Consumer Preferences for Selection of Solar Home Systems in Urban Areas, Pakistan

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ABSTRACT

Consumer preferences can lay foundation for determining key product attributes essential for the success of a product in the market, enabling the manufacturers optimally allocate resources towards imparting these critical attributes. However identification of consumer preferences especially for new products is a challenging task. This research investigates the consumer preference factors for solar home systems in Rawalpindi/Islamabad, Pakistan. Applying MCDM (Multi Criteria Decision Making) approach, AHP (Analytical Hierarchy Process) survey and analysis method is used for prioritization of the factors and comparison of decision alternatives. Fourteen factors grouped into five categories are selected. It has been found that the manufacturers have to emphasize on performance and functional attributes of these systems at this stage, the cost factors are comparatively lower in importance. Make and Warranty, Environmental and Physical features are also less important to the early adopters.

Key Words: **Analytical Hierarchy Process, Consumer Preference Factors, Multi Criteria Decision Making, Solar Energy in Urban Areas, Solar Energy User Preferences.**

1. INTRODUCTION

Energy plays a central role in the development of economy and standard of living in any country. The current resources are becoming unsustainable rapidly in the world likewise in Pakistan. To meet the growing demand, development of conventional forms of energy at reachable cost is supposed to be the prime responsibility of the government; however the recent shortage of energy and failure of the government to cope with the situation has led to public and political concerns about the security and future of energy; ultimately the new energy supply options are being discussed and opted including the renewable energy. Unfortunately most of the options currently being used like UPS, Generators are short term and a burden on national economy in terms of heavy import bills. Being fossil fuel dependant, the running cost associated with them is also a burden on national economy. The solar energy is abundantly available in the country and it is the need of the day to focus upon its extensive use and shift the people's investment to this side for a secure future and a healthy environment. There is substantial literature work on implementation of solar energy in rural and far off areas however little attention has been given to urban

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areas. Chinese as well as European origin solar PV panels, and complete solutions have already jumped into this market. But the market is at initial stage and there is an urgent need of knowledge of what the customer wants. Consumer preference study is an effective way to dig out the key areas for the manufacturers and investors for launching products that can gain wide acceptance. This research explores the consumer preference factors based on real market data and by conducting a survey on the selected factors, prioritization of these factors from the consumers is done using AHP. On the basis of this analysis conclusion are deduced and recommendations are made for effective penetration in this new market by the manufacturers.

2. LITERATURE REVIEW

Among the renewable sources, due to the increasing stress and the political problems with the hydro and nuclear power, the focus of the world is shifting fast to solar and wind energy (Mustansar Billah Hussain, [1]). The potential of wind energy is limited and most likely to remain prominent only in the coastal areas. Solar energy, abundantly available throughout Pakistan and addressing the issues of atmospheric pollution and climate change, is justifiably seen as the ultimate source to tap (Shinwari, et. al. [2]). Excellent geography, topography, climate and location of the country in the sunny belt, further supports it (Muneer and Asif, [3]; and Bhutto, et. al. [4]). Solar PV is the best way to use solar energy source, and is particularly suited to the small & medium power requirements and remote area applications (Mirza, et. al. [5]). The research on photovoltaic mainly encompass the requirement of its implementation of solar in far off and remote areas of Pakistan like Balochistan, Cholistan and Thar deserts for village electrification programs (Bhutto, et. al. [4]; Mirza and Ahmed, [5], and Mazhar, [6]). Knowledge of consumer preferences can be used by the manufacturer to allocate time and resources towards assurance of the critical attributes to attract the customer. The discovery of the critical consumer preferences is essential and beneficial, however is a difficult area especially for the products that are early in the technology diffusion and need an additional push so that early majority consumers can be attracted (Drucker, [7]; Chen, et. al. [8]; Rogers, [9] and Ulrich, [10]). But it is difficult to ask consumer at this early stage as the consumer have little knowledge (Ulwick, [11]). Although the consumer may not express what he wants, but it can be searched how he perceives a product, how his needs are shaped and how he chooses a product. Thus an entrepreneur can avoid working on a product having low potential of success in the market (Rochford, [12]).

Questionnaire design for survey research has always been challenging in terms of accuracy in measuring respondent's perceptions (Traugott and Lavrakas, [13]). Many ways have been adopted. The most traditional method is "Multiple Choice" being the easiest (Jerard, [14]; and Downing, [15]). It is used in two different forms; in SMC (Simple Multiple Choice) method, respondents have to choose one from the given alternatives, but it does not give any relationship of non-selected alternatives. (Sato, [16). In MMC (Modified Multiple Choice) method, respondent chooses top two preferred (or more) alternatives, hence, a more effective way to make up for the deficient information incurred by the SMC. But in this methodology neither the degree, to which an alternative is important, is clear nor any information regarding non-selected alternatives is obtained (Sato, [16]). Ranking Method asks respondents to rank all listed alternatives. The problem with this method is, the more number of alternatives a questionnaire offers the more difficult it becomes for the respondent to answer (Inglehart and Abramson, [17]). Another disadvantage of this method is that, it does not allow ties among the options under consideration (Sato, [18]). The Feeling thermometer method asks respondents to express their preference by marking their "temperature" for each alternative for a given question ranging from 0, the coldest feeling, to 100, the hottest, with 50, being neutral. It precisely clarify respondents judgments for each alternative, however consistency among responses to the alternatives is not always satisfactory (Sato, [19]). Another option of formatting questionnaires is AHP, developed by Saaty [20]. Since it was introduced, many research and field individuals and groups in various areas have used the AHP because of its user-friendly interface for multi criteria decision making. In this method data from a decision-maker's judgments, known as pair-wise comparisons, is aggregated and the degree of importance of each alternative is quantified. It identifies, not just the most important alternative but also points the preference for all other alternatives for each decision-maker and thus results in a clear understanding of respondent's preference (Sato, [21]). There is a plethora of factors affecting consumer choice for adoption of a new product in general and solar systems in particular. These factors include Economic, Environmental Social and Technical. Among all, high initial cost and pay

back periods are the most questioned factors. Ram and Sheth [22]) counted three main barriers for the adoption of innovation; Value, Usage and Risk. Shih and Chou [23] while working on customers concerns pointed out Price and Risk due to uncertainty as the two major factors. They further categorized risk factors as: (1) Government Policies, (2) Price, (3) Lifetime, (4) Reliability and Maintainability, (5) Improvement in Efficiency & Speed of New generation Products and (6) Price Variation in electricity produced by traditional fuel source. Goto and Ariu [24] considered Economic and Environmental factors along with counting some added value factors such as: (1) Economic Performance, (2) Initial Cost and Running Cost, (3) Environmental Performance, (4) Usability, (5) Indoor Comfort and (6) Safety. Sardianou and Genoudi [25] found middle aged and highly educated people most probable for opting renewable energy. Islam and Meade [26] found technology awareness a key factor and highlighted the need of education. Thirty-four technical and non-technical attributes of consumer preferences for solar energy solutions are identified and divided in five major categories i.e. Electrical, Physical, Certifications, Warranty and Economics, by Chen, et. al. [8]. During study, three critically important factors were pointed out as: (1) Power Warranty, (2) Panel Efficiency and (3) Time on Market. Moreover, three additional non-technical attributes were revealed as: (1) Panel Manufacturer's Reputation, (2) Name Recognition, and (3) Aesthetics. The solar energy solutions entrance in the urban market is at early stage and local manufacturers are just starting to invest in this sector. The consumer preference study at this stage can bring substantial benefits in order to get better penetration in the market. The purpose of this research is, to explore and rank the factors affecting a consumer decision for adoption of solar home systems in an urban area, and, on the basis of this study weigh the solutions available in the market by applying AHP. Domestic consumer market in Rawalpindi/Islamabad is selected in this study because of being the most densely populated area after Karachi and Lahore. Moreover, the high energy consumption makes it a prospect large future market for solar energy solutions. Five factors for consumer preferences divided into 14 sub-factors are selected after a deep insight into the literature and having expert opinion about these factors, keeping in view the present knowledge level of the general consumer. The solutions for the said analysis were picked, taking a standard 2.4KW system as base line and selecting three alternatives of the same capacities presently running in the market.

The next section describes the methodology adopted followed by how it is applied in this research. Section 4 gives detail of results and discussion and finally Section 5 concludes this paper.

3. RESEARCH METHODOLOGY

Initially developed by Saaty [20] and Yurimota & Masoi [27], AHP is designed to solve multifaceted problems involving multiple criteria. The decision-maker judges the relative importance of each criteria and specifies preference for each decision alternative. The output is a ranking which is prioritized indicating the overall preference for each of the decision alternatives. The AHP draws down the complexity in a hierarchy and derives ratio scale measures through pair-wise relative comparisons (Earnest). Once the pair-wise comparison done, the analysis involves three tasks: (1) Development of a comparison matrix at each level of the hierarchy starting from the second level and working down, (2) Computation of the relative weights for each element of the hierarchy, and (3) Estimation of the consistency ratio.

The pair-wise comparisons at a given level can be reduced to a number of square matrices having reciprocal properties.

$$A = [a_{ij}]_{n \times n}$$

as in the following:

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

In AHP, Saaty [20] recommended a scale of relative importance from 1-9 for making subjective pair-wise comparisons. 1 is used for the two factors equally important, 3 if one is slightly more important than second, 5 for strongly, 7 for very strongly and 9 for absolutely more important than second. After all pair-wise comparison matrices are made, the vector of weights, $w = [w_1 \ w_2 \ \dots \ w_n]$, is computed on the basis of Saaty's Eigenvector procedure. The computation of the weights is done in two steps. First,

the pair-wise comparison matrix, $A = [a_{ij}]_{n\times n}$, is normalized by Equation (1) and then the weights are computed by Equation (2).

$$a_{ij}^{*} = \frac{a_{ij}}{\Sigma_{i=1}^{n} a_{ij}} \quad (1)$$

for all j = 1, 2, 3, . . ., n.

$$w_i = \frac{\Sigma_{j=1}^{n} a_{ij}^{*}}{n} \quad (2)$$

for all i = 1, 2, 3, ..., n.

Saaty [20] showed a relationship between the vector weights, w, and the pair-wise comparison matrix A as:

$$A_w = \lambda_{\max} w \quad (3)$$

The $\lambda_{\max}$ value is a very important validating parameter in AHP and is used as a reference index to screen information by calculating the CR (Consistency Ratio) of the estimated vector. To calculate the CR, the CI (Consistency Index) for each matrix of order "n" can be obtained from Equation (4).

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (4)$$

The CR, can be calculated using Equation (5):

$$CR = \frac{CI}{RI} \quad (5)$$

where, RI is the random consistency index obtained from a randomly generated pair-wise comparison matrix. If CR < 0.1, then the comparison is acceptable, however, CR> 0.1 shows inconsistent judgments. In such cases, reconsideration and revision must be done to the original values in the pair-wise comparison matrix A. A three step procedure for AHP modelling as described by Saaty and used by McCarthy 2002 is followed. Following of the lines describe each.

4. MODELLING OF PROBLEM

4.1 Construction of Hierarchy

The problem is structured in a hierarchy starting from overall goal or objective and descending to the defined factors, sub-factors upto the lowest level. At Level-I the overall objective of the decision problem is placed, at Level-II, the major factors and Level-III is defined by 14 sub factors. The lowest level of the hierarchy consists of the decision alternative, the SHS (Solar Home Systems) which are kept here in general terms as Option 1-3. Fig. 1 depicts this hierarchy.

4.2 Establishment of Comparative Judgment through Consumer Survey

The next step involves determination of priorities of the elements at each level of the hierarchy. A set of comparison matrices of all the elements in each level of the hierarchy with respect to an element on the immediate higher level are constructed to prioritize the comparative judgment of each respondent into the ratio scale measurement. The preferences from the consumer are taken by using nine -point scale as defined by Saaty [20]. For this a questionnaire was launched among the respondents from different areas of the target region. A total of 70 respondents were approached, out of which, 50 completed the questionnaire. A total of 27 comparisons were taken which comprises of five major factors and fourteen sub factors. The respondent has to define how much a factor is important with respect to the other, and mark it on the scale placed between each pair under consideration.

4.3 Synthesis of Priorities and the Measurement of Inconsistency

The pair-wise comparisons were transformed into matrix of relative rankings for each level of the

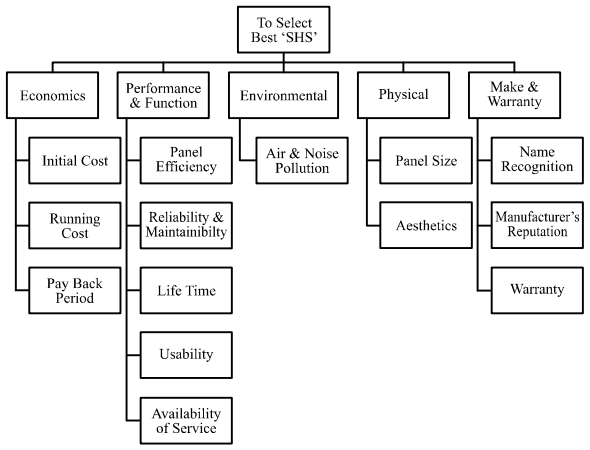

FIG. 1.

hierarchy. Geometric Means of the values for each comparison are used. Table 1 gives these values.

The next step is to develop the eigenvector or the relative weights, global weights, and the maximum eignvalue (λ_{max}). This step is followed by the calculation of CI Equation (4) and CR Equation (5) commencing the first phase of analysis. To reduce computational work and for sensitivity analysis the AHP software 'Expert Choice®' is used. The second phase addresses expert's opinion about the alternatives, weighed against the ranked criteria obtained through phase 1. Here the Data Grid feature of the software is used. In this feature the standards for levels of criteria are defined from the lowest to the highest and from this range the ranking is selected for a particular alternative.

TABLE 1. GEOMETRIC MEANS- CRITERIA-1 VERSUS CRITERIA-2

No.	Criteria-1	Criteria-2	Geometric Mean
1.	Economics	Performance & Function	1.023563
2.		Environment Friendliness	1.131871
3.		Physical Features	2.086606
4.		Make and Warranty	0.822012
5.	Performance & Function	Environment Friendliness	1.984545
6.		Physical Features	3.357951
7.		Make and Warranty	1.486204
8.	Environment Friendliness	Physical Features	1.482443
9.		Make and Warranty	0.985858
10.	Physical Features		0.80301
11.	Initial Cost	Running Cost	0.704
12.		Pay Back Period	0.774241
13.	Running Cost		1.418053
14.	Panel Efficiency	Reliability & Maintainability	0.644782
15.		Life Time	0.822025
16.		Usability	1.134986
17.		Availability of Service	1.02986
18.	Reliability & Maintainability	Life Time	1.274421
19.		Usability	1.614026
20.		Availability of Service	1.674295
21.	Life Time	Usability	1.600859
22.		Availability of Service	1.078643
23.	Usability		0.836879
24.	Space Required	Aesthetics	1.666893
25.	Name Recognition	Manufacturer's Reputation	0.538481
26.		Warranty	0.375796
27.	Manufacturer's Reputation		0.750098

4. RESULTS AND DISCUSSION

The synthesis done on the survey data collected for main factors affecting consumer decision, resulted in the order shown in the Fig. 2 and discussed in the coming section.

4.1 Preference of Level-II Factors

It is found that the top most priority for the consumers is 'Performance and Functional' attributes despite of the fact that the technology is still expensive from the general perspective. This is logical as the major concern to cope with the energy deficiency is to have an alternate which is at first good in performance and function. One reason of this is the fear of people for adoption of any new technology and limited knowledge on market availability of reliable solar systems. Moreover people do not have access to the users who can give them knowledge regarding the performance of these systems. 'Economics' got the second rank in the order of priority. Although it is below 'performance and function', still it is more important for people than 'Make & Warranty', 'Environment' and 'Physical features'. However cost remains a major issue among the discussion in the prospect users. Although the cost of solar panel has been reduced by nearly 50 percent in the last 2-3 years (Experts and Market Study), still the overall economy of technology has not reached to the grid parity yet, which is important for an alternative to prevail. Its heavy initial cost is also a psychological and economic barrier in the adoption. The third factor is 'Make and Warranty'. There is a band width of the models available in the market due to extensive Chinese products, that one cannot go for a single name and because of limited users of the technology it is difficult to select a name which is the most reliable. 'Environment Friendliness' is graded at the lower spot. In contrast to developed countries, we still have to reach that stage where environment friendliness is a concern to the people. At current stage, strive is for basic need that is to cope with the energy deficiency. The 'Physical Features' got the lower most value. One possible factor may be the reason people use houses and not flats mostly in Rawalpindi/Islamabad Area;

FIG. 2. RANKING OF LEVEL II FACTORS

thus eliminating the concerns over the space. The options of solar panels, aesthetically designed to suite the houses is also not a trend yet here; neither the majority of people have this mindset nor the people in the market have enough options to offer in addressing this issue.

4.2 Preferences for Level-III Factors

The Level-III includes fourteen sub factors. The ranking attained by each along with the weights, is shown in Fig. 3.

First we discuss the sub factors concerning with the top graded Level-II preference that is 'Performance and Function'. The mind of the consumer generally goes to 'Reliability and Maintainability' for the new product as it has got the top most position among all. The second most important criterion is the 'Life Time' of the system. The heavy cost associated with solar system obviously takes the thought to the life it offers. 'Panel efficiency' remained in middle, but still among all the other criteria it remained at 4th rank. A logical reason is that consumers having at least some knowledge, question this area. The 'Availability of Services' was also the major concern that how much a company would owe its product after the sale. 'Usability' or ease of use was at lowest level among 'Performance and Function sub-factors', but its overall ranking is at 9. This criterion is more important for majority of respondents than Manufacturer's Reputation, Name Recognition and Physical Features of the solar systems.

The second factor in priority 'Economics' include three sub-factors. The solutions in use, to cope with the load shedding in the last 5 years, have affected the consumer mind for running cost of any system. As people started using UPS and Generators, they faced the heavy running cost associated with them afterwards. The ranking of running cost at 3 shows clear concern of the people regarding this factor, for any new product they opt for their energy solution. 'Pay Back Period', however, remained in the middle.

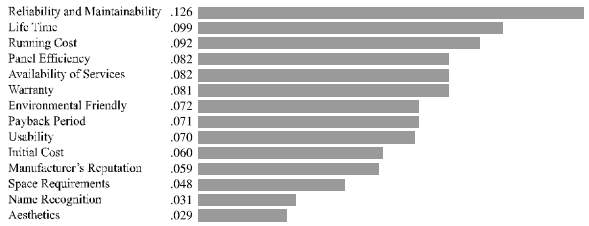

FIG. 3. RANKING OF LEVEL-III SUB-FACTORS

The logical reason behind this is, people generally think of the solution, which serve their purpose of load shedding solution for the time being; so this factor is lesser important near the respondents. The same is the case with 'Initial Cost'.

The next preference after Economics is 'Make and Warranty'. The top importance given, in this category is 'Warranty', placed at overall preference order 6. This shows its importance than Initial Cost, Pay Back Period and Usability. From consumer point of view, Warranty is among prime important decision factors. From variety of options available in the market this is among those criteria that can be taken from the manufacturer or supplier in documented form. Its ranking immediately after most of the performance and functional factors also shows that after having clarified about the performance, the consumer wants some surety for making his investment decision risk free. On the other hand the two other Sub-Criteria Manufacturer's Reputation and Name Recognition are among the lowest in the overall preference ranking. The apparent reason is that, there is not any single manufacturer who is famous until now, due to low adoption of solar users and low penetration in the market. The other result that can be deduced from this preference is concerned with the newly introduced products for which, the consumers keep eye on performance rather than name.

Although the overall preference order of 'Environment Friendliness' is at lower side, still the importance of the sub factor that this technology being free of air and noise pollution remained in the middle at number 7. This is also a key finding that the people are getting aware of the environmental effects of the energy systems. One logical reason is that the problems people are facing with the use of CNG generators, has shifted their minds to care more about the environment.

'Physical Features' has been placed at the lowest level in the survey. Generally, the people are not caring enough about the aesthetics at this stage. However, panel size is more concerned to the people than aesthetics.

4.3 Ranking of Decision Alternatives

The next portion is related to the second phase of the analysis which is the ranking of the alternatives against the preference weights assigned by the consumers, resulted from the AHP analysis. Three alternatives have been selected, which are SHS 1, 2 and 3

respectively against the three options, Option-1, Option-2, and Option-3 in the AHP model hierarchy. Fig. 4 shows synthesis results in the form of performance sensitivity graph.

5. CONCLUSIONS

At this early stage of solar market, the 'economy' of the technology with a weight of 0.22 is less prior to the potential customers than functionality of the SHS's having a weight of 0.30. For the early adopters the cost factor is far less important than performance and function. The manufacturer can penetrate into the market effectively by its system's performance and functional attributes, at this stage. In 'Economics' the importance of 'Running Cost' has emerged out to be highly weighted from the consumers. The 'Make and Warranty' features are third in order of ranking. People are not ready to rely upon just names or any reputation of the manufacturer. However a high global ranking of 0.081 given to its 'Warranty' sub-factor, emphasize the need of surety to be provided from manufacturer to penetrate into this market effectively. 'Physical Features' and 'Environment Friendliness' are lower in order of priority for most of the people. People show little concern over it. Thus, the manufacturer can compromise the physical features over the performance for the time being. AHP is an effective way to prioritze the consumer preferecnes in order to get to the best decision for opting among various alternatives. In survey it not only gives the best final alternatives rather it also prioritize the other contributing factors for decsion. So these factors can be addressed by the analyst according to their weights.

6. RECOMMENDATIONS

For effective penetration into the solar market the manufacturers have to emphasize on improving 'Performance and Functional Features' specifically Reliability, Maintainability, Life, Efficiency and Provision of services. Furthermore, by reducing running cost of the system and provision of suitable and reliable warranty, the manufacturer can get a marginal competitive advantage in the market.

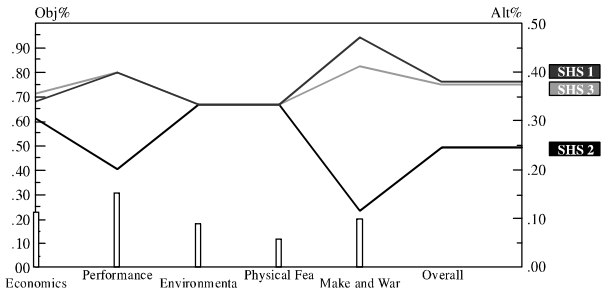

FIG. 4. PERFORMANCE SENSITIVITY GRAPH

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