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# Factors Influencing Social Perception of Residential Solar Photovoltaic Systems in Saudi Arabia

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**Abstract:** Saudi Arabia has taken major steps to shift from an oil-centered to more environmentally-focused economy. One approach made recently is to enable households to possess and generate electricity by using small-scale residential solar photovoltaic systems (RSPSs). However, the number of applications to install this technology in residences is significantly low. Social acceptance of solar energy is essential for a successful energy transition. Hence, the present study aims to examine factors that may potentially motivate or impede individuals from purchasing RSPSs based on the *diffusion of innovations* theory. A cross-sectional, web-based survey is conducted including 1498 participants from the five main regions of Saudi Arabia. Results revealed a good cognition level in relation to solar energy, where the majority (64–83%) of respondents are aware of the benefits. An overwhelming proportion of the respondents (97%) associate RSPSs with a significantly positive image, with no significant variation in the acceptance or rejection rates among the five areas covered by the survey ($p = 0.1$). The results also show high statistical significance for the differences between RSPS acceptors and rejecters in all innovation attributes ($p < 0.001$). However, the perception of *relative advantage* has a higher correlation with acceptance RSPSs. These perceived advantages were of rather long-term nonfinancial benefits, such as *environmental protection* against *global warming* and provision of *unlimited power*, rather than the *revenue* related to direct costs benefits. The study also revealed that the *installation cost* was the most significant barrier to adopting the RSPS, which can be a focus for RSPS dissemination policies.

**Keywords:** residential solar photovoltaic systems; public acceptance; innovation discussion; social perception

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## 1. Introduction

Both uncertainty over energy supply and the worldwide rapid population growth increase the tension and motivation to secure energy. These threats are becoming more severe as the effects of climate change become more harmful. Therefore, a shift toward renewable energy generation has been a global trend. For many countries of Middle East and North Africa, in general, and those of the Gulf Cooperation Council (GCC) in particular, substantial revenues derived from oil and natural gas exports have been an essential element in the development and growth of these countries, which was reflected in maintaining high levels of infrastructures and welfare, besides expanding regional and global influence through large-scale investments and sovereign wealth funds. This particularly holds true for Saudi Arabia, which has one of the world's largest proven oil reserves. Taking a leading role in oil production and exporting for decades, allowed Saudi Arabia to become a great power influencing the global energy landscape. However, in the past few years, Saudi Arabia has taken significant steps to add renewable energy into its energy mix, seeking a sustainable and clean energy supply. Different ministries and commissions have been working jointly under the newly announced economic reform plan Saudi Vision 2030, launching several initiatives and projects to achieve this goal [1].

Solar energy is seen as a promising alternative source of energy; harnessing it could take advantage of the high direct normal irradiance ranging between 9000 watt-hours per square meter per day (Wh/m$^2$/day) in summer months and 5000 Wh/m$^2$/day in winter months [2]. The King Abdullah City of Atomic and Renewable Energy (KACARE) was established by the government to promote the integration of indigenous renewable energy resources by conducting research and providing necessary data [3]. KACARE worked with King Abdulaziz City for Science and Technology along with other government agencies and universities to develop a roadmap for the successful development of the renewable energy industry. The roadmap was modified several times before it was comprehensively redesigned. In 2017, the Ministry of Energy Industry and Mineral Resources established the Renewable Energy Project Development Office (REPDO) to deliver renewable energy across Saudi Arabia. REPDO's primary mission is to ensure that the goals of renewable energy projects align with Saudi Vision 2030 and to ensure that all stakeholders involved in energy generation, regulation, measurement, research, and data acquisition are performing in harmony to achieve the countries' renewable energy goals [4].

In 2018, Saudi Arabia began developing renewable energy capability upward of 150–200 gigawatt (GW) that would span the entire value chain, from manufacturing to local and regional project development [5,6]. Saudi Arabia has also taken steps recently to encourage individuals to generate their electricity by adopting small-scale residential solar photovoltaic systems (RSPSs). Since July 2018, individuals in Saudi Arabia have been granted the right to install solar photovoltaic (PV) systems at their homes and connect them to the public grid [7,8]. This measure is meant to restrain the surging electricity consumption in the residential sector, which accounts for approximately 50% of the total electricity consumed locally [9]. Saudi Electricity Company (SEC), the local electricity company, has called upon individuals wishing to install RSPSs at their residence to submit their applications. However, only a small number of applications (approximately 3000 as of May 2018) have been received, which falls short of expectations [10]. The utilization of the RSPSs can be beneficial to individuals and relieve the public grid from electricity shortage; yet, the adoption of RSPSs in Saudi Arabia still encounters hurdles that need to be addressed.

There are a number of studies reviewing the current situation in the context of renewable energy technologies in Saudi Arabia. However, these studies mainly focus on reviewing the current situation of solar energy landscapes [11–13], comparing several types of renewable energy technologies [14–16], or different aspects (technical-focused analysis) of the renewable energy status in Saudi Arabia [17–20]. These studies indicated the high potential in Saudi Arabia for renewable energy in general, and for solar energy in particular. The residential sector was also indicated as a promising area to capitalize for RSPSs, yet the requisite need to address the existing gap on social-related studies of solar energy in Saudi Arabia was also highlighted [12,20]. In Saudi Arabia, there has been no in-depth investigation of the diffusion of RSPSs from a social perspective based on an innovation-oriented theoretical framework [21].

Given the important role that the residential sector can play in generating electricity in Saudi Arabia together with the lack of an in-depth, social-related investigation toward solar energy acceptance, it is vital to acquire robust and reliable data that elaborates on how Saudi residents perceive the adoption of RSPSs [10,21]. The authors of this paper are aware of some articles in which authors explicitly differentiate between the terms "acceptance" and "acceptability", where the former indicates a supportive behavior of an object or situation, and the latter refers to an attitude toward an object or saturation [22]. However, in this paper, the authors define the word "acceptance" to be "agreement with or belief in an idea or explanation [23] by showing a favorable attitude or positive reception."

Based on the *diffusion of innovations* theory, this study sheds light on the factors that may be associated with the acceptance or rejection of RSPSs by individuals in Saudi Arabia. *Diffusion of innovations* theory was used, among other theories, as a framework to conduct this research due to its applicability to the Saudi context and its close relationship between the system of social structure and the diffusion of innovations [24]. Therefore, this theory was used to conceptualize and develop an empirical investigation rather than to suggest a modification to the theory itself. Since the *diffusion of innovations* theory is a critical per-condition theory of how, why, and at what rate new innovations are spread, any novel endeavor to examine and illustrate the systemic process by which an innovation diffusion occurs is valuable, in both the theoretical and policy making domains.

The study was drawn from another work conducted by Poonnavich and Weerin [25]. They have investigated the public views of adopting RSPSs in Thailand yet with a slightly different framework and approach. The present study employed a study sample of a larger size. It also adopted a different approach and conducted a more sophisticated data analysis. Besides the scientific contribution that this study seeks to make towards the field of research, the novelty of both the context and policy implications will redound to the benefit of the local community, considering the significant role that the residential sector could play in the energy transitions currently underway in Saudi Arabia. Furthermore, energy initiatives in Saudi Arabia can diffuse easily into other similar Gulf Cooperation Council Arab states. In addition, as one of the world's largest fossil fuel suppliers, energy transitions in Saudi Arabia could have a significant influence on energy choices internationally. The present study, therefore, will provide fresh insights into these areas by studying prospective adopters of RSPSs in Saudi Arabia.

## 2. Diffusion of Innovations Framework

### *2.1. The Mechanism of Innovation Diffusion*

The concept of innovation diffusion has received considerable attention over the years. The *diffusion of innovations* theory was originated by the communication theorist and sociologist Everett Rogers [24]. Rogers defines an innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption". Other sociologists define innovation variously, similarly when categorizing the process of innovation adoption. Robertson [26] broadens the definition by referring to innovation as a "process whereby a new thought, behavior, or thing is conceived of and brought into reality". While Schumpeter [27] narrows the definition of innovation as "setting up of a new production function". Barnett [28] defines it as "any thought, behavior, or thing that is new because it is qualitatively different from existing forms".

Rogers describes diffusion as a process by which innovation is communicated over time among participants of a social system through certain channels [24]. Rogers suggests that four elements have a major impact on the diffusion of innovations: the innovation itself, social system, timing, and communication channels. Innovation diffusion is highly subject to the adopters' characteristics. Based on the degree to which adopters accept a new idea, diffusion manifests itself in various forms [24]. In this context, *diffusion of innovations* theory, categorizes adopters into four groups: early adopters, early majority, late majority, and laggards [24]. Generally, adopters go through five primary stages until they make the actual action to adopt a new idea. These stages are *knowledge*, *persuasion*, *decision*, *implementation*, and *confirmation* [29]. The *knowledge* stage commences when the individual realizes the existence of the innovation for the first time and starts to formulate knowledge about its nature and how it functions. At the third stage, *persuasion*, the individual forms an attitude toward the new idea. This attitude might be favorable or unfavorable, depending on the individual's action based on their characteristics. The term *persuasion* herein is oriented toward the receiver rather than toward the source. The next stage in the innovation-decision process is the *decision* stage, which is formed when a receiver engages in activities that result in deciding to adopt or reject the innovation. The fourth stage is the *implementation* stage, where an individual puts innovation into use. All three preceding stages, *knowledge*, *persuasion*, and *implementation* are mental exercises. However, in the *implementation* stage, these thoughts are summed up and put into practice, thus involving overt behavior change. The last stage in the innovation-decision process is the *confirmation* stage, at which an individual seeks reinforcement for the decision he or she has already made. At the *confirmation* stage, the individual tends to avoid any cause of dissonance and reduces it whenever it occurs [29].

The diffusion process is multidimensional and varies based on the type of innovation [30]. The adoption of innovations like solar PV systems is not necessarily determined by its availability in the market. Instead, it is subject to how adopters perceive the innovation attributes, which explains the wide variance (49–87%) of diffusion rates of different new ideas [24,31]. Rogers [24] identified a comprehensive set of innovation attributes. These attributes represent the *persuasion* stage of Rogers' model for an "innovation-decision process", and it includes *relative advantage*, *observability*, *complexity*, *compatibility*, and *trialability* [24].

Based on the *diffusion of innovations* theory, *relative advantage* is defined as "the degree to which an innovation is perceived as being better than the idea it supersedes" [24]. To ensure successful diffusion, an innovation must be perceived as offering greater advantages when compared to that of existing services or products. These advantages can be demonstrated in economic profitability, effort saving, impact on comfort, or an improvement in any other manner upon existing products or practices. *Observability* is "the degree to which the results of an innovation are visible to others" [24]. Innovation can be adopted faster if it is visible to others. Generally, the results of some ideas are easier to be described and observed than describing the nature of the innovation. Therefore, the *observability* attribute is considered to be a critical component in improving the diffusion effect. The third attribute, *complexity* (simplicity), is "the degree to which an innovation is perceived as relatively difficult to understand and use." [24]. The easier it is to use the innovation, the faster it diffuses, and vice versa. Some innovations are clear in their meaning to prospects adopters, while others require clarification to be understood. The fourth attribute is *compatibility* which is defined as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" [24]. Innovation must be in line with social norms and not cause a conflict with existing services or products. Some innovations require more time before they become acceptable. The fifth attribute, *trialability*, is "the degree to which an innovation may be experimented with on a limited basis" [24]. This includes innovations that can be temporarily tried and dispensed, making them easier to adopt after the trial. While this option is not common for most innovations (e.g., solar PV systems), wide adoption of a particular innovation can reduce the uncertainty a potential adopter might have before he or she decides to adopt it [24].

Much attention has been given to the consumers' perspective toward the adoption of renewable energy technologies over the past 20 years. Moreover, their consumption behavior is seen as a critical factor since it exceeds ecological limits, and its effect on the depletion of natural resources has become a highly discussed topic [32]. In general, consumers tend to resist to green innovation. Although the advantages of the innovative services or products may overweigh that of traditional ones, they fail to penetrate the market or acquire a considerable market share [33]. According to the authors of [34] reported that 40–90% of innovations across different product categories fail to survive in the market, and consumer resistance is ascribed as the primary cause of this failure. Hence, the dilemma regarding the adoption of small-scale solar PV systems must be investigated because of its critical role in electricity consumption behavior in Saudi Arabia.

Every society has various types of adopters with different cultural background and different demographic characteristics. This variation leads to different levels of speed in the adoption of innovation [35].

### *2.2. Consumer Behavior and Innovation Diffusion*

A considerable number of studies have focused on consumer behavior in the innovation of diffusion; however, studies considering the diffusion of solar energy from the consumer behavior perspective have appeared only recently [33,36]. The decision by a household to adopt an RSPS might be affected by various factors. These factors include endogenous elements (e.g., desire to conserve energy and technology awareness) and exogenous elements (e.g., market system, cost, and characteristics of PV systems) [37]. An exploratory survey [38] among the individuals in the Republic of Ireland; showed that factors such as upfront cost, the complexity of the solar PV system and the interference of the solar PV system with the day-to-day living style were critical. Another study carried out in Germany [39] suggested that the adoption of an RSPS as a concept is socially accepted by virtue of its environmental value, yet the economic feasibility is the main determinate of successful adoption.

A cost–benefit study on various options of microgeneration including solar energy, micro-wind, and micro combined heat and water concluded that even with the existence of incentive mechanisms, the long payback periods contributed to the failure of producing electricity production through micro-generation in the United Kingdom [40]. Poonnavich and Weerin [25] considered social acceptance factors involved in the adoption of RSPSs in Thailand. In their study, a total of 400 responses were collected through a survey conducted among individuals. Approximately 65.7% of the participants accepted the solar PV rooftop systems. Relying on the analysis of the collected data, they suggested that respondents with a higher level of education have a stronger tendency to adopt RSPS in their home. The authors of [25] also claim that the sense of contributing to solving the global warming situation by using renewable energy sources seems to be the most significant factor that encourages the respondents to purchase an RSPS.

In developing countries, a low level of technology awareness among potential adopters was identified as a critical hurdle. Thus, misleading information disseminated among individuals about technological advantages, besides the phobia of high cost, can prevent the diffusion of technologies [41,42]. In Pakistan, a study identified unawareness within the local community, high upfront cost, inadequate renewable energy policy, and lack of technical expertise as barriers in the diffusion of solar PV utilization [43]. Similarly, another study conducted in India suggested that economic and financial factors are the biggest hurdles in widespread solar PV adoption at the household level [44]. In comparison, in Nigeria, component failure, inadequate policies, building incompatibility, and complication in research and development were found to be the most significant barriers [45].

In the Middle East, many studies have investigated the potential of solar energy in terms of technical and legislative aspects. However, studies addressing social-related aspects have only rarely been conducted. Regardless of the enormous potential the Middle East states have, the integration of solar energy is still in the early stages [46].

Alrashed and Asif [47] investigated the end-users' perception of adopting different types of renewable energy technologies. A web-based survey and in-person approaches were used to collect 453 responses covering 16 major cities in Saudi Arabia. Their study aimed to understand the most preferred renewable energy technology among individuals that might adopt such technology; technologies included were solar PV systems, solar water heaters, and micro-wind turbines. They claimed that the participants preferred solar PV systems, and the majority of the participants showed a more positive attitude to purchase electricity generated by renewable sources rather than by conventional sources, even if the tariff was slightly more expensive. Although Alrashed and Asif [47] did not investigate in detail what possible factors might be behind the respondents' answers, the significantly high preference rate toward solar energy may indicate promising potential development of solar PV system adoption by the residential sector in Saudi Arabia.

The rapid changes in the landscape of energy supply and frequent failure or unavailability of the supply of electricity in remote areas of different parts in Saudi Arabia put more pressure on houses in urban areas to install RSPSs. This situation may ultimately boost the diffusion of RSPSs in the local context.

## 3. Research Questions and Hypotheses

This research has two goals. The first goal is to elucidate, from Saudi residents' perspective, the level of acceptance or rejection of the RSPSs. The second goal is to investigate the most significant factors that act as determinants of the individuals' decision by examining the following questions:

**RQ1.** *To what extent do individuals in Saudi Arabia, as an example of oil-rich Arab state, accept the notion of installing a residential solar PV system?*

**RQ2.** *What are the most critical factors influencing the individuals' decision in accepting or rejecting the adoption of a residential solar PV system?*

The following hypotheses were developed and tested by using empirical data to find the relationship between the factors included within the scope of this work.

**Hypothesis 1 (H1).** *The majority of the Saudi population accept the notion of installing a residential solar PV system in their homes.*

**Hypothesis 2 (H2).** *The most significant deciding factor in accepting residential solar PV systems is the revenue obtained by reducing electricity consumption and selling unused electricity to the service provider.*

## 4. Materials and Methods

Based on an extensive review of the extant literature on the adoption of renewable energy technologies, the authors attempted to select the most suitable approach to achieve the study objectives. The present study carried out in a descriptive and exploratory style to get in-depth understanding of influencing determinants on the adoption of RSPSs in Saudi Arabia by utilizing a case study approach. A case study is an empirical inquiry that examines a phenomenon within its real-life context. It is based on an in-depth investigation to gain insights and explore the causes of underlying principles which subsequently can guide future inference to similar contexts as well as identifying inference limitations [48]. Therefore, an in-depth study, of different attributes of Rogers' *diffusion of innovations* theory, using the case study approach, was conducted to provide a better understanding of potential determinants influencing the adoption of solar PV systems among households in the oil-rich state, Saudi Arabia. The study was a cross-sectional web-based survey of respondents in the five main areas in Saudi Arabia (Central, Northern, Eastern, Southern, and Western areas). This design was more suitable as the primary research question discusses the extent of RSPS acceptance, which is best described through frequencies and proportions. Compared with other longitudinal study designs, the cross-sectional study presents the advantage of assessing the prevalence, which accurately reflects the extent of RSPS acceptance [49].

A cross-sectional web-based questionnaire was distributed in a convenient way in several online channels, including Gmail, LinkedIn, WhatsApp, Twitter, and Facebook. While the study used a non-probability convenient sampling method that tries to represent the decision-making capacity in the Saudi communities, the authors did many efforts to guard against selection bias. The survey was distributed to all trending social, educational, political and media groups. Moreover, region-specific groups were also searched, and followers were invited to participate in the survey. In contrast, to avoid bias, the researchers avoided channels such as academic groups associated with renewable energy and environmental protection groups as they are expected to have greater knowledge and interest for solar energy. Considering the large youth segment in the Saudi population (46.3% are under the age of 40) which is also ranked first worldwide in smartphone use, a web-based approached was chosen as it appeals to a much wider audience with respect to cost and time constraints [50,51]. A pilot sample was used to test the validity of the questionnaire before it was deployed. The questionnaire used in this study comprises a demographic status section, solar energy cognition section, and an innovation attributes assessment section.

Data were gathered from March 2018 to May 2018 with 1500 interaction times and two missing attempts, thus resulting in 1498 collected responses; the error rate was <1% at a 95% confidence level. This limits type I error rate to (0.05), where results with $p$-value less than 0.05 are described as statistically significant, and results with $p < 0.01$ are described as highly significant.

### 4.1. Questionnaire Design

The web-based questionnaire was designed into sections to address the study questions and the postulated hypothesis. It included sections on participants' demographics, solar energy cognition, and innovation attributes assessment section. While the innovation attributes assessment section was directly related to the study questions, those on the demographic and the solar energy conditions are essential to determine the possible sources of bias, confounders, as well as determining gaps in participants' knowledge on the topic.

The study used a previously tested questionnaire [25], which was developed based on Rogers's *diffusion of innovations* theory. This reproduction of the questionnaire was important to allow comparability of study findings with other published papers, and therefore determine the specific characteristics that are related to the Saudi population. The questionnaire was reviewed by two experts in the field under study, and the Arabic translation was also revised and piloted to ensure ease of understanding and comparability. The reliability of the questionnaire was further tested as described in the Data Analysis section.

#### 4.1.1. Demographic Status

The respondents were asked questions, and they could select one answer among several options. First, they were required to choose what best matches their demographic status including nationality, gender, residential location, age, occupation, education, and income.

#### 4.1.2. Solar Energy Cognition

In the second section, the questionnaire assessed the respondents' perception of solar energy by asking them four questions. These four questions asked for the participants' own opinions on the reliability of solar energy, negative impact of solar energy to the environment, job creation in the solar power industry, and negative impacts of solar energy on local communities. The participants answers were received as a 5-point Likert scale, using the labels (1: Very low), (2: Low), (3: Moderate), (4: High), and (5: Very high), where lower values indicated weaker agreement with the statement, and higher values refer to stronger agreement with the statement. A Likert scale, also known as Likert-type scale, is a psychometric scale that is widely used for scaling responses in survey research [52]. The scale was introduced by Rensis Likert in 1932 using a 5-point scale to a statement to which respondents assess their level of agreement or disagreement. Although the 5-point scale might become 7 points or 3 points, and the agree–disagree scale may become high–low, very likely–not likely, the principle of the Likert scale remains the same [52,53]. In comparison to single statements, Likert scale was chosen given the potential to increases reliability, especially when measuring attitudes, emotions orientations and intentions [52].

#### 4.1.3. Innovation Attributes Assessment

Following these questions, the respondents were provided with a brief description about solar PV systems and a simplified diagram illustrating how the system works (see Appendix A). The respondents then were directed to answer a dichotomous Yes/No question, "Do you accept or reject the notion of installing an RSPS in your dwelling?" Based on their answers to this question, the respondents were divided into two groups, acceptors and rejectors. Next, each group was directed to answer 20 questions to precisely rate the possible factors that may have influenced their decision to accept or reject the notion of installing an RSPS in their home. The 20 questions were developed based on *diffusion of innovations* theory and categorized by four innovation attributes, namely *relative advantage, observability, complexity, and compatibility*. Each attribute represents five factors which respondents were asked to assess on a 5-point Likert scale.

*4.2. Innovation Attributes and Factors Selection*

Due to the complexity of Saudi Arabia electricity generation landscape and adoption of RSPSs, theoretical frameworks are more appropriate for the case-study investigation compared with technical frameworks. The former extends beyond the technical aspects of solar PV systems diffusion, by including the socio-economic and stakeholders' perception, to give a comprehensive picture of solar PV systems diffusion at the households' level. Considering such a framework is justified because of the interrelated multi-determinants that are involved in the adoption decision. With that being said, as critical per-condition theory, the *diffusion of innovations* theory was selected for the key role it could play in understanding how an idea or product diffuses through a specific population.

Despite criticisms of the *diffusion of innovations* theory (e.g., the one-way information flow, emphasis on individual blame at the expense of a more nuanced consideration of the social structures influence), the *diffusion of innovations* theory was used in a wide range of fields, including but not limited to, agriculture products, e-services, medical treatment procedures, and renewable energy technologies [24,33,54]. The *diffusion of innovations* theory is most effective when applied to new product launches, as well as when introducing an existing product to a new market.

Considering an RSPS as an innovation (only 1.3% of houses in the administrative regions of Saudi Arabia use solar PV systems) [55], the attributes of the *diffusion of innovations* theory can provide a valid basis from which to draw conclusions about the determinants that motivate or impede individuals from adopting this technology in Saudi Arabia. There are major challenges to dissemination of RSPSs, including obstacles that are common to the dissemination of new technologies, as well as those more related to the solar PV systems, such as the electricity grid and the built environment. Although there are several obstacles in the solar PV value chain, the present study seeks to identify critical factors that may act as motivators or disincentives throughout the perspective of sociotechnical systems regarding solar PV systems dissemination in Saudi Arabia.

The data collected were mainly assessed based on Rogers's innovation characteristics (*relative advantage*, *observability*, *complexity*, *compatibility*), which by potential adopters evaluate innovations. Each attribute plays a relative role, either positively or negatively, in the dissemination of RSPSs. Hence, the effect of these attributes was examined by asking the respondents to evaluate a list of factors that were subsumed under these attributes (see Table 1).

**Table 1.** Innovation attributes and factors definition (Reproduced with permission from [25]).

| Attributes | Factors | Factors Definition |
|---|---|---|
| **Relative Advantage** | Revenue | Reduce consumption and sell unused generated electricity |
| | Environment Protection | Reduce Greenhouse Gas emission |
| | Unlimited Power | Limitless power from the sun |
| | Global Warming | Mitigating global warming impact |
| | Technology Development | Solar power technology is expected to be developed constantly in the future |
| **Observability** | Income Statistics Monitoring | Revenues from electricity fed back to the grid can be monitored |
| | Neighbor Attitudes | Neighbor Attitude regards environment protection image |
| | Power Production Monitoring | Electricity generation can be monitored |
| | Greenhouse Gas Reduction Monitoring | Greenhouse Gas emission can be monitored |
| | Solar Energy Knowledge | System installation increases the knowledge about it |
| **Complexity** | Installation Space | Area required for system installation |
| | Availability of Service Providers | Difficulty of access to service providers |
| | Residence Location | Solar radiation potential of the location |
| | Maintenance | Complexity of maintenance |
| | Residence Structure | Durability of the roof and residence structure for system installation |
| **Compatibility** | Power System | Effect of a solar system on the existing one |
| | Land Use | Area of the system effect on the living pattern of the installer |
| | Installation Cost | Installation cost effect on living cost |
| | Global Trends | Compatibility of solar energy systems with global trends |
| | Social Values | Compatibility of solar energy systems with social values |

Based on Rogers's characteristics of innovations, these factors include all possible aspects that could influence individuals' decision-making. These factors have often appeared as strong determinants in studies on adopting renewable energy microgeneration technologies. The factors were selected, distributed, and carefully modified to fit into the Saudi context while maintaining the scope of each attribute as suggested by Rogers [24].

Although Rogers summarized his interpretation of each attribute, there are no absolute rules for what constitutes a certain attribute as one. For instance, regarding *relative advantages*, Rogers suggests that "The degree of relative advantage may be measured in economic terms, but social-prestige factors, convenience, and satisfaction are also often important components. It does not matter so much whether an innovation has a great deal of "objective" advantage. What does matter is whether an individual perceives the innovation as advantageous" [24]. The more positively a relative advantage of an innovation is perceived, the more rapidly it is going to be adopted, and vice versa.

While the authors of [25] limited the factor *revenue* included under the *relative advantage* attribute as "sell solar electricity," the present study has broadened the definition of *revenue* as "reduce consumption and sell unused generated electricity". The rationale is that both can fulfill economic advantage; generating revenue (sell excess electricity generated through a PV system to the national grid) and save on utility bills (consume less electricity imported from the national grid by consuming electricity generated from a PV system). The other four factors included under the *relative advantage* attribute (i.e., *environment protection*, *unlimited power*, *global warming*, and *technology development*) fall within "social-prestige, convenience, and satisfaction" components, as stated earlier [24].

Regarding, *observability* attribute, similar to any other innovation, observable results reduce uncertainty, encourage peer discussion, and increase the knowledge about the innovation, which eventually leads to higher rates of adoption. "Solar panels on a household's roof are highly observable, and a California survey found that the typical solar adopter showed his equipment to about six of his peers" [56]. The visibility of an innovation, as perceived by members of a social system, is positively related to its rate of adoption and vice versa [24]. This is correlated with the local positive perception (neighbors' attitude) which is affected by their knowledge on innovation, as well as its functionality monitoring [24]. For instance, the more electric vehicles appear in the streets, the more likely members of a social system to stimulate peer discussions and develop a piece of knowledge about them and ultimately form a perception or stance toward them. The same applies to RSPSs that are commonly observable on rooftops, which subsequently increase the probability to trigger peer discussions about their functionality [57].

Other measurable visible results of using a PV system are the amount of electricity generated by the PV system, statistics of revenues generated from electricity fed back to the grid, and monitoring Greenhouse Gas reduction. These factors fall within the visible components of *observability* attribute and could act as strong determinants.

As for *complexity* (simplicity) attribute, the simpler an innovation is to understand and use, the more likely it is to be adopted. Innovations that require adopters to develop new skills or understanding are less adopted than those that do not require such an effort [24]. From individuals' perspective, the complexity-simplicity in understanding and using an RSPS can be represented by the *installation space*, *maintenance*, *availability of service providers*, and *residence structure* and *residence location*. Certainly, there are also various external factors that may contribute to the complexity–simplicity continuum of RSPSs. However, in order to achieve the objectives of the present study, this component is restricted to the perspective of individual adopters.

Concerning *compatibility*, it is essential for an innovation to be compatible with potential adopters' needs, social, and religious values for easier adoption. An innovation should also be perceived as consistent, not only with deeply imbedded social norms but also with the past experience and the existing life patterns [24]. In a socially and religiously conservative country such as Saudi Arabia, these components could greatly influence individuals' decision-making. This includes the perception of the innovation as a socially-compatible addition, which in turn is affected by a positive image globally recognized as a trending product [24,58]. In addition, the innovation logistics (installation costs and land use) and integrability with the existing power system make it more compatible to adopt and consequently more favorable [24].

The literature showed that both motives and disincentives determinants are essentially context-dependent, (e.g., electricity tariffs, the economic stability of residents, type of available electricity sources, benefits and drawbacks of solar PV systems under local scenarios etc.). Yet, for critical motives and disincentives, most of these conditions and factors can be subsumed under the innovation attributes described in Rogers' *diffusion of innovations* theory [24,59].

### *4.3. Date Analysis*

Reliability testing across the four innovation attributes scales was conducted to check the internal consistency of the acquired set data. Normality testing was done to determine the appropriate statistical methods for data analysis (parametric or nonparametric tests). Shapiro–Wilk test and Kolmogorov–Smirnov tests are recommended in the literature for testing normality as they are superior in power for detecting significant deviations from normality [60]. These tests provide statistically significant results ($p < 0.05$) whenever the distribution of the numerical variable significantly differs from the normal distribution [60]. Nonparametric distributions are best described with the median for central tendency, the interquartile range for dispersion and the Mann-Whitney U test for comparing different medians with statistical significance. Furthermore, Spearman's rho rank correlation coefficient test was calculated to determine the rank correlation between the variables [61]. Further, the mean scores of the questions per attribute were calculated along with the frequencies and proportion for each question to identify the important variables in respondents' attitude. The chi-squared test and Fisher exact test were used to compare the categorical variables. The corresponding $p$-value was calculated for each statistical test, where results with a $p$-value less than 0.05 were considered to be statistically significant, and results with a $p$-value of less than 0.01 were considered to be highly significant.

## 5. Results

The questionnaire reliability testing results ranged between acceptable and good, where Cronbach's alpha internal consistency results ranged between 0.719 and 0.866 for different scales in the study [62].

### *5.1. Demographic Status*

Analysis of the respondents' demographic characteristics indicated that the majority were Saudi nationals, male, young (<40 years old), employed, and undergraduate educated, having a monthly income of less than 14,000 Saudi Riyals (SAR) (3733 USD), as shown in Table 2. The examination of the collected data shows no statistically significant variation in the acceptance or rejection rates among all demographic variables except for occupation ($p = 0.015$), where the self-employed category had the lowest acceptance rate (94.7%) in comparison to all other categories. Moreover, as summarized in Table 2, no significant variation in the acceptance or rejection rates was observed among the five targeted areas in this study (Central, Eastern, Southern, Western, and Northern areas).

**Table 2.** Frequencies and proportions of residential solar photovoltaic systems (RSPSs) acceptance based on demographic characteristics ($n$ = 1498).

| Characteristic | | Frequency | Percent | Accept RSPS | $p$-Value (with RSPS Acceptance) |
|---|---|---|---|---|---|
| **Nationality** | Saudi | 1420 | 94.8% | 97.5% | 1.000 [1] |
| | Non-Saudi | 78 | 5.2% | 97.4% | |
| **Gender** | Males | 1139 | 73.8% | 97.1% | 0.114 |
| | Females | 359 | 26.2% | 98.6% | |
| **Area** | Central area | 744 | 49.7% | 97.6% | 0.105 [1] |
| | Eastern area | 232 | 15.5% | 97.0% | |
| | Southern area | 96 | 6.4% | 96.9% | |
| | Western area | 353 | 23.6% | 98.6% | |
| | Northern area | 73 | 4.9% | 93.2% | |
| **Age** | 18–30 | 495 | 33.0% | 98.8% | 0.101 [1] |
| | 31–40 | 531 | 35.4% | 96.8% | |
| | 41–50 | 259 | 17.3% | 96.1% | |
| | 51–60 | 167 | 11.1% | 98.2% | |
| | 61–70 | 43 | 2.9% | 95.3% | |
| | 71 or more | 3 | 0.2% | 100% | |
| **Occupation** | Student | 244 | 16.3% | 99.6% | 0.015 * [1] |
| | Government employee | 524 | 35.0% | 97.1% | |
| | Private sector employee | 339 | 22.6% | 96.8% | |
| | Self-employed | 131 | 8.7% | 94.7% | |
| | Retired | 152 | 10.1% | 97.4% | |
| | Other | 108 | 7.2% | 100.0% | |
| **Education** | Postgraduate | 274 | 18.3% | 98.9% | 0.067 [1] |
| | Undergraduate | 874 | 58.3% | 96.7% | |
| | Secondary or equivalent | 314 | 21.0% | 98.7% | |
| | Junior high school | 29 | 1.9% | 93.1% | |
| | Elementary school | 6 | 0.4% | 100.0% | |
| | Informal education | 1 | 0.1% | 0% | |
| | Not gone to school at all | 1 | 0.1% | 100.0% | |
| **Income (SAR)** | Less than 5000 | 117 | 7.8% | 96.6% | 0.747 [1] |
| | 5000–9000 | 302 | 20.2% | 97.4% | |
| | 10,000–14,000 | 350 | 23.4% | 96.3% | |
| | 15,000–19,000 | 242 | 16.2% | 97.9% | |
| | 20,000–24,000 | 192 | 12.8% | 97.4% | |
| | 25,000–29,000 | 85 | 5.7% | 98.8% | |
| | 30,000–34,000 | 63 | 4.2% | 100.0% | |
| | 35,000–39,000 | 41 | 2.7% | 97.6% | |
| | 40,000 or more | 106 | 7.1% | 99.1% | |

* Statistically significant results ($p < 0.05$); [1] For these characteristics, Fisher exact test was used since some of the expected values were lower than 5, making chi-squared test results less accurate.

### 5.2. Solar Energy Cognition

The general trend in the data shows good knowledge of solar energy, as can be seen in Figure 1. Most participants agree on the continuity and persistence of solar energy-based electricity supply, disagree on solar energy harmfully effecting the environment and wildlife, agree that solar energy brings new business opportunities, and disagree on negative impacts on local communities.

The respondents were asked to assess four general statements based on a 5-point Likert scale. A total of 64.3% participants agree (or strongly agree) with the statement "Solar energy can ensure a continuous and constant supply of electricity," while 17.4%) disagree and 18.3% have a neutral attitude. While the responses to the statement "Solar energy harms environment and wildlife" were more one-sided with 90.2% not agreeing with the statement, only 7.8% of the respondents choose a neutral opinion. Moreover, the vast majority (82.6%) agree with the statement "Solar energy can bring new business opportunities". On the other hand, 5% disagree and 11.4% have an indifferent position.

Furthermore, rejection of the statement "Solar energy can have negative impacts on local communities" predominates (77.1%), while a neutral stance of 17.9% and a significant low agreement rate of 5% was observed (see Figure 1).

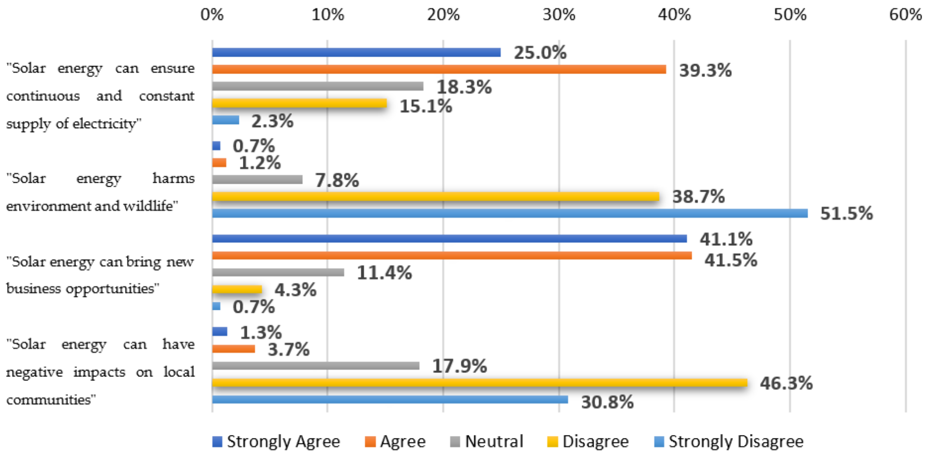


**Figure 1.** Respondents knowledge on solar energy ($n$ = 1498).

### 5.3. Innovation Attributes Assessment

When the respondents were asked whether they accept or reject the notion of installing an RSPS, the overwhelming majority (97.46%) accepted installing an RSPS at their residence (95% CI: 96.7% to 98.3%). Therefore, these results are consistent with the postulated hypothesis (H1), which states the "The majority of the Saudi population accept the notion of installing a residential solar PV system in their homes".

Regarding the results of the four attributes, the scores given to each attribute show that acceptors preferred to agree on the *relative advantage* attribute (median score 22), whereas rejectors preferred to agree on the *observability* attribute which was given the highest score in comparison to other attributes (median score 15). See Table 3.

**Table 3.** Statistics across different attributes and tests to ascertain differences in medians.

| Attribute | Testing Normality | | Median | Interquartile Range | Median by RSPS Acceptance | | | *p*-Value (Independent Samples Mann-Whitney U Test) |
|---|---|---|---|---|---|---|---|---|
| | Kolmogorov-Smirnov | Shapiro-Wilk | | | Accept RSPS | Reject RSPS | Median Difference | |
| **Relative Advantage** | <0.001 ** | <0.001 ** | 22 | 6 | 22 | 13 | 9 | <0.001 ** |
| **Observability** | <0.001 ** | <0.001 ** | 18 | 7 | 18 | 15 | 3 | <0.001 ** |
| **Complexity** | <0.001 ** | <0.001 ** | 18 | 7 | 18 | 12 | 6 | <0.001 ** |
| **Compatibility** | <0.001 ** | <0.001 ** | 19 | 6 | 20 | 14 | 6 | <0.001 ** |

** Highly significant ($p < 0.01$).

Concerning the *relative advantage* attribute, most of the acceptors agree on the positive effects of all variables of the *relative advantage*. The *unlimited power* variable, which refers to the inexhaustibility of solar energy for the generation of electricity, had the highest rates of respondents who agree on its positive effects. On the other hand, respondents who reject RSPS installation had higher disagree rates on the *revenue* component of solar energy, as shown in Figure 2a and Table 4.

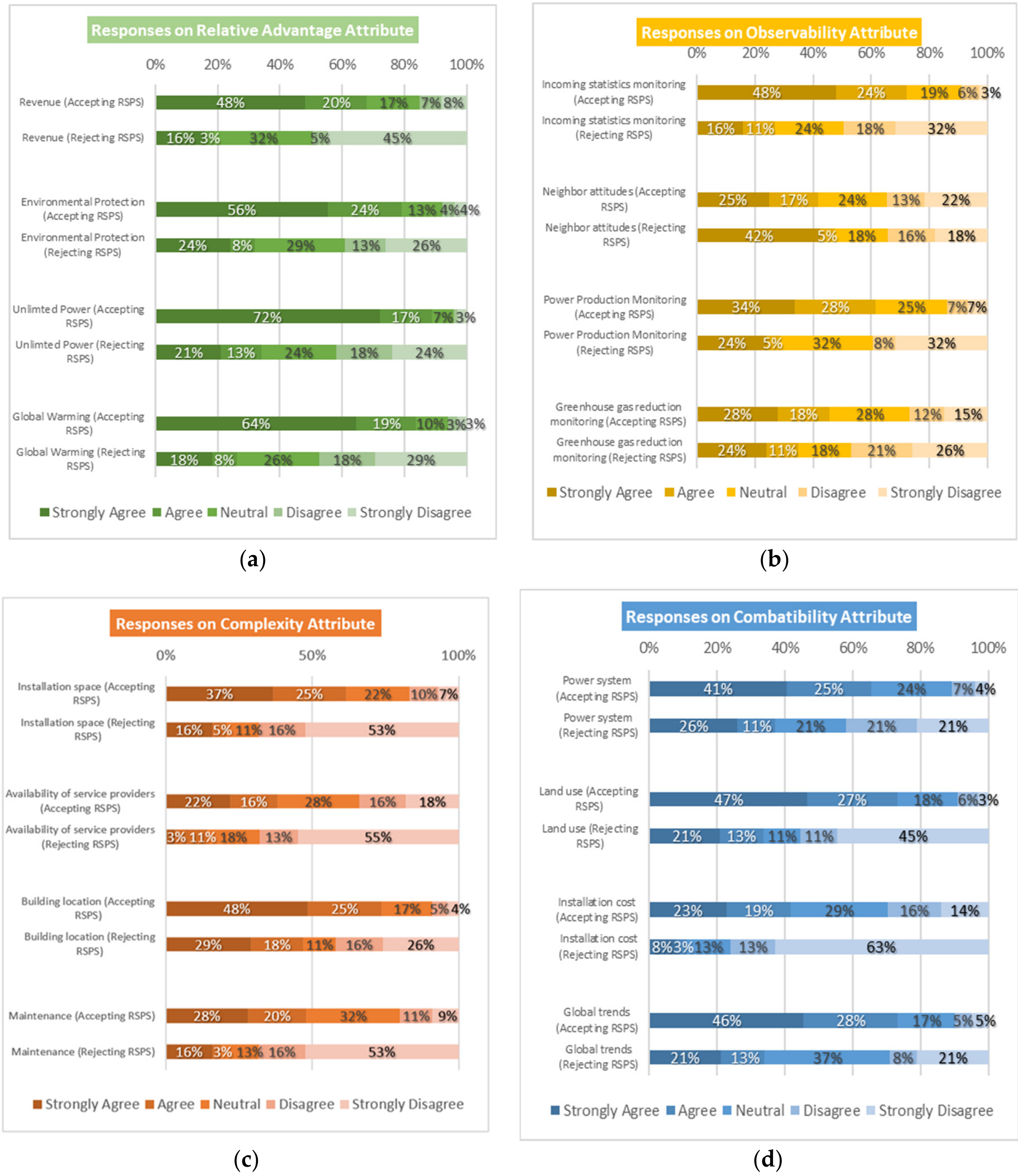


**Figure 2.** Participant response regarding the variables of the innovation attributes. (**a**) Participant response on *relative advantage* variables, (**b**) participant response on *observability* variables, (**c**) participants response on *complexity* variables, (**d**) participants response on *compatibility* variables.

Regarding *observability*, the results demonstrated a general trend for RSPS acceptors to agree on the positive effects of income monitoring, i.e., *power production monitoring* and *solar energy knowledge*, where the highest of these was *income statistics monitoring*. In contrast to all other variables across different attributes, RSPS rejectors had a higher rate of agreement on the *neighbor attitudes* variable as compared to that of RSPS acceptors (see Figure 2b and Table 4).

**Table 4.** The association between attributes/variables and accepting/rejecting RSPS installation.

| Attribute | Variable | Mean of Likert Scale | | Mean Difference | The Average Mean Difference for Attribute |
|---|---|---|---|---|---|
| | | Accept RSPS | Reject RSPS | | |
| Relative Advantage | Revenue | 3.93 | 2.39 | 1.54 | 1.53 |
| | Environment Protection | 4.24 | 2.89 | 1.35 | |
| | Unlimited Power | 4.55 | 2.89 | 1.65 | |
| | Global Warming | 4.38 | 2.68 | 1.69 | |
| | Technology Development | 4.27 | 2.87 | 1.40 | |
| Observability | Income Statistics Monitoring | 4.08 | 2.61 | 1.47 | 0.66 |
| | Neighbor Attitudes | 3.10 | 3.37 | −0.27 | |
| | Power Production Monitoring | 3.74 | 2.82 | 0.93 | |
| | Greenhouse Gas Reduction Monitoring | 3.32 | 2.84 | 0.48 | |
| | Solar Energy Knowledge | 3.82 | 3.13 | 0.69 | |
| Complexity | Installation Space | 3.74 | 2.16 | 1.59 | 1.13 |
| | Availability of Service Providers | 3.10 | 1.92 | 1.17 | |
| | Residence Location | 4.09 | 3.08 | 1.01 | |
| | Maintenance | 3.46 | 2.13 | 1.33 | |
| | Residence Structure | 3.80 | 3.26 | 0.54 | |
| Compatibility | Power System | 3.91 | 3.00 | 0.91 | 1.08 |
| | Land Use | 4.08 | 2.55 | 1.53 | |
| | Installation Cost | 3.20 | 1.79 | 1.41 | |
| | Global Trends | 4.06 | 3.05 | 1.00 | |
| | Social Values | 3.92 | 3.37 | 0.55 | |

The analysis of the *complexity* attribute revealed a general trend that RSPS acceptors agree on the positive effects of all *complexity* variables except for the *availability of service providers*. The highest agree rate of these variables was for the *residence location*. On the other hand, respondents who rejected RSPSs installation show several trends in disagreeing on the positive effects of *installation space*, *availability of service providers* (which had the highest disagree rate), and *maintenance* (Figure 2c and Table 4).

Concerning *compatibility*, RSPS acceptors generally agree on the positive effects of all variables related to *the compatibility* attribute, except for the *installation cost,* which scored 3.20 as the Likert scale mean value (Figure 2d and Table 4). The highest among these values was *land use* with a 4.08 mean value. Those who rejected RSPS installation had the highest disagree rate on the *installation cost* (see Figure 2d and Table 4).

The association between attributes and RSPS acceptance shows that the *relative advantage* was the most important determinant since the difference in the median score between acceptors and rejectors was 9 points (Table 3). Additionally, the most significant variable among all attributes was the effect on *global warming*, where the mean among the acceptors was 1.69 points more than that among the rejectors (Table 4). The second most significant variable was *unlimited power*, and the third was *revenue*. These results are not consistent with the postulated hypothesis (H2) which states, "The most significant deciding factor in accepting RSPS is revenue obtained by reducing electricity consumption and selling unused electricity to service provider." *Income statistics monitoring*, *installation space*, and *land use* had the highest mean difference among *observability*, *complexity*, and *compatibility* variables, respectively (Table 4).

None of the four attributes scores were normally distributed, as the statistical significance of Kolmogorov–Smirnov and Shapiro–Wilk show in Table 3 (therefore, nonparametric statistics are used for description and analysis, i.e., median, interquartile ranges, and Spearman's rho correlation coefficient). The highest median score was seen in the *relative advantage* attribute, which is also consistent with the higher median difference between RSPS accepting and rejecting groups, thus indicating a stronger association with the decision to accept RSPS installation. The lowest median difference was seen in the *observability* attribute.

The results of the correlation analysis between the four attributes indicate a moderate positive correlation (0.50–0.70), except for correlations between the *relative advantage* and *complexity* as well as the correlation between *observability* and *compatibility*, which were a low positive correlation (0.30–0.50). Furthermore, the strongest association was seen between the *relative advantage* and *observability* scores, followed by the correlation between *complexity* and *compatibility* scores (see Table 5).

**Table 5.** Correlation between different scales used in the study.

| | | Relative Advantage Score | Observability Score | Complexity Score | Compatibility Score |
|---|---|---|---|---|---|
| Spearman's rho Correlation Coefficient | Relative Advantage Score | | 0.633 ** | 0.466 ** | 0.507 ** |
| | Observability Score | 0.633 ** | | 0.530 ** | 0.487 ** |
| | Complexity Score | 0.466 ** | 0.530 ** | | 0628 ** |
| | Compatibility Score | 0.507 ** | 0.487 ** | 0.628 ** | |

** Correlation is significant at the 0.01 level (2-tailed).

## 6. Discussion

Many countries are reconsidering energy strategies and utilizing renewable energy. Social acceptance is a key factor in the success or failure of the sought-after energy transition. The outcomes of public review surveys form the basis of regulations and policy developed to promote the adoption of specific energy technologies. Therefore, it is crucial to identify how to evaluate acceptance in public review studies to ensure that the outcomes of these studies provide accurate and representative data that allow valid inferences to be made about local acceptance. Additionally, debates on energy supply infrastructure are often irrational and emotionally driven, as individuals at some level hold certain perceptions about different types of energy technologies. To allow for knowledgeable and informed decision making, it is essential to have a solid understanding of the psychological aspects of the representation of alternative energy systems and how to effectively assess them.

The content presented in this paper shows that there are various paths toward expanding the use of solar PV systems in Saudi Arabia. Each individual participating in this study followed particular motivations, implicating a specific set of identities and competencies. The demographic characteristics of the study participants who were collected by the web-survey do not fully represent the population in Saudi Arabia. The study population had 95% Saudi national participants, whereas they represent 62% of the population in Saudi Arabia. Similarly, the gender of the participants (74% of the study being male as compared to males making up 57.5% of the population) and the age distribution (68% were less than 40 years-in comparison to 46.3% of the population being under 40) were not representative of all Saudi Arabia residents [50]. Nonetheless, no significant association with the RSPS was observed among these demographic variables; therefore, the probability of bias remains low. Furthermore, the acquired study population reflects the decision-making capacity in a masculine society, where males in Saudi Arabia have more influence on family decisions [63].

The rate of accepting the notion of installing RSPS found in this study answers the RQ1 and is seen to be remarkably high when compared with the results of other similar studies used the same quantitative research approach. Poonnavich and Weerin [25] indicated that the acceptance ratio in Thailand was 67.8%, while Faysal [64] reported 78% in the southern part of Bangladesh. Similarly, two separate studies in the northern part of Pakistan and southern Punjab revealed that 81% and 82% of the respondents, respectively, were interested in RSPSs [65,66]. A study in Malaysia contended that 80% of the participants in the survey were highly interested in RSPSs [67].

This dissimilarity may be attributed to the different circumstances of the studies. The significantly positive image and high rate of acceptance of RSPSs found in this study may also be in line with a similar study conducted among residents in the Saudi Arabia, in which the participants' preferences for solar PV systems outweighed other given options of renewable energy applications [14,47]. The respondents' preference for solar energy may have been directly affected by the increasing number of announcements about large utility-scale solar energy projects in different parts across Saudi Arabia, which are being carried out under the national plan Saudi Vision 2030 that aims for a less oil-centered and more sustainable economy. Additionally, the long solar irradiation time Saudi Arabia enjoys and the rapid solar energy development in the neighboring countries (e.g., The United Arab Emirates and Jordan) may have also affected their perception.

Regardless of the variation of the development levels in the infrastructure, education system, and lifestyles across the country, the results show no significant variation among respondents from all five targeted regions of the country. These findings may point to no cultural-based differences in perception regarding solar energy technology across all regions in Saudi Arabia and can likely be attributed to the popularity of solar energy-based power, where electricity is only partially or completely not available (e.g., remote farms and desert pasture).

The median score of the *relative advantage* attribute was observed as the highest among the other attributes. These values are consistent with the results of Spearman's rho correlation coefficient test. Among the factors examined in the study, the location and structure of a house clearly act as determinants in the acceptance or rejection of RSPSs. Moreover, among all factors of the four innovation attributes, *global warming*, ranks as the most significant variable with a mean difference score of 1.69, followed by *unlimited power* (1.65) and *installation space* (1.59) (Table 4). While *unlimited power* is the most agreed upon variable, it also has a slightly higher agreed rate among rejectors. Therefore, the lack of appreciation of *global warming* among rejectors contributed more to their negative view of RSPSs. These prominent findings answer the research question RQ2 and reject the postulated hypothesis of H2 that suggests the factor *revenue* is the most significant deciding factor in accepting RSPSs. Although the variation between the scores of the three factors, *global warming*, *unlimited power*, and *installation space*, is low, the *global warming* factor ranking first might be attributed to the large young segment of respondents with current knowledge on *global warming* and safe renewable power sources, thus reflecting the population structure in Saudi Arabia. The level of awareness of *global warming* found in this study is consistent with that of Al-Mutairi's study [68], which assessed the level of awareness and knowledge about climate change among the community of the rural region of Tabuk (northern Saudi Arabia); and the study concluded that individuals involved in the study showed a moderate level of knowledge toward climate change issues, impacts, and solutions proposed by the authors.

The highly positive attitude toward RSPSs installation is an encouraging finding for the promotion of these technologies among individuals and for achieving the desired energy transition in Saudi Arabia. These findings also cause concern because they do not reflect the small number of applications made to install such technology [10], which indicates an existing gap between the individuals and the pertinent government agencies. Calling for application submission without building a solid foundation of policies and knowledge could cause a significant variation in the perception of prospects. This has important implications for the underlying policies, regulations, and information provision for RSPSs in Saudi Arabia.

To allow for intact decision making, it is vital to educate the targeted segment (i.e., households) by providing them with accurate information about solar energy technologies. Based on the findings of this study, the authors recommend developing a national interactive platform, where interested individuals can assess the required upfront investment, estimated electricity output, required space, and potential revenue based on their dwelling location prior to the purchase of RSPSs; they should be given the opportunity to develop a piece of knowledge in advance about both the advantages and disadvantages of RSPSs which consequently will help to ensure a successful and timely implementation of the technology.

Moreover, the net metering mechanism currently introduced by the Electricity & Co-Generation Regulatory Authority [7] might not seem attractive to end-users, as it only allows any excess electricity generated by end-users to be banked to their account for future consumption. Taking into consideration the high amount of electricity consumed by air conditioners in Saudi Arabia (especially in desert climate areas), it is less likely that any excess electricity will be accumulated for further consumption. Thus, an alternative incentive mechanism must be introduced to the public in a way that fosters plausible and constant injection of solar harvested electricity into the grid. Besides the guaranteed uptake, the authors suggest that the current net metering mechanism should be modified to allow individuals to sell back any excess electricity and receive payments based on how valuable the exported electricity is to the electricity system at certain times. (i.e., greater payment should be received for electricity exported in peak times). This would encourage individuals to reduce their electricity consumption during peak times by trying to secure excess electricity to export to the grid to take advantage of the high uptake rates at these particular times. Since the temperature and levels of energy demand vary significantly during the year in Saudi Arabia, the SEC has built a number of high-cost electricity generation plants across the country that are only to be used for a very short period of time (summer peak times) to reduce energy supply failure caused by the high demand for electricity. This challenge might be overcome if a time-based uptake scheme is introduced for homeowners.

Additionally, despite the fact that many countries have phased out feed-in tariff schemes with no replacement, and despite the consistently reduced cost for solar PV system components, it is essential in the Saudi context to design mid-term subsidizing programs that relieve the high upfront cost of RSPSs and encourage plausible integration without causing fluctuation or disrupting the standability of the electricity system. It is imperative for a country like Saudi Arabia, which consumes the equivalent of 1.5 to 2 million barrels of oil daily in electricity generation [69], to develop a national direct subsidy plan dedicated to homeowners to increase the RSPSs adoption rates. The increasing local consumption of a substantial portion of the total liquid petroleum is cutting directly into the oil export volume, which could have otherwise been exported at global market rates. Giving the fact that the petroleum is sold to the SEC at as low as 3% of the international market prices (approximately $3 per barrel) [70] and considering that the total government subsidies spent on energy and water in 2015 reached nearly 79 billion dollars [71], it could be argued that a portion of the government energy subsidies should be allocated for the support of homeowners in purchasing RSPSs.

Similar to other GCC countries, in an absolute monarchy like Saudi Arabia, revenues derived from exported oil and gas has facilitated to what so-called "ruling bargain", a mainly top-down social contract in which governments provide a wide range of subsidized services in return for their citizens' political acceptance [72]. The provision of low-priced energy has been, for decades, a primary element by which GCC states achieved their social, economic, and political objectives [73]. This justifies the present image of the survey respondents, where the non-financial benefits (limiting *global warming* and enabling *unlimited power* sources) are more valuable compared to financial benefits (*revenue*).

However, this policy has come at huge cost. Besides the fact that substantial portion of crude oil is being consumed domestically, which prevents Saudi Arabia from maximizing the value of its natural resources and extending its export base, low energy prices have created an illusion of abundance, which consequently resulted in excessive increase in energy consumption coupled with rapid population growth [12,73].

Following the steps of the other GCC states, it is fair to mention that Saudi Arabia has recently taken major steps in reforming the government subsidy structure. It has been gradually abolishing subsidies applied to various utility services including electricity. For instance, starting from January 2018, electricity tariffs for the residential sector have been hiked between 80–260% [74]. Although the new tariffs are still low according to international and regional standards, such measures would make purchasing an RSPS economically feasible as it helps to shorten the solar PV systems payback period and allow them to compete against hydrocarbons sources.

Furthermore, the study recommends that the government should consider adopting zero rating tax on solar PV system components in a way that does not violate the international trade law or other agreements that Saudi Arabia is a part of. Abolishing tax would be of assistance as it reduces the upfront cost of purchasing an RSPS, thus making it more affordable for individuals to possess.

In addition to the recommendation above, an introduction of long-term, low-interest loans can encourage more extensive implementation of RSPS among individuals. Unguaranteed high-interest loans may not fit conceptually and can be counterproductive as they increase the overall cost of solar PV systems by adding the cost of margin interest payments.

The empirical results reported herein should be considered in light of some potential limitations that need to be addressed to improve future research. The survey was conducted online, which was reflected in various demographic characteristics, even though controlling for these demographics indicated no significant variations in their subcategories. Additionally, the selected online survey methodology, was not applicable to those who do not have access to the internet. Moreover, the questions used in the questionnaire were closed-ended, Likert-type scale questions and a dichotomous question. Although these types of questions provide precise and clear answers, they do not provide a specific explanation of why a particular answer was chosen among other options. However, regardless of how the respondents formed their knowledge about solar energy and how they used the information presented in the questionnaire, the findings of this study clearly provide a valid basis from which to draw conclusions about the social perception on RSPSs adoption in Saudi Arabia.

As for future research directions, investigating the functionality between the pertinent government agencies based on an innovation-oriented theoretical framework may help elucidate how the involved parties should work jointly to enhance the inducement mechanisms and reduce the blocking mechanisms that have a great impact on the diffusion of RSPSs in Saudi Arabia. Furthermore, in-depth investigation of the *willingness to pay* could be an interesting point, providing more insight into the implication of a Saudi residence adopting an RSPS. Another aspect that could be of interest is the electricity consumption behavior among households who already installed RSPSs; a study could be conducted to analyze how their electricity consumption might have changed after installing the solar PV system. Finally, an open-ended, face-to-face approach would provide deep insight by allowing respondents to define central issues and explain the rationale behind their answers.

Generalizing the study findings to other countries should be guided by the similarities in context characteristics. While other oil-rich countries may share similar strategies considering transforming to other renewable energy sources, a special consideration should be given to the lower standard electricity prices in Saudi Arabia compared to the solar-generated electricity price. More comparable costs in other countries may result in changing adopters view for the relative advantages of RSPSs, which should be considered in innovation dissemination policies. In addition, as the adoption decision is individual at the family level, the perception of installation costs, as a limiting factor, may be correlated with the per capita income of a specific country.

## 7. Conclusions

The purpose of this paper was to investigate the social perception of RSPSs in the oil-rich Saudi Arabia. A cross-sectional, web-based survey was conducted among individuals to examine what factors may potentially act as a motivator or disincentive in the adoption of RSPSs based on the *diffusion of innovations* theory. The findings of this study demonstrated the individuals' overwhelming positive perception of the RSPSs with no significant variation in the acceptance or rejection rates among participants from the five main geographic regions of Saudi Arabia included within the scope of this work.

While the self-employed participants had lower acceptance rate for installation of RSPS, there were no significant differences between educational and income categories.

Participants' knowledge of solar energy was good, where the majority had correct views of solar energy renewability, environmental and communities' safety, and the creation of new job opportunities. The study also reviewed participants' perception of attributes and factors related to the diffusion of RSPS innovation, which showed high statistical significance for the differences between acceptors and rejecters in all four attributes. Acceptors appreciate the installation of RSPS for its *relative advantages*, while rejecters had a lower perception. However, these perceived advantages were the long-term benefits related to electricity costs. This includes reducing the effects of *global warming* as well as providing a source of *unlimited power* supply. Additionally, the study showed that the *installation costs* are the leading constraints that can drive participants to reject RSPS installation. The generalization of these findings to other oil-rich countries is guided by similarities in contexts, specifically a lower standard electricity prices and a similar per capita income.

This paper concludes that there is a requisite need to reconsider the current small-scale solar PV systems regulations. Moreover, the policies need to address the challenges to RSPS installation, which includes the installation costs. Supporting policies can include the provision of financial subsidies and low-interest loans for RSPS installation and a lower tax rate for RSPS components.

The findings of this paper can help policymakers and private agencies in Saudi Arabia design policies, regulations, and incentive programs that can address the challenges currently hampering the diffusion of such technologies among Saudi residents in an efficient and sustainable manner.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

The description of how an RSPS functions was presented to the respondents of the survey as follows: "A solar photovoltaic system works by capturing the sunlight and turning it into electricity for your home". Given the different sociodemographic characteristics of the respondents, and after using a pilot sample of the questionnaire, the authors of this paper gave this basic description to eliminate any possible ambiguity. In addition to this description, a simplified diagram of an RSPS layout was provided to the respondents as shown below.

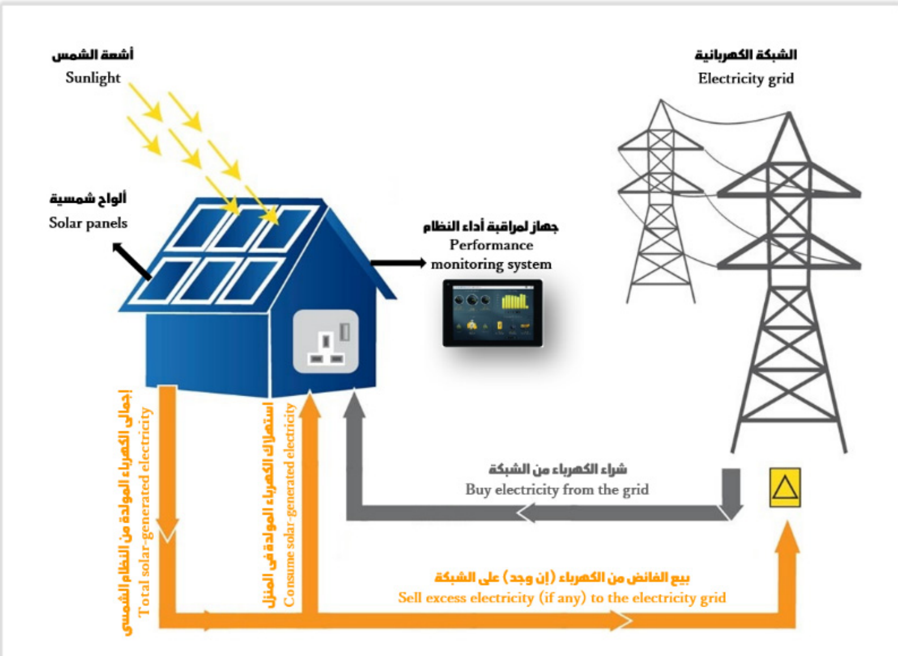


**Figure A1.** Simplified layout of an on-grid RSPS.

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