the structural model are also presented in Figure 3. The results imply a significant positive effect of all the factors except for the cost factor toward shifting to solar energy technology for residential use in KSA. By having a positive relation between variables, this implies that increasing the value of the dependent variables will increase the value of the dependent one, meaning that if we increase one unit of relative advantage, then 0.129 units of attitude will increase. In addition, if we increase one unit of perceived ease of use, then we will see an increase of 0.186 units of attitude, and so on. When having a negative relationship between variables, increasing the value of the independent variable will cause the decrease of the dependent one. Looking at the cost variable, a decrease of one unit of renewable energy cost will decrease the Saudi attitude toward using solar energy in their residences. Hence, all the hypotheses are accepted.

Hypothesis 1 (H1). *Attitude has a significant positive effect on the intention to use solar energy technology for residential use in KSA (H1: $\beta = 0.750$).*

Hypothesis 2 (H2). *Perceived ease of use has a significant positive effect on the attitude toward the use of solar energy technology for residential use in KSA (H2: $\beta = 0.186$).*

Hypothesis 3 (H3). *Perceived usefulness has a significant positive effect on the attitude toward the use of solar energy technology for residential use in KSA (H3: $\beta = 0.259$).*

Hypothesis 4 (H4). *The cost of solar panels has a negative effect on the attitude toward the use of solar energy technology for residential use in KSA (H4: $\beta = -0.019$).*

Hypothesis 5 (H5). *Environmental awareness has a significant positive effect on the attitude toward the use of solar energy technology for residential use in Saudi KSA (H5: $\beta = 0.397$).*

Hypothesis 6 (H6). *Relative advantage has a significant positive effect on the attitude toward the use of solar energy technology for residential use in KSA (H6: $\beta = 0.129$).*

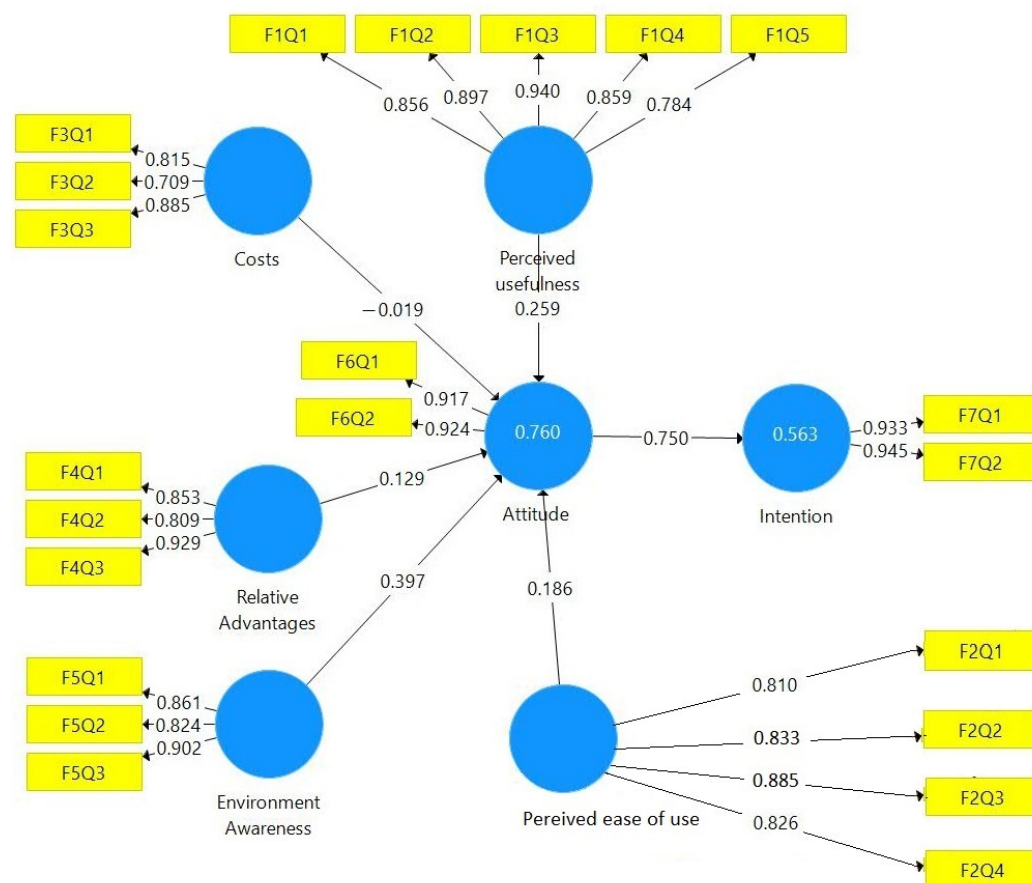


Figure 2. SmartPLS output of the structural model assessment.

We also measured the intensity of the relationship between variables using the effect of size measure (f square). Results are captured in Table 8. According to [1], f square values below 0.02 have no effect of size. Effect sizes of 0.02, 0.15, and 0.35 are referred to as modest, medium, and big, respectively [1]. From Table 8, we notice that the cost (0.001) does not have any effect of size on the attitude, while the relative advantages (0.022) variable has a modest effect on attitude and environment awareness (0.18) has a medium effect of size on the attitude. The perceived ease of use (0.037) and the perceived usefulness (0.180) have the largest effect on the attitude. Furthermore, attitude (1.289) has a huge influence on the intention, confirming our six hypotheses.

Table 8. Effect Size (f Square).

	Attitude	Costs	Environment Awareness	Intention	Perceived Ease of Use	Perceived Usefulness	Relative Advantages
Attitude				1.289			
Costs	0.001						
Environment awareness	0.180						
Intention							
Perceived ease of use	0.037						
Perceived usefulness	0.089						
Relative advantages	0.022						

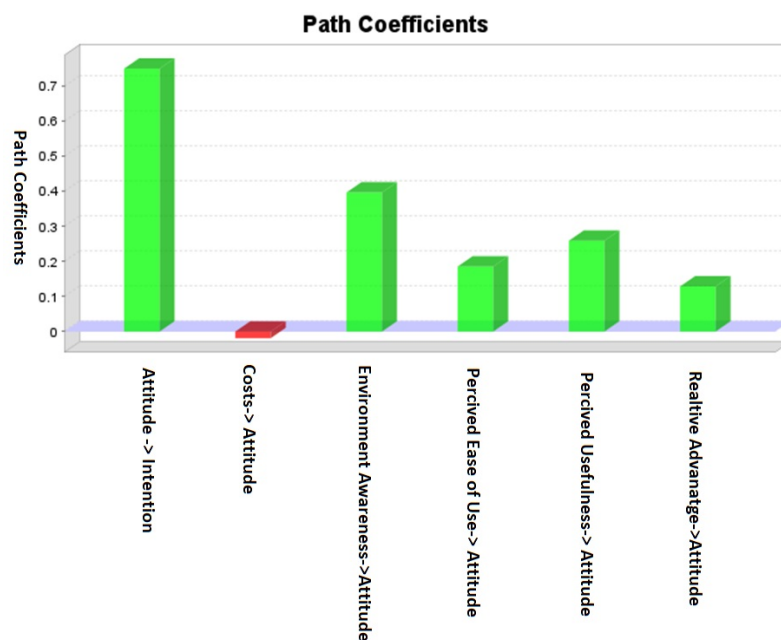


Figure 3. SmartPLS output of the path coefficients.

The findings of this study indicate that the primary obstacle impeding the public's willingness to switch to solar energy for home usage was cost. Since many of us may presume that the reason why so much energy still originates from gas and coal power plants is straightforward economics and that these fuels are less expensive, this may be perceived as obvious. Although it once held true, this premise has been disproved by recent drops in solar costs over the past ten years and an anticipated sharp rise in global oil prices [63]. The general opinion is that prices will surpass the triple-digit level, especially among investment banks. For instance, Goldman Sachs anticipates prices to reach \$100 per barrel later in 2022 and to keep growing thereafter [64]. A significant investment is required to purchase solar panels and all other equipment, especially if the consumers intend to pay for everything at once. Making the switch might initially appear pricey, but the KSA government and policymakers should make consumers better understand that in most instances, before they factor in the money, they will save on lowered power costs [65]. The government should come up with creative strategies to persuade prospective customers to install solar PV. Cities may implement local financial incentives provided by the government to encourage residents to install renewable energy sources on their premises. Grants or rebates are a couple of these incentives. Subsidies up front or cash incentives for solar PV equipment installation are some others. People who install solar PV systems may also be awarded low-interest or interest-free financing. Borrowers' lives will be made easier by the fact that the loan can be repaid through tax assessments.

This study also demonstrated that consumers who care about the environment are more likely to support green technology in their homes and are even more prepared to pay more. Whether they accept the scientific consensus or not, most people wish to protect the environment. Meetings should be held between policymakers and community leaders to establish plans. In order to increase awareness and draw more people, this might be accomplished by planning additional appearances at neighborhood activities, speaking with the local media about the environmental advantages of solar panels, and distributing fliers across the community. The community's education is one of the government's primary responsibilities. There could be many different worries about solar energy, ranging from affordability to concerns about the safety of solar panel components. Therefore, politicians should hold a workshop or any community-wide event that will enable citizens and business owners to learn the community's position on solar energy and the rules around solar permitting and installation to ensure that their people are receiving the correct

information. The government must produce easily accessed online information, giving citizens all the information they require directly on the community website.

5. Conclusions

Currently, countries are facing many challenges related to energy security and costs for households and businesses. Investing in new fossil fuel infrastructure will perpetuate existing risks and increase the threat to the environment. Moreover, the current availability of unclean energy may be limited in the future because it comes from nonrenewable sources. So, it is time to act. Recent developments have clearly demonstrated that most of the world's population lives in countries that are net importers of fossil fuels. By contrast, all countries have access to renewable energy, which offers a way out of dependence on imports. In recent years, KSA has taken significant steps to introduce innovative solutions such as clean and sustainable energy from renewable sources. Considering that solar energy can be used indefinitely without affecting its future availability, solar energy embodies the definition of sustainability. In addition to developing large-scale PV projects, KSA must also tap into its small-scale power generation potential, especially through the construction sector. Since July 2018, the Saudi government has been encouraging individuals to install and use small residential PV systems in their homes. However, to effectively execute such a fundamental strategic step requires some kind of coordination and understanding among the key players: politicians, investors, and, of course, the public. It is true that the use of technology is critical to the transition to clean energy, but it is the individual who decides how and whether to adapt to new technologies. Hence, in this research, we performed an empirical study in order to evaluate and understand the different factors influencing Saudi consumers' attitudes and intentions to use solar energy-based technology in their residences. An extension of TAM was proposed to investigate the effect of the perceived ease of use, perceived usefulness, relative advantages, cost, and environmental awareness on the perceived attitude and perceived intention to use solar energy-based technology in households. There were six hypothesized relationships in total, and research findings have proven the validity of the different introduced hypotheses. According to the outcome, hypothesis 1 is supported, and there exists a significant direct relationship between attitude and intention to use small-scale solar PV in residential use. This means that the higher the consumer's attitude toward solar PV, the higher the rate of adoption. The findings were consistent with the basic foundation of TAM, where results showed the direct relationship between the ease of use and the usefulness and the attitude toward the use of residential solar PV. Environmental awareness and perceived costs were also found to have a significant effect on consumers' attitudes toward residential solar PV adaption. While environmental awareness positively influenced consumer perceptions, perceived costs have negatively affected consumer perceptions. On the other hand, complexity had no influence on use intentions. Hence, hypotheses 3 and 4 were also supported. This research also considered the extent to which Rogers' supported effects of relative advantages could be applied to the adoption of residential solar PV systems in KSA. Hypothesis 6 was also supported, confirming the conclusions drawn by Rogers, with relative advantage increasing the rate of adoption of solar PV systems. The results conclude that while perceived ease of use, perceived usefulness, environmental awareness, costs, and relative advantages caused 76% of the variance of attitude toward the use of solar energy technology for residential use in KSA, perceived attitude causes 56% of the variance of intention toward the use of solar energy technology for residential use in KSA. Furthermore, when the perceived ease of use increases by one unit, the attitude toward solar energy increase by 0.186 units. Still, increasing the perceived usefulness by one unit will increase the attitude toward solar energy by 0.259 units. The same applies for environmental awareness when an increase by one unit increases the attitude toward solar energy by 0.397 units. Likewise, increasing relative advantages will increase the attitude toward solar energy by 0.129 units. Results also have shown that solar energy costs have a negative impact on the attitude toward the use of solar energy in households. Increasing the cost by one unit will decrease the perceived attitude by 0.019 units.

The KSA government and policymakers should take into account the basis of this research and create better awareness of the benefits of solar energy for their own people and worldwide use to increase adoption by household consumers. As household consumers better understand the contribution that the use of solar energy can make to society, they will easily adapt to the technology. This can be achieved through an outreach program targeting potential KSA consumers. This can be completed by introducing consumers to introductory events that will allow them to assess the relative advantages of solar energy and increase public awareness of environmental responsibility. The government can also spread information through advertisements on the ease of solar energy implementation through TV and broadcast or social media channels such as Twitter, Facebook, etc. As mentioned before in this research, the cost was one of the factors negatively affecting the public's wiliness toward the shift to solar energy. Hence, the government should find innovative ways to encourage potential consumers to install solar PV. One way is that authorities provide loan systems to give financial support to consumers at the initiation. The limited number of collected observations is one of the main limitations of this study; in future works, more elaborate ways to collect data may be used. The study only focused on the Jeddah region; thus, the views of the population that were taken into consideration may not be representative of all potential consumers in the kingdom. Hence, increasing the geographical coverage of the study should be one of the important points to address in future works.

This research also considered the extent to which Rogers' supported effects of relative advantages could be applied to the adoption of residential solar PV systems in KSA. Hypothesis 6 was also supported, confirming the conclusions drawn by Rogers with relative advantage increasing the rate of adoption of solar PV systems.

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