JOURNAL OF INTERNATIONAL CRISIS AND RISK COMMUNICATION RESEARCH
ISSN: 2576-0017
2024, VOL 7, NO 3

Estimating the Socio-Economic Impacts of Renewable Energy Systems in Low-Income Housing: Observations, Al-Suwaidi District in Riyadh, Saudi Arabia

Zeinab A. Elhassan[1], Samaher A. Fallatah[2] and Renad Alsekait[2]

1. Faculty of Architecture and Design, Department of Architecture Prince Sultan University – RENEWABLE ENERGY LABPrince Sultan University -Riyadh, KSA zabdallah@psu.edu.sa*
2. Department of Interior Design, College of Architecture and Design - Prince Sultan University- Riyadh, Saudi Arabia

https://orcid.org/0009-0004-2652-4109
Corresponding author: Zeinab A. Elhassan(Zabdallah@psu.edu.sa)

ABSTRACT
This study includes the analysis of renewable energy conservation with the implementation of PV systems for urban buildings at low-income housing systems in Riyadh. However, the PV (Photovoltaic) systems should be designed in such a way that they reduce energy consumption for daily climate factors. The installation of PV systems with their appropriate design should be considered a major principle in urban buildings, specifically in low-income houses for renewable energy conservation. To meet the technical and socio-economic needs of the users, it is required to develop sustainability practices that allow establishing the energy-efficient residential or urban design with the management of indoor temperatures and low economic losses in Al-Suwaidi District. The study focuses on evaluating the socioeconomic and technical aspects of the domestic urban district of Riyadh based on Building Integrated Photovoltaic (BIPV) systems to implement strategies for energy-efficient building designs at low-income houses. The data was collected from survey questionnaires to study the implementation of BIPV systems.
Keywords: Renewable Energy Systems; Low-income Houses; Riyadh; Al-Suwaidi District; Socio-Economic Effects; Photovoltaic (PV); Building Integrated Photovoltaic (BIPV)

1. Introduction

Resource-utility solar power projects have been developed across Saudi Arabia and will become the primary step towards the diversification of electricity production. However, the National Renewable Energy Program of the country focuses on achieving the goal of increment of share of The Saudi Arabian energy mix aims to use 3.45 GigaWatts (GW) of renewable energy by 2020 and 9.5 GW by 2023 [1]. According to this study, installing renewable energy systems, particularly solar rooftops, may prove affordable and enhance Riyadh's home scale's decarbonization of the power generation mix. The standard cost-benefit analysis has been performed to understand the viability of rooftop solar PV in multiple diverse households in Riyadh instead of a single household. According to the consumption level of electricity and a sliding scale, the households are categorized based on the residential pricing of electricity [2].

Significant socioeconomic effects could result from the implementation of renewable energy systems in low-income housing systems in Riyadh, Saudi Arabia. The energy costs could be reduced for residents which helps them to improve their economic well-being without relying on fossil fuels. As a result, positive environmental effects have occurred. Moreover, the exploitation of renewable energy systems could create jobs in the installation and maintenance departments. Furthermore, the initial costs can be higher for installing renewable energy systems in addition to the costs for their maintenance and repair could cause a financial burden for low-income families. A positive impact would likely result in the environment and socio-economic well-being of residents with the use of renewable energy systems in low-income housing in Riyadh. But, it would have to consider the costs associated with the maintenance and installation of renewable energy systems like BIPVs.

Recently, Riyadh has gained much attention in handling the issue of low-income housing caused due to the increased population. In Riyadh, existing low-income housing lacked basic amenities like electricity and water facilities. The houses mostly do not have adequate ventilation and insulation which results in the rising of extreme temperatures in the houses and a negative impact on the well-being and health of residents. It makes it difficult for low-income housing residents to explore job opportunities as they are located in areas distant from the city centers in Riyadh [3]. However, it can worsen poverty conditions and limit social mobility. The low-income housing issue in Riyadh has been addressed by the government of Saudi Arabia, which planned to establish new housing units and improve the existing conditions for low-income housing. For example, the Saudi Vision 2030 plan has been developed and aimed to create job opportunities for citizens and diversify the economy [4]. The major initiatives of the plan included the improvement of education and training while creating new jobs in various sectors such as renewable energy, healthcare, and technology. Furthermore, several private organizations and non-profit businesses have been provided affordable solutions for housing in Riyadh. As the problem of low-income housing in Riyadh is a complex issue, it needs a multifaceted approach to make sure that all residents get access to affordable and safe housing.

1.1 Low-cost Housing in Saudi Arabia's capital, Riyadh:

In recent years, Riyadh, Saudi Arabia, has experienced a significant increase in the need for affordable housing due to the city's growing population. The lack of affordable housing alternatives is a contributory factor of the substandard living conditions and overpopulation of residents. High land costs, a lack of government action, and an expanding population were the main contributors to the housing problem-solving [5]. The low-income households were mostly forced to live in inadequate and overcrowded housing. The study found that the low-income housing resided in peripheral areas of Riyadh which led to the segregation of residential housing and no access to services and amenities [6]. Due to the lack of affordable housing options, many families were compelled to reside in a single apartment. [7]. Another study also demonstrated that contributing factors to the problem of low-income housing were higher prices for land, a rising population, and a lack of government intervention [8]. The low-income households of Riyadh are struggling to spend their income largely on housing costs which led to poor living conditions. The Saudi Arabian low-income housing programs were not effective in addressing the housing crisis faced by low-income families due to the hindrance by lack of poor coordination and funding from government agencies [9]. The housing market has been negatively impacted by Saudi Arabia's ongoing economic crisis, which has reduced the number of cheap housing options and new home development for people with lower incomes[10],[11]. In conclusion, these literature studies recommended improving the affordable housing options for low-income residents in Riyadh by considering factors like land prices and population growth that contributed to the housing crisis.

1.2 SOCIAL AND ECONOMIC EFFECTS OF BIPV

As the perceptions and beliefs of the public are considered accurate, it is crucial to understand their perceptions regarding renewable technology [12] [13]. Effective tactics should have to be developed to implement the initiatives for PV technology acceptability based on the perceptions of the public. New renewable energies like PV systems should be considered as a framework to identify and develop solutions concerning the public reaction [14].

1.2.1 Social Impact of BIPV

1.2.1.1 Financial Influences

The positive outcomes for any business leader in society are the consumer’s sense of happiness and social position [15]. However, it has been realized that a higher rate of return is received for socially responsible businesses in addition to the commitment towards environmental and social principles [16]. The consumers of the commercial sector can gain the benefit of using photovoltaic energy by linking the products with sustainable energy generation. A residential or commercial structure is distinguished by BIPV visually [17]. In addition, BIPV is an integral part of the distinct design of the building and complements the green energy systems like lighting, TV, etc.

1.2.1.2 Behavior of Users

The study claimed that a viable source of renewable energy was the BIPV operations for consumers in homes based on the investigation of the economic and social effects of rural electrification programs thoroughly [18]. An energy infrastructure project was developed to understand the effects and provide benefits for developing countries. This project has impacted the people to ascertain the technical, economic, and social effects of the BIPV system while reducing the environmental effects [19] [20]. The lives of BIPV users changed with the PV electrification system in terms of economic, social, and technological aspects [21]. Urban and suburban lifestyles are linked with the BIPV systems as the residents get access to telephones, radios, computers, and lighting [22].

1.2.2 Economic Impact of BIPV

1.2.2.1 Costs and Benefits

The economic evaluation of PV systems should be considered the below-mentioned aspects, such as:

- The positive incentive programmes provided by the government PV systems like tax incentives or grants [23].
- Reduction of generating electricity costs through PV systems per annum [24].

1.2.2.2 System Costs

The PV installation has had an effect on the system costs expressed in US dollars per installed watt of direct-current peak power capacity (USD/Wp DC) [25]. When compared to PV systems, BIPV systems are expensive for the installation process, but the reasons are not clear for these price premiums, including larger margins, higher expenses, or other parameters. The costs for residential rooftop BIPV systems included installation labour costs and a bottom-up study of components. The system costs are 10% cheaper for BIPV systems than the rack-mounted PV systems [26]. The reports from 2007 to 2016 showed that there was an increment of sales rate of up to 8% for new homes with BIPV than rival PV. Based to some research studies, the global installed capacity of BIPV will range between 250 and 300 MW in 2021, and 1% of the total installed capacity of distributed PV systems as of 2010 [27]Due to the higher costs, BIPV has a higher market share than rack-mounted PV systems [28], and the total installed costs were $5.71/WP DC in 2020 [29].

1.2.3 Technical Impact of BIPV

1.2.3.1 BIPV Maintenance

In Ethiopia, PV technology was introduced and led to the cultural division between the system and its users while providing a shorter lifespan or poor performance for PV systems despite the guarantees of durability by manufacturers [30]. The studies concluded that BIPV components should be maintained or managed well technically by PV users [31-33]. However, there are difficulties with the installation and usage of systems to achieve quality intervention and quality assurance. As the buildings are required to be sustainable, buildings' roofs are able to include BIPV (Building Integrated Photovoltaic) systems. [34]. Therefore, it is required to design a low-energy house system using BIPV to determine the economic and social behavior of urban people [35]. In Riyadh, it is essential to consider a sustainable and optimum architectural design using BIPV for urban planning and providing benefits to the community. The purpose of the study is to determine the social and environmental effects of implementing BIPV systems in the residential sector, such as climate change and distribution barriers.

2. Location Data

2.1 Physical Al-Suwaidi District's Physical Characteristics and Planning

Riyadh, located in the central area of Saudi Arabia, is one of the seven primary administrative divisions within the country's geographical framework. Furthermore, it should be noted thatthis particular province holds the distinction of being the second largest in Saudi Arabia when compared to other regions. Its entire area spans an impressive 404,240 square kilometers (156,080 square miles).The total population in Riyadh was over 8,000,000 residents according to the latest statistics of the General Authority for Statistics (GAS, 2017) [36]. The subdivisions of Riyadh included five districts, such as Southern, northern, eastern, and Western districts. Moreover, there is a diversity in socio-economic status among residents of Riyadh, including upper-income groups of individuals in the northern area while southern and western areas have low-income group families. The facilities, locations, types, designs, and services of the people's houses are heavily influenced by the socio-economic level of the occupants. This plays a vital part in the decision-making process , according to Al-Gabbani, 1996. In this study, one of the southern neighbourhoods, Al-Suwaidi is considered to examine the effects of income level on the housing type and design and evaluate the improvement of such residences through the utilization of various forms of renewable power sources.

One of the most ancient and highest priority neighbourhoods of Riyadh is Al-Suwaidi, which has a geographical area of 5.42 Square Kilometers approx. The administration of Al-Suwaidi has been affiliated with the municipality of Al-Uraija, which is taking a southwestern part of Riyadh city and is bordered by the Western Ring road from the south and west side, Sultana neighbourhood from the south, and Dhahrat Al-Badiah neighbourhood from the north.

In Al-Suwaidi, the average housing price is above 1500 riyal/m2 based on studies of Arqam, 2021. By comparing with the housing prices of northern neighbourhoods, there is a difference of 3000 riyal/m2 (table 1). Five main roads of Al-Suwaidi are subdivided into small several ways for separating commercial and residential buildings (Figure 1). Two-floor residential buildings mostly exist with roofs and yards for the family to stay out when the weather is good (Figures 2 & 3). Some residential building units were established during the late 80s to 90s while some were built between the 70s and early 80s (Figures 2, 3, 4, and 5). Many commercial buildings resided near the sub and main roads to serve the basic needs of residents, such as pharmacies, laundries, grocery stores, etc. The commercial units were also established with two floors of buildings similar to the houses (Figure 6). The desert air conditioner was used mostly in early-built units (Figure 4) and the window air conditioner was used during the 80s and 90s (Figure 2). Since many buildings were built early, where cooling systems are expensive, it is not often to find a central cooling system in the neighbourhood. It is shown that the area has been planned by looking at the neighbourhood plan because many sub roads are not used a grid that leads to the ununified housing structure (Figure 1). Based on the diversity of demographic nature with several reefs that are erected by buildings, most of the southern neighbourhoods are characterized in Al-Suwaidi.

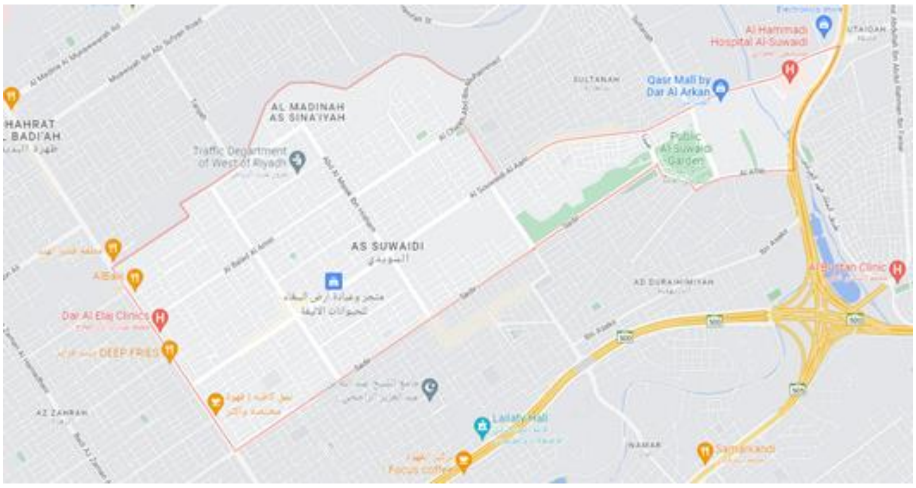
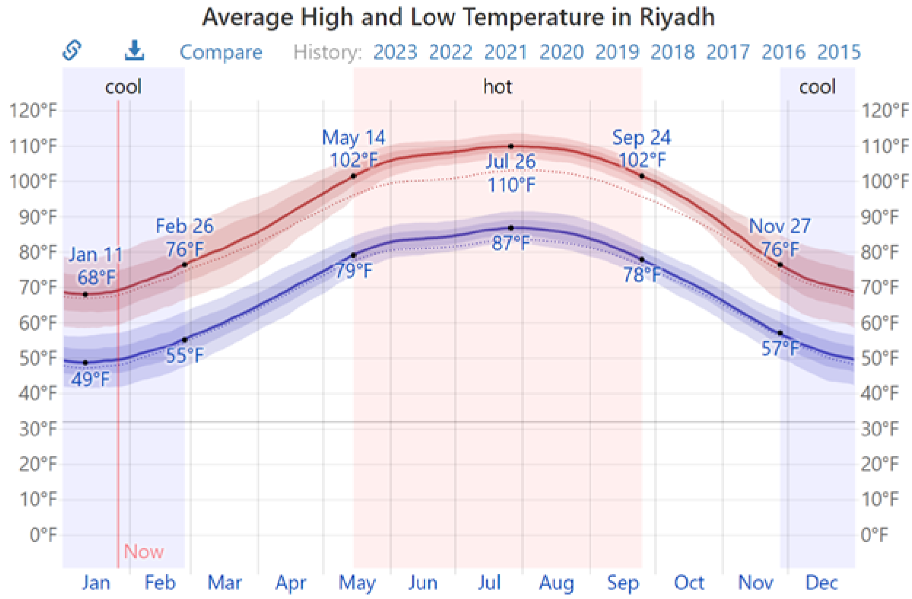


Figure 1: Main Roads in Al-Suwaidi

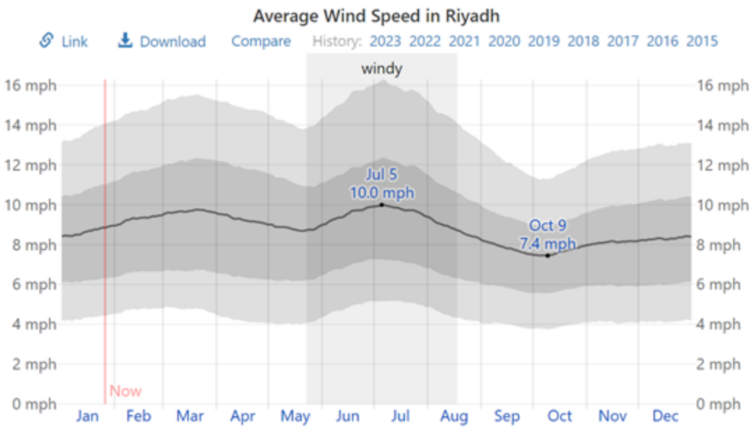
The luxurious neighbourhoods were located in the capital city during the 80s. There was a shift of real estate developers as their focus towards the north and looking out for a better quality of life. The low-income population has inhabited the Al-Suwaidi neighbourhood that has become less appealing and attractive to the residents. For example, Dar Al-Arkan real-estate Company developed a huge residential project that includes hundreds of residences ranging in different sizes and types of apartments and villas [37]. But, the desired outcomes were not achieved because the project was located in the southern region of Al-Suwaidi Main Street and the problems of poor accessibility and traffic were faced by residents. Thus, these initiatives were not successful, and developers moved to planned and attractive areas.

2.1 Climatic Conditions

Riyadh city is cold and a bit rainy during winter and hot or dry during summer. However, a long period of the summer season is considered in the city with an average temperature rate of above 102^0F. The temperature rises in May and reaches the peak level in July and August, finally, it starts to become low in October. The shorter period of winter lasts for December and January with the average temperature below 76^0F. The typical range of temperature is from 49^0F to 110^0F over the year.



There was a poor rate of rainfall in Riyadh with an average of 0.2 inches. During March, the rainfall reaches the peak level with an average of 0.3 inches over the years. The rainfall was not reported for July and August months.



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

The average wind speed of 5.25 miles per hour was reported in Riyadh over the year. July had the most wind speeds with an average rate of 9.8 miles per hour. The static wind speed was observed from August to May with an average rate of 7.6 miles per hour even though October was the calmest month.

3. Methodology

This study contributes to the understanding of public perception regarding renewable energy sources, specifically focusing on Building-Integrated Photovoltaics (BIPV) systems. By analyzing real-world BIPV installations and expected patterns of BIPV adoption across different districts within the Al-Suwaidi area, the research aims to provide valuable insights into the factors influencing BIPV adoption among low-income households. Furthermore, this study will enhance our understanding of the socio-economic and environmental impacts of BIPV systems on low-income communities and how to develop effective policies and strategies to promote the wider adoption of renewable energy technologies in the region.

The public perception regarding renewable energy sources is the major concern of the research area and is a framework for analysis [38]. All samples of BIPV services and expected patterns of BIPV for all districts of Al-Suwaidi will be analyzed based on statistical tests. This study included randomly selected participants to detect the location.

3.1 Methods used in Data Collection

The data collection method is used as retrieving responses from a significant number of respondents through the distribution of questionnaires [39]. It is a feasible method to reach the reviewers significantly for providing better outcomes with a statistical analysis. This study investigates how the living conditions could have changed for some families over time. As shown in below Figure 9, the overview of research study was presented to determine the positive views and barriers concerning the use of BIPV while identifying the location background.

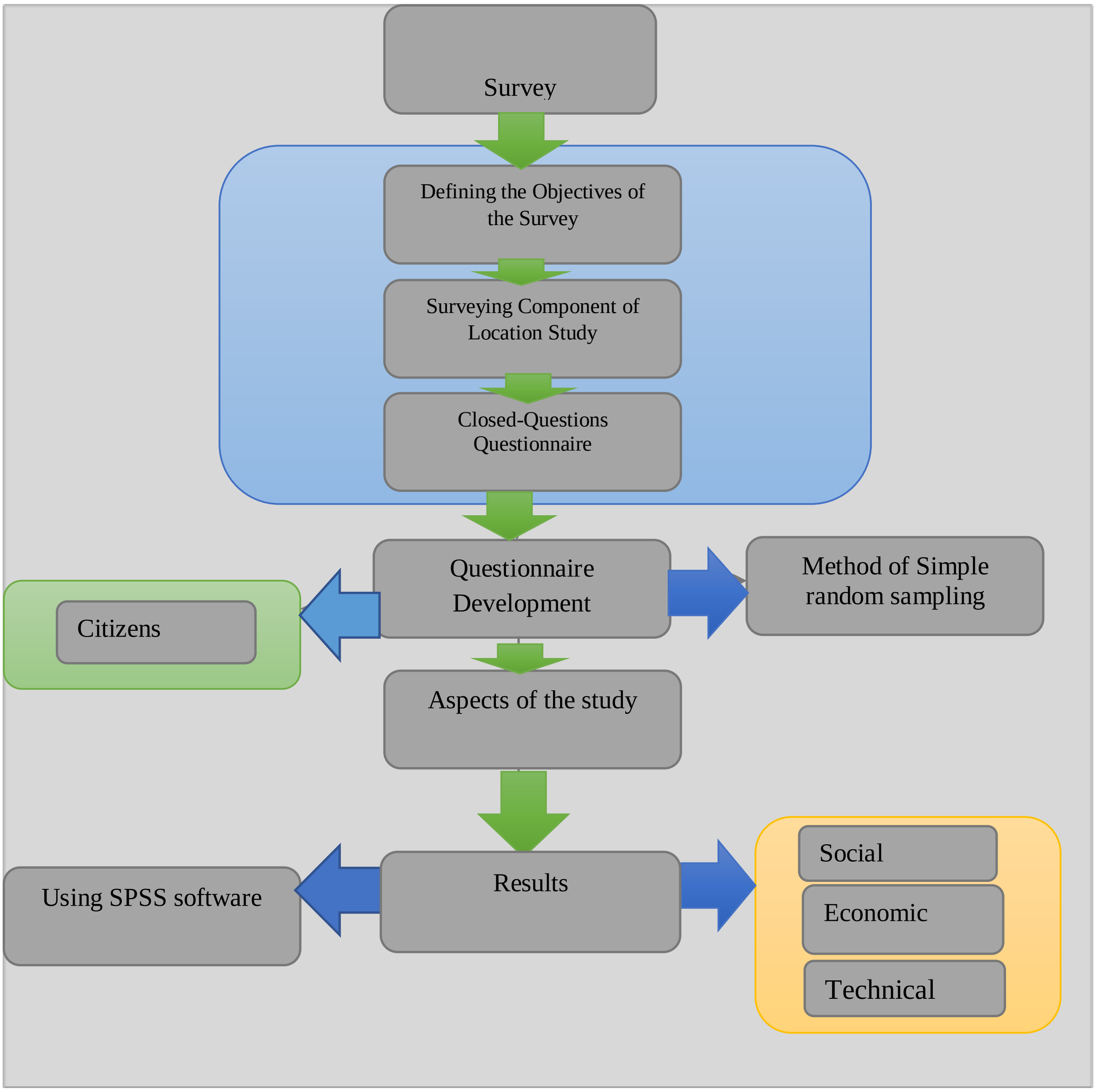


Figure 9: Overview of Research Study

3.2 Objectives of the Survey

Specifically, the study demonstrates its well-defined goals, such as data collection and analysis for future user research. To implement the BIPV technology, assessment of public acceptance and perception of PV technology is used as an effective strategy to detect the issues or problems faced by the residents of Riyadh. However, BIPV systems were developed for different communities, households, and authorities in the location.

3.2.1 Surveying Component of Location Study

This research incorporates direct interviews with government officials and local stakeholders in the Al-Suwaidi District, as part of a comprehensive examination of the region's population and public service infrastructure. However, these services were rendered to be surveying, registering, and analysing the occupied areas of Al-Suwaidi District with low-income families. The requirements for location were discussed in the below sections.

3.2.2 Study of Socio-Economic, Technical, and Environmental Aspects

It is required to study the environmental, technical, and socio-economic effects of households. Because improper use of resources leads to negative effects on people due to improper socio-economic, environmental, and technical behaviour.

3.2.3 Field Study Procedure of Research Sample

3.2.3.1 Citizens

A random selection of population was considered to test the samples in Al-Suwaidi District. At that point, a sample in Al-Suwaidi District was selected, including households which used BIPV. The citizens can get access to the facilities where the contributions are being consumed. New facilities have been created even in areas where local opposition to them has been mostly muted. Furthermore, the lack of dialogue about new social improvements is caused by the isolation of concerned citizens [40, 41].

3.2.4 Simple Random Sampling

The collection, presentation, analysis, and interpretation of data are considered as stated objectives from the statistical perspective. However, the primary process is data collection, where randomization is applied as it is the base for many methods of statistical analysis. It is not useful to perform statistical analysis and relevant interpretation when the assumption of random sampling cannot hold. Thus, it requires gaining knowledge about sampling before investigating the methodology section of statistical analysis.

3.2.5 The Research Sample

A sample that accurately reflects eligible respondents and a roster of homes from different districts of Riyadh was obtained based on the randomly selected 50% of population from a total number of respondents (n=300) who used BIPV systems.The study's main objective was to achieve a random sample based on sampling and estimation statistical methods [42]. However, the method of designing and implementing sample techniques were carried out for the objective of using questionnaire surveys, and chosen the sample of families from Al-Suwaidi District.

4. Results and Discussions

The collected data from the primary quantitative sources is analysed based on online questionnaire surveys. The data analysis has been performed using survey responses to achieve research aims and objectives for deriving meaningful conclusions regarding the socio-economic effects of the use of renewable energy systems like BIPV. Therefore, this section presents the results and analyses of survey responses using percentage analysis, Descriptive statistics, Chi-square, t-test, ANOVA, and other statistical tests and correlation tests, to understand the role of residential renewable energy systems in terms of socioeconomic factors.

4.1 Percentage Analysis

This percentage analysis is used to evaluate and compare the results for particular categories like age, gender, education level, total income, employment status, satisfaction with using solar systems, and use of renewable energy at home.

4.1.1 Age, Gender, and Education Status

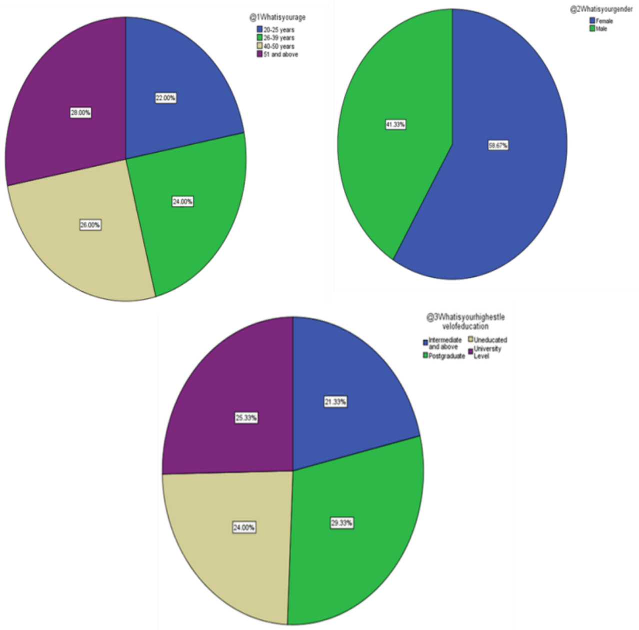


Figure 10: Pie-Charts for Age, Gender, and Education Status

The SPSS results provided that a higher number 28% of respondents were in the age range of 51 and older. while a lower number of responses was recorded for 20 to 25 years at 22%. The female respondents were higher with 58.67% compared to male respondents, i.e. at 41.33%. The study has a greater percentage of postgraduates at 29.33%, the second highest respondents were from the university level with 25.33%. Finally, the intermediate and above educational level was chosen by a smaller number of respondents as [40, 41].

4.1.2 Household Income and Employment Status

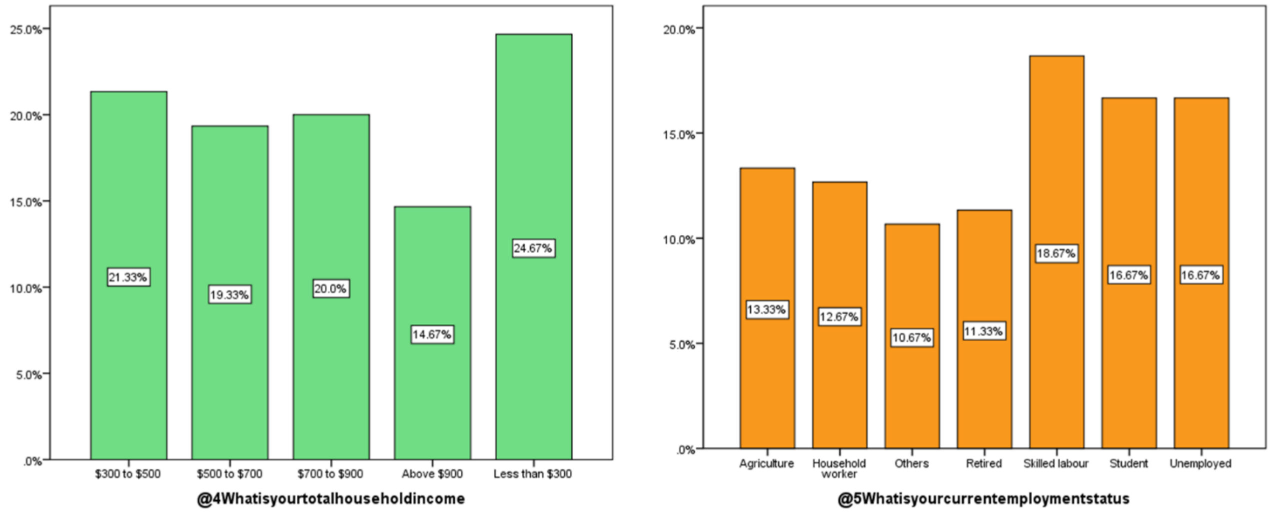


Figure 11: Bar Charts for Household Income and Employment Status

The study showed higher responses reported for low-income households with less than $300 at 24.67% and less number of respondents were from the category of above $900 income households as [43] at 14.67%. Skilled labour was the main employment status of the respondents at 18.67%. Moreover, the percentage analysis results depicted 16.67% of people were unemployed and students, 13.33% of people were employed as agriculturists, 12.67% of people were household workers, and 11.33% of respondents were retired people.

4.1.3 Renewable Energy, Benefits, and Reasons for Using Solar Systems

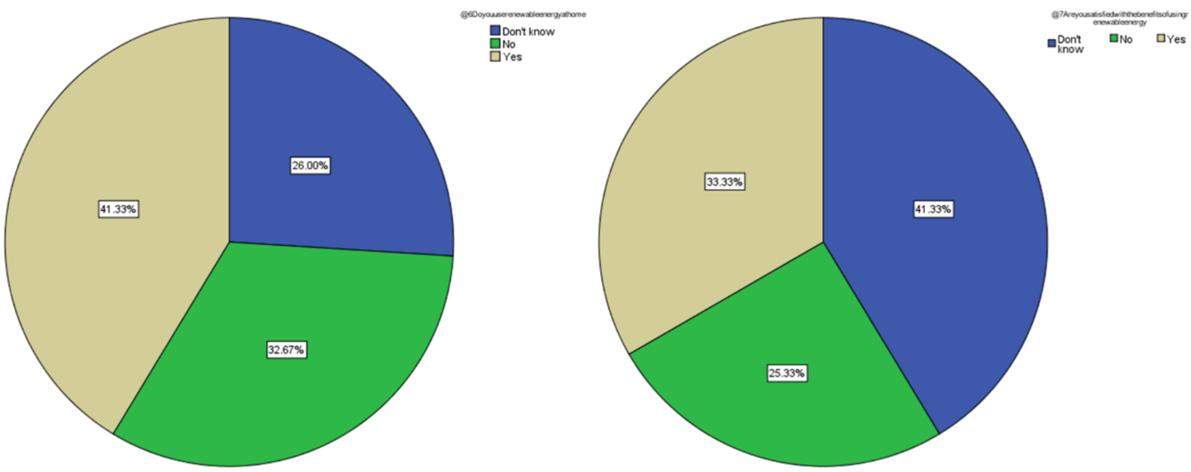


Figure 12: Demographics for Renewable Energy and Benefits of using BIPV Systems

Many people opined that they used renewable energy (41.33%) at their homes and some respondents did not use them (32.67%). However, 26% of people did not know about renewable energy systems. Furthermore, the results depicted that 33.33% of people were satisfied with using renewable energy systems and 25.33% of respondents were not satisfied.

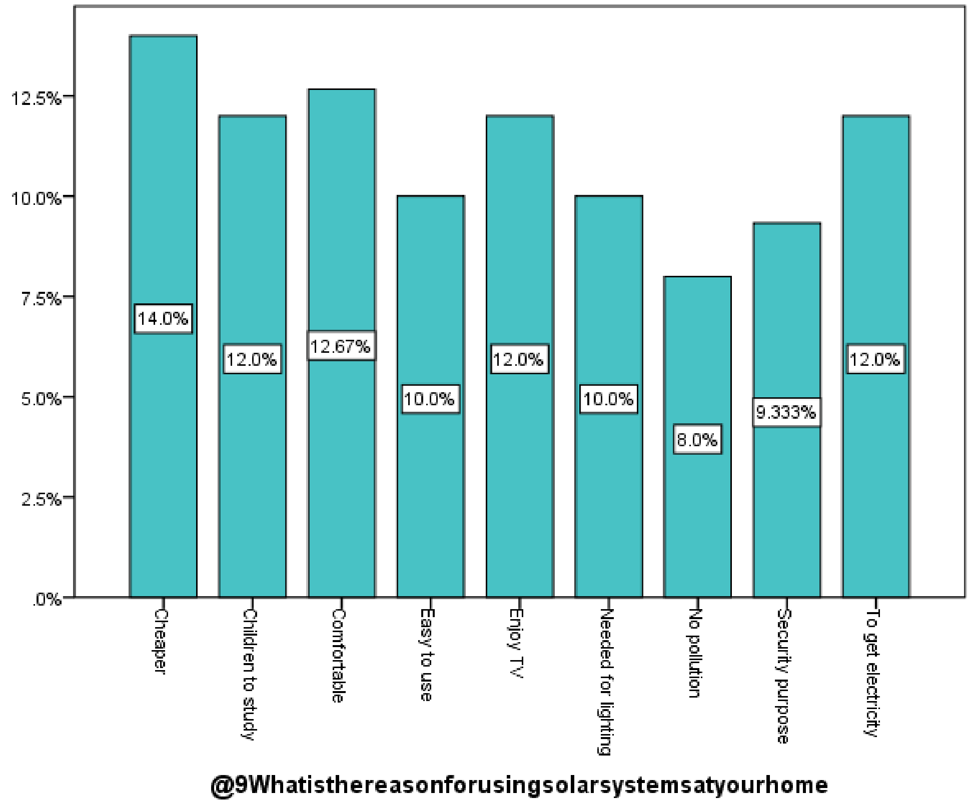


Figure 13: Bar Chart for Reasons of using Solar Systems at Your Home

Mostly, people chose solar systems due to their affordability or availability at cheaper costs (14%) and some respondents reported for different reasons enjoy TV [43, 44], children, studying, and getting electricity with an equal response rate of 12%. No pollution was chosen by a smaller number of people with a response rate of 8%.

4.2 Statistics, Descriptive

Statistics, Descriptive

	n	The minimum value.	The Maximum Value	Average Value	Standard Deviation
@8aItdoesnteffectthehomeenvironment	150	1	4	2.55	1.109
@8bEasyaccessandinclusion	150	1	4	2.57	1.149
@8cEasilymaintained	150	1	4	2.41	1.100
@8dItdoesntoccupyalargespaceathome	150	1	4	2.43	1.089
@8eItsuppliesrequiredenergyatasuitableprice	150	1	4	2.48	1.157
@8fIthasnorepeatedfailuretodistributethecurrentsourc	150	1	4	2.49	1.128
@8gItisanalternativetothepowersupply	150	1	4	2.65	1.093
@8hEasieraccesstoBIPVsolarenergy	150	1	4	2.43	1.052

@8iThenumberofsolarpanelsincreasedwiththeincreaseof	150	1	4	2.55	1.167
@10aImprovedwellbeingofwomenandchildren	150	1	5	2.83	1.368
@10bMoreopportunitytostudyathome	150	1	5	2.71	1.407
@10cImprovedqualityoflife	150	1	5	2.89	1.429
@10dAdvancedcommunication	150	1	5	3.13	1.344
@10ecleanindoorair	150	1	5	2.94	1.429
@10fWatchingTVandlistentobroadcasts	150	1	5	3.03	1.474
@10gLessburningofkerosenelampsandwicks	150	1	5	2.85	1.432
@10hMoresocialgatherings	150	1	5	2.82	1.381
@10iIncreasedefficiencyindoingdomesticworks	150	1	5	2.87	1.406
@10jComfortablelife	150	1	5	2.96	1.474
@10kImprovedhealthcondition	150	1	5	3.21	1.464
@10lIncreasedstatusinthecommunity	150	1	5	3.09	1.390
@10mLesshassleforlighting	150	1	5	2.97	1.428
@11aIncreasedhouseholdincome	150	1	5	3.09	1.406
@11bDiversifiedsourceofincome	150	1	5	3.18	1.433
@11cNopollution	150	1	5	3.14	1.316
@11dReducedenergyexpenses	150	1	5	2.93	1.334
N (list-wise) Valid	150				

There were no missing responses for all questionnaires and reported 150 responses. The maximum response rate was observed as 5 for the questionnaire survey while the minimum response rate was reported as 1. The average responses of 10d, 10f, 10k, 10l, 11a, 11b, and 11c were closer while 10a, 10b, 10c, 10e, 10g, 10h, 10i, 10j, 10m, and 11d were having nearer average responses and 8d to 8i questionnaire included closer average responses. The highest standard deviation was observed as 1.474 for variables of watching TV and listening to broadcasts (10f) and comfortable life (10j) while the minimum value was retrieved for easier access to BIPV solar energy (8h), i.e. 1.052 [45],.

4.3 Test of Normality

In order to, the normality test will be carried out to determine whether collected data to socio-economic effects of using renewable energy systems at low-income house case study is usually distributed or not. In the study, the ShapiroWilk test is used as the dataset has lower than 2000 elements, i.e. 150 elements.

The Normality Tests

	Kolmogorov Smirnov[a] Test			Shapiro Wilk Test		
	The Statistic	df	Sig.	The Statistic	df	Sig.
@8aItdoesnteffectthehomeenvironment	.176	150	.000	.859	150	.000
@8bEasyaccessandinclusion	.191	150	.000	.845	150	.000
@8cEasilymaintained	.198	150	.000	.859	150	.000
@8dItdoesntoccupyalargespaceathome	.199	150	.000	.861	150	.000
@8eItsuppliesrequiredenergyatasuitableprice	.174	150	.000	.845	150	.000
@8fIthasnorepeatedfailuretodistributethecurrentsourc	.180	150	.000	.854	150	.000
@8gItisanalternativetothepowersupply	.184	150	.000	.858	150	.000
@8hEasieraccesstoBIPVsolarenergy	.192	150	.000	.870	150	.000
@8iThenumberofsolarpanelsincreasedwiththeincreaseof	.182	150	.000	.840	150	.000
@10aImprovedwellbeingofwomenandchildren	.189	150	.000	.892	150	.000
@10bMoreopportunitytostudyathome	.212	150	.000	.874	150	.000
@10cImprovedqualityoflife	.161	150	.000	.884	150	.000
@10dAdvancedcommunication	.160	150	.000	.899	150	.000
@10ecleanindoorair	.178	150	.000	.884	150	.000
@10fWatchingTVandlistentobroadcasts	.165	150	.000	.875	150	.000
@10gLessburningofkerosenelampsandwicks	.156	150	.000	.882	150	.000
@10hMoresocialgatherings	.170	150	.000	.888	150	.000

@10iIncreasedefficiencyindoingdomesticworks	.146	150	.000	.886	150	.000
@10jComfortablelife	.183	150	.000	.872	150	.000
@10kImprovedhealthcondition	.190	150	.000	.863	150	.000
@10lIncreasedstatusinthecommunity	.183	150	.000	.888	150	.000
@10mLesshassleforlighting	.164	150	.000	.885	150	.000
@11aIncreasedhouseholdincome	.200	150	.000	.882	150	.000
@11bDiversifiedsourceofincome	.175	150	.000	.877	150	.000
@11cNopollution	.163	150	.000	.903	150	.000
@11dReducedenergyexpenses	.161	150	.000	.902	150	.000

a. Lilliefors Significance Correction

From the questionnaire survey's sample data, 150 people responded in total , conducted in this research study [46],. They were analysed further to derive conclusions about the impact of renewable energy systems on low-income houses [43, 44],. However, the above Table shows the test statistics for normality. The Shapiro-Wilk test was used as the case study has only 150 elements. From the table, the p-value results for dependent variables was 0.000 (<0.05) which means the data deviated from the normal distribution or data was not distributed normally.

4.4 Reliability Analysis

This study aimed to construct a 16-question questionnaire survey to assess the impact of renewable systems on low-income households. The survey aimed to evaluate the influence of these systems on social and economic aspects, as well as the satisfaction levels of the respondents [46],. However, the questionnaire was developed based on multiple Likert scale statements similar to a 5-point Likert scale with responses that vary, “strongly disagree” and “strongly agree” and 4-point scale with “very high” to “low”. To find out whether the questionnaire could measure the dependent variables reliably, the Cronbach alpha test was conducted.

Statistics of Reliability

Test of Cronbach's Alpha[a]	Test of Cronbach's Alpha Based on Standardized Items[a]	N of Items
-.007	-.023	26

a. The negative value is a result of the average covariance among items being negative. The assumptions of the reliability model are violated by this. It is advisable to verify the item codings.

In this case, it was obtained as -0.007 it represents the fact that the measuring device has a lower level of reliability. In addition, this suggests that there is a poor level of internal consistency with relation to the data sampled. The “Item Total Statistics” for Cronbach Alpha results showed that the overall reliability was not improved at a higher rate even though some of the variables like 11b, 11b, 10k, 10l, 8a, 8b, 8c, 8d, 8e, 8f, etc. It would reach to 0.340 for 8d, 10c, 10d, 10g, 10i, 10j, 11a, and 11d variables. Therefore, these variables were considered for further tests as they passed the reliability although they did not improve the Cronbach alpha value and were not acceptable for reliability.

4.5 The test of Chi-Square :

This test was carried out to find out if the responses submitted contain answers that are identical to one another.

Test Statistics

	@8dItdoesntoccupyalargespaceathome	@10cImprovedqualityoflife	@10dAdvancedcommunication	@10gLessburningofkerosenelampsandwicks	@10iIncreasedefficiencyindoingdomesticworks	@10jComfortablelife	@11aIncreasedhouseholdincome	@11dReducedenergyexpenses
Chi-Square	3.333[a]	1.200[b]	3.867[b]	3.200[b]	6.200[b]	3.933[b]	5.933[b]	3.467[b]
df	3	4	4	4	4	4	4	4
Asymp. Sig.	.343	.878	.424	.525	.185	.415	.204	.483

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 37.5.

b. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 30.0.

The p-values resulted as 0.484, 0.204, 0.415, 0.185, 0.525, 0.424, 0.878, and 0.343 for different chosen variables like 11d, 11a, 10j, 10i, 10g, 10d, 10c, and 8d, respectively. However, all these social and economic factors have significant p values higher than 0.05 signify that the null hypothesis was not disproved. Consequently, no discernible differences existed. in responses for these questionnaires of “very high” to “low” and “strongly agree” to “strongly disagree”.

4.6 T- test ,Independent Samples

Non-parametric tests reveal that the data that are not regularly distributed for multiple independent samples are useful to evaluate whether a particular variable differs between multiple variables.

Test Statistics[a,b]

	@10cImprovedqualityoflife	@10dAdvancedcommunication	@10gLessburningofkerosenelampsandwicks	@10iIncreasedefficiencyindoingdomesticworks	@10jComfortablelife	@11aIncreasedhouseholdincome	@11dReducedenergyexpenses
Chi-Square	3.192	4.991	3.105	2.314	6.076	1.192	2.630
df	3	3	3	3	3	3	3
Asymp. Sig.	.363	.172	.376	.510	.108	.755	.452

a. Kruskal Wallis Test

b. Grouping Variable: @8dItdoesntoccupyalargespaceathome

The Test of Kruskal Wallis was carried out to figure out the significance of multiple independent factors. and obtained results as shown in the above table. The p-value was displayed, i.e. asymptotic is appropriate for a large sample. The Sig. values were 0.363, 0.172, 0.376, 0.510, 0.108, 0.755, and 0.452 for 10c, 10d, 10g, 10i, 10j, 11a, and 11d, respectively that depicts there were no significant outcomes. Therefore, no significant difference of independent variables resulted, such as improved quality of life, advanced communication, less burning of kerosene lamps and wicks, increased efficiency in doing domestic work, comfortable life, increased household income, and reduced energy expenses with the variable of not occupying large spaces at home.

4.7 Analysis of Variance

To test the significant difference in social and economic effects of the use of renewable energy systems like BIPV at low-income houses, the Friedman test was conducted. It was used for the repeated measures of analysis of variance to test the null hypothesis of whether the multiple responses of the same population [42],.

Statistics [Test]

n	150
Chi-Square	22.356
df	7
Asymp. Sig.	.002

a. Friedman Test

The results of the Friedman test yielded a p-value of 0.002, which is less than 0.05. It indicates that there was a substantial distinction between these categories.

4.8 Correlation Analysis

It is appropriate to evaluate the correlation between the socio and economic effects of implementing renewable energy systems like BIPV at low-income houses [32],. However, Spearman's test was conducted as the data is non-normal and It's useful for evaluating the degree to which one independent variable affects another dependent variable.

Correlations

			@8dItdoesntoccupyalargespaceathome	@10cImprovedqualityoflife	@10dAdvancedcommunication	@10gLessburningofkerosenelampsandwicks	@10iIncreasedefficiencyindoingdomesticworks	@10jComfortablelife	@11aIncreasedhouseholdincome	@11dReducedenergyexpenses
Spearman's rho	@8dItdoesntoccupyalargespaceathome	Correlation Coefficient	1.000	.021	.027	.046	.081	.081	-.013	.068
		Sig. (2-tailed)	.	.803	.741	.579	.323	.325	.875	.405
		N	150	150	150	150	150	150	150	150
	@10cImprovedqualityoflife	Correlation Coefficient	.021	1.000	.086	.059	.135	.165*	-.071	.077
		Sig. (2-tailed)	.803	.	.295	.471	.100	.044	.388	.350
		N	150	150	150	150	150	150	150	150
	@10dAdvancedcommunication	Correlation Coefficient	.027	.086	1.000	.128	-.050	.098	.172*	.198*
		Sig. (2-tailed)	.741	.295	.	.119	.547	.233	.035	.015
		N	150	150	150	150	150	150	150	150
	@10gLessburningofkerosenelampsandwicks	Correlation Coefficient	.046	.059	.128	1.000	.121	-.018	-.024	.054
		Sig. (2-tailed)	.579	.471	.119	.	.139	.823	.768	.509
		N	150	150	150	150	150	150	150	150
	@10iIncreasedefficiencyindoingdomesticworks	Correlation Coefficient	.081	.135	-.050	.121	1.000	-.019	.134	-.014
		Sig. (2-tailed)	.323	.100	.547	.139	.	.818	.103	.867
		N	150	150	150	150	150	150	150	150
	@10jComfortablelife	Correlation Coefficient	.081	.165*	.098	-.018	-.019	1.000	.161*	-.068
		Sig. (2-tailed)	.325	.044	.233	.823	.818	.	.049	.410
		N	150	150	150	150	150	150	150	150
	@11aIncreasedhouseholdincome	Correlation Coefficient	-.013	-.071	.172*	-.024	.134	.161*	1.000	.019
		Sig. (2-tailed)	.875	.388	.035	.768	.103	.049	.	.815
		N	150	150	150	150	150	150	150	150
	@11dReducedenergyexpenses	Correlation Coefficient	.068	.077	.198*	.054	-.014	-.068	.019	1.000
		Sig. (2-tailed)	.405	.350	.015	.509	.867	.410	.815	.
		N	150	150	150	150	150	150	150	150

The 0.05 level (2-tailed) of significance for correlation is met.

Spearman's correlation coefficient values for each questionnaire were lower than 0.4 which indicates a weak positive relationship between 10c, 10d, 10g, 10i, 10j, and 11d except for 11a (-0.013). Further, the significant values of independent variables need to be considered to determine the relationship between socio and economic factors and renewable energy system installation which does not occupy a large space. The results indicated that the statistically significant values approach 0.05 for all questionnaires[47]. Therefore, there was no relationship between these variables, such as improved quality of life, advanced communication, less burning of kerosene lamps and wicks, increased efficiency in doing domestic work, comfortable life, and reduced energy expenses with the factor of not occupying large spaces at home. Hence, it was not required to perform a regression analysis to evaluate the correlation between socioeconomic factors and residential solar panel usage [46].

5. Conclusion

Saudi Vision 2030 necessitates a transition to renewable energy systems to mitigate climate change and enhance energy security. This study contributes to this imperative by investigating the socio-economic and environmental impacts of Building-Integrated Photovoltaic (BIPV) systems in low-income households within the Al-Suwaidi district of Riyadh[48]. The decentralized energy system can improve the power supply and lower carbon emissions. This study focuses on evaluating the real-world implementation of Building-Integrated Photovoltaic (BIPV) systems among low-income families in the Al-Suwaidi district of Riyadh. It explores the potential of community energy schemes to foster the wider adoption of renewable energy technologies such as BIPV. The research findings indicate that many respondents experienced significant socio-economic benefits from utilizing solar systems in their homes. These benefits included improved quality of life, reduced space requirements, increased efficiency in domestic tasks, enhanced communication, decreased reliance on kerosene lamps and wicks, reduced energy expenses, and increased household income.

In this study, a series of questionnaire surveys were used to determine the participant views on using renewable systems and understand their socio-economic behaviours with the use of BIPV systems. Most participants (41.33%) used renewable energy systems at their houses and gained benefits. In resonance with this, the participants chose solar BIPVs because they can be available at affordable prices as one of the prime reasons. The participants were asked to share their opinions regarding social and economic benefits on a 0.5 scale from “strongly agree” to “strongly disagree” and environmental benefits on a four-point scale from “very high” to “low”. The descriptive analysis and test of normality were conducted that revealed the chosen random sampling data was not distributed normally based on the Shapiro-Wilk test. Then, Cronbach Alpha test results evident that some environmental, economic, and social factors passed the reliability, such as does not occupy large spaces at their homes, increased household income, reduced energy expenses, increased efficiency in domestic works, less burning of kerosene lamps and wicks, advanced communication, and improved quality of life. The chi-square test resulted in insignificant differences in responses for social, economic, and environmental factors while the Kruskal-Wallis test revealed no significant differences between social and environmental factors. Furthermore, Based on Friedman's test, a significant difference was observed between social and environmental aspects of the use of solar BIPV systems[49]. Furthermore, the correlation analysis results demonstrated that all social and economic factors like advanced communication, increased efficiency in domestic works, reduced energy expenses, less burning of kerosene lamps and wicks, and improved quality of life except the increased household income were weakly correlated with the environmental factor of not occupy large spaces[50]. In addition, these social and economic factors were not related to the aspect of not occupying large spaces because of higher significant values than 0.05. Therefore, this study determined that no socio-economic effects resulted regarding the environmental factor of occupying large spaces in low-income houses in the Al-Suwaidi district.

Acknowledgements: The authors would like to express their sincere gratitude to Prince Sultan University, particularly the College of Architecture and Design, and its departments of Architecture and Interior Design. We extend our deepest appreciation to the Dean, Vice Dean, and respective department chairs for their unwavering support and the provision of outstanding facilities.

References

1. Lopez-Ruiz, H. G., Blázquez, J., & Vittorio, M. (2020). Assessing residential solar rooftop potential in Saudi Arabia using nighttime satellite images: A study for the city of Riyadh. *Energy Policy*, *140*, 111399. doi:10.1016/j.enpol.2020.111399
2. Lopez-Ruiz, H.G., J. Blazquez, and M. Vittorio, *Assessing Residential Solar Rooftop Potential in Saudi Arabia Using Nighttime Satellite Images: A Study for.* 2019.
3. Alhubashi, H. H. M. (2012). *Housing sector in Saudi Arabia: A study of challenge and opportunities of homeownership for the middle and low income* (Master's thesis, UniversitatPolitècnica de Catalunya).
4. Balalaa, M. S., Ben Mabrouk, A., &Abdessalem, H. (2021). A wavelet-based method for the impact of social media on the economic situation: The Saudi Arabia 2030-vision case. *Mathematics*, *9*(10), 1117. doi:10.3390/math9101117

5. Mubarak, F. A. (2004). Urban growth boundary policy and residential suburbanization: Riyadh, Saudi Arabia. *Habitat International*, *28*(4), 567-591. doi:10.1016/j.habitatint.2003.09.005
6. Tayeh, N. N. (2018). Urban Regeneration to Reclaim Sustainability in Cities: The Case of Down Town Riyadh, KSA. In *International Conference for Sustainable Design of the Built Environment-SDBE London*.
7. Haidar, E. A., &Bahammam, A. S. (2021). An optimal model for housing projects according to the relative importance of affordability and sustainability criteria and their implementation impact on initial cost. *Sustainable Cities and Society*,*64*, 102535. doi:10.1016/j.scs.2020.102535
8. Mohanna, A.B. and A. Alqahtany, *Identifying the preference of buyers of single-family homes in Dammam, Saudi Arabia.* International Journal of Housing Markets and Analysis, 2019.
9. AlQahtany, A., *People's perceptions of sustainable housing in developing countries: the case of Riyadh, Saudi Arabia.* Housing, Care and Support, 2020.
10. Susilawati, C. and M. Al Surf. *Challenges facing sustainable housing in Saudi Arabia: a current study showing the level of public awareness*. in *Proceedings of the 17th Annual Pacific Rim Real Estate Society Conference*. 2011. Pacific Rim Real Estate Society.
11. Al-Qahtany, A. M. (2014). *The development of a consensus-based framework for a sustainable urban planning of the city of Riyadh* (Doctoral dissertation, Cardiff University).
12. Knapp, L., et al. (2020). Will consumers really pay for green electricity? Comparing stated and revealed preferences for residential programs in the United States. *Energy Research & Social Science*, *65*, 101457. doi:10.1016/j.erss.2020.101457
13. Naber, R., et al. (2017). Scaling up sustainable energy innovations. *Energy Policy*, *110*, 342-354. doi:10.1016/j.enpol.2017.07.044
14. Gomesh, N., et al. (2013). Study on Malaysian's perspective towards renewable energy mainly on solar energy. *Energy Procedia*, *36*, 303-312. doi:10.1016/j.egypro.2013.06.263
15. Klugman, S., H. Stripple, and T. Lönnqvist, *A climate neutral Swedish industry–An inventory of technologies*. 2019, IVL Svenska Miljöinstitutet.
16. Li, D., Chow, S., & Lee, E. (2013). An analysis of a medium size grid-connected building integrated photovoltaic (BIPV) system using measured data. *Energy and Buildings*, *60*, 383-387. doi:10.1016/j.enbuild.2012.12.032
17. Sinke, W. C. (2019). Development of photovoltaic technologies for global impact. *Renewable Energy*, *138*, 911-914. doi:10.1016/j.renene.2019.01.086
18. Buraidah, M., et al. (2017). High efficient dye sensitized solar cells using phthaloylchitosan based gel polymer electrolytes. *Electrochimica Acta*, *245*, 846-853. doi:10.1016/j.electacta.2017.07.073
19. Scoones, I. (2015). *Sustainable livelihoods and rural development*. Practical Action Publishing Rugby.
20. Chowdhury, M. S., et al. (2020). An overview of solar photovoltaic panels' end-of-life material recycling. *Energy Strategy Reviews*, *27*, 100431. doi:10.1016/j.esr.2020.100431
21. Rabaia, M. K. H., et al. (2021). Environmental impacts of solar energy systems: A review. *Science of The Total Environment*, *754*, 141989. doi:10.1016/j.scitotenv.2020.141989
22. Krebs-Moberg, M., et al. (2021). Third generation of photovoltaic panels: A life cycle assessment. *Renewable Energy*, *164*, 556-565. doi:10.1016/j.renene.2020.10.086
23. James, T., et al. (2011). Building-Integrated Photovoltaics (BIPV) in the Residential Sector: An Analysis of Installed Rooftop System Prices. *Contract*, *303*, 275-3000.
24. O'Shaughnessy, E., et al. (2019). Addressing the soft cost challenge in US small-scale solar PV system pricing. *Energy Policy*, *134*, 110956. doi:10.1016/j.enpol.2019.110956
25. Rauf, O., et al. (2015). An overview of energy status and development in Pakistan. *Renewable and Sustainable Energy Reviews*, *48*, 892-931. doi:10.1016/j.rser.2015.04.064
26. Li, Y., et al. (2017). Indacene Dithiophene: a promising building block for high performance polymer solar cells. *Journal of Materials Chemistry A*, *5*(22), 10798-10814. doi:10.1039/C7TA03561C
27. Borenstein, S. (2017). Private net benefits of residential solar PV: The role of electricity tariffs, tax incentives, and rebates. *Journal of the Association of Environmental and Resource Economists*, *4*(S1), S85-S122. doi:10.1086/693441
28. Horowitz, K. A., et al. (2018). Distribution system costs associated with the deployment of photovoltaic systems. *Renewable and Sustainable Energy Reviews*, *90*, 420-433. doi:10.1016/j.rser.2018.02.055
29. Liu, Z., et al. (2020). Revisiting thin silicon for photovoltaics: a techno economic perspective. *Energy & Environmental Science*, *13*(1), 12-23. doi:10.1039/C9EE02797C
30. Wassie, Y. T., &Adaramola, M. S. (2021). Socio-economic and environmental impacts of rural electrification with Solar Photovoltaic systems: Evidence from southern Ethiopia. *Energy for Sustainable Development*, *60*, 52-66. doi:10.1016/j.esd.2021.01.006

31. Saka, A. B., Olawumi, T. O., &Omoboye, A. J. (2017). Solar photovoltaic system: a case study of Akure, Nigeria. *World Scientific News*, *83*, 15-28.
32. Chaurey, A., &Kandpal, T. C. (2010). Assessment and evaluation of PV based decentralized rural electrification: An overview. *Renewable and Sustainable Energy Reviews*, *14*(8), 2266-2278. doi:10.1016/j.rser.2010.02.002
33. Zeinab, A. M. E., Muhammad, F. M. Z., &Kamaruzzaman, S. (2012). Design and performance of photovoltaic power system as a renewable energy source for residential in Khartoum. *International Journal of Physical Sciences*, *7*(25), 4036-4042.
34. Brabec, C.J., et al., *Organic photovoltaics.* 2003: Wiley Online Library.
35. Park, S. M., & Park, S.-Y. (2013). Power weakening control of the photovoltaic-battery system for seamless energy transfer in microgrids. In *2013 Twenty-Eighth Annual IEEE Applied Power Electronics Conference and Exposition (APEC)*. IEEE.
36. Al-Otaibi, O.M., Alzamil, W.S. and Alzamil, W.S., Original Paper The Impact of Property Management on the Value of Residential Product in Saudi Arabia.
37. Aspalter, C., Dashkina, A., Aldosar, A. S., & Singh, S. (2008). *The state of social welfare in Asia* (Christian Aspalter, Antonina Dashkina, Adel. S. Aldosary, Surendra Singh, Eds.). Casa Verde.
38. Hussain, A., Arif, S. M., & Aslam, M. (2017). Emerging renewable and sustainable energy technologies: State of the art. *Renewable and Sustainable Energy Reviews*, *71*, 12-28. doi:10.1016/j.rser.2016.11.001
39. Fthenakis, V., &Leccisi, E. (2021). Updated sustainability status of crystalline silicon-based photovoltaic systems: Life-cycle energy and environmental impact reduction trends. *Progress in Photovoltaics: Research and Applications*, *29*(10), 1068-1077. doi:10.1002/pip.3373
40. Baetens, R., Jelle, B. P., &Gustavsen, A. (2010). Properties, requirements and possibilities of smart windows for dynamic daylight and solar energy control in buildings: A state-of-the-art review. *Solar energy materials and solar cells*, *94*(2), 87-105. doi:10.1016/j.solmat.2009.09.018
41. Cannavale, A., et al. (2020). Smart electrochromic windows to enhance building energy efficiency and visual comfort. *Energies*, *13*(6), 1449. doi:10.3390/en13061449
42. Kelly, D., Harper, D. J., & Landau, B. (2008). Questionnaire mode effects in interactive information retrieval experiments. *Information Processing & Management*, *44*(1), 122-141. doi:10.1016/j.ipm.2007.07.001
43. Ghoudelbourk, S., et al. (2020). Selective harmonic elimination strategy in the multilevel inverters for grid connected photovoltaic system. *International Journal of Advanced Intelligence Paradigms*, *15*(3), 317-339.
44. Rao, T. E., et al. (2022). Performance Improvement of Grid Interfaced Hybrid System Using Distributed Power Flow Controller Optimization Techniques. *IEEE Access*, *10*, 12742-12752. doi:10.1109/ACCESS.2022.3164078
45. Jamal, I., et al. (2022). A comprehensive review of grid-connected PV systems based on impedance source inverter. *IEEE Access*, *10*, 89101-89123. doi:10.1109/ACCESS.2022.3186686
46. Sathik, M. J., et al. (2020). A five-level boosting inverter for PV application. *IEEE Journal of Emerging and Selected Topics in Power Electronics*, *9*(4), 5016-5025. doi:10.1109/JESTPE.2020.2976770
47. Optimizing energy use, cost and carbon emission through building information modelling and a sustainability approach: A case-study of a hospital building.
48. Fahmy, M., et al. (2017). On the green adaptation of urban developments in Egypt; predicting community future energy efficiency using coupled outdoor-indoor simulations. *Energy and Buildings*, *153*, 241-261.doi:10.1016/j.enbuild.2017.07.073
49. Khahro, S. H., et al. (2021). Optimizing energy use, cost and carbon emission through building information modelling and a sustainability approach: A case-study of a hospital building. *Sustainability*, *13*(7), 3675. doi:10.3390/su13073675
50. Mahdy, M., et al. (2022). The impact of using different weather datasets for predicting current and future energy performance of residential buildings in Egypt. *Energy Reports*, *8*, 372-378. doi:10.1016/j.egyr.2022.01.024