Solar energy for sustainability in Africa; the challenges of socio-economic factors and technical complexities

Rashid Maqbool[1,*], Stephen Arome Akubo[2]

[1,*] Department of Mechanical and Construction Engineering, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK. E-mail: rashid.maqbool@northumbria.ac.uk

[2] Department of Mechanical and Construction Engineering, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK. E-mail: stephen.akubo@northumbria.ac.uk

Abstract

The world is faced with increased energy resources depletion, fluctuating costs, global warming, greenhouse gas emissions, air pollution, and poor health effects which characterize traditional energy sources. All of these difficulties would be considerably alleviated if renewable energy were not widely used. This study draws from existing literature to propose a conceptual model that underpinned the focus on the relationship between solar energy projects and sustainability dimensions (economic, social and environmental sustainability). Socio-economic factors and technical complexities were tested to ascertain the moderating effect on solar energy and sustainability. A mixed research approach comprising quantitative and qualitative methodologies was integrated to carryout this study. The qualitative study was based on a case study of an ITC centre powered by solar energy in an academic institution in Nigeria. Whereas the quantitative study depended on a survey with 227 valid responses taken through snowball sampling from the professionals working in the energy industry. Hierarchical multiple regression using SPSS 26 was carried out for the moderation analysis of the socio-economic factors and technical complexities towards sustainability dimensions. Results showed that solar energy has a strong positive direct effect on sustainability in all aspects of economic, social and environmental dimensions. The socio-economic factors is seen to have a moderating effect on the positive relationship between solar energy and all the three dimensions of sustainability. Whereas technical complexities determine inverse moderating effect only on the relationship between solar energy and economic sustainability. The findings predict that the socio-factors are the major challenges in hindering the overall sustainability in Africa rather than technical complexities, hence leading to a major concern for the economic, social and environmental dimensions. A similar outcome is also validated by the Case study of ITC centre powered project of solar energy. This study recommends a detailed model of solar energy development in terms of its potential and challenges in the developing parts of the world.

Keywords: Solar energy; economic sustainability; social sustainability; environmental sustainability; socio-economic factors; technical complexities.

1. Introduction

Global solar energy demand is quite volatile and varies greatly between countries. According to International Energy Agency (IEA) (2020), by the end of 2019, a total of 629 GW of solar energy had been installed around the world. Honduras now has enough solar PV capacity to supply 12.5 percent of the country's electrical energy, while Australia is approaching 11 percent. Italy, Germany, and Greece can supply between 7% and 8% of their annual domestic electricity demand, respectively (IEA, 2020).

Due to the depletion and environmental devastation caused by fossil fuel and biomass usage, several scholars (Kabir et al., 2018; Sukhatme and Nayak, 2017; Lewis, 2016; Maqbool & Jowett, 2022) advocate the hypothesis that renewable energy should be used to replace, not simply supplement, fossil fuel use. Solar energy is especially preferred because it has a low carbon footprint (Sharif et al., 2021; de Souza Grilo et al., 2018). The integration of solar energy as an essential renewable energy source (Sukhatme and Nayak, 2017) with circular economy is a pivotal component of sustainability. Solar photovoltaic (PV) capacity in the United States reached 88.9 GW by the end of 2020, enough to power 16.4 million American households (Muhammed & Tekbiyik-Ersoy, 2020). However, if not built or managed effectively and holistically, solar power can still result in waste products and other consequences throughout its life cycle and the by-products of its processing (Heath et al., 2020). International Energy Agency (2020) reported the top ten countries by solar energy capacity by 2019 shown in Figure 1.

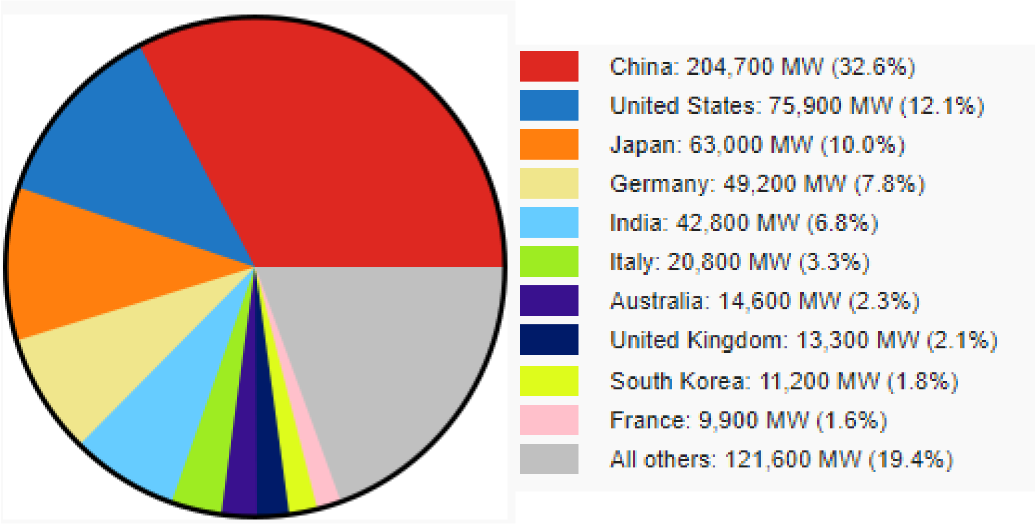

Figure 1: Ten top solar energy countries by capacity by 2019 (Source IEA, 2020)

Solar energy is gaining traction currently globally but not without accompanying challenges, as well as opportunities. Therefore, there is a need for management to apply socio-economic principles to ensure that its development potential and its attendant challenges are appropriately managed. Realizing the solar energy potential necessitates using a planning lens that considers not only speed and immediate cost, but also the broader holistic sustainable advantages that can be realised along the value chain.

This study aims to investigate the impact of solar energy on the economic sustainability, environmental sustainability and environmental sustainability under different socio-economic challenges and technical complexities. In order to meet the study aim, the following objectives were placed performed in this research.

(i) To evaluate the opportunities for the development and implementation of sustainable management practices on solar energy.

(ii) To understand the challenges of solar energy in achieving the sustainable development.

The challenges of socio-economic factors in developing African countries for the solar energy sustainability entail major threats to the clean-energy services, energy waste reduction, energy conservation, energy efficiency, energy security and CO^2 emissions reduction. Moreover, these challenges are also the major threats on the global scale as well as at the local settlements. These threats cannot be fully equipped until and unless and unless the government and local scale circular policies for solar energy are not formulated. In addition to socio-economic challenges, the technical complexities are also the hardcore aspects of the solar technologies, which need to be addressed to make it easily accessible at the local scale. This relationship will allow the urban energy system to cope with their specific sustainability challenges, as well as harness their opportunities. However, there is not much research that focuses on the socio-economic factors and technical complexities, more especially on its influences on the solar energy sustainability in urban areas settlements. The rationale for this research is categorised into two, the practical rationale and theoretical rationale.

The issues of sustainable management of solar energy are elusive in most parts of the world inspite of the UN sustainable development goals (UNECE, 2017) that seek to meet the targets and vis-a-viz clean energy generation and utilization. The challenges and drawbacks of solar energy technologies are issues of great concern in sustainable management. In some cases, there is no adequate policy framework to enforce the sustainability of the solar energy system. On the other hand, the existing policies are not matched up with implementation and required enforcement that comply with sustainability standards. In other cases, the problem may be energy wastage and other poor energy sustainable practices, high carbon emissions, or a gross violation of quality control and quality assurance standards in the generation, distribution and maintenance of solar energy systems. Based on the foregoing, this research seeks to understand the challenges and opportunities of solar energy sustainability in urban areas.

In a nutshell, the theoretical rationale for this study stems from the fact that there are insufficient studies in the literature to assess the impacts of solar energy on sustainability under different socio-economic challenges and technical complexities. This study will, therefore, seeks to make a significant contribution to the academic literature in this area.

2. Literature Review

This part of the research reviews several studies from the existing literature that are relevant to the current investigation. By drawing on relevant books, articles, journals, and conference papers, this part of the study advances a critical analysis of sustainable development and sustainability issues in the general context of the emerging global solar energy system with the instrumentality of sustainable management policies, sustainability concept, models, and dimensions.

2.1 Sustainability

Several scholars and researchers have tackled the term sustainability from various perspectives, based on the subject at hand and the viewpoint from which it is seen. Therefore, the term "sustainability" has a variety of definitions in the literature. According to Van Zon (2002), the terms "sustainability" and "sustainable" first appeared in the Oxford English Dictionary in the second part of the twentieth century. The core word for sustainability is "sustinere," which means "to keep going." It has a variety of synonyms, including keep, maintain, and preserve. "Sustinere-eco," according to Agyekum-Mensah et al (2012), is a phrase that has sparked a lot of controversy about what it means to hold or preserve the environment.

2.1.1 Sustainability Models

There are several theories and models of sustainability in the literature. Jenkins (2016) proposed sustainability theories that are focused on and coordinate social reactions, financial matters, ecological concerns and social issues. An economic model support monetary capital and financial involvements; an environmental model looks to organic variety and natural respectability; a political model looks to social frameworks that acknowledge human dignity. This model prioritises key components which must be sustained - economic, ecological, and political. In the model of sustainability by Todorov and Marinova (2009), they classified sustainability models into quantitative, physical, conceptual and standardizing models. Thatcher (2014), as well as Irhoma (2017), proposed four models of sustainability (Figure 2): The three pillar model (also referred to as the Triple Bottom Line or Three circle Model), the Prism Model (also referred to as the Four Pillars Model); Nested Circle of Sustainability Model (also referred to as the Concentric Circles Model or Egg of Wellbeing Model); and the Two-tiered sustainability equilibria Model. This research work shall focus on the three pillar model of sustainability as a theoretical framework upon which it is based.

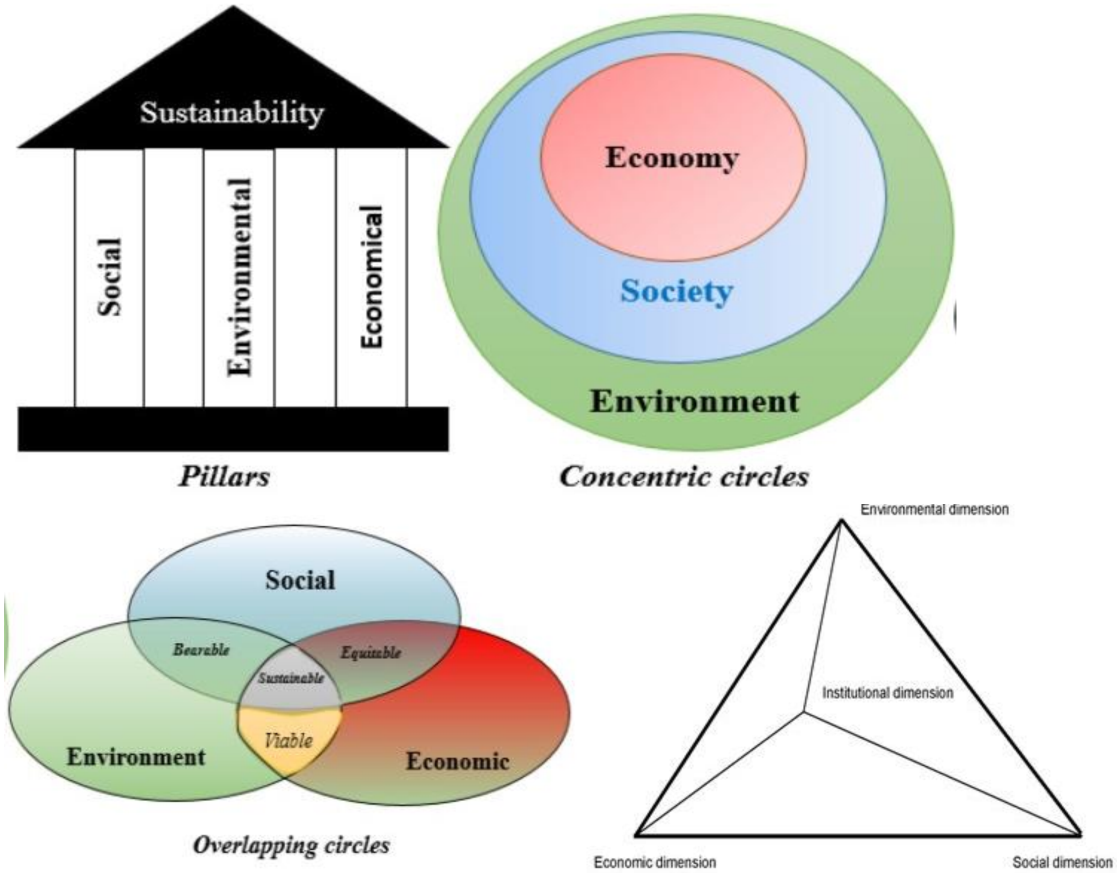

Figure 2:Models of sustainability (Source: Irhoma, 2017)

2.1.2 The Three Pillar Model of Sustainability

The three pillar model of sustainability is based on the mathematical concept of a Venn diagram embedded with the overlapping circles which depict the important sustainability types of social, economic, and environmental goals, and the intersection of these three elements leads to overall sustainability. The overlap at the point of interception accurately depicts that all of the domains involved are satisfactory sustainability. However, this those not necessarily mean that sustainability must cover every one of these domains. The various aspects – economic, social and environment are not exclusively dependent upon one another, any of these areas could stand alone and pursue a target of attaining sustainability. There is a growing argument in the literature that of the three aspects of suitability in the three-pillar model - the economic, social and environmental aspects, the environmental concerns are more fundamental and should be given more consideration in the pursuit of sustainability (Brockhaus et al. 2017). This argument is in line with the view of Howes et al. (2017), which state that the environment is critical in supporting the economy and the society. To put it another way, the environment can survive without human societies and economies, but economies and societies cannot survive without the resources of the environment, making the environment domain the most significant in this idea (Wagner, 2015). Economic advantage must be based on long-term activities that work within society's and nature's restrictions. Figure 3 shows the various components of the three pillar model of sustainability.

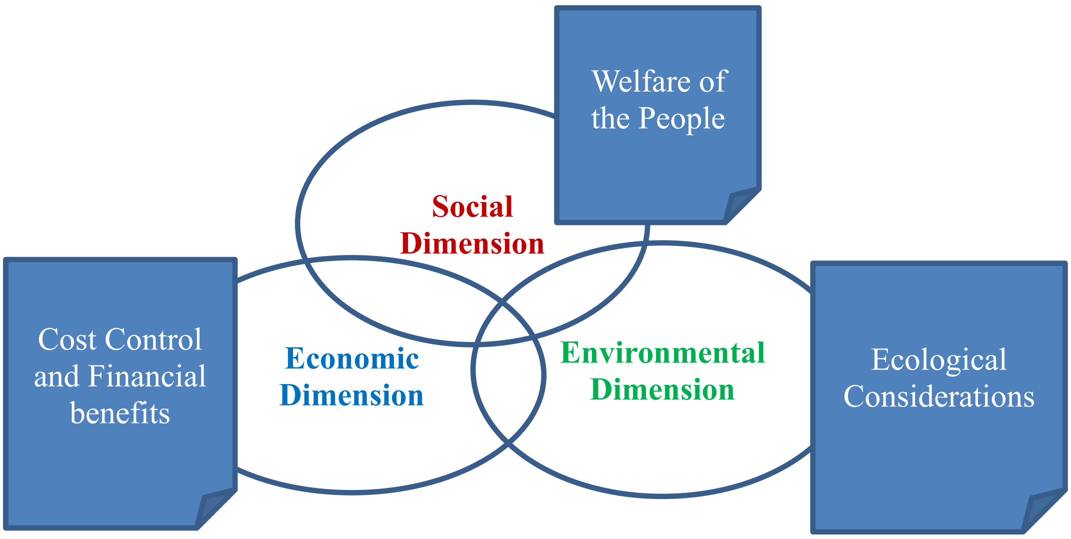

Figure 3: Three Pillar Model of sustainability (Modified from the overlapping circle sustainability model after Irhoma, 2017)

The essential feature of the environmental line of sustainable development is the preservation of environmental resources for future generations. In other words, it emphasises the need for environmental protection through the efficient use of energy resources. It also emphasises the importance of reducing greenhouse gas emissions and ecological imprint (Maqbool & Amaechi, 2022; Maqbool et al., 2022). This is because environmental measures, like the social line, have an impact on the long-term viability of organisations.

2.1.3 Solar Energy Security for Sustainability

There have been no studies in the Solar Energy field that have attempted to investigate sustainability in terms of the combined implications and influence of socio-economic issues, and technical challenges. These difficulties have not been thoroughly examined, and as a result, no comprehensive solution has been devised to solve them and enhance current solar energy sustainability issues in metropolitan settings. Sustainable energy generation, efficient use, industrial process efficiency, life cycle assessment, carbon footprint, and overall sustainable development are all concerns. As a result, the goal of this research is to fill this gap in the sustainability literature.

2.2 Solar Energy System in Urban Area

According to Grubler et al. (2012), more than half of the world's population lives in cities, and these cities are expected to absorb almost all of the world's population expansion through 2050, totalling an additional three billion people. The growth of the rural population in many emerging countries will be dwarfed by population movements to cities in the next decades. The world is already primarily urban in terms of energy consumption. According to this study, cities account for 60–80 percent of global final energy use (Grubler et al., 2012).

Grubler et al. (2012) proposed two perspectives of urban energy systems, functional and spatial perspectives. The functional viewpoint considers urban sites and their urbanisation to encompass not only the physical locations of people and economic activity, but also the types of activities they engage in, and the infrastructure and functional framework services provided by urban agglomerations. Urban regions are increasingly defined by functional qualities, which are represented in the analysis of urban energy systems. Alternatively, the traditional spatial concept of cities as defined by political or geographical limits has shifted to urban agglomerations, which include greater metropolitan areas or urban populations.

Broadly speaking, energy systems are categorised into two types based on their sources as:

(i) Non-Renewable Energy and
(ii) Renewable Energy

2.2.1 Energy Translation

Fossil fuels (oil, gas, coal) are deemed non-renewable because their use depletes scarce resources such as fuel, gas, and coal. Maqbool (2018) distinguishes between renewable and non-renewable energy. Renewable energy, on the other hand, is free and naturally renewed, and it is frequently used to deliver energy in four critical service points: electricity, rural off-grid power generation, water and air heating and cooling. Solar energy, wind energy, hydroelectric energy, geothermal energy, tidal energy, wave energy, nuclear energy, and biomass are examples of alternative energy sources (renewable energy). Solar energy is argued by some literature (Sengupta et al., 2021; Owusu & Asumadu-Sarkodie, 2016), to stand out among other renewable energy sources since most of the others, whether directly or indirectly, rely on the sun upon. For example, wind energy indirectly comes from the sun since it is required to drive the wind; hydroelectric energy also comes from the sun because the sun produces evaporation, which vaporises and falls back as rain. Rain falls into rivers or is flooded downhill into rivers, and the force of the rain is captured in hydroelectric dams to generate electricity. Similarly, biomass comes from the remains of plants that are produced when the sun causes photosynthesis to occur.

2.2.2 Solar Energy and Sustainability

When the sun's rays strike the solar panel, electrical energy is generated. Several scholars (Sukhatme and Nayak, 2017; Kabir et al., 2018; Lewis, 2016) support the view that solar energy should be used to replace, not simply supplement, fossil fuel consumption, due to the depletion and environmental damage it produces. This is the viewpoint of Shahsavari and Akbari (2018) and Rigo et al. (2019), who believe that solar energy is eternal and attainable, and that it is necessary for future livelihood, particularly in developing nations for rural areas. Similarly, GNESD (2007) asserts that solar photovoltaic energy is the most cost-effective means to promote health, claiming that health improvement is impossible without it.

One of the major problems of the solar energy system is the high initial installation cost; for example, in 2022, the average price per watt for solar energy in the United States is $2.77 (Energysage, 2022)., though it is much better than the price of 2016, which was $3.70, still not enough for easily acceptable on wider public level (Energysage, 2016). Furthermore, most household solar panels have efficiency of 10–20 percent, which is another flaw in solar technology (Hermann et al., 2014). Solar energy, like other kinds of renewable energy, is influenced by weather conditions (Kratschmann & Dütschke, 2021). Although it is a free source of energy, there are only a few sites with ideal climatic conditions for the installation of solar panels, such as the sun's radiation angle and daytime. Electricity production will not be cost-effective enough in this manner if the climatic conditions are not suitable. Another issue with solar energy is the storage of electricity. Solar energy is transported to batteries before entering the distribution network. Despite advancements in the technology of battery production, they remain expensive and not economical for use. Many firms are now presently pursuing research to develop cost-effective batteries. However, none of them has been able to considerably reduce the cost of batteries. Solar energy technologies have also been chastised for requiring a big amount of land to be produced. Solar power generation on a large scale frequently necessitates enormous areas of land. A 1 MW solar power plant with crystalline panels (about 18 percent efficiency) would require approximately 4 acres (16,187 m^2) of land, while thin film technologies (12 percent efficiency) would require approximately 6 acres (24,281 m^2) (Kabir, et al., 2018; Castillo, Silva, and Lavalle, 2016; Görig and Breyer, 2016).

Nonetheless, it is expected that the future cost of designing and manufacturing solar panels would decrease due to economies of scale in future solar system production such that solar energy will become a more accessible and cost-effective source of energy. Other components' performance constraints, like batteries and inverters, are also areas where there is an opportunity for improvement, further research and development.

From a holistic point of view, the gains of solar energy, overweigh the demerits.

From the review of the literature, this study has put forward the following hypotheses:

H1: Solar energy has a positive effect on economic sustainability.

H2: Solar energy has a positive effect on social sustainability.

H3: Solar energy has a positive effect on environmental sustainability.

2.3 The Role of Socio-economy Factors Towards Sustainability

Stakeholder involvement, uncertainty in communicating with stakeholders, and investment matters are all socio-economic factors that affect sustainability. Because the development of transformational projects and radical technology is expected to have far-reaching socio-economic consequences. Sustainable development necessitates the recognition of a diverse set of stakeholders, including primary stakeholders (investors, managers, suppliers, employees, customers, government and policymakers) who are directly involved in the process, as well as secondary stakeholders (such as pressure groups) who are not directly involved in a market relationship but can have a significant impact on a company's business (Lyon et al, 2020; Maqbool et al., 2022). Sustainable development innovation is more complicated than traditional market-driven innovation because of the added interacting constraints from social and environmental issues. Past research on innovation dynamics has implicitly acknowledged the importance of key stakeholders, but has undervalued the role of secondary stakeholders, who are frequently highly influential in sustainable development innovation. The ambiguity of stakeholders is another key socio-economic aspect. This could be due to the fact that different stakeholders have different aims, demands, and perspectives. Additionally, particular stakeholders may have irreconcilable views of one another over ethical, religious, cultural, societal, or other problems (Bocken and Geradts, 2020; Lyon et al., 2020).

From the review of existing literature carried out in this part of the research, the following hypotheses are developed for this study:

H4: Socio-economic factors inversely moderate the positive relationship between solar energy and economic sustainability.

H5: Socio-economic factors inversely moderate the positive relationship between solar energy and social sustainability.

H6: Socio-economic factors inversely moderate the positive relationship between solar energy and environmental sustainability.

2.4 The Role of Technical Complexities Towards Sustainability

Jun, Qiuzhen, and Qingguo (2011) discussed the organisational contingency theory, which is based on the moderating influence of uncertainty and risk management in the context of project use of new technology. Organizational complexity, uncertainty, dynamic complexity, intra-organizational complexity, marketing complexity, temporary complexity, development complexity, environmental complexity, and structural complexity were all factors captured in a broader spectrum view of project complexities in the literature (Molepo, Marnewick, and Joseph, 2019; Luo et al., 2017). Molepo, Marnewick, and Joseph (2019) went into much detail about the origins of these issues. Organizational complications develop when a project involves a big multidisciplinary team or when numerous organisations interact. The project's technical and design requirements, as well as the project's broad scope, can all contribute to technological complexity. Uncertainties in a project might arise from differences in project costs or in project goals and outcomes. Multiple and frequent changes in the project and management process might lead to dynamic difficulties. Collaboration with other organisations or communication failures between participating businesses can cause intra-organizational complications. Unpredictable market variables, a high level of rivalry, and demand and supply variations can all contribute to marketing difficulties. Unanticipated future limitations, such as changes in government or company ownership, can cause temporal complexity. Poor management of an endeavour or a development plan can lead to development complexity. Environmental concerns linked with the project's location may add to the project's environmental complexity. The project manager's level of control over restricted resources or a lack of top management support for the project may cause structural complexity.

From the review of existing literature carried out in this part of the research, the following hypotheses are developed for this study:

H7: Technical Complexities inversely moderate the positive relationship between solar energy and economic sustainability.

H8: Technical Complexities inversely moderate the positive relationship between solar energy and social sustainability.

H9: Technical Complexities inversely moderate the positive relationship between solar energy and environmental sustainability.

2.5 Research Framework

The literature review has attempted to do justice to the concept of sustainability. It has done an overview of notable definitions cut across time and a variety of researchers. It has outlined empirical theories of sustainability, discussed its models and dimensions, and has zoomed in on the triple bottom line theory. A critical review and synthesis of the literature on sustainability was carried out, upon which a literature gap was drawn for this study. The literature review on solar energy elucidates the imperativeness of a paradigm shift in the solar energy system of urban areas towards sustainability in the selection of energy sources, stating views on solar energy and its distinct characteristics amongst other energy sources.

After a review of the literature relevant to this study, in line with the research objectives, Figure 4 gives a conceptual model of the current study. This framework seeks to establish a direct relationship between solar energy and sustainability, as well as the moderating effect of socio-economic factors and technical complexity.

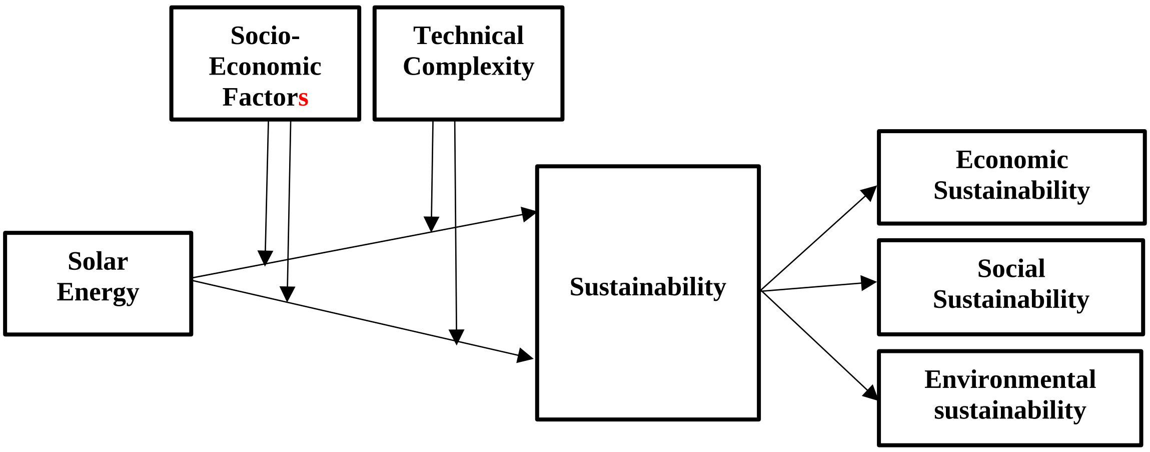

Figure 4: Research Framework

3. Methodology

3.1.Research Design

This study used the Mixed-method strategy to collect the data. The rationale for this strategy is that it provides a comprehensive and all-encompassing data set to achieve the objectives of the research. Also, the use of these two research designs complements one another as well as validates the data collected and the research outcomes. It compensates for the constraints of the primary research method, supplements the core design, makes stronger inferences, and provides a diverse, elaborate, and comprehensive view of the study findings. In a nutshell, these rationales are summed up by the word "triangulation," in which the project study design approaches a design from many angles or perspectives but converges at a point, with various designs confirming one another (Anguera et al., 2018; Levitt et al., 2018).

3.2.Data Collection

3.2.1. Data Collection for Quantitative Study

The quantitative research method used for this study enables the collection of numerical data based on a developed questionnaire. The research generates primary data from a structured outline survey through questionnaires that are digitally distributed. The use of surveys to collect raw data is very suitable for investigating quantifiable variables and can also be used to generate digital data from the respondents of this study.

3.2.1.1 Questionnaire Design

The questionnaire design includes a brief description of the research goals and objectives, as well as certain aspects of ethical considerations such as confidentiality. The questionnaire was managed using Survey Monkey software. The link to the questionnaire was sent to the respondents using the respondents online. The questionnaire was divided into two parts - Part A covers demographic questions, while Part B covers topics related to the research question.

The questionnaire was created using a five-points Likert Scale. The score of the first point is "strongly disagree", the second point score is "Disagree", the third point score is "Neutral", the fourth point score is "Agree", and the fifth point score is "Strongly agree."

The major reason to use the five-point Likert scale instead of the seven-points and nine-point Likert scales is the response rate and response quality increase with it (Babakus & Mangold 1992; Devlin et al., 1993; Hayes, 1992). Moreover, it also helps reducing the respondents' “frustration level”, which in turn results in a good response rate to accept.

3.2.1.2 Measurement of Scales

The questionnaire for this study was developed in line with the research questions and based on six variables (independent, moderating and dependent variables). The independent variable is solar energy; the moderating variables are socio-economic factors and technical complexities, while the dependent variables are the economic dimension of sustainability, the social dimension of sustainability and environmental dimension of sustainability.

Measurement of Solar Energy (SE)

Solar Energy was measured using the scales of El-Khozondar and El-Batta (2018) and Sindhu, Nehra and Luthra (2016). Ten dimensions used include alternative energy, uniqueness, alternative energy, clean energy, carbon footprint, installation cost, increased supply, constant supply, environmental sustainability, economic sustainability social sustainability

Measurement of Socio-economic Factors (SEF)

This is based on the scale of Abrar, Akram and Mahmood, (2021); and Ul-Haq et al. (2020) with four dimensions. They are household income, educational level, household size and age.

Measurement of Technical Complexities (TC)

Technical Complexities is based on the scale of Barki et al. (1993); and Wallace et al. (2004) They comprise three dimensions, technology, technical complexities, and new technology.

Measurement of Economic Sustainability (ES)

This is based on the scale of Maqbool (2018), O'Brien et al., (2015) and Wu ~~Yuen~~ et. a~~A~~l (2021). It has nine dimensions, including cost, affordability, billing, employment, business cost, initial installation rate, revenue generation, subvention, and gross domestic product.

Measurement of Social Sustainability (SS)

It is based on the studies of Hussain et al. (2021) Garnett et al. (2017) and Liu et al. (2018). It has eight dimensions, namely, community involvement, employment, social engagements, urbanization, risk assessment, awareness, social amenities, and quality of life.

Measurement of Environmental Sustainability (ENV)

Is based on scales from Levaggi et al. (2020) and Ahmadi et al., (2020) with twelve dimensions. These are environmental sustainability, carbon footprint, health, noise pollution, air pollution, smell pollution, dust pollution, water pollution, emission reduction, clean energy, health impact, and environmental friendliness.

3.2.1.3 Sampling Technique

Probability or non-probability sampling methods are commonly used for research sampling (Singh and Singh, 2018). In probability sampling techniques, all elements or members of the population have the same probability of being selected in the sample, while in non-probability sampling techniques, there is no equal opportunity. The sample was generated using purposeful snowball sampling techniques to get quality responses for this study.

The sample population was industry professionals and academic researchers. The sample size for this study is 227 respondents spread all over Africa.

3.2.2. Data Collection for Qualitative Study

Data Collection was through email discussions, on-site measurements and local documents. The case study for this research is a solar powered ITC center located in Kogi State Polytechnic, Lokoja, Nigeria

3.3.Method of Data Analysis

3.3.1. Analysis of Quantitative Data

Reliability analysis was carried out using the Cronbach's alpha. Moreover, Correlation Analysis was also carried out to evaluate the strength of the relationships between the variables. Also, the moderation variables were analyzed in SPSS using hierarchical regression analysis (Golhar, Choudhari, and Patil, 2021).

3.3.2. Qualitative Study Analysis

The generalization technique is used in the analysis of this case study, which is more analytical and cognitive than statistical, founded on the principles of reasoning (Hayes and Heit, 2018). Based on evidence from the case, the study will adopt the naturalistic generalization through which, the researcher can consider the investigated case as a microcosm of a larger system macrocosm.

4. Research Findings

The purpose of this section is to present the results of the online questionnaire as well as the results of the case study method used. Also, data analysis is a necessary and vital component of any research investigation in order for researchers to make sense of the data obtained. This section also presented the different analysis techniques carried out on the collected data and the findings are presented.

4.1.Quantitative Study Data Presentation and Analysis

4.1.1. Data Compilation and Screening

Before undertaking any statistical study, it is important to first ensure that the obtained data is clean by screening it to ensure that it is usable, reliable, and valid (Ouassou and Jensen, 2019). Results collected from the online questionnaire using jotform,com were exported to Ms Excel and imported to SPSS 26. In the screening of data, four rows were removed from the dataset as a result of blank data of up to 30 percent of the row. Also, for two rows where data was missing, an average of data entry was taken to prevent blank entry. This was done using the “BLANKCOUNT” command in MS Excel.

Outliers such as unengaging respondents were removed from the dataset. The data set was checked for any unengaged response by taking a standard deviation of the various rows. Two cases of unengaged responses were removed as the respondent answered to “agree” on every item on the Likert scale.

4.1.2. Demographic Analysis

The demographic information is collected in the first section of the questionnaire utilised in the study. Researchers collect demographic data to describe the persons or organisations in their study on a regular basis. These data are presented in the form of a narrative, a table, charts, or graphs, with basic frequency statistics utilised in the analysis (Connelly, 2013).

In the current research, the respondents are asked four demographic questions such as age, gender, highest academic qualification, and job designation. This is because the study requires a more tailored response. A frequency and descriptive statistics of the demographic variables are done using SPSS and the results presented in Table 1 and Figures 5 to 8.

Table 1: Respondents Demographic Statistics

Item	Category	Frequency (227)	Percent
Gender	Male	147	64.76
	Female	80	35.24
Years of work experience	1-5 years	39	17.2
	6-10 years	103	45.4
	11-15 years	28	12.3
	16-20 years	21	9.3
	21-25 years	18	7.9
	25-Above years	18	7.9
Job Designation	Director	17	7.5
	General Manager	22	9.7
	Line Manager	19	8.4
	Researcher	137	60.4
	Post Graduate Researcher	30	13.2
	Other	2	.9
Qualification of Respondents	Degree	52	22.9
	Masters/PhD	175	77.1

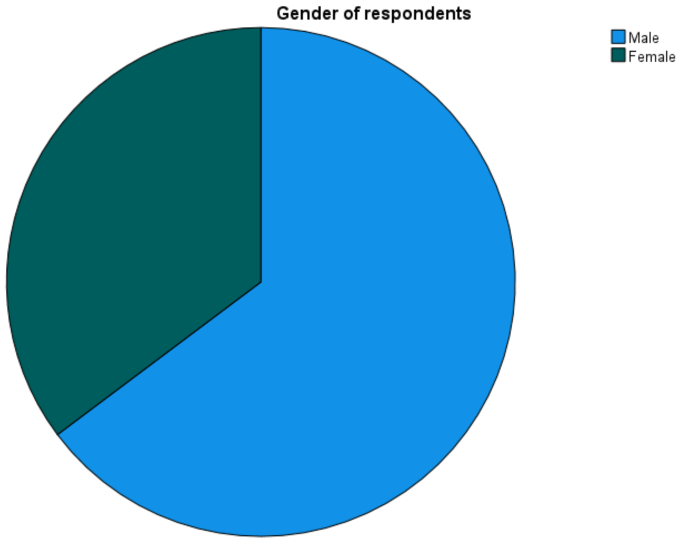

Figure 5: Gender of respondents

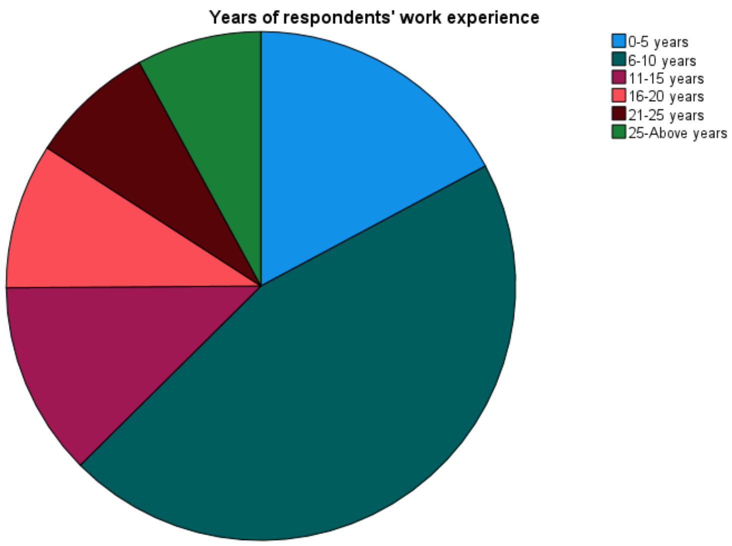

Figure 6: Years of respondents' work experience

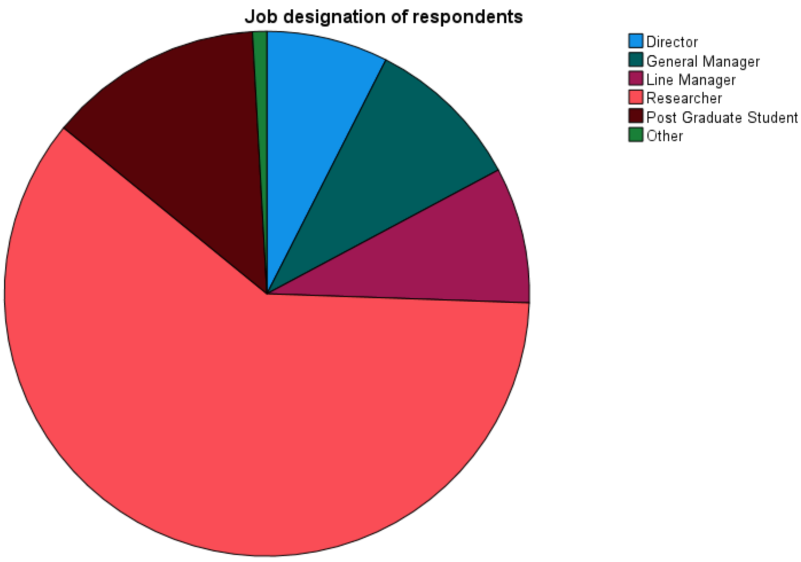

Figure 7: Job designation of respondents

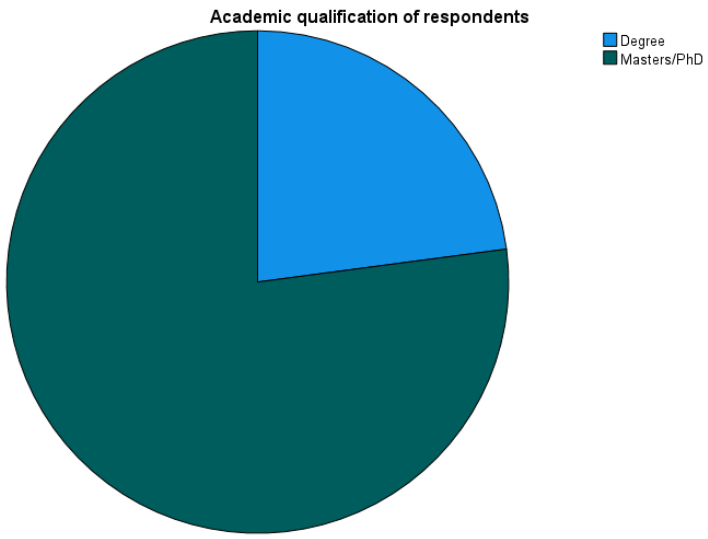

Figure 8: Academic qualification of respondents

4.1.3. Reliability and Validity Analysis

Reliability analysis was carried out using Cronbach's Alpha in SPSS using measured variables. The result of the Cronbach's Alpha for this research is 0.94 which is excellent as per the acceptance range in the literature and threshold guidelines (Taber, 2018; Tsang, Royse and Terkawi, 2017).

Table 2 shows the descriptive statistics for demographic variables done using SPSS 26.

Table 2: Descriptive Statistics

Factor	Cronbach's Alpha	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
CE	0.820	4.07	.556	.310	-.999	.162	4.233	.322
POL	0.867	4.17	.525	.275	-.902	.162	2.717	.322
SEF	0.846	2.3678	.45194	.204	.811	.162	2.153	.322
TC	0.116	3.9236	.75130	.564	-.732	.162	.774	.322
ES	0.713	4.0514	.51464	.265	-.281	.162	.406	.322
SS	0.783	4.2638	.60007	.360	-1.511	.162	4.593	.322
ENV	0.895	4.2287	.54146	.293	-.975	.162	2.968	.322

Factor Analysis is important for testing hypotheses, accounts for measurement error, and allows for testing complex multivariate models, Factor analysis for this study was done using varimax rotation with Kaiser normalization to group all the independent, mediating, moderating and dependent variables. The commonality value was found to be over 0.5 for all the variables, so accordingly all were retained for performing the data analysis. The lowest commonality value was found for Technical Complexity (TC) which had a value of 0.515, which is still within the acceptable range. All the retained values are shown in Table 4 and the scree plot in Figure 9. Similarly, the KMO and Bartlett's test was also performed which highlights the acceptable values, as shown in Table 3.

Table 3: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.853
Bartlett's Test of Sphericity	Approx. Chi-Square	1042.425
	df	28
	Sig.	.000

Table 4 highlights the communalities of factors involved in this research.

Table 4: Communalities

Factor	Initial	Extraction
SE	1.000	.659
CE	1.000	.704
POL	1.000	.749
SEF	1.000	.824
TC	1.000	.515
ES	1.000	.767
SS	1.000	.686
ENV	1.000	.704
Extraction Method: Principal Component Analysis.		

Figure 9 highlights the scree plot of the factors involved in this research.

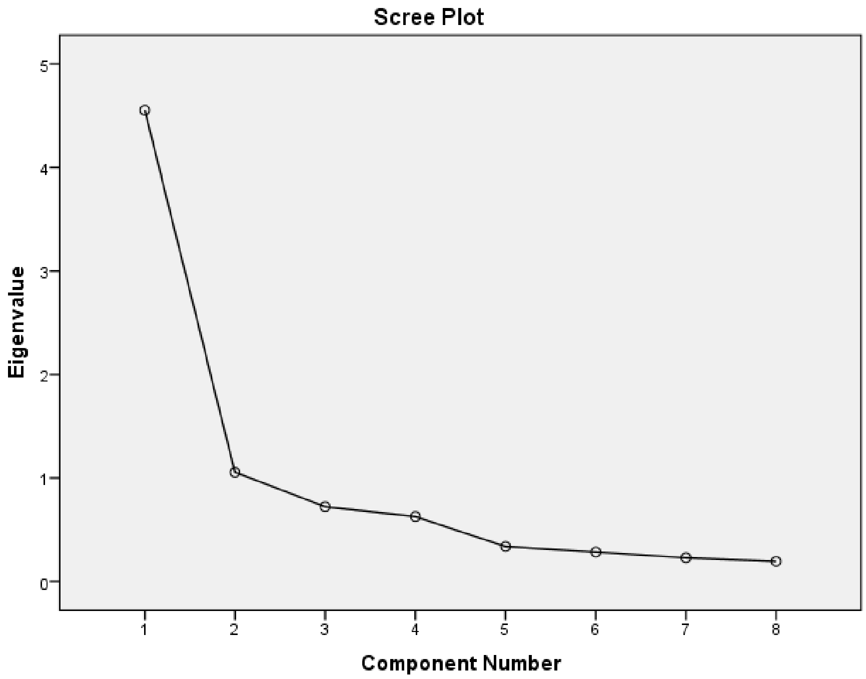

Figure 9: Scree Plot

4.1.4. Correlation Analysis

Correlation analysis was carried out to determine the dependency or statistical relationship between the variables. Table 5 shows the results of the correlation carried out on the computed variable. If the P-value or significance value is <0.05 it is meaning that the chance of error is less than 5%, This means the non-significant chance of error, therefore, a strong relationship.

Table 5: Correlation of variables

Correlations						
Factor	SE	SEF	TC	ES	SS	ENV
SE	1	-.053	.272**	.482**	.431**	.372**
SEF	-.053	1	.090	.124	-.076	-.016
TC	.272**	.090	1	.525**	.224**	.289**
ES	.482**	.124	.525**	1	.582**	.564**
SS	.431**	-.076	.224**	.582**	1	.682**
ENV	.372**	-.016	.289**	.564**	.682**	1
**. Correlation is significant at the 0.01 level (2-tailed).						

4.1.5. Hierarchical Regression Analysis

In the hierarchical regression analysis, moderation occurs when the relationship between independent and dependent variables depends on another variable known as the moderating variable, which is used to determine the diminishing impact of moderating variable on the independent and dependent relationships. The dependency or interaction on the moderating variable may be categorical or quantitative (Cohen et al., 2003).

Moderation analysis is carried out in hierarchical regression analysis whereby, the moderator is a third variable that affects the zero-order correlation between the dependent and independent variables, or the value of the slope of the dependent variable on the independent variable. Hierarchical multiple regression analysis determines the moderating analysis to a representation of the interaction between the independent variable and its determinants (Cohen et al., 2003).

4.1.5.1.Moderation Analysis for Economic Sustainability

Moderation Analysis using hierarchical regression analysis in SPSS 26 for the effect of socio-economic factors and technical complexities on economic sustainability was carried out. It was observed that the relationship between solar energy and economic sustainability is largely deviated by the moderating influence of socio-economic factors and technical complexities. The results predict that the socio-economic factors and technical complexities have strong influences on the solar energy choices while contributing to economic sustainability. Better socio-economic conditions technical expertise and availability can provide a guaranteed outcome of economic sustainability through innovative solar energy technologies. The summary of the results is shown in Table 6.

Table 6: Moderation Analysis on Economic Sustainability

Regression Models	**Economic Sustainability**		
Attribute	β-value	t-value	R^2
Model 1			.339
SE	.582***	10.733	
Model 2			.532

SE	.422***	8.639	
SEF	.159***	3.361	
TC	.404***	8.093	
Model 3			.571
SE	.544***	3.213	
SEF	1.495***	4.745	
TC	-.832**	-2.531	
SESEF	-1.662***	-4.266	
SETC	1.607***	3.749	

*p < .10, **p < .05, ***p < .01

Figure 10 and Figure 11 are the slopes, which show the effect of moderation analysis carried out when economic sustainability is the dependent factor. The slop analysis presented in Figure 10 and Figure 11 shows a clear deviation in the relationships between solar energy and economic sustainability after the involvement of the moderating factors of socio-economic factors and technical complexities.

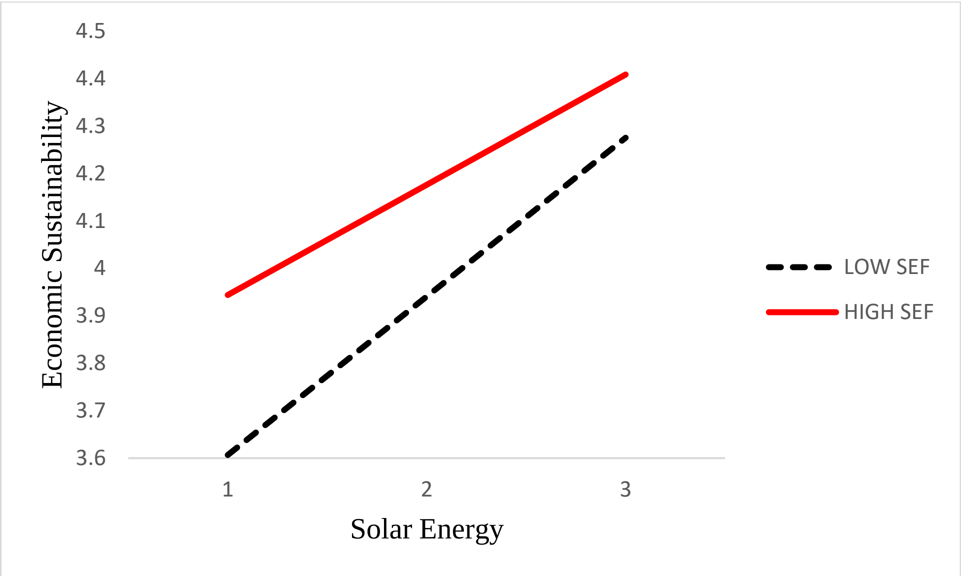

Figure 10: Moderation effect of SEF on Economic Sustainability

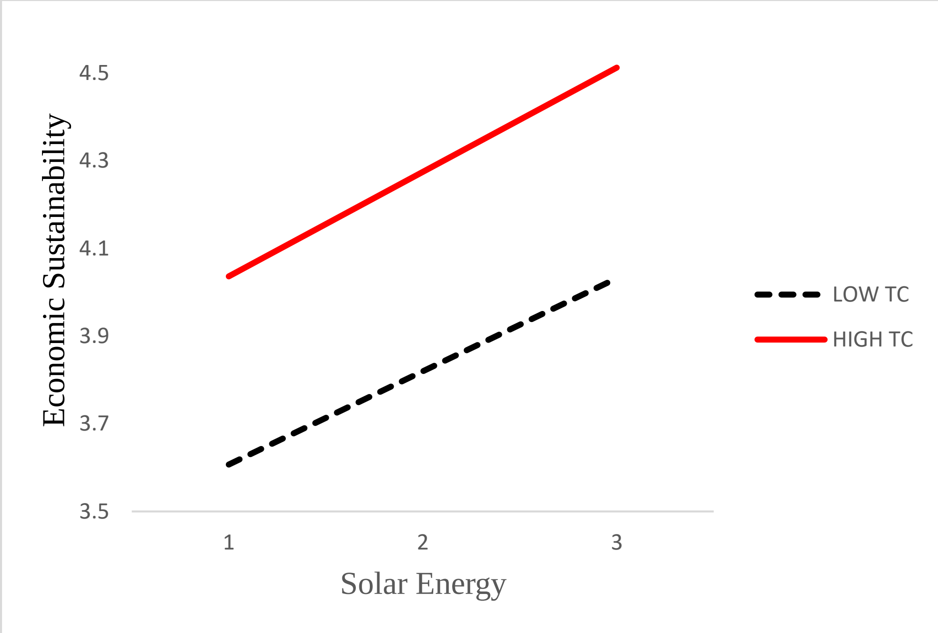

Figure 11: Moderation effect of TC on Economic Sustainability

4.1.5.2.Moderation Analysis for Social Sustainability

Moderation Analysis using hierarchical regression modelling in SPSS 26 for the effect of socio-economic factors and technical complexities on social sustainability was carried out and a summary of the results is shown in Table 7. The relationship between solar energy and social sustainability is largely deviated by the moderating influence of the socio-economic factors, whereas no significant change was observed in the relationship with the involvement of the technical complexities. The results predict that the socio-economic factors have a strong influence on the solar energy choices while contributing toward social sustainability. However, the technical complexities do not seem to be interfering between the solar energy choices and the social sustainability. Reasonable socio-economic conditions can enhance social sustainability through innovative solar energy technologies, and when there is a socio-economic concern, the technical complexities are not considered to be any big issue.

Table 7: Moderation Analysis on Social Sustainability

Regression Models	**Social Sustainability**		
Attribute	β-value	t-value	R^2
Model 1			.300

SE	.547***	9.810	
Model 2			.314
SE	.502***	8.498	
SEF	.027	.474	
TC	.120**	1.992	
Model 3			.359
SE	1.152***	5.571	
SEF	1.315***	3.415	
TC	-.214	-.533	
SESEF	-1.625***	-3.413	
SETC	.398	.760	

*p < .10, **p < .05, ***p < .01

Figure 12 and Figure 13 are the slopes, which show the effect of the moderation analysis carried out when social sustainability is the dependent factor.

The slop analysis presented in Figure 12 shows a clear deviation in the relationships between solar energy and social sustainability after the involvement of the moderating factors of socio-economic factors. Whereas the slop analysis presented in Figure 13 highlights that the technical complexities does not lead to any significant change between the independent factor of solar energy and the dependent factor of social sustainability.

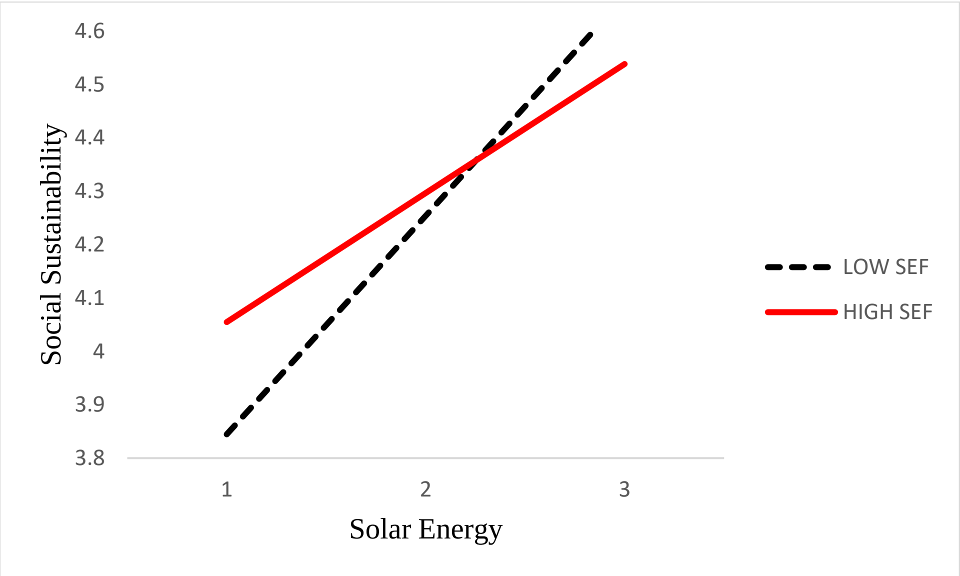

Figure 12: Moderation effect of SEF on Social Sustainability

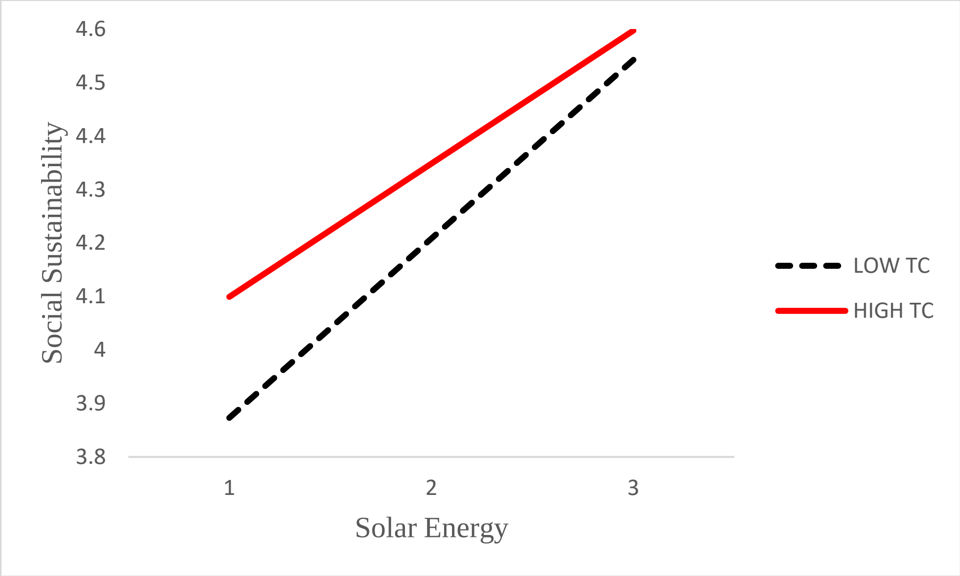

Figure 13: Moderation effect of TC on Social Sustainability

4.1.5.3.Moderation Analysis for Environmental Sustainability

Moderation Analysis using hierarchical regression in SPSS 26 for the effect of socio-economic factors and technical complexities on environmental sustainability was carried out. It was found that the relationship between solar energy and environmental sustainability is largely diverged by the moderating influence of the socio-economic factors, however, no significant change was observed in the relationship with the involvement of the technical complexities. The results predict that the socio-economic factors have a strong influence on the solar energy choices while contributing toward environmental sustainability. However, the technical complexities do not seem to be interfering between the solar energy choices and the environmental sustainability. Reasonable socio-economic conditions can enhance environmental sustainability through innovative solar energy technologies, and when there is a socio-economic concern, the technical complexities are not considered to be any big issue.

The summary of the results is shown in Table 8.

Table 8: Moderation Analysis on Environmental Sustainability

Regression Models	**Environmental Sustainability**		
Attribute	β-value	t-value	R^2
Model 1			.292

SE	.540***	9.634	
Model 2			.335
SE	.464***	7.967	
SEF	.036	.646	
TC	.209***	3.510	
Model 3			.388
SE	1.183***	5.852	
SEF	1.425***	3.789	
TC	-.123	-.313	
SESEF	-1.753***	-3.769	
SETC	.390	.762	

*p < .10, **p < .05, ***p < .01

Figure 14 and Figure 15 are the slopes, which show the effect of the moderation analysis carried out with environmental sustainability as a dependent variable. The slop analysis presented in Figure 14 shows a clear deviation in the relationships between solar energy and environmental sustainability after the involvement of the moderating factors of socio-economic factors. Whereas the slop analysis presented in Figure 15 highlights that the technical complexities does not lead to any significant change between the independent factor of solar energy and the dependent factor of environmental sustainability.

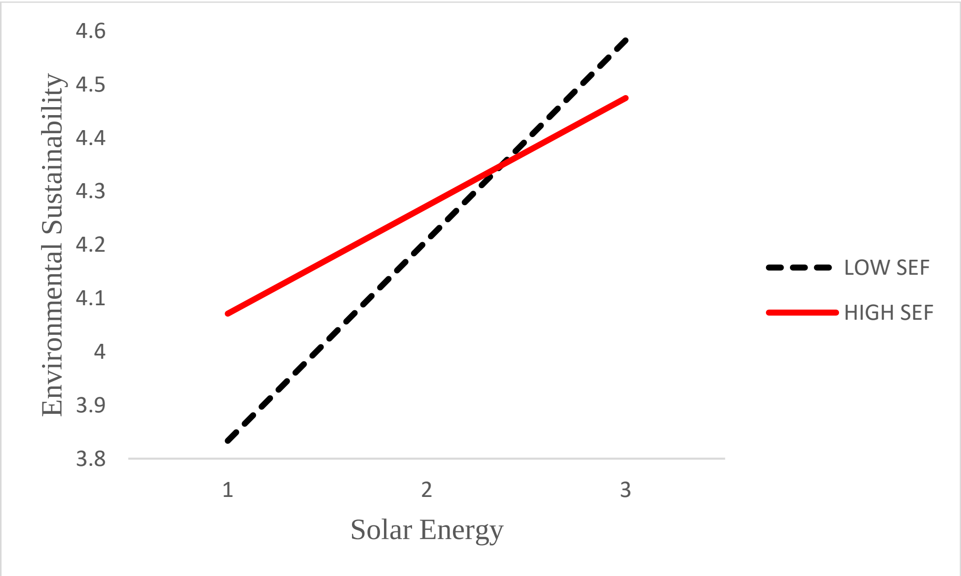

Figure 14: Moderation effect on Environmental Sustainability

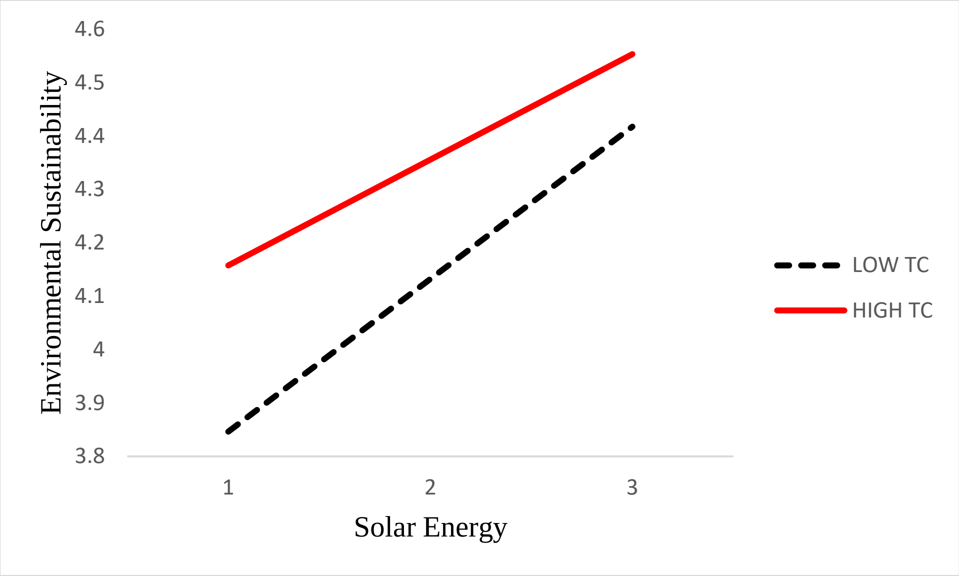

Figure 15: Moderation effect on Environmental Sustainability

The Hierarchical Multiple Regression test on the moderating effect of socio-economic factor show significant p-values (<0.05) for all the sustainability dimensions (economic sustainability, social sustainability, and environmental sustainability). However, the Hierarchical Multiple Regression test shows that the technical complexities only intervene in the relationship between solar energy and economic sustainability, whereas it does not show any moderating influence over social sustainability and environmental sustainability.

4.2.Qualitative Study Result Presentation and Analysis

The case for this study is the ICT centre of Kogi State Polytechnic, Lokoja Kogi State. A Tertiary Education Trust Fund (TETFUND) sponsored solar energy powered computer and internet centre open to academic staff and researchers of the polytechnic.

4.2.1. Photovoltaic Design

A stand-alone PV system was designed with dual function as a car park and its roof was used to support the 12 photovoltaic panels. The entire system includes solar panels, batteries, converters and inverters,

4.2.2. Economic Analysis

The breakdown of the cost of installation for the photovoltaic system is shown in Table 9.

Table 9: Cost of installing the photovoltaic system

No.	Component	Amount (USD)
1	120W monocrystalline Silicon Module	$160
2	Deep Acid Lead battery 83.2Ah	$16
3	Charge controller	$190
4	Inverter (1Kw)	$160
5	Total Cost	

The average daily electricity usage for the ITC centre is estimated at a cost of 0.3USD/Kwh. The average National Grid cost of electricity in Nigeria is put at 0.1USD/Kwh (Enongene et al., 2019). The initial cost of installing and use of the photovoltaic system is more expensive than the national grid. However, with a lifespan of 25 to 30 years, the photovoltaic system will become less expensive.

4.2.3. Environmental Analysis

The life cycle assessment in terms of electricity generation is done to determine the amount of CO^2 emission that is reduced by the solar energy system in the Polytechnic. Data from the amount of CO^2 emitted through national grid electricity generation in Nigeria is 440 gCO^2eq/Kwh (Enongene et al., 2019). The institution of the case study does not have the equipment to measure the average life cycle assessment based on Nordin et al (2020) was used to ascertain the amount of CO^2 emission from the PV system, which is estimated as 161.3 gCO^2eq/Kwh.

To calculate the Emission saved through solar energy use in Kogi State Polytechnic Lokoja (KSPE), subtract the Estimated Emission of PV (EE PV) from the Nigerian Emission rate (NigE) (see Eq 1).

$$KSPE = NigE - EEPV \quad \ldots\ldots\ldots\ldots\ldots (Eq\ 1)$$

$$KSPE = 440 - 161.3 = \ 278.7\ \text{gCO2eq/Kwh}$$

Hence, by installing and use of solar energy, the institution has been able to reduce CO^2 emissions up to 278.7 g CO2eq/Kwh, which highlights the significant benefits of the usage of solar energy from the environmental sustainability perspective.

5. Discussion

This study began with a model proposing that solar energy has a direct effect on the various facets of sustainability, it also proposes a moderation impact of socio-economic factors and technical complexities on solar energy and sustainability. From the demographic variables in this research, the finding on gender (Table 1) show that 64.5% of the respondents are male while 35.2% and female. This shows a fairly balanced gender representation in this study. Also, from the years of work experience (Table 1), most of the respondents representing 45.4% have between 6 to 10 years of experience. This shows that the respondents have a substantial experience in their respective jobs making the result of this study valid. From table 3 on job description, 137 respondents representing 60.4% are researchers, 13.2% are postgraduate researchers, 9.7% are general managers, 8.4% are line managers, 7.5% are directors with 0.9% who have chosen not stated their job role as other. The level of academic qualification of respondents (Table 1) favour this study, as 77.1% have Master's degree or a PhD, while 22,9% who have a first degree. Similarly, the Cronbach's Alpha analysis shows a high value of 0,942 which indicates strong reliability of the result of this study. The Pearson Correlation (Table 5) indicate a strong correlation between most of the variable, which is also a positive reflection of the findings of this study.

5.1.Role of Solar Energy on Economic Sustainability

Results from the direct relationship analysis (detailed result available in section 4) has indicated a strong positive direct relationship between solar energy and economic sustainability as seen in the result presented in section 4. Thus, these findings go in the favour of the hypothesis H1, as;

H1: Solar energy has a positive effect on economic sustainability.

The findings of this study are in line with the findings of Luckett and Needham (2021), who is of a similar view that solar energy can build strong and diverse economic benefits. They agree that solar energy is sustainable, emphasizing the eminent energy transition to solar energy sources, which they described as feasible and achievable. Solar energy consumption would help to meet the energy need as well as achieve the sustainable development goal of cheap, assessable and clean energy that results in the wellbeing of all. There is a concern in the study of Kabir et al. (2018) about the initial high cost of installation of photovoltaic systems. This view is in tandem with the result of the case study analysis carried out in this present study. However, with a life span of about 25 to 30 years, the overall long-term gains and long run economic advantages make solar energy economically sustainable. In addition, there is the “ripple effect” gains of job creation and triggering economic activities in urban communities.

5.2.Role of Solar Energy on Social Sustainability

Results from the direct relationship analysis (detailed result available in section 4) has indicated a strong positive direct relationship between solar energy and economic sustainability as seen in the regression analysis findings. Also, the p-value is <0.05 which shows a significant impact of solar energy on social sustainability. Moreover, positive and significant correlation was also observed between the solar energy and social sustainability dimension. So, the hypothesis H2 is accepted by the findings of the regression analysis, as;

H2: Solar energy has a positive effect on social sustainability.

The findings of this study are in line with Geall and Shen (2018) who advanced the benefits of solar energy to communities such as rural electrification, social involvement, and improvement of quality of life for urban dwellers.

These findings are also in line with the study of Abrar, Akram and Mahmood (2021). However, at the same time, it implies that the age of household members, sexual orientation, employment status and academic qualification are not determinants of solar energy sustainability in any of the three dimensions – economic, social, and environmental.

5.3.Role of Solar Energy on Environmental Sustainability

The regression findings also highlight that the relationship in between solar energy and environmental sustainability is significant at $p<0.05$. These findings predict that solar energy also contributes to bringing environmental sustainability. The correlation analysis between solar energy and environmental sustainability was also found significant. Thus, the hypothesis H3, which shows a direct relationship between the solar energy and environmental sustainability, is accepted, as;

H3: Solar energy has a positive effect on environmental sustainability.

Similar findings were also observed in the case study of the ITC centre powered by solar energy in an academic institution in Nigeria, which reveals a 278.7 g CO^2eq/Kwh reduction in carbon footage as a result of solar energy usage. The direct relationship in the regression analysis (detailed result available in section 4) is also strong for the factor. Solar energy is clean of air, water and land pollution (Lewis, 2016).

5.4. Role of Socio-economic Factors and Technical Complexities on Economic Sustainability

From the hierarchical regression analysis (detailed result available in section 4) carried out, the hypothesis (H4) that proposes that socio-economic factors inversely moderate the positive relationship between solar energy and economic sustainability was accepted. Similarly, the hypothesis (H7) that Technical Complexities inversely moderate the positive relationship between solar energy and social sustainability was also accepted. Thus, the following hypotheses are accepted;

H4: Socio-economic factors inversely moderate the positive relationship between solar energy and economic sustainability.

H7: Technical Complexities inversely moderate the positive relationship between solar energy and economic sustainability.

This is evidenced by significant p-values (see Table 6) in the hierarchical regression analysis. The inverse impacts of socio-economic factors and technical complexities in between solar energy and economic sustainability were also highlighted in the slope analysis in Figure 10 and Figure 11. So, the socio-economic and technical challenges are the key hindrance factors to economic growth in developing African countries. This assertion is particularly important in Africa and other developing countries where rural electrification is challenging as most of the population does not have access to the national grid (Lee and Shepley, 2020).

5.5. Role of Socio-economic Factors and Technical Complexities on Social Sustainability

The hierarchical regression analysis (detailed result available in Table 7) carried out in this study, with the hypothesis (H5) that proposes that socio-economic factors inversely moderate the positive relationship between solar energy and social sustainability was accepted, as;

H5: Socio-economic factors inversely moderate the positive relationship between solar energy and social sustainability.

The inverse impact of socio-economic factors between solar energy and social sustainability is also highlighted in the slope analysis presented in Figure 12.

However, the hypothesis (H8) that technical complexities inversely moderate the positive relationship between solar energy and social sustainability was not accepted. The slope analysis presented in Figure 13, also highlighted that there is not any significant inverse impact of technical complexities in between the impact of solar energy on social sustainability. The work of Wallace et al. (2004) agrees with this finding. This means that technical complexities though impact solar energy but do not significant negative changes to the adoption of solar energy sustainability.

5.6. Role of Socio-economic Factors and Technical Complexities on Environmental Sustainability

H9: Technical Complexities inversely moderate the positive relationship between solar energy and environmental sustainability.

These findings of the hierarchical regression analysis depict that, socio-economic factors inversely moderate the relationship between solar energy and environmental sustainability. The inverse impact of socio-economic factors between solar energy and environmental sustainability was also highlighted in the slope analysis presented in Figure 14.

Thus, hypothesis H6 is accepted, which is as;

H6: Socio-economic factors inversely moderate the positive relationship between solar energy and environmental sustainability.

Hypothesis H9, which proposed that technical complexities inversely moderate the positive relationship between solar energy and environmental sustainability was not accepted. Similarly, there is no significant inverse moderating role of technical complexities was observed between the solar energy and environmental sustainability by the slope analysis presented in Figure 15. It predicts that in order to gain the environmental sustainability the influence of socio-economic factors is rather put more harmful impacts on the environmental dimension of sustainability compared to any sort of inverse impact of technical complexities. Thus, H6 is accepted, however, is not found to be accepted on the significant level of $P<0.05$.

6. Conclusion

This study concludes that there is a direct positive relationship between solar energy and all dimensions of sustainability. The study was drawn based on a thorough literature review to propose a conceptual model to test and validate in this research. The research was conducted using the mixed-method approach, consisting of quantitative and qualitative data. The quantitative data was based on survey data of 227 African professionals working in the energy industry, contacted through a snowball approach. Whereas in order to validate and take the qualitative view, a review of a case study in African based was also done, the case study was of an ITC centre powered by solar energy in an academic institution in Nigeria. The quantitative data was analysed by the hierarchical regression analysis through SPSS 26, which also provides a direct linkage between solar energy and dimensions of sustainability. Moreover, the inversely moderating influence of socio-economic factors and technical complexities in between the solar energy and sustainability dimensions was also measured.

The findings highlight that solar energy has a direct and significant impact on economic, social and environmental sustainability. So, it means solar energy is a cheap and environmentally friendly source of energy which can meet the needs of developing countries while not compromising on any sort of environmental aspects. Through the hierarchical multiple regression analysis, it was also observed that socio-economic factors inversely moderate the positive relationship between solar energy and all the dimensions of sustainability (economic sustainability, social sustainability and environmental sustainability). So, the findings predict the importance of socio-economic conditions in the communities of developing African and other developing countries. In order to gain a real sustainability in all aspects of economic, social and environmental dimensions, the socio-economic conditions need to be better placed for the general public living in these communities. It can rightly say that the sustainability of any community is well linked to its socio-economic conditions.

Finally, the study establishes that technical complexities inversely moderate only in between the relationship between solar energy and economic sustainability, and no significant impact of technical complexities was observed on social sustainability and environmental sustainability. So, it can be seen that when there is an intention to gain sustainability in any developing community, technical complexities do not prevail over any serious sort of challenge. These findings were also validated by the case study analysis of ITC centre powered by solar energy in an academic institution in Nigeria. Where the center has successfully reached its sustainability targets with no pressure of any sort of technical difficulties. So, it can be the rightly pose that in order to gain sustainability the socio-economic conditions are the major pre-requisites to meet rather than being worried about technical and innovative technologies.

List of Abbreviations

CO_2 = Carbon Dioxide

ENV = Environmental Sustainability

ES = Economic Sustainability

GW = Gigawatts

H = Hypothesis

IEA = International Energy Agency

KMO = Kaiser-Meyer-Olkin

Kwh = Kilowatt hours

MW = Megawatt

PV = Photovoltaic

SE = Solar Energy

SEF = Socio-economic Factors

SPSS = Statistical Package for the Social Sciences

SS = Social Sustainability

Std. Error = Standard Error

TC = Technical Complexities

TETFUND = Tertiary Education Trust Fund

UN = United Nations

USD = US Dollar

$ = Dollar

References

Abrar ul Haq, M., Akram, F. and Mahmood Malik, H.A., 2021. Impact of Renewable Energy Usage on Household Energy Cost: A Moderating Role of Demographic Factors. *International Journal Of Computing and Digital System*.

Agyekum-Mensah, G., Knight, A. & Coffey, C. (2012), 4Es and 4 Poles model of sustainability: Redefining sustainability in the built environment, *Structural Survey*, *30*(5), 426-442. https://doi.org/10.1108/02630801211288206

Ahmadi, A., Esmaeilion, F., Esmaeilion, A., Ehyaei, M.A. and Silveira, J.L. (2020) Benefits and limitations of waste-to-energy conversion in Iran. *Renewable Energy Research and Application*, *1*(1), pp.27-45.

Anguera, M.T., Blanco-Villaseñor, A., Losada, J.L., Sánchez-Algarra, P. and Onwuegbuzie, A.J. (2018) Revisiting the difference between mixed methods and multimethods: Is it all in the name?. *Quality & Quantity*, *52*(6), pp.2757-2770.

Babakus, E., & Mangold, W. G. (1992). Adapting the SERVQUAL scale to hospital services: an empirical investigation. *Health services research, 26*(6), 767-786.

Barki, H., Rivard, S., Talbot, J. (1993) Toward an assessment of software development risk. Journal of Management Information Systems 10 (2), 203–225.

Bocken, N. M., & Geradts, T. H. (2020). Barriers and drivers to sustainable business model innovation: Organization design and dynamic capabilities. *Long Range Planning*, *53*(4), 101950.

Brockhaus S., Fawcett S., Knemeyer A., and Fawcett A. (2017) "Motivations for environmental and social consciousness: Reevaluating the sustainability-based view", Journal of Cleaner Production, Vol. 143, pp. 933-947.

Castillo, C.P., Silva, F.B., & Lavalle, C. (2016). An assessment of the regional potential for solar power generation in EU-28. *Energy Policy, 88,* 86–99.

Cohen, Jacob; Cohen, Patricia; Leona S. Aiken; West, Stephen H. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences*. Hillsdale, N.J: L. Erlbaum Associates. ISBN 0-8058-2223-2.

Connelly, L.M. (2013). Demographic data in research studies. *Medsurg Nursing*, *22*(4), pp.269-271.

de Souza Grilo, M.M., Fortes, A.F.C., de Souza, R.P.G., Silva, J.A.M. and Carvalho, M. (2018) Carbon footprints for the supply of electricity to a heat pump: Solar energy vs. electric grid. *Journal of Renewable and Sustainable Energy*, *10*(2), p.023701.

Devlin, S. J., Dong, H. K., & Brown, M. (1993). Selecting a scale for measuring quality. *Marketing research*, *5*(3), 12-17.

El-Khozondar, H.J. and El-Batta, F. (2018) Solar Energy as an alternative to conventional energy in Gaza Strip: Questionnaire based study. *An-Najah University Journal for Research-A (Natural Sciences)*, *32*(32 (1)).

Energysage. (2016). *How Much Does the Average Solar Panel Installation Cost in the U.S*. Accessed on March 2016 at https://news.energysage.com/how-much-does-the-average-solar-panel-installation-cost-in-the-u-s/

Energysage. (2022). *How much do solar panels cost in 2022?* Accessed on 15 June 2022 at https://news.energysage.com/how-much-does-the-average-solar-panel-installation-cost-in-the-u-s/

Enongene, K.E., Abanda, F.H., Otene, I.J.J., Obi, S.I. and Okafor, C. (2019) The potential of solar photovoltaic systems for residential homes in Lagos city of Nigeria. *Journal of environmental management*, *244*, pp.247-256.

Garnett, K., Cooper, T., Longhurst, P., Jude, S., & Tyrrel, S. (2017). A conceptual framework for negotiating public involvement in municipal waste management decision-making in the UK. *Waste Management*, *66*, 210-221.

Geall, S. and Shen, W. (2018) Solar energy for poverty alleviation in China: state ambitions, bureaucratic interests, and local realities. *Energy research & social science*, *41*, pp.238-248.

GNESD. (2007). *Reaching the Millennium Development Goals and Beyond: Access to Modern Forms of Energy as a Prerequisite*. Roskilde, Denmark: Global Network on Energy for Sustainable Development (GNESD).

Golhar, A.R., Choudhari, N.K. and Patil, A.K. (2021) May. Prediction of aluminium content in a metal using SPSS based linear regression analysis. In *Journal of Physics: Conference Series* (Vol. 1913, No. 1, p. 012002). IOP Publishing.

Görig, M., & Breyer, C. (2016). Energy learning curves of PV systems. *Environmental Progress & Sustainable Energy, 35*(3), 914-923.

Grubler, A., Bai, X., Buettner, T., Dhakal, S., Fisk, D.J., Ichinose, T., Keirstead, J.E., Sammmer, G., Satterthwaite, D., Schulz, N.B. and Shah, N. (2012) Urban energy systems.

Hayes, B.E. (1992). Measurement Customer Satisfaction: Development and Use of Questionnaire, ASQC Quality Press, Milwaukee, WI.

Hayes, B.K. and Heit, E. (2018). Inductive reasoning 2.0. *Wiley Interdisciplinary Reviews: Cognitive Science*, *9*(3), p.e1459.

Heath, G.A., Silverman, T.J., Kempe, M., Deceglie, M., Ravikumar, D., Remo, T., Cui, H., Sinha, P., Libby, C., Shaw, S. and Komoto, K. (2020) Research and development priorities for silicon photovoltaic module recycling to support a circular economy. *Nature Energy*, *5*(7), pp.502-510.

Hermann, S., Miketa, A., & Fichaux, N. (2014). Estimating the renewable energy potential in Africa: A GIS-based approach. Working Paper 70. Accessed on March 2016 at http://www.irena.org/DocumentDownloads/Publications/IRENA_Africa_Resource_Potential_Aug2014.pdf

Howes, M., Wortley, L., Potts, R., Dedekorkut-Howes, A., Serrao-Neumann, S., Davidson, J., Smith, T. and Nunn, P. (2017) Environmental sustainability: a case of policy implementation failure?. *Sustainability*, *9*(2), p.165.

Hussain, S., Xuetong, W., Maqbool, R., Hussain, T. and Shahnawaz, M., 2021. The influence of government support, organizational innovativeness and community participation in renewable energy project success: A case of Pakistan. *Energy*, p.122172.

International Energy Agency (IEA). (2020). Solar PV – Analysis. Accessed on September 13, 2021, at https://www.iea.org/reports/solar-pv

Irhoma, A. (2017) *Development of a sustainability management system for petroleum companies*. Nottingham Trent University (United Kingdom).

Jenkins, W. (2016) Sustainability theory. *Berkshire Encyclopedia of sustainability.* Oxford University Press *1*(1), pp.380-384.

Jónasdóttir, S.K., Hand, C., Misener, L. and Polgar, J. (2018) Applying case study methodology to occupational science research. *Journal of Occupational Science*, *25*(3), pp.393-407.

Jun, L., Qiuzhen, W., & Qingguo, M. (2011). The effects of project uncertainty and risk management on IS development project performance: A vendor perspective. *International Journal of Project Management, 29*(7), 923-933.

Kabir, E., Kumar, P., Kumar, S., Adelodun, A.A. and Kim, K.H. (2018) Solar energy: Potential and future prospects. *Renewable and Sustainable Energy Reviews, 82*, pp.894-900.

Kratschmann, M., & Dütschke, E. (2021). Selling the sun: A critical review of the sustainability of solar energy marketing and advertising in Germany. *Energy Research & Social Science, 73*, 101919.

Lee, J. and Shepley, M.M (2020) Benefits of solar photovoltaic systems for low-income families in social housing of Korea: Renewable energy applications as solutions to energy poverty. *Journal of Building Engineering*, *28*, p.101016.

Levaggi, L., Levaggi, R., Marchiori, C., & Trecroci, C. (2020). Waste-to-Energy in the EU: The effects of plant ownership, waste mobility, and decentralization on environmental outcomes and welfare. *Sustainability, 12*(14), 5743.

Levitt, H.M., Bamberg, M., Creswell, J.W., Frost, D.M., Josselson, R. and Suárez-Orozco, C. (2018) Journal article reporting standards for qualitative primary, qualitative meta-analytic, and mixed methods research in psychology: The APA Publications and Communications Board task force report. *American Psychologist*, *73*(1), p.26.

Lewis, N.S. (2016) Research opportunities to advance solar energy utilization. Science, 351(6271), p.aad1920.

Liu, S. and Yan, M.R. (2018) Corporate Sustainability and Green Innovation in an Emerging Economy—An Empirical Study in China. Sustainability, 10(11), p.3998.

Luckett, R. and Needham, C. (2021) Marketing Strategies to Use Solar Energy in Homes. *Open Journal of Business and Management*, *9*(6), pp.2950-2976.

Luo, L., He, Q., Xie, J., Yang, D., & Wu, G. (2017). Investigating the relationship between project complexity and success in complex construction projects. *Journal of Management in Engineering*, *33*(2), 04016036.

Lyon, C., Cordell, D., Jacobs, B., Martin-Ortega, J., Marshall, R., Camargo-Valero, M. A., & Sherry, E. (2020). Five pillars for stakeholder analyses in sustainability transformations: The global case of phosphorus. *Environmental science & policy, 107,* 80-89.

Maqbool, R. (2018). Efficiency and effectiveness of factors affecting renewable energy projects; an empirical perspective. *Energy, 158*, pp.944-956. https://doi.org/10.1016/j.energy.2018.06.015

Maqbool, R., & Amaechi, I. E. (2022). A systematic managerial perspective on the environmentally sustainable construction practices of UK. *Environmental Science and Pollution Research*, 1-18. https://doi.org/10.1007/s11356-022-20255-5

Maqbool, R., & Jowett, E. (2022). Conserving a sustainable urban environment through energy security and project management practices. *Environmental Science and Pollution Research*.

Maqbool, R., Rashid, Y., & Ashfaq, S. (2022). Renewable energy project success: Internal versus external stakeholders' satisfaction and influences of power-interest matrix. *Sustainable Development*. https://doi.org/10.1002/sd.2327

Molepo, P. M., Marnewick, A., & Joseph, N. (2019, June). Complexity factors affecting research and development projects duration. In *2019 IEEE Technology & Engineering Management Conference* (TEMSCON) (pp. 1-6). IEEE.

Muhammed, G., & Tekbiyik-Ersoy, N. (2020). Development of renewable energy in China, USA, and Brazil: A comparative study on renewable energy policies. *Sustainability, 12*(21), 9136.

Nordin, A. H. M., Sulaiman, S. I., Shaari, S., & Mustapa, R. F. (2020). Life-cycle assessment of residential-scale grid-connected photovoltaic system in Malaysia based on monocrystalline silicon modules. *International Journal of Power Electronics and Drive Systems, 11*(2), 677.

O'Brien, M., Schütz, H., & Bringezu, S. (2015). The land footprint of the EU bioeconomy: Monitoring tools, gaps and needs. *Land Use Policy, 47,* 235-246.

Ouassou, M. and Jensen, A.B. (2019) Network real-time kinematic data screening by means of multivariate statistical analysis. *SN Applied Sciences*, *1*(6), pp.1-19.

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering, 3*(1), 1167990.

Rigo, P.D., Siluk, J.C.M., Lacerda, D.P., Rosa, C.B. and Rediske, G. (2019) Is the success of small-scale photovoltaic solar energy generation achievable in Brazil?. Journal of Cleaner Production, p.118243.

Sengupta, M., Habte, A., Wilbert, S., Gueymard, C., & Remund, J. (2021). *Best practices handbook for the collection and use of solar resource data for solar energy applications* (No. NREL/TP-5D00-77635). National Renewable Energy Lab. (NREL), Golden, CO (United States).

Shahsavari, A. and Akbari, M. (2018) Potential of solar energy in developing countries for reducing energy-related emissions. Renewable and Sustainable Energy Reviews, 90, pp.275-291.

Sharif, A., Meo, M.S., Chowdhury, M.A.F. and Sohag, K., 2021. Role of solar energy in reducing ecological footprints: An empirical analysis. *Journal of Cleaner Production*, *292*, p.126028.

Sindhu, S., Nehra, V. and Luthra, S., 2016. Identification and analysis of barriers in implementation of solar energy in Indian rural sector using integrated ISM and fuzzy MICMAC approach. *Renewable and Sustainable Energy Reviews*, *62*, pp.70-88.

Singh, S. and Singh, S. (2018) Sampling techniques. Journal of Indian Statisticak Association. Vol 32. Pp 71-75.

Sukhatme, S.P. and Nayak, J.K. (2017) Solar energy. McGraw-Hill Education.

Taber, K.S. (2018) The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education*, *48*(6), pp.1273-1296.

Thatcher, A. (2014) August. Theoretical definitions and models of sustainable development that apply to human factors and ergonomics. In *Human factors in organizational design and management. XI Nordic Ergonomics Society Annual Conference* (Vol. 46).

Todorov, V., & Marinova, D. (2009). Models of sustainability. In *Proceedings of MODSIM 2009 International Congress on Modelling and Simulation*. The Modelling and Simulation Society of Australia and New Zealand.

Tsang, S., Royse, C. F., & Terkawi, A. S. (2017). Guidelines for developing, translating, and validating a questionnaire in perioperative and pain medicine. *Saudi journal of anaesthesia*, *11*(Suppl 1), S80.

Ul-Haq, M.A., Malik, H.A., Akram, F. and Al Mutawa, E.K., 2020, December. Monetary Benefits of Solar Energy for Smart Cities Development. In *2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT)* (pp. 1-5). IEEE.

UNECE (2017) Energy for Sustainable Development in the UNECE Region. United Nations Economic Commission for Europe Geneva 2017.

Van Zon H. (2002). *Geschiedenis & duurzame ontwikkeling. Duurzame ontwikkeling in historisch perspectief: Enkele verkenningen* [History & sustainable development. Sustainable development in a historical perspective: Some explorations]. Nijmegen/Groningen: Werkgroep disciplinaire verdieping duurzame ontwikkeling.

Wagner, M. (2015). The link of environmental and economic performance: Drivers and limitations of sustainability integration. *Journal of Business Research*, *68*(6), 1306-1317.

Wallace, L., Keil, M., Rai, A. (2004) How software project risk affects project performance: an investigation of the dimensions of risk and exploratory model. Decision Sciences 35 (2), 289–321.

Wu, X., Zhuang, Y., Bai, W., Zhou, Y., & Wang, Y. (2021). Optimal Subsidy Policy for Green Energy Trading Among Three Parties: A Game Theoretical Approach. *IEEE Access*, *9*, 86321-86330.