Factors Affecting Public Willingness to Adopt Renewable Energy Technologies: An Exploratory Analysis

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Abstract: Renewable energy has become an important element of today’s modern technology targeting high-efficiency energy production. As part of its 2030 Vision, Saudi Arabia is aiming to increase its energy production through renewable sources. The purpose of this research study is to explore the factors affecting public willingness to adopt renewable energy technologies in the western region of Saudi Arabia. This was achieved through an extensive literature review of previous studies conducted worldwide and resulted in the extraction of 19 factors that affect public willingness to adopt renewable energy technologies. Following a quantitative research design, random cross-sectional data of 416 participants using the extracted factors were collected via an online questionnaire survey. Following a dimension reduction statistical approach, key components were extracted with exploratory factor analysis using principal component analysis. Five main components clustering the 19 extracted factors were revealed: cost and government regulations and policies, public awareness and local market, environment and public infrastructure, residential building, and renewable energy technology systems. The implications of this research study assist in guiding governments, regulations and policy makers, marketing agencies, and investors to better understand the concerns and enablers of renewable energy technologies adoption from the public perspective.

Keywords: exploratory analysis; factor analysis; renewable energy technologies; willingness; adoption; public perception; Saudi Arabia

1. Introduction

Conventional energy production and consumption is significant for the health of economies, but at the same time causes environmental degradation [1]. Saudi Arabia recognizes the vital necessity of renewable energy application and enhancement to attain energy security and to release some of its production for export rather than local consumption with high subsidies [2]. It has ample potential for solar energy but unfortunately lags behind other countries due to the capacity of installed renewable energy technologies (RETs) [3]. It also lacks mass-scale joint ventures that may permit a similar application of renewable energy resources to that of other prominent countries [3]. Saudi Arabia should be involved in the development and implementation of RETs, regardless of being the world’s main fuel producer and exporter or the biggest consumer of fuel in the Middle East [2]. The Saudi Arabian government’s interest in solar power is based on its objective of retaining its oil exporting capacity along with the increasing local consumption of oil for power [4]. The declining prices of photovoltaic solar cells makes the application of solar energy in certain locations feasible,
cost-effective, and competitive [2]. Renewable energy resources development and utilization requires the establishment of a comprehensive policy [5]. The feed-in tariffs (FIT) scheme is recognized as being widely used and as an efficient proven strategy for promoting renewable energy by providing developers and consumers with significant benefit [5]. Implementing this scheme in Saudi Arabia will prospectively enhance the progress of renewable energy in the region. Furthermore, using intelligent home technologies to monitor and control RETs will positively enhance energy performance [6].

According to the Saudi Arabian Vision 2030 [7], many ambitious plans for the renewable energy market were set, including the localizing of RETs and industrial equipment manufacturing. In addition, it will ensure the promotion of RETs with the steady liberalization of fuel prices. Furthermore, a preliminary aim of producing 9.5 gigawatts of renewable energy was set as part of the Vision 2030 objectives. As part of this expansion in the renewable energy sector, focus will be placed on research, development, and manufacturing.

A previous study that focused on the willingness to adopt RETs in the western region of Saudi Arabia resulted in many positive findings [8], including the potential for the adoption of these technologies by the public. The study showed that research respondents had a background knowledge on the following renewable energy sources: solar, wind, sea wave, hydroelectric, geothermal, and biomass. Furthermore, it also concluded that the key factor influencing the willingness to adopt RETs is of an economical nature.

As a continuation to the aforementioned research on the willingness to adopt RETs in the western region of Saudi Arabia, there is a need to explore in detail the factors influencing public adoption of RETs in Saudi Arabia. Identifying these influencing factors and grouping them into those counted as significant factors will make the process of establishing public policies to promote these technologies much clearer. Furthermore, the private sector will use these influencing factors by targeting and fulfilling the public requirements for distributing their RETs products.

Before investigating the factors influencing public adoption of RETs locally in Saudi Arabia, it is important to review the available and recently conducted research in various countries with similar objectives. This will assist in easing the process of identifying the required factors as well as exploring the perception of different cultures worldwide in this context. The energy technologies of the future are influenced by public preferences [9]. The five main attributes that the public considers are risk of disaster, economic security, individual costs and discomfort, occupant impact, and value [9]. According to reference [10], individual income is not considered as an important factor for adopting RETs. Instead, the perceived usefulness of the technology is the major key factor. This is because people will be affected by the technology’s economic benefit, convenience, satisfaction, and impression. A United Nations report explored the dispersion of RETs through science, technology, and innovation [11]. It concluded that national renewable energy pathways will differ from one country to another. Also, policy mixes are important for encouraging RETs development. Finally, it emphasizes the significance of international and regional cooperation.

A study conducted in Mexico City, Mexico, concluded that communication is a very important factor that affects social acceptance, which in turn has an influence on RETs social acceptance [12]. In China, unexpected research results showed that reducing electricity charges contributed to higher innovation levels in RETs [13]. At the same time, the study revealed that a tariff surcharge subsidy does not have an important effect on RETs innovation. In rural areas in China, RETs received a great deal of attention due to the residents’ need to enhance their housing conditions [14]. The study found that the most significant factor for RET implementation in rural China was initial investment. Moreover, other influential factors included subsidies, financial support, after-sale maintenance, and communication. The findings of a study carried out in Senegal on RET promotion among the public showed that tariffs policies could encourage the diffusion of RETs [15]. For the successful growth and diffusion of renewable energy in Denmark, a research study concluded with a number of recommendations, in brief, they were: political support, use of local resources, ensuring access to reliable economic resources, establish networks among the community, establish a platform for information exchange,
and become totally self-sufficient with local resources [16]. Public perception of RETs was studied in South Korea and it was found that the Fukushima accident in nearby Japan caused a noticeable difference on the public perception of RETs [17]. The study showed that before the accident, the public considered the cost of RETs as their main relevant factor, whereas after the accident, public attitude towards RETs became the main relevant consideration. In 2009, the Malaysian government publicized the National Renewable Energy Policy and Action Plan to support and increase the development of renewable energies [18]. Unfortunately, the lack of public awareness and acceptance of renewable energy in Malaysia were the reasons for the adoption of renewable energy remaining in the early stages. The younger Malaysian generation was more willing than the older generation to pay more for renewable energy sources. This could be due to easier access to information on renewable energy for younger people. Environmental innovation in the form of RETs was not adopted widely by consumers in the United Kingdom [19]. The study concluded that the promotion of green electricity or RETs does not depend on green values only, but also strong social norms and what innovation means to the public. A study in Yemen on RET implementation by the public showed that the public acceptance of RETs in rural zones was greater than that in urban zones [20]. Furthermore, the conclusions encourage the implementation of pilot projects, as it played a vital role in increasing public acceptance through publicizing information on RETs, which would in turn achieve sustainable development. Public perception of RETs was studied in a survey in Portugal [21]. In general, the public there had a progressive attitude toward RETs and were supportive of its projects. Moreover, the public had low levels of knowledge on RET costs, FIT, and their effects on electricity bills. The acceptance of RETs would be reduced if the Portuguese perceived negative economic effects from them. RETs in the United Kingdom and a number of European countries face resistance to implementation and a reluctance to investment by the public, which is considered a barrier to the development of the RET sector [22]. As solutions to make RETs more appealing to the public, options such as structuring economic incentives, rebound effects, and visual impacts should be considered. Financial solutions such as Sukuk, which is an Islamic finance Shari’ah-compliant instrument could be used by policy makers as an incentive to promote RETs adoption in general, as it works on controlling the amount of financing leverage [23,24].

From the above literature review, it can be seen that people from different countries have different perspectives on the adoption of RETs. This supports the importance of studying the factors influencing public adoption of RETs on case-by-case bases. The purpose of this study is to identify and explore the key factors influencing the Saudi public willingness to adopt RETs in the western region, Saudi Arabia. To proceed with this step and to identify these key influencing factors, it is necessary to compile a comprehensive list of factors influencing the adoption of RETs worldwide based on a literature review. Then, it would be ideal to have this list evaluated by the citizens and residents of Saudi Arabia through a survey questionnaire and analyze the data to derive the key factors influencing public adoption of RETs according to the Saudi Arabian perception.

2. Materials and Methods

Following the methodology diagram presented in Figure 1, an extensive literature review was done to extract the main factors influencing public willingness to adopt RETs from previous studies carried out in different countries. A search for references was made through the Saudi Digital Library (SDL), Google, and Google Scholar search engines. Keywords such as “factors”, “public”, “renewable energy technology” were used in the search process. The extracted factors are presented in the following section.

A quantitative research design was followed using a random sampling process to collect cross-sectional data using an online questionnaire survey conducted via Google Forms. This study is a continuation of a previous study [8]. Thus, the extracted factors were included in the designed online questionnaire survey. A sample of 416 respondents were asked to evaluate the importance of each of the extracted factors on affecting their willingness to adopt RETs on a 6-point scale (i.e., extremely
important, important, neither important nor unimportant, unimportant, extremely unimportant, and not applicable). More detailed information on the collected sample such as: respondents’ socio-demographic characteristics, their background knowledge on RETs, their willingness to adopt RETs, statistical power and effect size of the sample, spatial and temporal context of the data, and a descriptive analysis of the used sample, can be found in reference [8].

Following a dimension reduction statistical approach, exploratory factor analysis using principal component analysis (PCA) with an orthogonal rotation method (i.e., varimax) was conducted to extract the key components of factors affecting the willingness to adopt RETs. Furthermore, reliability analysis was conducted to validate the questionnaire survey, and the extracted components, using Cronbach’s alpha (α), as a measure of scale reliability. The Statistical Package for Social Sciences (SPSS version 22.0) [25] was used to analyze and interpret the data. The results and discussion of this study are presented in the subsequent sections.

Figure 1. Methodology diagram.

3. Results and Discussion

The extensive literature review concluded with the identification of 19 factors influencing public willingness to adopt RETs from previous studies in different countries. Twenty-seven studies were cited to compile the 19-factor list. Table 1 illustrates the extracted 19 factors along with their associated references.

Reliability analysis of the 19 factors in the questionnaire survey resulted in a Cronbach’s α of 0.76, demonstrating a satisfactory level of reliability of the used factors (i.e., >0.70) according to [26–28]. Further, none of the 19 factors showed an increase in the reliability level if removed from the questionnaire survey.

A PCA was performed for the 19 factors (Table 2) with orthogonal rotation (varimax) [26,29]. The Kaiser-Meyer-Olkin (KMO) measure confirmed the sampling adequacy for the analysis [30]. KMO = 0.764, which is considered acceptable according to [26,31], and all KMO values for individual factors were > 0.546, which is above the acceptable bare minimum of 0.5 [26,32]. Eight items had values between 0.80 and 0.90, six items had values between 0.70 and 0.80, and five items had values between 0.5 and 0.7. Bartlett’s test of sphericity $\chi^2 (171) = 1498.291, p < 0.001$, showed that between-factor correlations were appropriately large for the PCA. An initial analysis was conducted to attain eigenvalues for each component in the data. Figure 2 presents the five extracted components (black dots) with eigenvalues over Kaiser’s criterion of 1.0 (dashed line) with eigenvalues ranging from 1.08 to 3.87 before rotation.
and from 1.72 to 2.55 after rotation (Table 2), and in combination explained 51.53% of the variance as detailed in Table 2. Given the large sample size ($N = 416$), and the convergence of the scree plot and Kaiser’s criterion on five components, this is the number of components taken in the final analysis. Table 2 shows the factor loadings after varimax rotation. The factors that cluster on the same components propose that: component 1 signifies cost and government regulations and policies; component 2 signifies public awareness and the local market; component 3, environment and public infrastructure; component 4, residential building; and component 5, RET systems.

Table 1. List of extracted factors affecting the willingness to adopt renewable energy technologies (RETs) from the previous literature.

| Factors Affecting Public Willingness to Adopt RETs                                      | References |
|----------------------------------------------------------------------------------------|------------|
| Security and reliability of RETs as a source of energy                                 | [9,11,17,19,20,33–38] |
| The adoption of RETs stimulates local investments and supports job creation            | [9,34,35,39] |
| The adoption of RETs reduces the consumption of fossil fuel                            | [16,33,36,39] |
| The adoption of RETs will reduce environmental impact and climate change               | [9,16–18,21,33,35,36,40–46] |
| The adoption of RETs reduces the load and consumption of public electricity utilities  | [20,40] |
| Initial cost of owning and installing RETs                                             | [9,11,12,14,17,19–21,33–37,39,40] |
| Government regulations and policies supporting the adoption of RETs                    | [15,16,22,34,35,37,42,47–50] |
| Government subsidies and incentives to RET adopters                                    | [13–16,22,35,37,39,47,51] |
| Public awareness and availability of information on RETs                                | [12,14–19,22,33–35,37,38,40,41,46,48,52–55] |
| Cost of RET maintenance and after-sales support                                        | [9,14,17,36,55,56] |
| Localization of RET manufacturing industry                                             | [11,13,16,20,21,37,39,40] |
| Payback period of RETs                                                                  | [9,36,37] |
| Aesthetic view of RET systems                                                          | [22,35–37] |
| Residential building ownership status                                                   | [9,56] |
| Residential building age                                                                | [56] |
| Complexity of RET systems                                                               | [10,12,19,36,38,57] |
| Compatibility of RET systems with residential building and existing infrastructure      | [9–11,19,35,36,38,57] |
| Negative effects/impacts of RETs (e.g., noise, risk, vibration, space use, etc.)       | [9,33,36,53] |
| Availability of RET systems in local markets                                           | [9,36,37] |
Table 2. Summary of exploratory factor analysis results for the willingness to adopt RETs (N = 416).

| Factors                                      | Cost and Government Regulations and Policies | Public Awareness and Local Market | Environment and Public Infrastructure | Residential Building | RET Systems |
|----------------------------------------------|---------------------------------------------|----------------------------------|--------------------------------------|----------------------|-------------|
| Payback period of RETs                       | 0.75                                        | 0.01                             | 0.14                                 | 0.09                 | 0.18        |
| Cost of RET maintenance and after-sales support | 0.71                                        | 0.10                             | 0.10                                 | 0.04                 | 0.06        |
| Initial cost of owning and installing RETs   | 0.67                                        | -0.06                            | 0.29                                 | -0.05                | 0.17        |
| Government subsidies and incentives to RET adopters | 0.60                                        | 0.44                             | 0.00                                 | 0.03                 | -0.01       |
| Government regulations and policies supporting the adoption of RETs | 0.52                                        | 0.34                             | 0.09                                 | -0.12                | -0.08       |
| Public awareness and availability of information on RETs | 0.23                                        | 0.72                             | 0.15                                 | -0.09                | 0.02        |
| The adoption of RETs stimulates local investments and supports job creation | 0.12                                        | 0.58                             | 0.03                                 | 0.09                 | 0.07        |
| Localization of RET manufacturing industry   | -0.10                                       | 0.54                             | 0.25                                 | 0.32                 | -0.02       |
| Availability of RET systems in local markets | 0.05                                        | 0.38                             | 0.31                                 | -0.05                | 0.33        |
| The adoption of RETs will reduce environmental impact and climate change | 0.06                                        | 0.18                             | 0.76                                 | 0.03                 | 0.00        |
| The adoption of RETs reduces the consumption of fossil fuel | 0.20                                        | -0.02                            | 0.73                                 | -0.06                | -0.01       |
| The adoption of RETs reduces the load and consumption of public electricity utilities | 0.24                                        | 0.38                             | 0.47                                 | 0.00                 | -0.02       |
| Security and reliability of RETs as a source of energy | 0.35                                        | 0.12                             | 0.38                                 | -0.05                | -0.07       |
| Residential building age                     | -0.03                                       | 0.02                             | 0.02                                 | 0.86                 | 0.10        |
| Residential building ownership status         | -0.02                                       | 0.04                             | -0.06                                | 0.82                 | -0.02       |
| Compatibility of RET systems with residential building and existing infrastructure | 0.28                                        | 0.11                             | -0.10                                | 0.41                 | 0.36        |
| Negative effects/impacts of RETs (e.g., noise, risk, vibration, space use, etc.) | 0.16                                        | -0.02                            | -0.01                                | -0.01                | 0.75        |
| Complexity of RET systems                   | 0.03                                        | -0.07                            | 0.04                                 | 0.14                 | 0.71        |
| Aesthetic view of RET systems               | -0.06                                       | 0.38                             | -0.10                                | -0.01                | 0.58        |
| Eigenvalues after rotation                  | 2.55                                        | 1.96                             | 1.80                                 | 1.76                 | 1.72        |
| % of variance                               | 13.43                                       | 10.30                            | 9.48                                 | 9.25                 | 9.07        |
| α                                            | 0.84                                        | 0.77                             | 0.80                                 | 0.83                 | 0.79        |

Extraction Method: PCA. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in seven iterations. Note: Factor loadings over an absolute value of 0.30 appear in bold and cross-loadings in bold italic font.
It worth mentioning that determinant of the resulted correlation matrix equals 0.025 > 0.00001, indicating that multicollinearity or singularity is not problematic in the used dataset according to [24]. Furthermore, another orthogonal rotation method (equamax), and other oblique rotation methods (direct oblimin and promax) were used and retained the same extracted five components and their clustered factors. This indicates the consistency of the results in both cases, when correlation between components is permitted, or not permitted. Reliability analysis of the extracted five components was conducted after computing the mean of the clustered sets of factors corresponding to each of the five subscales. As presented in Table 2, all five components demonstrated high levels of reliability (i.e., > 0.70) [27], Cronbach’s $\alpha$ of 0.84, 0.77, 0.80, 0.83, and 0.79, respectively.

For the purpose of this exploratory study, item loadings that fall in the range of absolute values between 0.3 and 0.4 are considered the bare minimum considered worth interpreting according to [26,58]. Despite it being common to eliminate factors with cross loadings, factors with a loading of >0.3 were retained for interpretation.

The factor loadings presented in Table 2 show that five factors pertaining to the cost of RET systems and government regulations and policies namely payback period of RETs, cost of RET maintenance and after-sales support, initial cost of owning and installing RETs, government subsidies and incentives to RET adopters, government regulations, and policies supporting the adoption of RETs, are clustered in the first component. This shows that the cost-pertaining aspects of RETs and associated government regulations and policies are major concerns affecting the willingness to adopt RETs. Moreover, factors ordered based on loading scores in this component show that factors describing the cost of RET systems loaded higher than factors describing government regulations and policies-related items. This indicates the concerns priority as the cost effectiveness and benefits of RETs, then the cost-related regulations and policies controlling them.

Furthermore, four factors pertaining to public awareness and local market, namely: public awareness and availability of information on RETs, the adoption of RETs stimulates local investments and supports job creation, localization of RET manufacturing industry, and availability of RET systems in local markets, are clustered in the second component. This indicates that the availability of information on RETs and level of public awareness through marketing campaigns showing the benefits of adopting RETs for individuals, the community, the local manufacturing industry, and the market, are significant enablers affecting the willingness to adopt RETs.

Moreover, four factors pertaining to the environment and public infrastructure, namely: the adoption of RETs will reduce environmental impact and climate change, the adoption of RETs reduces the consumption of fossil fuels, the adoption of RETs reduces the load and consumption of public electricity utilities, and security and reliability of RETs as a source of energy, are clustered in the third component. This indicates that the effectiveness of RETs in saving the environment and the resulting benefits to public infrastructure and savings of natural resources are significant factors
affecting the willingness to adopt RETs. Other studies resulted in a similar cluster of factor analysis that involved environmental related factors but was named differently, such as relative advantage and a environmental effect [59,60].

The results also show that three factors pertaining to the residential buildings, namely: residential building age, residential building ownership status, and compatibility of RET systems with residential building and its existing infrastructure, are clustered in the fourth component. This indicates that residential building-related aspects are significant concerns affecting the willingness to adopt RETs, which can be addressed through RET marketing campaigns and, investor understanding of RETs customer needs.

The last three factors pertaining to RET systems, namely: negative effects/impacts of RET (e.g., noise, risk, vibration, space use, etc.), complexity of RET systems, and aesthetic view of RET systems, are clustered in the fifth component. This indicates that RET system-related aspects are significant concerns affecting the willingness to adopt RETs, which can also be addressed through RET marketing campaigns, investor understanding of RETs customer needs, and enforced government regulations and policies on the RETs local market.

The cross-loading factors presented in Table 2 (in bold italic front) indicate a complex structure. The item: security and reliability of RET as a source of energy, which loaded higher in component 3 (environment and public infrastructure), almost equally cross-loaded in component 1 (government regulations and policies). This suggests that government regulations and policies are expected to cover RET system security and reliability aspects.

Furthermore, government subsidies and incentives to RET adopters and government regulations and policies supporting the adoption of RETs which loaded higher in component 1 (government regulations and policies), also cross-loaded in component 2 (public awareness and local market). This indicates that the government should also have a role in enforcing public awareness through marketing campaigns and shaping the local market of RETs through its regulations and policies, beyond the design of financial-related policies and regulations for RETs.

Moreover, the adoption of RETs reduces the load and consumption of public electricity utilities, and aesthetic view of RET systems, while also cross-loading with component 2 (public awareness and local market). This also indicates the expected role of government in controlling (e.g., through a labeling scheme) RET systems in the local market in terms of their energy savings and reducing the load on public utilities, in addition to their aesthetic suitability from an urban planning perspective.

Further, the item: availability of RET systems in local markets, loaded higher in component 2 (public awareness and local market). However, it also cross-loaded in components 3 and 5, i.e., environment and public infrastructure and RET systems, respectively. This indicates the availability concern of RET systems, which have the technical specifications that sufficiently contribute to saving the environment and reducing the load on public utilities.

Finally, the item localization of RET manufacturing industry loaded higher in component 2 (public awareness and local market). However, it also cross-loaded in component 4 (residential building). This indicates the expected compatibility of locally manufactured RET systems with the local infrastructure of residential buildings.

4. Conclusions

The main objective of this study was to explore factors affecting the Saudi public willingness to adopt RETs in the western region of the Kingdom of Saudi Arabia. Exploratory factor analysis was conducted on a 19-factor questionnaire survey. Five main components were extracted using PCA and varimax with Kaiser normalization rotation. The analysis results clustered all factors in five main components, affecting the willingness to adopt RETs. These components of factors are, namely, cost and government regulations and policies, public awareness and local market, environment and public infrastructure, residential building, and RET systems. The study concludes that these five main components are crucial to Saudi public willingness to adopt RETs. Furthermore, the study reveals
the complex factors affecting public willingness to adopt RETs, indicating the shared responsibility among RET stakeholders. This in turn will assist in guiding governments, regulation and policymakers, marketing agencies, and investors in designing better targeted regulations and policies, developing better understanding of public concerns and coping strategies, needs, and adoption enablers.

Results of the factor analysis conducted in this study are purely explanatory, as they represent patterns within the used dataset. Therefore, further data collection and analysis in different spatial and temporal contexts is recommended as a future research direction.

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