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Harnessing Solar Energy Technologies: A response to the energy crisis

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Abstract. *Globally, harnessing solar energy technology, and managing costs, depletion and pollution has become a topical theme. The study examined factors that determine solar energy technology (SET) adoption readiness by sampling 1510 households in South Africa, Botswana, Malawi, Seychelles, Zambia and Zimbabwe. Targeted user identifiers and capabilities improved the perceived economic value of solar energy technology was established. Several perceived economic values, barriers and drivers were established as factors determining the readiness of a society to adopt solar energy technologies. A model to determine solar energy technology adoption readiness was developed. The study recommended the need for government energy policies that promote the affordability of solar energy technologies. Furthermore, the issue of perceived uncertainty, beliefs about consequences and consumer asymmetric require interventions by development agencies and solar energy companies. Furthermore, there is a need for e-platforms and mobile platforms to provide critical information on servicing, installation, backups and the creation of information hubs and innovation hubs.*

Keywords: Identifiers, Capabilities, Perceived economic value, Solar energy technology, Adoption readiness

JEL Codes: O31; O32

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1. Introduction

For many decades, Southern Africa has failed to capitalize on solar energy technologies (SET) to enjoy its share of solar power, a universal resource. This is so despite the compelling evidence of what Rai, Reeves & Margolis (2016) posit as the availability and ability of SET to capture energy from the sun to augment conventional sources in meeting the ever-increasing energy demand. The low uptake of SET against a mismatch between the demand and supply of conventional energy due to increased urbanization (Ahmed, Rashid, Adeel & Dutta, 2022) and inadequate investments in renewable energy (Etongo & Naidu, 2022) should be a cause for concern for advocates of solar energy technologies. Globally, there is a low uptake of SET, as noted by Kihlström and Elbe (2021); approximately 60% of greenhouse emissions are accounted for through energy production and consumption. Furthermore, according to Makonese et al. (2011), the rise in electricity demand is projected to increase as economies continue to expand. Noting the aforementioned, there is a need for rapid steps to embrace solar energy technologies, yet there is little or no evidence of urgency from key energy market players to harness it. The advantage of solar energy technologies, according to Jingura, Musademba & Kamusoko (2013), is their reliance on the sun, which in this case is a renewable source found in abundance in nations located in the tropics and sub-tropics. The key question is: Why is it that developing nations are not effectively and successfully harnessing such a massive benefit in the face of energy shortfalls in both industrial and domestic areas, coupled with its positive contribution to environmental management?

This study explores ways to enhance the harnessing of solar energy technologies in a bid to manage environmental damage emanating from fossil fuel energy production and consumption, thus mitigating the energy supply and demand gap. It proposes and validates a framework that can be deployed to influence the readiness of society to adopt SET sustainably. The major objective of this study was to examine the capability of adopting SET as a strategic response to the threatened supply of traditional sources of energy and environmental concerns.

1.1 Literature review

Despite the abundance of solar energy technologies (SET) in the market, there is little evidence of Southern African nations harnessing them for energy creation. The Southern African region has historically experienced one of the worst energy crises. This has resulted in prolonged load-shedding, thus fundamentally suspending economic and social activities and forcing local energy suppliers to institute power cuts on both industry and households, thus affecting most business and social activities.

Furthermore, there have been wide calls on international, continental, regional, and national platforms for nations to adopt solar energy technologies (Guta et al., 2017; Rai, Reeves and Margolis, 2016) as a way to mitigate energy challenges (Osunmuyiwa and Kalfagianni, 2016). For instance, SET could be a

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key driver of global efforts to induce a paradigm shift towards green economies with green energy (Ahmed, Rashid, Adeel and Dutta, 2022), poverty eradication (Etongo and Naidu, 2022) and ultimately sustainable development (Osunmuyiwa and Kalfagianni, 2016). However, Etongo and Naidu (2022) noted the lack of transformation of global energy systems towards energy sustainability through SET adoption, especially in developing countries. The onset of the Russia - Ukraine war has given rise to far-reaching effects and wider cost implications in the energy value chain. The rising cost of fuel and gas since the onset of the Russian-Ukraine War could have triggered the adoption of SET. However, Mothala, Thamae & Mpholo (2022) argued that the uptake of SET is insignificant. The majority of South African nations are failing to fully adopt SET to enjoy a share of the abundant renewable natural resources from the sun. These countries need to have a paradigm shift to utilize renewable energies, especially solar energy, by capitalizing on current and future solar energy technologies. The potential for SET is enormous (Guta et al., 2017) and its exploitation is minimal; however, energy demand is projected to rise exponentially in the near future. However, due to strategic misalignment (Mothala et al., 2022) not much has been done, considering that the uptake of SET remains below expectations.

Globally, harnessing SET has become a topical theme in energy platforms (Guta et al, 2017; Rai et al., 2016). Issues such as costs, depletion, and pollution have also propelled the debate on SET. Following a series of debates on the adoption of SET at the international level, amid calls against fossil fuels spanning many decades, its adoption has taken off the ground. In a report on energy progress (World Bank, 2022) the use of renewable energy (SET included) globally grew more than five percentage points in 2019, resulting in a stake of around 26.2 percent of global electricity consumption compared to 25.3 percent in 2018 among electricity consumers. According to Rai et al (2016), photovoltaic technology, which is part of SET, among various sustainable solar technologies, appears to be a more attractive source of energy owing to its characteristics of noiselessness (Brown & Hendry, 2009), non-carbon dioxide emissions during operation (Strupeit, 2017), scale flexibility, and simple operation and maintenance (Masson & Kaizuka, 2020). Since the 1960s, Africa has been trailing with technology (Ashinze, Tian, Nazir and Shaheen, 2021); it is now time to fully harness it as a way of life with the rest of the world, especially to manage energy resources. The high energy demand to sustain economic growth and development seems to be forcing Southern African economies to continue to rely on conventional energy sources (Etongo & Naidu, 2022) despite the continuing escalation of costs in the global marketplace, but also has some negative environmental impact. Despite these issues, South African economies do not seem to take heed of the call for SET.

The need to create a vibrant market for solar energy in Southern Africa to enhance the harnessing of SET is becoming a clear regional objective. This would improve solar energy use, yet the results continue to point towards advocacy for more hydropower and thermal power. The energy sector in Southern Africa has the highest contribution of 2.5 tons of carbon dioxide equivalent per capita in Africa (OECD, 2022c). Statistics from the IEA (2022) show that the South African economy is based on coal, making it the continent's largest contributor to carbon dioxide in 2020, accounting for 32.7% of continental emissions. Clean energy in the Seychelles energy mix is under 5% (IRENA, 2019), and despite the advent of incentivized schemes, there was a low uptake with 406 homes between 2013 and 2021. According to Schmela et al (2018), market enhancements support the market institutions, players, and procedures that encourage SET deployment. However, according to Timilsina, Kurdgelashvili, and Narbel (2012), an upsurge in the demand

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for SET is anticipated. In support of the assertion above, policies for establishing and maintaining this market have been adopted, as noted by Aarakit, Ntayi, Wasswac, and Adaramolad (2021). This could be through designing standards, education, and licensing, yet not much has been realized so far. This should help promote the development of energized sustainable renewable energy. According to Ahmed et al (2022), policies could enhance the capacity of local SET manufacturers to sell directly to customers at affordable prices, thus facilitating market development. The efforts of Southern African governments have not generated enough public funds to promote solar energy markets in the region. The funding potential through appropriations has not been fully utilized to help fund SET as an alternative form of renewable energy source. Such funding models, if fully embraced, could bridge the solar energy and traditional source pricing gap. Essentially, this would reduce the cost of SET through research and development, subsidies, education, and training (Beck & Martinot, 2004).

As noted by Etongo and Naidu (2022), in Seychelles, even though there is statutory recognition of renewable energy products, high costs in terms of customs duty on the importation of technologies are the major deterrent to accessibility by most people. Furthermore, Aarakit et al. (2021) posited that even higher learning institutions engage in collaborative research efforts on SET for industries and households. Most governments in Southern Africa have committed to advancing energy sustainability in terms of universal energy access, renewable energy, and energy efficiency (Ashinze et al., 2021) thus adopting clean energy sources towards a more green economy with minimal environmental impacts. What needs to be highlighted here is that, even though these strides have been taken, evidence on the ground is exactly the opposite of the intended results. There are numerous institutional barriers, thus discouraging suitable infrastructure development and an ideal marketing environment that, according to Ashinze et al (2021), is conducive to SET requiring the integration of technical, infrastructural, and statutory changes.

1.1.1 Theoretical Framework

In the past decade, there has been remarkable attention towards the adoption of technology. In this vein, there is a plethora of theoretical models of technology users' behavior in adopting new technologies. These models include Davis's (1989) popular technology acceptance model (TAM) which has been extensively tested empirically since its inception, focusing on computer-based information systems. Other models include the Theory of Reasonable Action (TRA) by Fishbein and Ajzen (1975), Diffusion of Innovations (DOI) by Rogers (1995), Theory of Planned Behavior (TPB) by Ajzen (1985, 1991), Technology Acceptance Model 2 (TAM2) by Venkatesh and Davis (2000), and Technology Acceptance Model 3 (TAM3) by Venkatesh and Bala (2008). As argued by Ma and Liu (2004), there is abundant literature on TAM, and there have been mixed and inconclusive results from extant empirical tests. Empirical tests are extensive and vary in direction, statistical significance, and degree. Even though such scenarios have always been present in social sciences as a result of the complexity of human behaviours, it results in undermining TAM precision. The quest by academicians and practitioners to identify the antecedents of user acceptance behavior has been growing exponentially. This study proposes a framework that can be used to predict readiness for SET adoption in urban development.

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1.1.2 Empirical Literature Review

Concerning Sub-Saharan Africa, more than 50% of households are clean energy-deficient. This scenario, as noted by Guta et al. (2017) in Ethiopia, offers an enormous opportunity in terms of increasing solar energy technology adoption, even though the current situation shows that it is comparatively low. Several factors influence the adoption of SET in households, including payment mechanisms, availability of grid electricity (Guta et al, 2017), installers and neighbors anticipated financial gains, and concerns around operating and maintaining the technologies (Reyes-Mercado & Rajagopal, 2017). Furthermore, education attainment, sex of those who head the household, income (Zeru & Guta, 2017) and affordability (Zeru & Guta, 2017) are key drivers of SET adoption. To accomplish meaningful sustainable development, it is necessary to consider the accessibility, affordability, and reliability of energy sources.
Based on DOI theory, consumers make decisions on the evaluation of solar innovation, and Ahmed et al. (2022) point out that compatibility, complexity, comparability, observability, and confirmability are the major factors used by consumers to assess solar innovations. In essence, they point to the need for individuals and private and public institutions to prioritize technology and household characteristics when formulating policies to upscale solar innovation adoption.

Given the crucial nature of energy transition in enabling climate resilience and sustainable development, other determinants of SET uptake include accessing credit and household incomes, as established by Etongo and Naidu (2022). They further detailed several factors under the two banners (drivers and barriers), including access to loans, environmental friendliness, perceptions, energy security, cost saving, and being the propellers of households in adopting SET. Etongo and Naidu (2022) also point out four critical adoption barriers at the household level: existing loans, high initial costs, cheap electricity, and payback periods. On the other hand, household economic status, media effectiveness, information asymmetry, level of education, and lack of awareness were also noted by Zeru and Guta (2017) as major forces that determine the diffusion of solar energy technologies in communities.

1.1.3 Conceptual Model

Figure 1 depicts the proposed relationship between and among the study constructs. In the model shown in Figure 1, the targeted user identifier and targeted user capability define the attributes of the targeted user in terms of socio-demographic and socio-economic aspects of households and the nature of expected decision making and ultimately assign some economic value to the technology. Ultimately, perceived economic value, motivators, and barriers are classes of variables that have been assumed to have the targeted user being pushed away or pulled towards understanding solar energy technologies. Having understood the status of the targeted user, it is possible to determine the level of readiness to adopt or not adopt solar energy technologies. In essence, the model users can then determine the required level of readiness, status, and effort.

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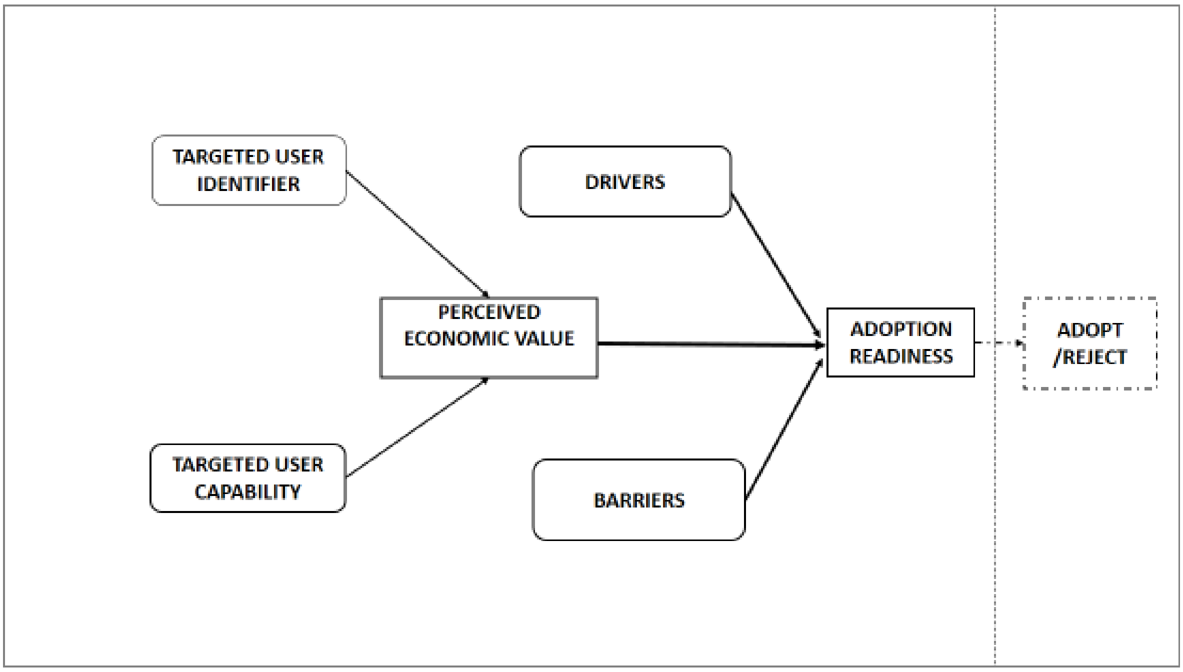

Figure 1 Proposed solar energy technologies adoption readiness study model
Source: Authors' own creation, (2024)

Figure 1 caption: The figure depicts the proposed solar energy technologies adoption readiness study model. It shows how the study concepts relate to each other. It shows proposed predictors of perceived economic value (targeted user identifier and targeted user capability. It further shows that perceived economic value, drivers and barriers are proposed predictors of adoption readiness.

The following hypothesized relationships were then modelled under structural equation modelling (SEM), derived from the proposed study model in Figure 1:

H1: Targeted user identifier positively and strongly impacts perceived economic value
H2: Targeted user capability positively and strongly impacts perceived economic value
H2: Barriers positively and strongly impact SET adoption readiness
H4: Drivers positively and strongly impact SET adoption readiness
H5: Perceived economic value positively and strongly impact SET adoption readiness

1.1.4 Study Novelty and Contribution

In most developing nations, SET is expected to become a widespread phenomenon as a substitute for fossil fuel energy, yet this seems to be happening slowly. There are negative externalities, both to the environment and the social structure, in general, due to the production and consumption of fossil energy

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by households. The acceleration of the upward trend is essential, as continued sustainable energy system development for households requires the creation of mechanisms that would help in the assessment, deployment, and evaluation of the status of adoption of SET in terms of appropriate policies, systems, attitudes, culture, and ethical practices. Such practices require an examination of economic, social, and physical environments in terms of SET. This study proposes and validates a framework that can be deployed to influence the readiness of society to adopt SET sustainably. The framework will be specifically designed for a developing nation that still uses traditional forms of energy (firewood, coal, kerosene, cow dung, electricity, petroleum gas, and diesel) to meet household energy requirements.

1.2 Materials and Methods

This study focused on analysing societal perspectives regarding the enhancement of solar energy in the Southern Africa region. In line with related studies (Aarakit et al., 2021; Etongo & Naidu, 2022; Hatamifard Farajallah & Mirdamadi, 2023; Mothala et al., 2022; Zeru and Guta, 2017) it employed a quantitative approach was employed for data collection. This study investigated the determinants of SET adoption for sustainable development. The study population consisted of households in the selected districts of South Africa, Botswana, Malawi, Seychelles, Zambia, and Zimbabwe. The study employed A structured questionnaire to collect data from a sample 11550 households of 2310 households (385 households with a margin of error of 4.91% generated using the 2023 online sample size calculator for each of the six countries). The validity of the instrument in terms of face and content was assessed by expert raters before piloting. In terms of research instrument reliability, the study used Cronbach's alpha coefficient and composite reliability for constructs derived from the questionnaire that had been piloted on 150 respondents, who were then excluded from the sample. Valid responses contained 1510 questionnaire copies, giving a response rate of 65.4%. The cut-off criterion for participation was one being above the age of 18 years and being a citizen in the respective country. The questionare was self administered, were an four research assistants were selected in each of the six countries to administer in person.

1.2.1 Scale and dimensions of the study

A five-point Likert scale based on strongly disagree (1), disagree (2), not sure (3), agree (4), and strongly agree (5) was adopted. As shown in Table 1 below, the study was anchored on six constructs with 46 observed variables linked to different constructs. These constructs are as follows: targeted user identifier (9 items), targeted user capability (4 items), drivers (7 items), barriers (8 items), perceived economic value (3 items, which are latent variables measured from 12 items), and adoption readiness (6 items). These are the constructs and their respective number of measures for the proposed solar energy technologies adoption readiness model (SETAR). The constructs and their related observed variables.

Table 1 Scale and dimensions of the proposed SETAR model – showing constructs used in the study and their corresponding measures including the source.

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<table>
<tr>
<td>DRIVERS (7)

Direct marketing, Advertisement (Rai et al., 2016)
Peer effect (Corbett, 2022; Etongo & Naidu, 2022; Graciano, Fiaschetti & Atkinson-Palombo, 2019; Palm & Eriksson, 2018; Palm, 2017)
Cost-saving (Etongo & Naidu, 2022; Fikru, 2020)
Energy autonomy (Etongo & Naidu, 2022; Qureshia, Ullah & Arentsen, 2017)
Energy security (Etongo & Naidu, 2022; Ford et al., 2017; Zander, 2020).
Environment friendliness (Etongo & Naidu, 2022; Qureshia, Ullah & Arentsen, 2017; Ugulu, 2019)</td>
<td>TARGETED USER IDENTIFIER (9)
Landholding, land size, Access to credit (Hadush & Bhagwat, 2019)
Income (Guta, 2020; Rahut, Mottaleb, Ali & Aryal, 2017)
Dependency ratio (Etongo & Naidu, 2022; Guta, 2020; Rahut et al., 2017)
Education level and Household size (Aarakit et al., 2021; Anteneh, 2019; Briguglio & Formosa, 2017; Grimm, Lenz, Peters, & Sievert, 2019; Guta, 2018; Jan Ullah, & Ashfaq, 2020; Kurata, Matsui, Ikemoto & Tsuboi, 2018); Rahut et al., 2017)
Position in household and employment status (author, 2023)</td>
<td rowspan="3">BARRIERS (8)

Government policy
Energy reliability (Aarakit et al., 2021; Blimpo & Cosgrove-Davies, 2019; Tahir, Ahmad, Abd-ur-Rehman, Shakir 2021)
Grid access (Aarakit et al., 2021; Aklin, Cheng & Urpelainen, 2018; Hyun, Taghizadeh-Hesary & Shim, 2021; Kurata et al., 2018; Manjeri, Ssennono & Adaramola, 2021)
Initial investment costs in terms of High installation costs, long payback period, shorter repayment terms, interests costs, tax costs (Aarakit et al., 2021; Barrie & Cruickshank (2017); Bensch, Grimm, Huppertz, Langbein & Peters, 2018; Collings & Munyehirwe, 2016; Palit, Malhotra, Pandey & Bankoti, 2013; Rai et al., 2016)
Flexible payment mechanism in terms of Existence of instalment payment terms to cover initial investment costs as a motivation (Aarakit et al., 2021; Adwek et al., 2020; Creti & Barry, 2020; Hyun et al., 2021; Kizilcec et al., 2021; Lighting Global, 2020; Rastogi, 2018; Sanyal Prins, Visco & Pinchot, 2016; Rolffs, Ockwell & Byrne, 2015; Yadav, Heynen & Palit, 2019)
Perceived Uncertainty, Beliefs about Consequences, Consumer Asymmetric (Reyes-Mercado & Rajagopal, 2017)</td>
</tr>
<tr>
<td>ADOPTION READINESS (6)
Good financial investment, Frontier of technological innovation, Foreign sources of energy, Hedging prices, Local utility, Environmental concerns (Rai et al., 2016)</td>
<td rowspan="2">PERCEIVED ECONOMIC VALUE (3 AND 12)
perceived Usefulness: Working more quickly, Increasing productivity, Makes the Job Easier (Davis, 1989)
Perceived ease of use: Easy to learn, understandable, Easy to become skilful, Controllable (Davis, 1989)
Perceived institutionalized support: After-sales service, Installation services, Maintenance services, Backup supplies, Assured durability (authors, 2023)</td>
</tr>
<tr>
<td>TARGETED USER CAPABILITY (4)
Access to information disseminators, Access to training, Educational status, access to critical knowledge status (author, 2023)</td>
</tr>
</table>

Source: Authors' own creation from sources cited in text, (2024)

1.2.2 Methods of analysing data

For data analysis, the data were edited, coded, and classified to systematically present the results using narration, figures, and tables. SPSS version 20 and AMOS version 22 were used as statistical tools for analysis. Quantitative data were analyzed at a significance level of 0.05. The statistical analysis included frequencies, Cronbach's alpha, means, standard deviations, correlations, and path coefficients. Structural equation modelling was used to confirm or reject the hypotheses.

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1.3 Results

1.3.1 Demographic characteristics

Table 2 Characteristics of the sample - in terms of gender and age of the research participants.

Variable	Class	Frequency	%
Gender	Males	898	59.5
	Females	612	40.5
Age	Less than 30 years	319	21.1
	30-55 years	721	47.7
	Above 55 years	470	31.1

Source: Authors' own creation from primary data, (2024)

Table 2 shows that there are gender imbalances, given that 59.5% of participants were male and 40.5% were female. Furthermore, most respondents (47.7%) were 30-55 years of age.

1.3.2 Sample adequacy

Table 3 Kaiser-Meyer-Olkin and Bartlett's Test - results on sample adequacy

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.966
	Approx. Chi-Square	12269.935
Bartlett's Test of Sphericity	df	630
	Sig.	.000

Source: Authors' own creation from primary data, (2024)

In Table 3 above, the Kaiser-Meyer-Olkin measure of sampling adequacy of 96.6% with a statically significant Bartlett's Test of Sphericity and approximate chi-square of 12269.935 indicates that the sample was adequate, thus allowing further manipulation of the dataset.

1.3.3 Descriptive statistics and instrument reliability

The results in terms of means, standard deviations, and correlations among the study variables, including the reliability measures (composite reliability, CR, and Cronbach's alpha), are depicted in Table 4 below. The variables were coded as follows: targeted user identifier (FID), targeted user capability (FAC), drivers (DIV), barriers (BAR), perceived economic value (PEV), and adoption readiness (ARE).

Table 4 Means, standard deviations, Cronbach alpha and correlations among the study variables

Variables	Mean	Std. Dev.	CR	Alpha	FID	FAC	PEV	DIV	BAR	ARE	No. of items
1. FID	3.34	1.186	0.947	.942	1						9

2.	FAC	3.43	1.380	0.970	.970	.529**	1					4
3.	PEV	3.31	1.311	0.921	.921	.520**	.432**	1				3
4.	DIV	3.18	1.267	0.950	.947	.757**	.490**	.603**	1			7
5.	BAR	3.33	1.170	0.939	.932	.677**	.615**	.595**	.665**	1		8
6.	ARE	3.10	1.287	0.947	.942	.602**	.497**	.489**	.597**	.572**	1	6

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

Source: Authors' own creation from primary data, (2024)

Based on the findings shown in Table 4 above, it can be noted that there is a strong and positive association between constructs. The r range between .432 and .757 was significant at $p < .01$. The correlation results indicate the existence of significant linear relationships between any two constructs. In terms of descriptive statistics, the results lean towards agreement, which is above the median value of 3.00. The study preferred the Pearson product-moment correlation based on the assumption of a continuous distribution. In terms of reliability, which Kline (2011) noted as a quality criterion of a construct, Cronbach's alpha and CR were above. The cut-off point of .600, as recommended by Hair, Hult, Ringle and Sarstedt (2017). Therefore, the results were deemed excellent, and Taber (2018) posits that Cronbach's alpha is vital in indicating the reliability of scales concerning item equivalence within single construct scales. Therefore, the results indicate internal consistency with regard to each construct and allow further data analysis through structural equation modelling (SEM).

1.3.4 The measurement model

There is abundant evidence of pitfalls when SEM assumptions are not upheld (Kumar & Upadhaya, 2017; Wah, Fitriana, & Arumugam, 2023) in terms of biased regression weight estimates in the final model. It was assumed that the dataset was normally distributed, as pointed out by Kumar and Upadhaya (2017), with a minimum level of validity and reliability, as noted by Dijkstra and Henseler (2015), of positively correlated constructs. To achieve this, data screening procedures were performed based on the central limit theory. Needless to mention, the skewness (-.516 to 1.463) and kurtosis (-1.412 to -.981) of the items were individually reviewed, as advised by Hair, Henseler, Dijkstra, Sarstedt (2014), who set skewness and kurtosis ranges of -1.96 to +1.96 and -7 to 7 respectively. The results confirmed the normal distribution of the dataset. First, it involves the design, testing, and adjustment of the measurement model. This was done through the assessment of construct structure in terms of the model fit indices in Table 6 and the model validity measure in Table 7 below.

Structural model fit indices: The results of the measurement model design and testing are illustrated in Table 4 and Figure 2.

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Table 5 modified fit indices for the measurement model

FIT INDECES	ACCEPTABLE THRESHOLD	FIT INDICE VALUES	INTERPRETATION
X2/DF	Between 1 and 3	1.341	Excellent
RMSEA	< 0.060	0.034	Excellent
PClose	> 0.050	1.000	Excellent
CFI	> 0.950	0.984	Excellent
SRMR	< 0.080	0.032	Excellent

X2/DF, chi-square value; RMSEA, root mean square of approximation; PClose, probability of close fit; CFI, comparative fit index; SRMR, standardized root mean residual.
Source: Authors' own creation from AMOS output, (2024)

The fit indices shown in Table 5 above were excellent, implying a good fit for the measurement and structural models.

Structural model validity measures: To validate the components of the proposed model, AVE, square root of AVE, MSV, MaxR (H), and implied correlations were computed and are presented in Table 6 below.

Table 6 Model validity measures

		AVE	MSV	MaxR (H)	1	2	3	4	5	6
1	Targeted user identifier	0.673	0.653	0.971	**0.820**					
2	Drivers	0.734	0.653	0.973	0.808	**0.857**				
3	Barriers	0.692	0.561	0.959	0.749	0.733	**0.832**			
4	Adoption readiness	0.752	0.419	0.974	0.647	0.637	0.632	**0.867**		
5	Targeted user capability	0.891	0.428	0.971	0.561	0.515	0.655	0.527	**0.944**	
6	Perceived economic value	0.795	0.433	0.922	0.568	0.658	0.658	0.553	0.464	**0.892**

Ave, average variance extracted; MSV, maximum shared variance; MaxR (H), maximum reliability.

Source: Authors' own creation from AMOS output, (2024)

About the soundness of measures to represent theorized concepts, construct validity (convergence and discriminant validity) was conducted, and the results are shown in Table 6 above. Convergence validity, as posited by Hair, Ringle and Sarstedt (2013), concerns the positive association of measures within a construct, and it is an assumption on SEM. This was assessed using the AVE, and the rule

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of thumb, as noted by Hair et al. (2013), is that the AVE should be greater than 0.5, and in this case, all were above the threshold of 0.5. This confirms convergence validity. As noted by Hair et al. (2017), discriminant validity focuses on the uniqueness of a construct. This was assessed by comparing the square root of the AVE with implied correlations, as recommended by Fornell and Larcker (1981). In such cases, the square root of AVE should be greater than the highest implied correlation with any other construct (Hair et al., 2013). The results in the table above indicate discriminant validity, as the square root of AVE was greater than the highest implied correlations. Furthermore, the results for other validities are within the set thresholds, as noted by Pallant (2010) that MSV should be less than the AVE, the inter-construct correlation should also be less than the square root of AVE, and MaxR (H) should be greater than 0.8.

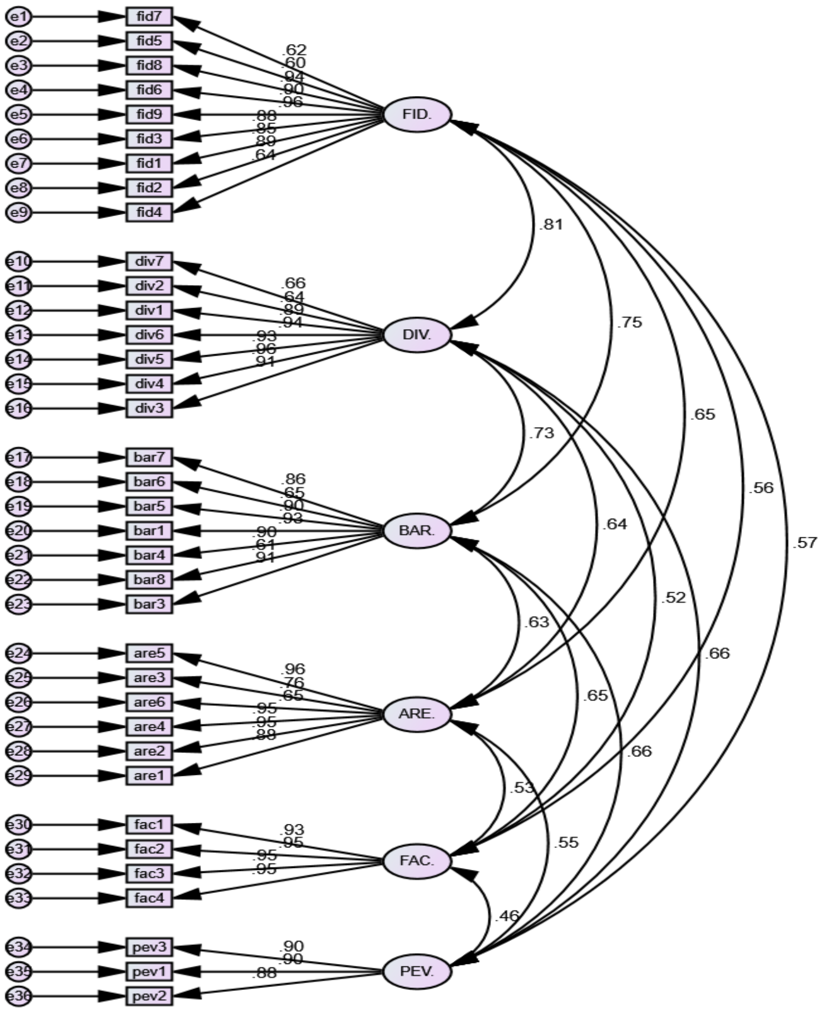

Figure 2 Measurement model
Source: Authors’ own creation from AMOS output, (2024)

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Figure 2 caption: This figure depicts latent variables with oval shapes, and observed variables shown by rectangular shapes. Factor loadings for observed variables per each construct are shown on single-direction (unidirectional) arrows for causal relationship and their direction. Construct correlations are depicted in bidirectional and oval-shaped arrows showing no clear causal relationship direction. The residuals as they are unobserved are depicted by a small circle on the right side of the model.

After turning the proposed study model into a measurement model as illustrated in Figure 2, all items in the figure had good factor loadings (values above 0.500) and were retained based on the improved reliability and validity shown in Table 5 and Table 6 above respectively. After considering the fit indices, the measurement model was accepted, which allowed the researchers to move on to the next step of running the structural equation model.

1.3.5 Structural Equation Model

As illustrated in Figure 3 structural model was produced, and the fit indices were inherited from the measurement model as they reflected an excellent model fit. Furthermore, the model validity measures inherited from the measurement model fell within the recommended acceptability threshold.

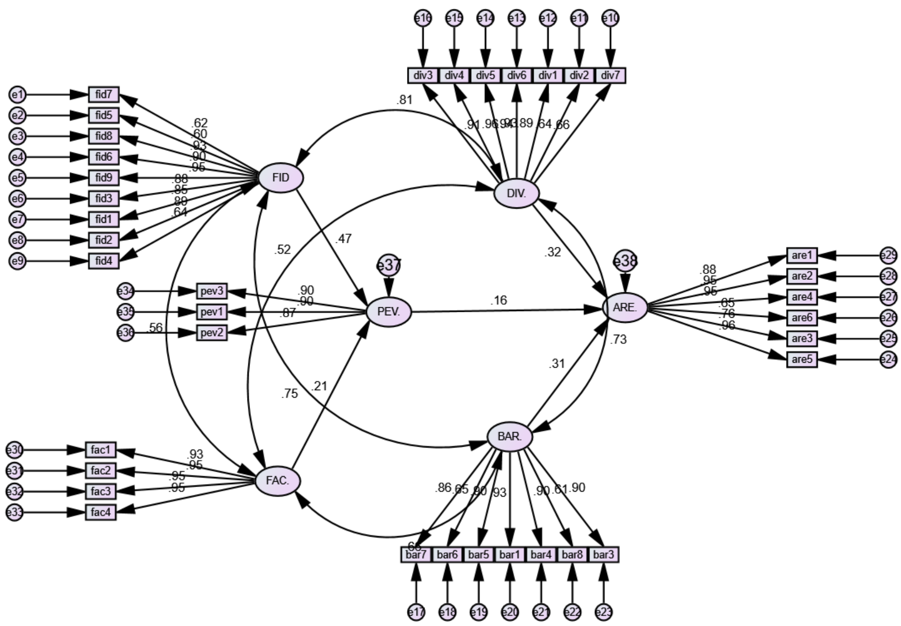

Figure 3 Path diagram for structural equation model
Source: Authors' own creation from AMOS output, (2024)

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Figure 3 caption: The figure depicts latent variables as oval shape, observed variables shown by rectangular shapes. Factor loadings for observed variables per each construct are shown on single direction (unidirectional) arrows for causal relationship and its direction. Construct correlations are depicted in bidirectional and oval-shaped arrows showing no clear causal relationship direction. The residuals as they are unobserved are depicted by a small circle on the right side of the model. Path coefficients are depicted by unidirectional arrows running from one latent variable to the other.

The path diagram in Figure 3 indicates that the FID and FAC are statistically significant predictors of PEV. Furthermore, the results indicated that PEV, DIV, and BAR significantly predicted ARE. This allowed hypothesis testing and structural model interpretation (the model is shown in Figure 3).

1.3.6 Hypotheses testing

Table 7 path relationships of constructs showing the results in terms of path relationships and the confirmation of hypotheses.

Hypotheses	**Path**	**Estimate**	**S.E.**	**C.R.**	**P**	**Results**
Targeted user identifiers positively and strongly impact perceive economic value	PEV←FID	0.468	0.095	6.617	***	Supported
Targeted user capability positively and strongly impacts perceived economic value	PEV←FAC	0.208	0.058	3.409	***	Supported
Barriers positively and strongly impact SET adoption readiness	ARE←BAR	0.311	0.08	4.405	***	Supported
Drivers positively and strongly impact SET adoption readiness	ARE←DIV	0.318	0.101	4.411	***	Supported
Perceived economic value positively and strongly impacts SET adoption readiness	ARE←PEV	0.162	0.058	2.979	0.003	Supported

***Results supported at significance level $p \leq 0.001$ level

Source: Authors' own creation from AMOS output, (2024)

The path coefficients in table 7 represent the impact's significance and direction based on the predictors of an independent variable. As shown in Table 7, the targeted user identifier and targeted user capability strongly predicted perceived economic value (β value =0.468 and 0.208; p-value = .000). Furthermore, barriers, drivers, and perceived economic value were established as predictors of SET adoption readiness (β = 0.311, 0.318, and 0.162; p = .000, .000, and .003, respectively). The revised model is depicted in Figure 4 based on the confirmed hypotheses.

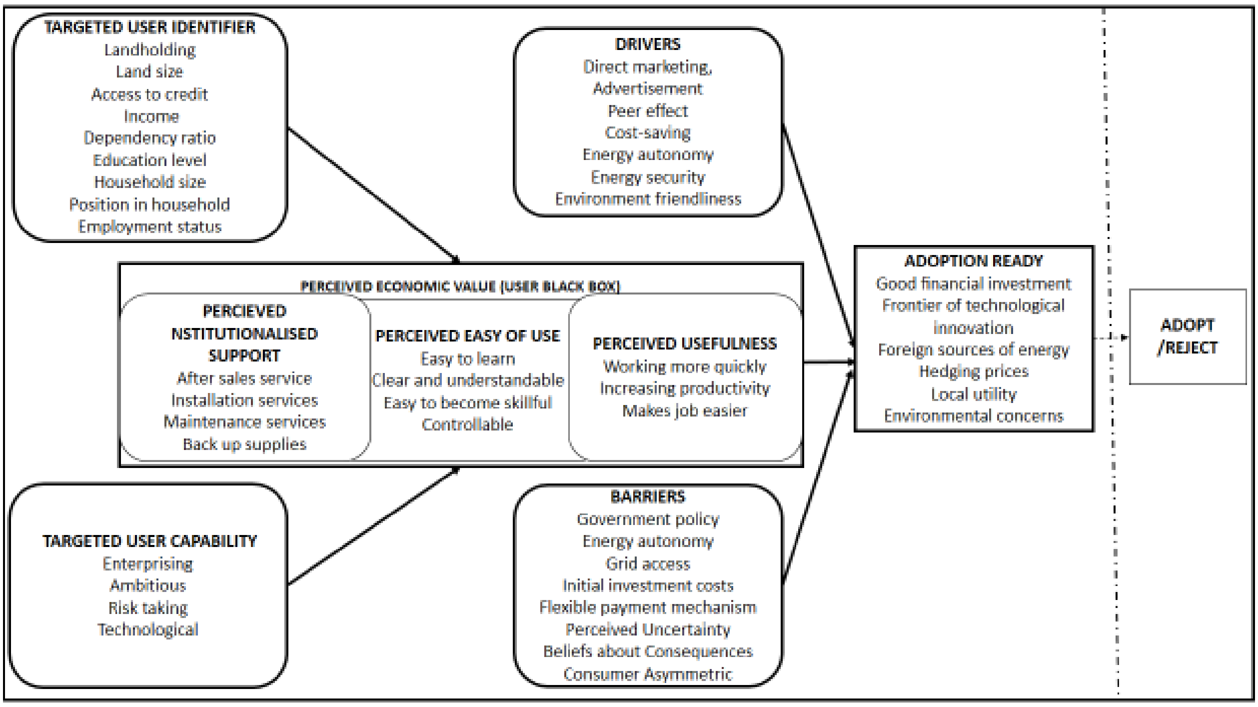

Figure 4 SETARM (solar energy technology adoption readiness) –
Source: Authors' own creation, (2024)

Figure 4 caption: Latent variables are depicted as being bold, observed variables are shown by not being bold. Single direction (unidirectional) arrows for causal relationship and its direction.

1.4 Discussions

Technology, including SET, is a critical resource in the day-to-day lives of people in their communities. SET provides platforms on which households can access cleaner energy sources, such as electricity, an essential resource for attaining the sustainable development of national economies (World Bank, 2018). The following sections discuss these findings:

Targeted user identifier and perceived economic value: Targeted user identifiers were positively and strongly associated with perceived economic value. The coefficient of the target user identifier implies that when a household has a certain level of individual characteristics mixed in terms of landholding, land size, access to credit, income, dependency ratio, position in the household, employment status, education level, and household size, the likelihood of improved perceived economic value in terms of a given SET is relatively increased. However, employment status, landholding, and land size slightly increased the probability of households assigning a higher perceived economic value to SET compared to the dependency

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ratio, household size, position in the household, access to credit, education level, and income. In support of the findings of Etongo and Naidu (2022), the role of these household characteristics is not by chance; rather, it is inherent in most households and includes such socio-demographic characteristics. This result concurs with Aarakit et al. (2021), who found that position in the household, employment status, education and wealth, house type, and household size were the major determinants of how households would economically perceive solar technologies, as also supported by Adwek et al. (2020) and Yadav et al. (2019). Practically, SET is relatively expensive (Lighting Global, 2018) and may not be affordable for the majority of households. Therefore, this strong positive association may be moderately accounted for by access to credit and rising incomes.

Target user capability and perceived economic value: In terms of target user capability having a strong and positive association with perceived economic value, access to media, access to training, education status, and prior knowledge were found to be the key items measuring target user capability that allowed the target user to understand the required solar energy technologies. These capabilities help the target user to manage the risks associated with novelty and the ability to adapt to new technologies. The findings support the fact that capabilities, as noted by Zeru and Guta (2017), are a key success factor in households' ability to economically perceive a product or service. As most adopters are urbanites, a strong positive association between perceived economic value and readiness for solar energy adoption, particularly its uptake, is essential. This is supported by Zeru and Guta (2017) and Wolske et al. (2017), who noted that when the majority of those adopting SET were in urban areas and more educated, they depended on opinion leaders or early adopters.

Solar energy technology adoption readiness: We established that a unit change in each of the predictors (barriers, drivers, and perceived economic value) had a significant impact on readiness to adopt solar energy technology. There was also a statistically significant difference between the groups.

Based on these findings, it is inferred that there are barriers that create problematic scenarios in influencing readiness to adopt solar energy technology. These barriers include government policy, energy reliability, grid access, initial investment costs (high installation costs, long payback period, shorter repayment terms, interest costs, tax costs), flexible payment mechanisms (instalment payment, initial investment costs) as supported by Aarakit et al. (2021), perceived uncertainty, beliefs about consequences, and consumer asymmetry, as noted by Reyes-Mercado and Rajagopal (2017). The results indicate that SET adoption readiness is unlikely in households with grid access and if the investment for solar is assumed to be high. Understandably, this is simply because if households have grid access, they may lack solar energy adoption readiness, as SET would be comparatively expensive. Furthermore, it is unlikely in circumstances where the government fails to incentivize adoption and where there is no clarity in terms of perceived uncertainty, beliefs about consequences, and consumer asymmetry regarding after-sales service, installation services, maintenance services, and backup supplies.

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Second, drivers are expected to positively push the levels of solar energy adoption readiness. The results confirm that drivers include direct marketing, advertisement, peer effect, cost-saving, energy autonomy, energy security, and environmental friendliness. The results indicate that direct marketing and advertising, as supported by Rai et al. (92016) had a positive effect on the rise in the levels of solar energy technology adoption readiness. Furthermore, as supported by Etongo and Naidu (2022), high levels of peer effect, the cost-saving ability of SET, its provision of energy autonomy, and energy security coupled with its being environment friendly are established to be the key drivers that propelled adopters in terms of solar energy technology adoption readiness.

In line with the literature (Ahmad, Tahar, Cheng & Yao, 2017; Kardooni, Yusoff & Kari, 2016; Nkundabanyanga, 2020), it was established that perceived economic value in terms of perceived usefulness (working more quickly, increasing productivity, making the job easier) and perceived ease of use (easy to learn, understandable, easy to become skilful) impact solar energy technology adoption readiness. Furthermore, perceived institutionalized support (after-sales service, installation services, maintenance services, and backup supplies) has also been established as measuring perceived economic value that ultimately impacts solar energy technology adoption readiness. However, perceived institutionalized support is novel and requires further empirical testing through confirmatory studies.

1.5 Conclusion and Policy Implications

Readiness to adopt solar energy technology provides latent power to significantly improve the efficient utilization of solar energy. This would reduce the perennial energy access gap in the region. Readiness to adopt solar energy technology provides an instantaneous and achievable alternative to electricity access. Nevertheless, SET adoption readiness remains insignificant in Southern Africa, regardless of grid electricity unavailability. This study focused on examining factors that influence readiness to adopt solar energy technology (such as target user identifier, target user capability, drivers, and perceived economic value) using survey data for households in South Africa, Botswana, Malawi, Seychelles, Zambia, and Zimbabwe. The contribution to the literature about these findings on solar energy technology adoption readiness includes (i) the multivariate analysis that adopted a five-factor model analysis and (ii) the study was located in countries in the tropics with immense solar energy potential coupled with low grid access and less availability in terms of electricity. Our findings imply that there is a need for governments to formulate energy policies that can disentangle the high installation costs (payback period, repayment terms, interest costs, and tax costs) and flexible payment mechanisms (instalment payment and initial investment costs). These policies would have the capacity to support SET affordability. There is also a need for the creation of innovation hubs whose responsibilities would be to decentralize energy matters and at the same time tailor such products to meet households' needs and allow for localized innovative models in terms of SET products, SET financial products, and SET marketing. Furthermore, the issues of perceived uncertainty, beliefs about consequences, and consumer asymmetry require interventions by development agencies and solar companies in terms of continued marketing innovations by addressing these social issues for consumers. In addition, there is a need for policy interventions that would bolster extension services by including energy issues, as this can be meaningful in changing households' livelihoods. Furthermore, there is a need for ICT developments that would provide e-platforms and mobile platforms with critical information on servicing, installation, backups, and other pertinent information on SET. This can be enhanced by creating information hubs and linking them to e-and mobile platforms. Concerning the SETAR model, the government, development agencies, and the corporate world could capitalize on using it to understand the readiness of society, communities, customers, and consumers to adopt SET. There were several limitations, including the use of new variables with scales that had never been measured for this purpose (perceived institutionalized support, target user capability, and other target user identifiers). However, these scales require further validation. Second, the analysed data ignored information on the type of SET used by households and other households (those in rural areas). Therefore, future research could focus on collecting data based on the type of solar energy technology and incorporating all types of households engaged.

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