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Factors influencing the adoption of solar energy in Harare West: A case of Bloomingdale, Harare.

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Abstract. This study investigated factors influencing adoption of solar energy in Bloomingdale, Harare. The study was prompted by widespread switch from the traditional electricity to solar energy experienced in Zimbabwe. A positivism philosophy, quantitative approach and explanatory survey design were adopted. ZETDC clients were targeted and systematic sampling was used to select a sample of 127 respondents. SPSS version 19 was used to analyse data collected using structured questionnaires. Results showed that as high as 79.2% of the respondents had adopted solar energy as an alternative source of energy. The study revealed that clients are sensitive to the costs of mainstream electricity and find solar energy cheaper to install, maintain and consume. It was also noted that ZETDC is unable to provide adequate electricity with frequent power cuts forcing consumers to adopt solar energy as a backup energy plan. On the other hand, results showed that awareness of the positive social and environmental impacts of solar energy had little influence in the adoption of solar energy in Bloomingdale, Harare. Factor analysis also confirmed that incapability of the existing utility firm to provide adequate electricity and the financial and economic capacity of consumers were key determinants in the adoption of solar energy in Harare.

Keywords: *solar energy; electricity; mainstream electricity, electricity utility firm, environmental impact.*

1. Introduction

Globally, there has been notable increase in the adoption of cleaner and renewable energy (Hulshof and Mulder, 2020). The current global trends in switching from carbon emissions to green revolution and other underlying causes may spell doom to electric utilities companies. Ruggiero and Lehkonen (2017)'s study on renewable energy growth in China showed that electric utilities are pressured to increase clean energy production. The adoption of renewable energy had been found to improve the utilities' environmental performance. Castaneda et al. (2017) evaluated the effect of technology transformation on the Colombian electricity utility industry. It was noted that solar rooftop generation is a major threat for the performance of utilities. Guta (2018) examined determinants of household adoption of solar energy technology in rural areas in Ethiopia and noted that gender, household wealth, education and awareness were key factors.

Changing climatic conditions and global warming has resulted in more droughts negatively affecting electricity generation and transmission in Africa particularly in Central and Southern Africa. It is

estimated that there shall be serious energy shortages in Southern Africa region in the coming 20 years. With water levels at Kariba Dam dwindling due to continued siltation, electricity generation and distribution in Zimbabwe has been constrained over the recent years. Rainfall patterns in the country are likely to remain very unpredictable. However, the demand for solar energy in Zimbabwe has remained strong over the years. A survey conducted by the Zimbabwe Energy Regulatory Authority (ZERA) in 2018 showed that the use of solar energy in Zimbabwe is expected to rise by more than 20% for the 5-year period to 2023. Over the years, the supply of electricity has remained erratic and has also been considered very expensive compared to regional rates. This has triggered a major shift to alternative sources of energy including solar. As at December 2020, about 3% of the Zimbabwe Electricity Transmission and Distribution Company (ZETDC) clients had totally switched from ZETDC energy to solar energy. Over the years, ZETDC has failed to secure enough power imports for winter crop farming forcing most farmers to install solar energy as an alternative. Approximately 70% of ZETDC clients had adopted alternative sources of energy for cooking, charging phones, lighting and refrigeration among many others (ZETDC, 2020). It has been noted that just around 61% of all households in Zimbabwe, both in the rural and urban communities depend on firewood for their cooking and heating requirements (Ministry of Energy and Power Development, 2012). The alternative energy sources are considered to be environmentally friendly and more reliable as compared to fossil or hydro powered energy largely relied upon by ZETDC. The growth in demand for solar energy is therefore a threat to ZETDC as many companies and households have adopted a dual-energy scheme. However, there have been limited studies focusing on the factors influencing the adoption of solar energy in Zimbabwe.

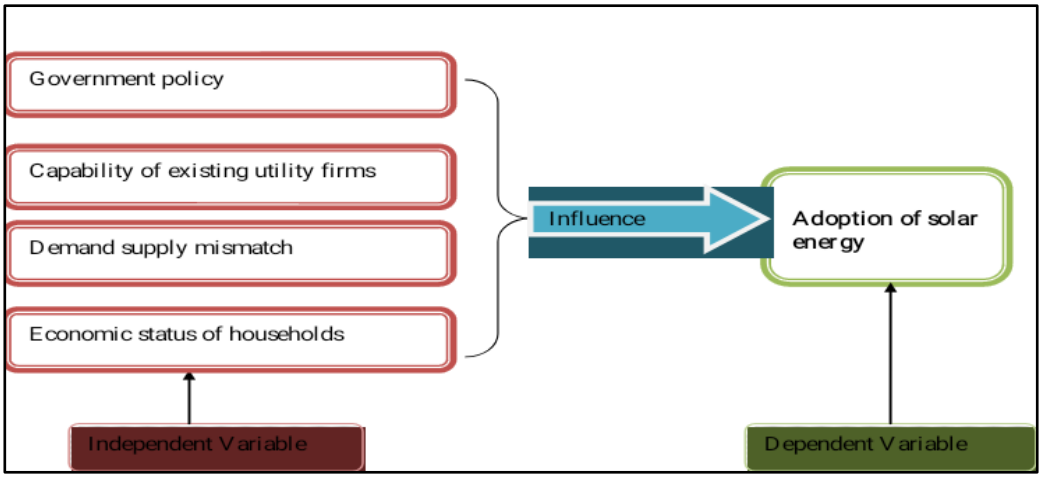
The surge in solar energy adoption in Zimbabwe adversely affects the performance of ZETDC, yet it plays a strategic role in national growth and development. Most of its customers have shifted to alternative sources of energy and little attention has been focused on the reasons in a local context. By December 2020, 3% of ZETDC clients had totally switched to solar energy and as high as 70% had adopted alternative sources of energy (ZETDC, 2020). There is therefore need to analyse factors influencing the adoption of solar energy so that ZEDTC can undertake correctional measures to ensure survival in the long term. This paper therefore examines factors influencing solar energy adoption in Harare West, using the ZETDC as the case study.

2.Literature review

Tornatzky and Fleischer (2018) are of the view that organizations' internal environments, technological developments and environment affect innovation adoption processes. In support of the observations by Rogers (2018), Le et al. (2011) also endorsed key attributes 19 in the acceptance of any innovation. Dedrick and West (2004) went further to highlight the first five attributes mentioned by Rogers as applying in almost all cases of new innovations across industries. Glynn et al. (2019) noted that the same organisational factors also affect adoption. Furthermore, factors such as total ownership cost (Shapiro and Varian, 2008), boundary spanners (Macaulay et al., 2016) and relevance to the organization (Goode and Stevens, 2000) could also fall into this category. There are other intervening factors like government policy on renewable energy, external factors and the utility electricity tariff which can also alter the supply and demand matrix.

Factors influencing adoption of alternative sources of energy

There are a number of factors affecting technology innovations such as solar energy. Tirop and Nganga (2018) are of the view that organizations' internal environments, technological developments and the external environment affect innovation adoption processes. They claim that government policy on renewable energy and the utility electricity tariff system can also alter the supply and demand matrix. Figure 1 below shows the factors influencing the adoption of alternative sources of energy.

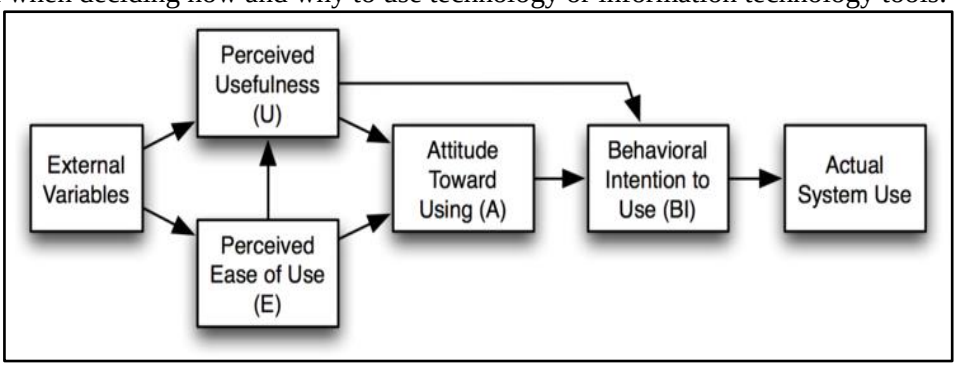


Source: Author (2022)

Figure 1. Drivers of solar energy adoption.

Solar energy is perceived to be cheaper, safer and environmentally friendly when compared to the traditional fossil-powered sources of energy (Maponga, 2018). Neves, Henriques and Vilas (2019) argue that there is an inadequate investment in the electricity grids for most developing countries. Several countries in Africa therefore import electricity to cover up for the shortage in the local production of energy. In Zimbabwe, Maponga (2018) argues that even with the importation, only 21% of the rural people who have access to electricity and 80% of the urban people have access to electricity. The researcher notes that these developments demonstrate that there is a serious problem with the national power utility. This presents to any potential player in the energy sector, a huge opportunity for energy supply in its various forms, especially the need for cleaner energy sources. It should also be noted that just above 5 300 institutions in Zimbabwe are not electrified and these include clinics and schools in the country, especially in the rural areas. This could provide a big opportunity for decentralized mini-grids to address the power needs in each and every community. Overall, there are also over ten thousand other facilities which include pumps which are currently powered, and an equal number of other facilities (such as pumps) are electrified and this is a great opportunity in the sector and presents a challenge to the current market leader, ZETDC (Mzezewa and Murove, 2017). Usually when the leading company in a sector is failing to serve the market adequately, this normally results in the creation of gaps which new competitors may exploit and gain entrance in the market (Kotler and Opresnik, 2019).

In terms of theoretical framework, this study was guided by the Technology Acceptance Model (TAM) indicated in Figure 2. The TAM was initially suggested by Davis (1989) as an analytical tool to characterize, trace and explain the reasons, behaviours, attitudes and opinions among people in an organization when deciding how and why to use technology or information technology tools.



Source: Davis et al. (1989)

Figure 2. Technology acceptance model (Davis, 1989)

The theory explains the adoption of specific new technologies. As shown in Figure 1, the key variables to this equation are Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). Bagozzi, Davis and Warshaw (1992) say that new technologies such as personal computers are complex leading to the existence of uncertainty in the minds of decision makers with respect to their successful adoption. People hence form attitudes and intentions towards trying to learn to use the new technology prior to initiating efforts directed at using it.

As shown above, the attitudes are shaped by PEOU and PU which in turn are shaped by other external variables. The two variables would then lead to the development of a positive attitude towards the innovation or new idea being introduced until there is an intention to use, which is then translated into actual use (Ma and Liu, 2011).

The TAM can therefore be used on any situation where the advancement of technology is made and the area of concern is on acceptability. This study noted that solar energy is a technical product and its adoption falls directly under the technology adoption model. As such, the TAM provides an opportunity for understanding what could have influenced the adoption of solar energy adoption in Harare, Zimbabwe.

Empirical literature review

Mzezewa and Murove (2017) say that a total of 1400 MW are being produced by the various power stations in the country, both thermal and hydro power stations. The nation's current energy requirements are just above 2400 MW and the difference of over 1000 MW is what is being imported and managed through demand side management.

This lack of sufficient energy in the country is the cause for concern and brings about serious threats to ZETDC in the medium to long term future. Existing electricity utilities especially those using fossil-fuel plant are also shifting from their stable and predictable situation to confront challenges emanating from the use of alternative energy services (Frondel et al., 2010). This study notes that to look into the shortages of electricity and consider that as a threat to electricity companies may not be enough without looking into the potential of alternative sources of energy in the form of renewable sources like solar energy.

A study conducted by ZERA (2018) showed that indeed there is potential for new players in the energy sector in Zimbabwe especially with regard to renewable sources. The researcher notes that this presents a serious threat to ZETDC as the viability of these renewable sources of energy could trigger more customers to move away from the national grid or in the most probable cases, reduce their dependence on the ZETDC energy in favor of other alternatives. It is therefore important to understand the factors influencing the adoption of solar energy as an alternative source of energy to enable traditional utility companies to survive.

It is noted that studies on the determinants of solar energy adoption have been carried out mostly in developed countries (Ruggiero and Lehkonen, 2017; Castaneda et al., 2017; Guta, 2018). There is limited literature on developing countries like Zimbabwe with operating environments different from those obtaining in developed countries. There is need to conduct similar studies to establish whether or not the results remain consistent with those obtained in advanced countries. This study therefore uses the ZETDC as the case study.

3.Methodology

The study adopts the positivism philosophy which assumes that reality is fixed and can be objectively measured mathematically or statistically. The positivism philosophy was relevant as it allowed use of existing theory to test data. The researcher was also objective and detached from research processes in this study.

This study adopted a quantitative approach in order to allow the use of scientific techniques. The quantitative approach is objective and makes use of numerical or statistical techniques which aligns with the positivism philosophy. The quantitative approach also facilitated use of descriptive statistics and inferential statistics. The study adopted an explanatory survey design. An explanatory research explains

the cause and effect relationships between variables in a study (Greenfield, 2016). This was appropriate for the current study given the need to explain the factors behind solar energy adoption in Zimbabwe. The survey strategy was meant to ensure that a bigger sample size was adopted cost effectively in a shorter time scale. In this study, the target population was made up of 186 consisting ZETDC clients based in Bloomingdale suburb, Harare, Zimbabwe. Using Yamane (1967)'s sample size calculation formula, the estimated sample size was 127 selected using systematic sampling.

A structured questionnaire was used to gather data and it was prepared using a five point Likert scale with five (5) options namely; strongly agree, agree, uncertain, disagree and strongly disagree was used. The respondents were given five working days to complete the questionnaires at their own time or make any consultations as might be necessary. The rationale for use of questionnaires was that they enabled faster and cost effective collection of data.

The Statistical Package for the Social Sciences (SPSS) version 19 was used to analyse quantitative data collected through closed ended questions. Data were entered into SPPS and cleaned for potential errors. The mean, standard deviation, frequencies and percentages were the main descriptive statistics used. Factor analysis was also used to reduce the data into key factors influencing adoption of solar energy in Harare Zimbabwe. Data were presented using tables, pie charts and graphs generated from SPSS.

Ethical considerations

Informed consent of the respondents was sought so that they voluntarily took part in the study. The researcher did not force the respondents to participate in the study. Anonymity was ensured by not requesting the names or any positive identification of the respondents. Respondents also completed the questionnaires at their own time in the absence of the researcher to enhance privacy. Data collected from the respondents were not shared with third parties to ensure confidentiality.

4. Presentation and discussion of results

A total of 127 questionnaires were distributed to the respondents. Due to persistent follow ups, 109 questionnaires were received. An examination of the questionnaires returned showed that 8 were not fully completed and 101 questionnaires were valid. The valid response rate was therefore 79.5%. This was above the minimum of 70% generally deemed acceptable for generalizing results in quantitative studies (Jackson, 2015). A Cronbach's alpha reliability test was carried out to establish the internal consistency of the 12 five-point Likert scale items operationalizing factors influencing the adoption of solar energy in Bloomingdale, Harare. The reliability values range from 0 to 1 and a minimum value of 0.7 is normally deemed acceptable (Greenfield, 2016). Table 1 shows the results.

Table 1. Reliability Statistics.

Cronbach's Alpha	N of Items
0.788	12

Source: Primary Data

In this study, the reliability value was 0.788 which was above 0.7. As such, the study inferred that the Likert scale items were highly reliable in measuring the determinants of solar energy adoption in Bloomingdale, Harare.

4.1 Demographic information

Table 2 below cross tabulates gender and education levels of the respondents.

Table 2. Demographic characteristics

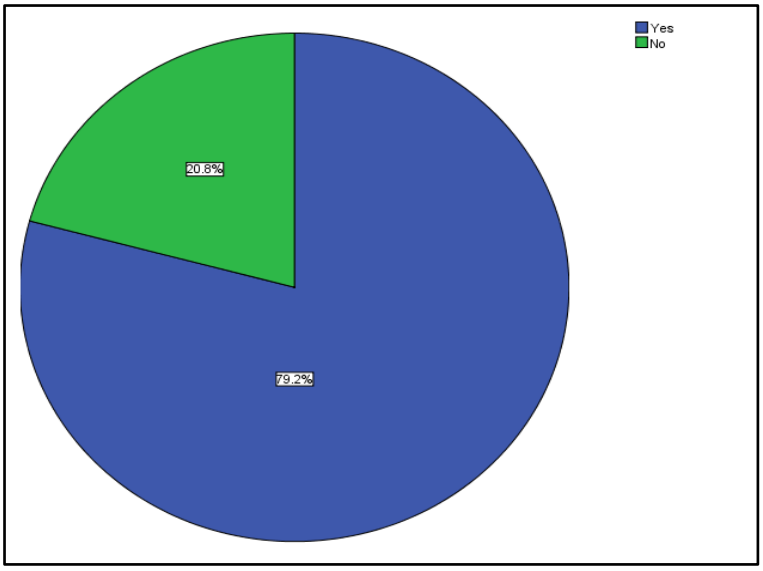
			Highest level of education					
			High school	Certificate/ Diploma	First degree	Post-graduate degree	Other	Total
Gender	Male	Count	11	10	13	10	3	47
		% of Total	10.9%	9.9%	12.9%	9.9%	3.0%	46.5%
	Female	Count	15	13	11	11	4	54
		% of Total	14.9%	12.9%	10.9%	10.9%	4.0%	53.5%
Total		Count	26	23	24	21	7	101
		% of Total	25.7%	22.8%	23.8%	20.8%	6.9%	100.0 %

Source: Primary data

Table 2 shows that out of 101 respondents, 46.5% were males and 53.5% were females. This meant that there was a fair gender parity thus avoiding gender biased responses on the factors influencing the adoption of solar energy. The results also show that 25.7% of the respondents had high school education, 22.8% had certificates or diplomas, 23.8% had first degrees 20.8% had attained post graduate qualifications and the remaining 6.9% cited other qualifications. Since 74.3% of the respondents had some tertiary level education, it was noted that the respondents could appreciate the determinants of solar energy adoption in Bloomingdale, Harare.

4.2 Solar Energy Adoption

The respondents were asked to indicate if they used solar energy within their homes. Figure 3 illustrates the responses received.



Source: Primary data

Figure 3. Solar energy adoption

Figure 3 shows that 79.2% of the respondents had adopted solar energy and 20.8% had not yet used solar energy within their homes. This meant that most (79.2%) of the respondents had used solar energy and could most likely express the reasons behind their decisions. This finding echoed previous surveys

conducted by ZERA (2018) and ZETDC (2020) which showed increased usage of alternative sources of energy in Zimbabwe.

4.3 Factors influencing the adoption of solar energy

In order to establish the factors influencing the adoption of solar energy as an alternative energy source in Harare, respondents were asked to indicate the extent to which they agreed or disagreed with 12 pre-identified factors. A 5-point Likert scale with strongly disagree (=1), disagree (=2), uncertain (=3), agree (=4) and strongly agree (=5) was used. The mean and standard deviation were calculated for each item. In line with the scale adopted, a mean rating above 3.000 indicated general agreement while a mean rating below 3.000 indicated general disagreement. A standard deviation above 1.500 showed that the actual ratings were more dispersed from the mean while a value less than 1.500 showed that the actual ratings were closer to the calculated mean. The results were as shown in Table 3 in descending order of the mean.

Table 3. Descriptive Statistics

	N	Mean	Std. Deviation
I find it expensive to connect electricity in off-grid areas	101	3.92	1.155
I find existing electricity tariffs too expensive	101	3.79	1.177
I find it expensive to maintain existing power infrastructure	101	3.75	1.170
I use solar energy in line with my economic and financial status	101	3.75	1.152
I use solar energy to avoid power cuts on the national grid	101	3.63	1.325
I get inadequate electricity from ZETDC	101	3.55	1.367
I believe ZETDC provides poor service quality	101	3.45	1.338
I use solar energy as backup energy	101	3.37	1.354
I support Government policy on renewable energy	101	2.60	1.364
I am attracted by the advantages of solar energy	101	2.45	1.446
I try new technologies and innovations	101	2.44	1.367
I support the use of green energy	101	2.38	1.272
Valid N (listwise)	101		

Source: Primary Data

The results show that all the standard deviations were less than 1.500. This meant that most of the responses were closer to the calculated means. Table 3 also shows that there was relatively strong agreement on the items that 'I find it expensive to connect electricity in off-grid areas (mean = 3.92), 'I find existing electricity tariffs too expensive' (mean = 3.79), 'I find it expensive to maintain existing power infrastructure (mean = 3.75) and 'I use solar energy in line with my economic and financial status' (mean = 3.75). A key theme from these items is that solar energy is considered cheaper to install, maintain and consume when compared with electricity from utility companies. This supports the assertions made by Maponga (2018) that solar energy is cheaper and safer. The results were also in line with Guta (2018)'s study in Ethiopia which found out that household income influenced adoption of solar energy technology.

The results further show that respondents moderately agreed to the items that 'I use solar energy to avoid power cuts on the national grid' (mean = 3.63), 'I get inadequate electricity from ZETDC' (mean = 3.55), 'I believe ZETDC provides poor service quality' (mean = 3.45) and 'I use solar energy as backup energy' (mean = 3.37). These items collectively suggest that respondents adopted solar energy due to the inability of ZETDC to provide adequate electricity. This finding supports Mzezewa and Murove (2017)'s study which also noted deficits in the supply of electricity in Zimbabwe.

On the other hand, the results show that respondents were in disagreement to the items that 'I support Government policy on renewable energy' (mean = 2.60), 'I am attracted by the advantages of solar energy' (mean = 2.45), 'I try new technologies and innovations' (mean = 2.44) and 'I support the use of green energy' (mean = 2.38). It was noted that consumers' knowledge about alternative sources of energy and the environmental and social impacts did not significantly influence the adoption of solar energy in Harare. This was contrary Ruggiero and Lehkonen (2017)'s study on renewable energy growth in China which showed that consumers pressured utilities firms to increase clean energy production.

4.4 Factor Analysis

In order to statistically confirm the main factors influencing adoption of solar energy suggested by the descriptive statistics, factor analysis was conducted at 5% level of significance. The KMO and Bartlett's Test shown in Table 4 was used to establish if it was suitable to conduct the data reduction exercise. A minimum measure of sampling adequacy of 0.5 is required in order to proceed with factor analysis (Jackson, 2015). Jack

Table 4. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.771
Bartlett's Test of Sphericity	Approx. Chi-Square	1.440E3
	Df	66
	Sig.	.000

Source: Primary Data

In this study, the KMO measure of sampling adequacy was 0.771. This was above 0.5 and thus showed that factor analysis could be done. The principal component analysis extraction method and Varimax rotation were used to extract the key themes or latent factors behind solar adoption as an alternative source of energy. The results were as shown in Table 5.

Table 5. Total Variance Explained

	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.37	36.413	36.413	3.549	29.577	29.577
2	4.05	33.748	70.162	3.401	28.340	57.916
3	1.90	15.893	86.055	3.377	28.138	86.055
4	.524	4.370	90.424			
5	.364	3.032	93.456			
6	.239	1.992	95.449			
7	.188	1.569	97.018			
8	.119	.990	98.008			
9	.103	.856	98.863			
10	.060	.504	99.367			
11	.052	.429	99.796			
12	.024	.204	100.000			

Extraction Method: Principal Component Analysis.
Source: Primary Data

Table 5 indicates that three (3) components were extracted with rotated sums of squared loadings of 3.549, 3.401 and 3.377 which accounted for 29.6%, 28.3% and 28.1% of the variation in factors influencing adoption of solar energy respectively. Put together, the three themes explained a cumulative 86.1% of the variation in the factors influencing the adoption of solar energy in Bloomindale, Harare. This suggests that the three components are critical in influencing consumer behaviour towards adoption of solar energy. To identify the components, the rotated component matrix, shown in Table 6, with the factor loadings was used. Factor loadings less than 0.5 were suppressed in order to clearly show component (s) on which the items highly loaded.

Table 6. Rotated Component Matrix

	Component		
	1	2	3
I support Government policy on renewable energy			.873
I find existing electricity tariffs too expensive		.952	
I get inadequate electricity from ZETDC	.959		
I find it expensive to maintain existing power infrastructure		.938	
I use solar energy in line with my economic and financial status		.922	
I use solar energy as backup energy	.898		
I believe ZETDC provides poor service quality	.890		
I use solar energy to avoid continuous power cuts on the national grid	.958		
I support the use of green energy			.912
I try new technologies and innovations			.896
I find it expensive to connect electricity in off-grid areas		.762	
I am attracted by the advantages of solar energy			.892

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Source: Primary data

Table 6 indicates that items which highly loaded on component 1 were 'I get inadequate electricity from ZETDC' (factor loading = 0.959), 'I use solar energy as backup energy' (factor loading = 0.898), 'I believe ZETDC provides poor service quality' (factor loading = 0.890)' and 'I use solar energy to avoid continuous power cuts on the national grid' (factor loading = 0.958). Component 1 was therefore interpreted as incapability of existing utility firms to provide adequate electricity which forces consumers to consider solar energy as an alternative source of energy. This finding was in line with Neves et al. (2019)'s argument that there is inadequate investment in the electricity grids for most developing countries.

Items which loaded highly on component 2 were 'I find existing electricity tariffs too expensive' (factor loading = 0.952), 'I find it expensive to connect electricity in off-grid areas' (factor loading = 0.762), 'I find it expensive to maintain existing power infrastructure' (factor loading = 0.938) and 'I use solar energy in line with my economic and financial status' (factor loading = 0.922). Component 2 was therefore considered as financial and economic capacity of consumers. This confirmed Tornatzky and Fleischer (2018)'s assertions that utility electricity tariff systems can alter the supply and demand matrix.

Table 6 also shows that items which loaded highly on component 3 were 'I support Government policy on renewable energy' (factor loading = 0.873), 'I support the use of green energy' (factor loading = 0.912), 'I try new technologies and innovations' (factor loading = 0.896) and 'I am attracted by the

advantages of solar energy' (factor loading = 0.892). Component 3 was deemed as knowledge of social and environmental benefits of solar energy. However, this component had little impact towards the adoption of solar energy in the context of the study.

5. Conclusion

The study concluded that ZETDC's incapability to provide adequate electricity to its clients as well as the fragile financial and economic capacity of its consumers were the key factors influencing the adoption of solar energy in Bloomingdale, Harare. Persistent power cuts forced consumers to install solar energy as a backup strategy. The clients' high sensitivity to costs associated with mainstream electricity also influenced the adoption of solar energy in Bloomingdale, Harare. The study concluded that, despite usage of solar energy, clients had little awareness of the social and environmental benefits of solar energy adoption.

5.1 Recommendations

The study recommended that ZETDC increase investment into its power generation capacity in order to address the demand and supply mismatch in the provision of electricity in Harare. Reliable electricity could prop of consumer confidence and thus reduce the switch to alternative sources of energy. ZETDC could achieve through mobilizing financial resources from central government as well as regional and international lenders comfortable with the risk profile of parastatals. It was further suggested that ZETDC review its tariffs downwards in line with the financial and economic status of its clients so as induce consumption of the mainstream electricity. Given the growing calls for cleaner and renewable energy, a further study focusing on consumer awareness of the advantages of solar energy was suggested. The study could also examine the capacity of existing electricity utility firms to adopt solar energy into their business models.

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