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DEPARTMENT OF ECONOMICS

ECONOMIC VIABILITY OF SOLAR PHOTOVOLTAIC ELECTRIFICATION SYSTEM IN HOUSEHOLDS IN KUMASI

A THESIS SUBMITTED TO THE DEPARTMENT OF ECONOMICS IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN ECONOMICS

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DECLARATIONS

I hereby declare that this submission is my own work towards the MSc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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BSTRACT

Ghana faces its fourth energy crisis which started in 2012. This energy challenge and the rising concern of climate change have led to consideration of renewable energy sources for electricity generation in the country. The discrete choice experiment was used to determine the economic viability of solar photovoltaic systems in households in Kumasi as a means of helping reduce the impact of the energy crisis. The conditional logit model in R software was used for the analysis. The effect of prices on the choices of respondents, and their maximum willingness to pay for various types of solar photovoltaic systems were assessed. The findings revealed that households in Kumasi preferred solar photovoltaic systems that powered as many of their appliances as possible at affordable prices. Although willing to pay more for each additional appliance, prospective customers appeared to have a pre-conceived price beyond which maximum willingness to pay was slightly offset. Solar photovoltaic systems are economically viable but require some form of financial assistance to deploy them in Kumasi.

DEDICATION

To my family.

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I thank, first of all, the Creator for seeing me through the entire course load.

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CHAPTER ONE

INTRODUCTION

1.1 Background

The rapid population growth and expanding economy of Ghana requires huge amounts of energy for sustenance. There has been increasing demand for energy for both residential and commercial use in response to the rapid population growth. In the population census conducted by the Ghana Statistical Service (2012), the country's population was estimated to be 24,658,823; a 30.4% increase over the year 2000 population census of 18,912,079. The current projected growth rate of electricity demand is 11% (Awate-Adamson, 2014). As the population continues to increase, the electricity demand also surges. Therefore, the current energy crisis could be attributed partly to the increase in energy demand as a result of the rising population.

The fossil fuels shortage due to high crude oil prices on the world market and the inconsistent supply from Nigeria(Center for Energy policy and analysis, 2007) have also been major contributors to the energy crisis. The crisis has also been due to the state's inability to provide the right incentives and a misaligned regulatory structure which have failed to attract the much needed investments into the electricity sector (Acheampong & Ankrah, 2014)There has also been the unavailability of natural gas to power generating plants following the inability of the West African Gas Pipeline (WAGP) to feed the country from Nigeria. The issues of climate change have forced an international consensus on the need to adopt a clean energy economy (Opoku, 2010). This has led to an increasing interest in deploying renewable energy technologies as a means of supplying energy needs in a sustainable manner (Oliver & Jackson, 1999).

Ghana like many African countries is endowed with renewable energy resources like wind, biomass and solar energy (2007). Developing these have the potential of ensuring Ghana's energy security and also help mitigate the negative climate change impacts of non-renewable energy production and utilization. As part of ensuring energy efficiency in the country, solar photovoltaic electrification could be deployed in households to provide electricity whenever there is power outage to reduce pressure on the national grid. By so doing, households could enjoy improved welfare whiles the country enjoys increasing economic growth.

1.2 Problem statement

The current power outages in the country has posed major economic challenge for Ghanaians. Suburban settlements in Ghana and even large cities such as Accra, Kumasi and Takoradi struggle with the most basic electricity needs. Many business investors have been warded off from investing in economic activities in the country (Adam et al., 2014) with the fear of running at a loss with the current situation. It has also posed educational, health and social challenges in the country. A large percentage of workers have been laid off with quite a number unemployed in the country. Also, students have been unable to study in the night when there are power outages resulting in poor performance and health centers have been unable to use certain machines which are very vital in the execution of their duties. In addition, some homes have witnessed fire outbreaks and breakdown of appliance as a result of the frequent and sudden power outages.

Since the sectors of the economy rely greatly on energy for production of goods and services, solar photovoltaic electrification should provide a service that enables achievement of economic, social and environmental development (Wamukonya, 2007). Though, solar photovoltaic electrification has been deployed in the country, its penetration with other renewables is 0.05% (Energy

Commission, 2015) which is very minimal. Also, the higher upfront cost (Coughlin & Cory, 2009) associated with solar photovoltaic systems has contributed to the reduction in their proliferation in many countries worldwide. It is therefore imperative to research into the sustainability of the technology in Ghana. Quite a number of researches have been done in the country for the deployment of the photovoltaic technology((Ashiboe-Mensah (2014), Kumi & Brew-Hammond (2013), Opoku, (2010)) but these seem inadequate for the country's development. Out of the few that have been done, much attention has been given to households in the northern sector but few in the southern sector of the country. There is the need for such researches in Kumasi located in the southern sector with the second largest population after Accra in Ghana.

1.3 Aim and objectives

In view of the above problem, this study aims at determining the economic viability of solar photovoltaic systems in Ghana using evidence from households in Kumasi. The specific objectives of the study are

1. To assess the effect of the prices of solar photovoltaic systems on the choices made by respondents
2. To determine the willingness of households to pay for different types of solar photovoltaic systems

1.4 Justification of the study

High-quality energy and electricity services are complimentary factors for social and economic development (Wamukonya, 2007). Ghana has the aim of achieving 10% additional electricity generation from renewable energy sources by 2020 as a measure to reduce the energy problem. With the present and projected decline in the cost of photovoltaic over the years and expected increase in price of oil in coming years, photovoltaic systems are likely to be cost-effective over conventional grid. This study seeks to determine how much households in Kumasi are willing to pay for solar photovoltaic systems in their homes and how their preferences are affected by the prices of the systems. This study will help government and policy makers to design appropriate policies for households if found feasible. It would provide employment in the country which will boost economic activities for national development thereby aiding in the achievement of the country's goal.

1.5 Organization of study

The study is in five sections: chapters one, two, three, four and five. The first chapter introduces the study with the background, problem statement, aim and objectives and the justification of the study. Chapter two reviews existing literature, the theory underpinning the study and other studies in this area. Chapter three looks at the method used for the study and the data analysis. Chapter four looks at the results and its discussion whiles chapter five ends the research with the major findings, conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1. Background

This chapter provides an overview of electricity in the country, renewable energy, solar photovoltaic technology, theoretical framework of the study and empirical studies on viability of solar photovoltaic.

2.2. Electricity in Ghana

Before 1966, production and supply of electricity in Ghana were carried out with a number of isolated diesel generators and standalone supply systems dispersed across the country. These could not provide enough power to meet the needs of the people. As a result, the Akosombo and Kpong Hydroelectric plants were completed and commissioned in 1966 and 1982 respectively. The demand for electricity exceeded the capabilities of the two plants. This led to the development of the Takoradi Thermal Plant and the West African Gas Pipeline to expand power generation in the country. There have also been efforts to link Ghana's power generation facilities with that of neighbouring countries like the Ghana-Togo-Benin transmission line as well as the Ghana-La Cote D'Ivoire interconnection. As the Ghanaian economy continues to grow, there are many challenges remaining in meeting the increasing demand for electricity in the region. Over the years, the country has experienced four major energy crises and the first three have been attributed to drought and low water levels in the Akosombo dam especially. This fourth energy crisis according to experts cannot be attributed to low water levels like previously.

Electricity serves as a key input for most activities in modern economies. According to the Ministry of Energy (2012), it accounts for 69% of modern energy used in the industrial and services sectors.

Economic growth, urbanization and rural electrification have caused increasing demand for electricity over the past decade. Brew Hammond and Kemausuor (2007) reported that, the country's Gross Domestic Product (GDP) grew at an average of 5.5% per annum between 2000 and 2008 whiles her urban population share went up from 44% to 52% between 2000 and 2010. They further noted that Ghana experienced compound annual growth in peak power demand of about 1.4% from a base of 1,258 Megawatts in 2000 to 1,423 Megawatts in 2009, and growth in cumulative energy demand of 3.3% annually from 7,539GWh in 2009. The total grid or public electricity generated in 2011 was 10,167 Gigawatt-hour against 12,874 Gigawatt-hour in 2013, a 6% rise over the previous year according to Ghana Energy Commission (2014).For 2012, the total electricity requirement was expected to increase ranging between 12,394 and 14,673 Gigawatthour as against 15,725 and 16,500 Gigawatt-hour in 2013. It stated that an installation gap of 500600 Megawatts thermal gas plant equivalents should have been in place by then. Also, the existing power plants were unable to attain full generation capacity as a result of limitations in fuel supply owing to rising fuel prices and uncertainty in rainfall and water inflows into the hydroelectric power facilities.

Technical and financial issues have affected the supply of adequate electricity to meet the growing demand. In the western sector, the outage of one combustion turbine unit which provides inadequate power creates problems during maintenance outages. Some outmoded transmission lines and sub-station and the reduction in scheduled imports have been technical issues affecting the country's electricity generation. Also, tariffs have been left unadjusted to meet the increased cost of power generation from the additional power generated from thermal plants to hydro power generation which has led to a rise in the cost of production. The total monthly revenue generated is unable to meet even the monthly fuel purchases not to mention the other production costs

(BrewHammond & Kemasour, 2007). The rising demand and the inability to meet it over the years have led to the energy problem which has affected various activities in the country. VALCO operations have been interrupted several times over the past 10 years due to power unavailability issues. Several small-scale companies have collapsed due to the current energy crisis in Ghana. Again, both local and foreign investors have lost interest investing in economic activities leaving a reasonable percentage of the population especially graduates unemployed. The crisis has led to a reduction in productivity in the services and industry sectors. It has also contributed to the rising inflation rate in the country. The rising prices of fuel required for power generation and their associated environmental impact have led to consideration for renewable energy as the best alternative in curbing the energy crisis.

2.3. Renewable energy

The research and testing of new energy generation methods and technologies, in all forms, continues at an ever increasing pace with the hope of eliminating our dependence on fossil fuels with both implementable and profitable alternatives" (Lial, 2011). This has led to consideration of renewable energy worldwide to meet energy demand. Renewable energies are derived from natural processes and are replenished at a faster rate than they are consumed. Common sources are solar, wind, geothermal and biomass. Renewable energy is considered more advantageous than fossil fuels when considering energy security and climate change. Fossil fuels cause high environmental impacts through the production of solid toxic waste, consumption of larger volumes of water, emission of larger amounts of hazardous gaseous products and greenhouse gases. Renewable energies on the other hand are clean, reliable and safe for use. They give minimal air emissions compared to fossil fuels. They also represent a great business employment opportunities. The high probability of renewable energy in helping solve energy issues has led to the formulation of renewable energy policies by over a hundred countries worldwide. Some countries have through their policies had funding from European Union, World Bank, Shell British Petroleum and other donor agencies both locally and international. Governments have also funded some of such renewable energy projects.

The share of renewable energies in the global energy has been increasing over the years. According to the British Petroleum (2014), they now account for more than 5% of global power output and renewable energy used in power generation has risen by 16.3% and accounted for a record 5.3% of global power generation. China recorded the largest incremental growth, followed by the US. Globally, wind energy grew by 20.7% and accounted for more than half of renewable power generation growth. Solar power generation grew even more rapidly by 33% but from a smaller base. A growing number of cities, states, and regions such as Djibouti, Scotland and Tuvalu are developing strategies to transition to 100% of their electricity from renewable sources (REN 21 steering committee, 2014). The government of Cape Verde has the ambition to meet energy demands in the country with 100% renewable energy. Kenya, Ethiopia and Rwanda are also investing heavily in solar, geothermal and wind and gradually moving away from traditional hydropower sources as demand for power continues to surge and their economies grow. According to the International Energy Agency (2014), renewable energy could make up over a quarter of global electricity generation by 2020.

Ghana is not left out when it comes to countries that aim at deploying renewable energies to expand their power generation. The National Electrification Scheme of Ghana was initiated in 1989 with the aim of achieving 100% electrification by 2020. This policy stipulated that communities with more than 500 people will have access to electricity by 2020. This calls for other means of generating power in the country since it will be difficult to achieve this aim with only the two major means of power generation, hydro and thermal. As such, with the endowment of renewable energy sources such as wind, solar, mini hydro and biomass that can be exploited for electricity production, Ghana aims at deploying 10% of them by 2020. Building Integrated Photovoltaics offers a plausible means of decreasing demand on the national grid (hydroelectric power) while also increasing the renewable component of the nation's energy mix simultaneously especially by incorporating them in new buildings in urban areas (Ashiboe-Mensah, 2014). Renewable energies are currently providing just 0.13% of the country's electricity generation and are projected to increase substantially over the decade because of the government commitment and legal frameworks that are being put in place (KICP, 2009)The development and use of renewable energy resources have the potential to ensure Ghana's energy security and mitigate the negative climate change impacts.

2.3.1. Solar energy

Solar energy converts sunlight into usable energy. Solar power generation enjoyed very rapid growth in 2014, with a 38% increase (British Petroleum, 2014). Solar is starting to have a noticeable impact in terms of sources of power generation growth, contributing nearly 15% of the growth of global power in 2014. The International Energy Agency (2014) states that solar energy is the newest major source of energy in the energy mix and it makes up less than 1% of the electricity market today but could be the world's biggest single source by 2050.

The sub-Saharan region of Africa receives about 3-4 kilowatt per hour of solar energy. A number of studies have proved the potential of solar energy in Ghana. The SWERA Ghana Project report revealed the average solar irradiation for Ghana to be 5 kilowatt hour per meter square per day and Wa, in the Upper West region having the highest level of solar irradiation in country at 5.520 kilowatt hour per meter square per day (Kpeglo, 2013). To be able to convert solar energy into electricity, technology plays key role. Photovoltaic and solar heating and cooling are well established solar technologies. Photovoltaic cells produce electricity directly, while solar thermal systems produce heat for buildings, industrial processes or domestic hot water. Thermal systems can also generate electricity by operating heat engines or by producing steam to spin electric turbines. Photovoltaic cells are mostly used because of their environmental friendliness, low maintenance requirement, possibility of expandability, no fuel requirement, and no noise generation (Muhammad, 2012). They also have the highest cost reduction potential among all renewable energy sources (IRENA, 2013).

2.3.2. Photovoltaic technology

The photovoltaic was first built by Bell Laboratories in 1954. It uses solar cell to convert direct sunlight to electricity. A solar cell is a unit that delivers only a certain amount of electricity. Three types of solar cells exist based on the basic material and their level of commercial maturity - traditional or thin film solar cells, second generation solar cells and third generation solar cells (IRENA, 2013). The traditional solar cells are mostly flat-plate and made from crystalline silicon. They constitute a greater percentage of all photovoltaic cells and a greater portion of them are used on owner occupied dwellings (Wissink, 2013). The second generation solar cells are made from amorphous silicon or non-silicon materials such as cadmium telluride. Third generation solar cells are made from a variety of new materials besides silicon such as solar inks using conventional printing press technologies, solar dyes and conductive plastics.

Solar cells are very small and each one generates a few watts of electricity. In order to use solar electricity for electrical appliances which require a particular voltage for operation, a number of solar cells are connected together to form a solar panel or module. The panels are either mounted at a fixed angle facing south or mounted on a tracking device that follows the sun, allowing them to capture greater amounts of sunlight. A combination of solar panels forms a solar array and hundreds of them are interconnected to form large utility-scale photovoltaic systems which are often used in industrial applications.

The major components of solar PV systems are solar panels, batteries, charge controllers and inverter. The solar system turns on automatically in the morning and off automatically at night. From the rising to the setting of the sun, it converts sunlight into electricity. When sunlight is absorbed by solar cells, the solar energy knocks electrons loose from their atoms allowing the electrons flow through the material to produce electricity. This process works even on cloudy or rainy days at a low production and conversion efficiency. The panels produce current only at daylight hours. Thus, the battery attached to the system stores power which is released for usage at night. The performance of a solar cell is measured in terms of efficiency at turning sunlight into electricity. Only sunlight of certain energies will work efficiently to create electricity and much of it is reflected or absorbed by the material that makes up the cell. Low efficiencies mean that larger arrays are needed.

The deployment of solar photovoltaic systems globally is gradually increasing. The world has added more solar photovoltaic capacity since 2012 than in the previous decades. The total global capacity overtook 150 Gigawatts in early 2014. Germany and China initiated large-scale photovoltaic development since 2013. Also, China, Japan and USA have been the leaders in the global photovoltaic market. The photovoltaic capacity in Africa has increased from 26 Megawatts in 2000 to 1334Megawatts in 2014 (IRENA, 2015) with South Africa having the highest capacity of 992 Megawatts in 2014 from 8 Megawatts in 2000 in Africa. The country had a drastic increase of 147 Megawatts in 2013 to 992 Megawatts in 2014.

In Ghana, the first solar photovoltaic system is the six array 2Megawatts solar park at Pungu near Navrongo in the Upper East Region which was commissioned by the Volta River Authority (VRA) in May 2013. It is currently the only operating commercial photovoltaic system in the country built at a cost of $8 million. Ongoing projects in the country include the proposed 10 Megawatt solar power project by VRA in Northern Ghana and the 155 Megawatts solar photovoltaic project to be funded and built by Blue Energy which could be the largest in Africa upon completed. The Blue Energy project will be built at a cost of $400 million at Nzema near Aiwiaso in the Western Region. It is predicted to increase the country's electricity capacity by 6% and also cut emissions of 5.5 million tonnes of CO_2. The project is to begin by the end of 2015 with the installation of 630,000 photovoltaic modules to supply electricity to power 220,000 homes. It is expected to create thousands of jobs and contribute $100 million in tax to the government over its lifetime. Also, a number of households and institutions such as hotels, schools, hospitals have deployed solar power as either their main electricity supply or an alternative energy source when there is power outage. Solar energy utilisation has however been limited owing to its comparatively higher cost.

From the British Petroleum statistics, photovoltaic share of global electricity are expected to increase by 16% by 2050, a significant increase from 11% goal in 2010 if the cost of solar photovoltaics reduce by 25% by 2020, 45% by 2030, 65% by 2050 leading to a range of $40 to 160Megawatt hour assuming a cost of capital of 8% and the capacity installed each year rises from 36Gigawatts in 2013 to 124 Gigawatts per year on average, with a peak of 200Gigawatts per year between 2025 and 2040. This increase could be due to the fact that the technology is still developing very fast; efficiency rates and durability are increasing and the cost keeps decreasing with high velocity (Wissink, 2013).

2.3.2.1. Grid connected and off-grid applications

Solar photovoltaic systems are either connected to the grid or not. For grid connected systems, the photovoltaic panels first use the solar electricity to supply all the power required. In daylight hours, when the solar system generates more electricity than it is consumed, surplus electricity travels through the meter into the local power grid. However, when there is no or insufficient light, or when the consumer requires more energy than the installation is capable of providing, the electrical grid guarantees the supply of necessary electrical energy. Over the course of the month, if the solar system produces more electricity than what is consumed, the electric bill is credited for the surplus electricity. Owners are credited the same rate as if they purchased the electricity from their local utility. The components of a grid-connected photovoltaic system are the photovoltaic modules, a power inverter, a safety device to power down at failures in the grid, main services panel and an electricity meter.

Off-grid photovoltaic systems consist of a renewable energy source, which generates direct current power, a battery bank that stores the direct current power, and an inverter or charger unit. The charge controls the charging of the storage batteries. The inverter converts direct current power to clean and reliable alternating current electricity for use. When the sun is up, the solar panels generate power to charge the battery bank and provide electricity. At night, the inverter or charger automatically runs electrical equipment from the battery bank. These can also be connected to the grid for the battery bank to be charged by utility power.

The solar systems are either installed on the roof-top of buildings, other structures or on the earth's surface. The 2 Megawatt photovoltaic system in Ghana covers 9.6 acres of land and the 155 Megawatts Blue Energy project will also cover large areas of land. This implies that for projects with huge capacities, large areas of land would be required. As such, land that could be put into much beneficial use would have to be used for such projects. To curb this problem, the systems could be installed on the roof-tops of buildings to reduce the area of land that goes into the deployment of the technology. They could be deployed in the urban areas where electricity demand is rapidly growing (Lial, 2011) and rural areas where there is low energy demand and grid extension is more costly. This could ease the pressure on the grid.

2.3.2.2. The cost of solar photovoltaic systems

The capital cost of a photovoltaic system is composed of the photovoltaic module cost and the balance of system cost. Module typically ranges between 30-50% of the total cost of the system. The remaining costs include the balance of system and the installation - which can be as low as 20% for utility-scale photovoltaic plants, 50-60% for residential applications, and as a high as 70% for off-grid systems, including energy storage usually batteries and back-up power (British Petroleum, 2014). Solar costs have declined and photovoltaic systems have experienced considerable growth since 2003 especially in China, Japan, Germany and the United States (Carlisle, Kane, Solan, & Joe, 2014). According to British Petroleum (2014), prices of panel modules have dropped from around \$100 per watt peak in 1975 to below \$0.60 per watt peak in 2014. Total system prices have also fallen, dropping 15-23% per annum between 2010 and 2013. Installation costs have also fallen and it has been attributed to the steep reduction in photovoltaic modules. From 2008 to 2012, the annual average module prices on the US market fell by \$2.60 per watt representing about 80% of the total decline of photovoltaic system prices over that period (Barbose, Darghouth, Weaver, & Wiser, 2013). Non-module costs have also declined over the long term but have remained flat in recent years. The growth in photovoltaic deployment could be as a result of the reduction in the prices.

2.3.2.3. Solar photovoltaic systems versus conventional grid

There exists a debate on solar photovoltaic systems and conventional grid as to which is less costly. On one hand, some believe that photovoltaic systems are costly than conventional grids because of their high initial costs but these tend to be relatively cheaper when spread over their life cycle. On the other hand, some have argued that solar photovoltaic systems are the least cost option for rural electrification in relation to the conventional grid. This argument has been based on the fact that the rate of growth of energy demand in rural areas is relatively low and the cost of extending conventional grid to rural areas is high. Again, some attribute it to the rising fuel cost needed to keep the grid in operation. The Organization of the Petroleum Exporting Countries (OPEC) has proved this by increasing oil prices from $1.57 per barrel in 1961 to $55.09 per barrel in 2015 (Statista, 2015) though there have been fluctuations in the prices between the two periods. The World Bank has also projected oil prices to increase from $57.5 per barrel in 2015 to $61.2 per barrel in 2016, $63.7 per barrel in 2017, $66.3 per barrel in 2018, $69.1 per barrel in 2019, $71.9 per barrel in 2020 and $88.3 per barrel in 2025. Photovoltaic could have an upper hand over conventional grid because of their expected decline in cost over oil prices in coming years. Also, oil reserves have been projected be exhausted by the next thirty to forty years.

Different studies have also revealed that the tariff cost from solar photovoltaic systems is very high whiles that of conventional systems is relatively low. However, a study conducted by Harish and others reported savings on electricity costs and reduced kerosene usage in Karnataka after deploying solar lighting systems (Harish, Iychettira, Raghavan, & Kandlikar, 2013). The feed-in tariff paid for electricity from large-scale photovoltaic installations in Germany fell from over 40 Connecticut per Kilowatt hour (ct/kWh) for installations connected in 2005 to 9 Connecticut per Kilowatt hour (ct/kWh) for those connected in 2014. Disparities in the tariffs of the two systems could be as a result of the global average costs which are generally used for all countries (Wamukonya, 2007).

Subsidies for conventional grid system might be the main reason why they have a lower cost than the solar photovoltaic systems. This accounts for why subsidies should also be made available for solar photovoltaic to reduce the tariff and increase its demand. Arora (2013) expects subsidies to provide the major application of solar photovoltaic in urban residential rooftop and provide the market growth needs to reduce prices. Opoku (2010) who determined the viability of a 20 MW Solar Thermal Electric-Power Plant operating in northern Ghana also realized that the plant's viability was dependent on judicious mix of major capital subsidies and modest feed-in tariffs in the hope that Central Receiver System (CRS) cost would drop significantly.

Conventional grid systems meet almost all end user demand whiles solar photovoltaic has the limitation that it can only be used for lighting and powering low-voltage appliances like television, radio and mobile phones (2007). High power consuming appliances like air conditioners and water heaters require additional capacities for their operation (Bijli Bachao Team, 2015). The inverters connected to the photovoltaic system handle such high load.

2.4. Theoretical framework

2.4.1. Random utility theory

The random utility theory is the theory underpinning the study. This theory uses the assumptions of economic rationality and utility maximization. The individual is assumed to make a choice that provides the maximum benefit known as utility. When presented with many alternatives, it is assumed that the only reason respondents will choose alternative *i* is if and only if it derives the greatest utility in the choice set (Wissink, 2013). Thus,

$$U_{in} > U_{jn} \forall j \neq i$$

It is assumed that the indirect utility function comprises a deterministic component V_i and a random component e_i. The value of V_i can be determined because it can be observed whiles the random component cannot be measured. This is because the deterministic component relates to the alternatives in the choice sets. The deterministic component can be modeled as the sum of part-worth utilities that depend on the different attributes and their levels as

$$V_{in} = \beta o + \beta 1\, X_{in1} + \beta 2\, X_{in2} + \ldots \ldots . + \beta k X_{ink} = \sum_k \beta k X_{ink}$$

To be able to model the random component, a distribution is assigned to the random element and then probability of choice is estimated. Thus, the model becomes

$$U_i = V_i + e_i$$

Since the random component cannot be observed and measured by expressing the probability that individual n will choose alternative as

$$P_n(i) = P(U_{in} > U_{jn}) \forall j \neq i$$

Thus, the likelihood that prospective customers' choice is *i,* is also the likelihood that *i* is more useful than other alternatives in the choice set. Moreover, the utility yielded by an alternative is assumed to depend on the utilities associated with its composing attributes and attribute levels. The rational choice and random utility theories have similar assumptions. As the study seeks to present alternative products to consumers to make their choices, the two theories will be most relevant to this study.

2.5. Empirical Review

Several studies have investigated the viability of solar photovoltaic systems in different countries and regions globally. The studies have employed various techniques in measuring the viability of the technology. Some have considered the technical viability, others economic, yet others ability to meet end user needs, save time and reduce emissions.

Kolhe et al. (2002) conducted a study on the economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India. Upon realizing a drop in prices of photovoltaic modules in 1990, they considered it highly economical compared to the 4 million diesel pump-sets to be energized for electricity generation for the over 80,000 villages without electricity in India. Sensitivity analysis was done for energy demand using a life-cycle cost computation. The study revealed that photovoltaic powered systems were the lowest cost option at a daily demand up to 15 kilowatt-hours even under unfavourable economic conditions. For favourable economic parameters, photovoltaic systems were competitive up to 68kilowatthoursper day. The comparisons were intended to give a first-order indication of when a standalone photovoltaic system should be considered for application. According to them, as the cost of photovoltaic systems decreased and diesel costs increased the break even points occurred at higher energy demand.

Wamukonya (2007) studied the viability of solar home system electrification for Africa's development. He identified Africa has less than 40% of its population living without electricity and decentralized photovoltaic systems had been the dominant technology with the fact that they were cost effective. He was with the assertion that photovoltaic systems had the potential to meet the growing energy needs of African countries. Using a service based analytical approach; he reviewed the effectiveness of solar home systems in Africa in meeting users' expectations. The analysis was done on the premise that, solar home system project had been deployed because they were cost effective, could meet end-user demand, have the ability to alleviate poverty, could save time and reduce emissions. However, a close review of the actual cost of the systems given the services they provided revealed that most of the promises remained unmet and therefore questioned the wisdom of using public funds to support the system at the expense of more appropriate technologies.

Li et al. (2011) conducted a study on domestic application of solar photovoltaic systems in Ireland considering their economic viability. He realized that solar electricity generation had not been very popular in Ireland either on a large or domestic scale. The unclear economics of domestic solar photovoltaic systems under Irish conditions was considered the biggest obstacle for expanding the installation of photovoltaic systems in Ireland. Evaluation of the economic viability of a domestic solar photovoltaic system was done on a case by case basis. The software programmes HOMER and Microsoft Excel 2007 were used for the energy and economic analyses. Economic analysis of eight sample domestic solar photovoltaic systems available in Ireland was presented. He found out that, the domestic solar photovoltaic system is not economically viable under current conditions in Ireland and still do not look promising even if better financial support is given.

Kebede (2015) conducted a viability study on grid-connected solar photovoltaic system in Ethiopia. 35 locations were assessed for their technical potential considering a 5MW photovoltaic power plant in each site. Also, economic viability study of a 5MW photovoltaic grid-connected power plant in Addis Ababa area was further conducted. Input data sources for the study included the National Meteorological Agency of Ethiopia and the Surface Meteorological and Energy Dataset of NASA. HOMER and RETScreen software were used in the study. Financial indicators showed that the proposed solar photovoltaic system was economically viable but it might not be sufficiently attractive for commercial investors unless an incentive mechanism was introduced.

Further scenario analysis indicated that the upcoming feed-in tariff law for solar photovoltaic power generation could influence the investment decision of the private sector.

Though all the available research determined the viability of the solar photovoltaic, the analysis was done from different perspectives with economic viability as a major consideration in all. Some have employed engineering approach whiles others have used the economic approach using case studies and surveys in determining the viability of photovoltaic systems. This research seeks to employ the discrete choice experiment to achieve this same aim. The above studies have not concentrated on the price of solar systems and their effect on household choices as well as their willingness to pay for the system before their implementation and that is what the study seeks to do using the discrete choice experiment approach.

CHAPTER THREE

METHODOLOGY

This chapter elaborates on the process of choosing the method that will be conducted to estimate the opinion of households about deployment of PV systems in their homes as additional power supply to the national grid and how the data obtained will be analyzed.

3.1. Study Area for the Choice Experiment

Kumasi is the second largest city in Ghana and the capital of the Ashanti Kingdom. It is also the headquarters of the Ashanti Region. The city has a population of 2,119,101 (Kumasi Metropolitan Assembly, 2015). It covers a land area of approximately 254 square kilometers. According to the 2010 population and housing census, Kumasi has 440, 283 households with an average household size of 4 persons. Households get their electricity supply from the Electricity Company of Ghana (ECG). Kumasi is a large industrial and commercial center.

3.2. Sampling frame and Sample size

Households in Kumasi constituted the population of study for this research. This group is made up of a large number of households and because time was a limiting factor, hundred households were considered. Under the discrete choice experiment, a minimum sample size of thirty is recommended for reliable results. Also, the total number of observations obtained under the choice experiment is the number of respondents multiplied by the number of questions. Hence, the hundred samples provided 500 observations.

3.3. Discrete Choice Experiment

The desire to understand consumer demand for goods and services where revealed preference data on the actual choice made by individuals could not be used led to consideration of other techniques for deriving preferences. The discrete choice experiment is one outcome of the search. Discrete choice experiments are quantitative techniques for eliciting preferences that can be used where there is no revealed preference data. They are usually used for new products and services that are still undergoing development or those that are not yet available on the market. This method presents hypothetical alternative programme, goods or services to individuals and seeks their preference. The discrete choice experiment uses the random utility theory which has been presented in the theoretical framework of the study. Researchers are able to discover the value individuals place on selected attributes of a programme, product or service.

A number of researches such as those on health and the environment have been conducted using the choice experiment technique (Vega & Alpízar, 2011). The choice experiment has also been used by other researchers in their study on solar photovoltaic systems. One of such research was conducted by (Wissink, 2013) on how home buyers appreciate installed photovoltaic systems in Eindhoven. Towhidul (2014) also used the method in conjunction with an innovation diffusion model to predict the adoption time probabilities of photovoltaic solar panels by households.

In the choice experiment, each alternative is described by several characteristics termed attributes. The respondents' choices depict the values they place on each attribute. Vega and Alpizar (2011) have stated that upon comparison with other valuation methods like travel cost and contingent valuation, choice experiments can create hypothetical but realistic scenarios for consumers and generate restoration alternatives for the affected good. The method can be used to estimate respondents’ willingness to pay for products (Alfines et al. 2004). In the context of the solar photovoltaic systems deployment, discrete choices experiment is very useful because individual choices of solar photovoltaic systems could be based on their characteristics.

3.3.1. Designing the Choice Experiment

Choice experiment requires the adoption of an experimental design to study the effect of the attribute levels (independent variables) on the dependent variable. Within this discrete choice experiment, respondents were presented with hypothetical photovoltaic system choices which varied by attributes and levels of those attributes. Attributes are variables with more than one fixed level. An experimental design requires consideration of factors such as attributes, attribute levels, choice sets, questionnaire design, data input, analysis and interpretation. The stages for conducting the discrete choice experiment have been outlined below.

3.3.2. Attribute Establishment

At this stage, relevant attributes to the study were identified to serve as a guide for the formulation of choice sets. The attribute name adopted was “type”. Based on this, five types of solar systems namely “type 1”, “type 2”, “type 3”, “type 4” and “type 5” were used. These were chosen mainly by considering the basic appliances that are used by households. The appliances were precisely two bulbs, television, fan, iron and fridge. They are shown in Appendix 1. Basic appliances were the option because the solar photovoltaic systems were considered in this study as stand-by sources of electricity when there is power outage and households might prefer using certain basic appliances to cut down the cost of their systems. The cost estimates for these solar photovoltaic systems were obtained from three different solar system consultancies and their averages were used. The wattages of appliances as specified by the Electricity Company of Ghana were used in the cost estimation. This is evident in Appendix 2. Also in the table are the hours of usage daily by households. These assumptions were meant to give room for trade-off to be made by respondents.

3.3.3. Assignment of Attribute Levels

After the identification and establishment of attributes, attribute levels were assigned. These represent the numerical or qualitative value of attributes in given alternatives. The levels reflect the range of situation the respondents would expect to experience. The study considered three attribute levels. These were “price”,” warranty” and “appliance”. The prices for the types of appliances to be presented to respondents were 4200 GH cedis for type 1, 5200 GH cedis for type 2, 13,500 GH cedis for type 3, 15,700 GH cedis for type 4 and 16,800 GH cedis for type 5. Warranty represents the lifespan of the appliances and it is 25 years for all the types of solar photovoltaic systems.

3.3.4. Choice sets and Questionnaire design

Hypothetical alternatives were generated from the attributes and levels using the R software. The output from the software is provided in Appendix 3. A combination of the attributes and levels gave the choice sets. Five blocks of choice sets were obtained from the software output and these formed the basis for the questionnaire design. Five different sets of questionnaire were designed. Each set contained five questions with three alternatives. Respondent also had the option of not choosing any of the alternatives. Samples of the questionnaires are provided in Appendix 4. On top of each choice set, there were nine direct questions.

1. The gender of the respondent
2. The location of respondent in Kumasi

3. Their occupation
4. Whether respondents worked in private or government institutions
5. The monthly income of respondents
6. Whether they used light bulbs, television, fan, fridge and iron at home. Room was given for other additional appliances
7. Whether respondents knew about solar systems
8. If respondents had heard about energy efficiency
9. Whether those who knew about energy efficiency practiced

`Samples of the questionnaire have been provided in the Appendix.

3.4. Data Collection

The questionnaires were administered by a three-member team. The random sampling technique was used to collect the data. The households in Asokwa, Ayeduase and Ayeduase New Site were interviewed. 45 respondents were interviewed in Ayeduase and Ayeduase New Site and 55 in Asokwa. The data was collected in five days.

3.5. Data input

Once the data was collected, it was fed into SPSS where each respondent had five choices with three options each providing multiple rows of data. The variables were Identity (ID), block, question 1, question 2, question 3, question 4 and question 5. The data is provided in Appendix 5.

3.6. Data Analysis

The data was analysed using the conditional logit model in R software. This model estimated respondents' preferences for attributes of solar photovoltaic systems in the discrete choice experiment. The output was used to determine the effect of the prices of solar photovoltaic systems on respondent's choices. This was estimated using the model

$$V_{in} = \beta o + \beta 1\ type\ 2 + \beta 2\ type\ 3 + \beta 3\ type\ 4 + \beta 4\ type\ 5$$

Also, the respondents' willingness to pay (WTP) for the different types of solar was calculated using the formula

$$WTP = - \frac{\beta_{type}}{\beta_{price}}$$ (Aizaki, Nakatani, & Sato, 2015)

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

4.1. Demographic data

All the 100 questionnaires were filled by households giving a total of 500 observations.

4.1.1 Age

Out of the 100 respondents, 61 were males and 39 were females. 24 respondents were in within the 20 years age range and 33 were within the 30 years age range. Again, 16 respondents were within the 40 years age range whiles 10 respondents were in their fifties. Also, 10 respondents were within the 60 year age range whiles 7 respondents withheld their age.

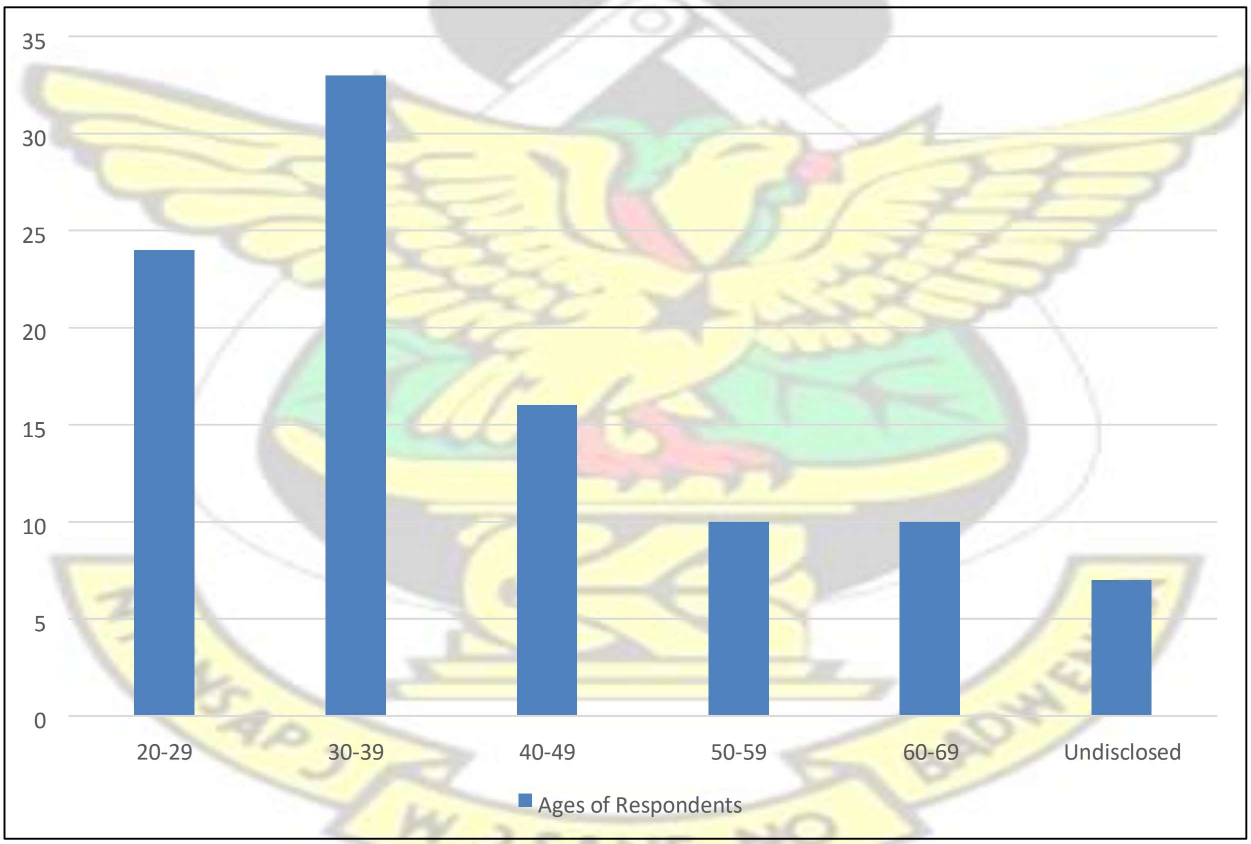

Figure 3.1: Bar graph showing the number of respondents and their ages

4.1.2 Location

45 of the households were in the non-residential areas, that is Ayeduase and Ayeduase New Site whiles 55 were in the Asokwa residential area residential.

4.1.3 Occupation

The respondents included, traders, teachers, bankers, farmers, construction industry workers (carpenters, plumbers, masons), hair dressers, electricians, medical staff (biochemist, pharmacist, nurses, laboratory technicians, physiotherapist, optician), managers (estate, logistics, bank), artist, geologist, lawyer, engineers (telecommunication and civil), sales agent and marketer and entrepreneur. Five respondents did not indicate their occupation.

4.1.4 Type of institution

19 of the respondents worked in government institutions whiles 76 worked in private organizations. Again, five respondents did not provide information as to whether they worked in private or government organizations.

4.1.5 Monthly Income

27 respondents received monthly salaries below 1000 GH cedis and 23 received monthly salaries between 1000 GH cedis and 2000 GH cedis. Also, 16 respondents received monthly salaries between 2000 GH cedis and 5000 GH cedis whiles 14 respondents received monthly salaries above 5000 GH cedis. However, 20 respondents did not disclose their monthly salaries.

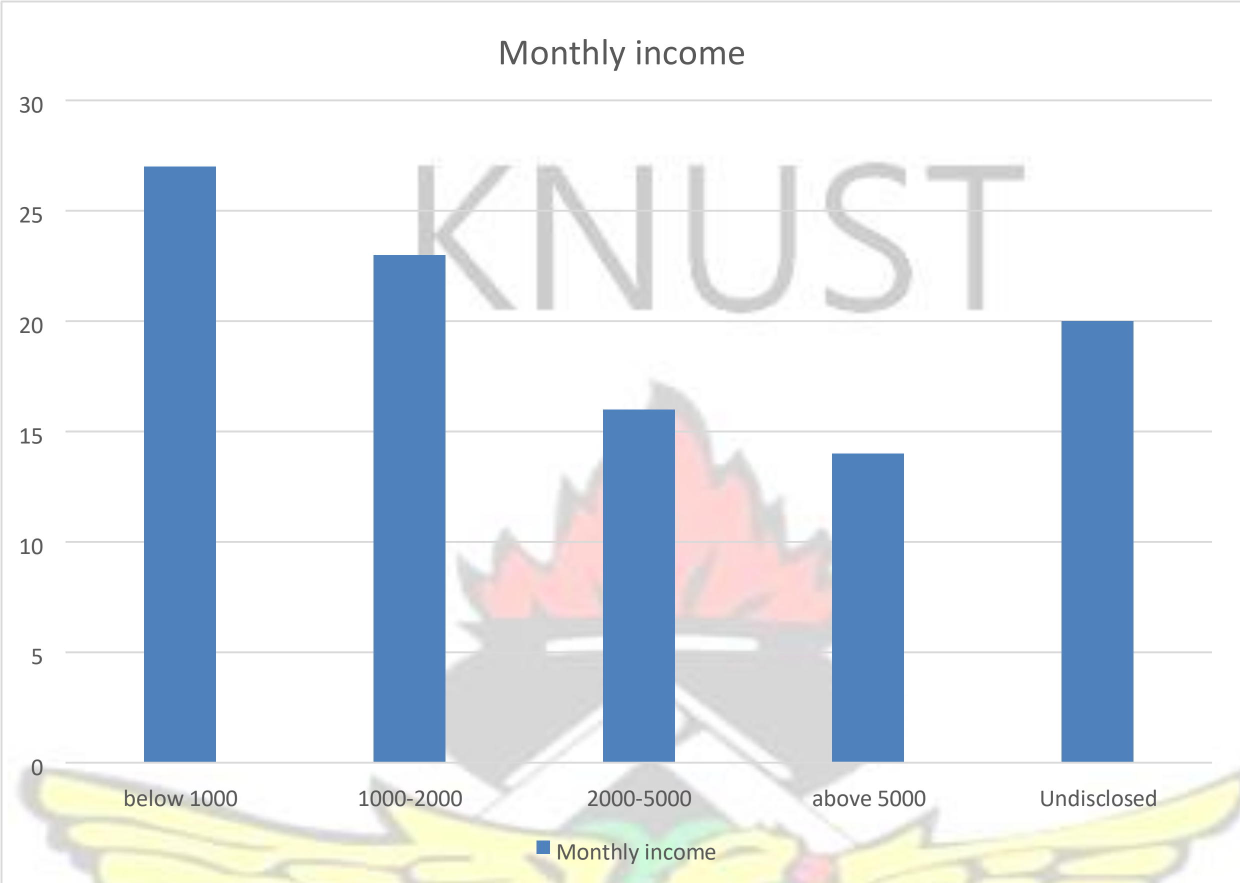

Figure 3.2: Bar graph showing the number of respondents and their monthly income

4.1.6 Household Appliances

92 households had all the five appliances presented to them. That is light bulb, television, fan, fridge and iron. Out of the 92 who used all the appliances, 55 respondents used additional appliances such as radio, microwave, kettle, computer, washing machine, water pump, water heater, rice cooker, printer, blender, sewing machine and air conditioner. 7 households used all the appliances except fridge. Out of these 4 households used radio in addition to the four appliances.

4.1.7 Knowledge on solar systems

67 of the respondents has some form of knowledge about solar systems whiles 23 of them had no knowledge about solar systems.

4.1.8. Knowledge and practice of Energy Efficiency

84 respondents knew about energy efficiency whiles 16 had no idea about energy efficiency. Out of those who knew about energy efficiency, 60 households practiced it whiles 24 households did not practice it.

4.2. Results

Using the conditional logit analysis in the R software, the following results were obtained from the choice experiment data. The types of solar photovoltaic systems in the results are as follows:

Type 1 - 2 light bulbs

Type 2 - 2 light bulbs + television

Type 3- 2 light bulbs + television + fan

Type 4- 2 light bulbs + television + fan + fridge

Type 3- 2 light bulbs + television + fan + fridge + iron

Table 4.1: Output for relationship between price of the various types of solar photovoltaic systems and respondent choices

	Coefficient	Exp(coefficient)	Std. Error	z	P-value
ASC	-1.004	0.366	0.335	-3.000	0.003

Type2	0.381	1.464	0.389	0.981	0.327
Type3	1.853	6.376	0.342	5.412	0.000
Type4	2.872	17.665	0.343	8.367	0.000
Type5	3.510	33.457	0.339	10.358	0.000
Price	-0.000132	1.000	0.000	-8.815	0.000

Rho-squared = 0.2752471

Adjusted rho-squared = 0.2665909

Akaike information criterion (AIC) = 1016.721

Bayesian information criterion (BIC) = 1042.009

Number of coefficients = 6

Log likelihood at start = -693.1472

Log likelihood at convergence = -502.3604

From the results, variables type 3, type 4 and type 5 have significantly positive coefficients indicating that consumers value type 2, type 3 and type 4 higher than type 1. The coefficient of price is significantly negative indicating consumers' preference for cheaper solar systems. The adjusted rho squared is over 0.2 implying that the result is a good fit.

Table 4.1: Output for respondents' willingness to pay

	Appliances	MWTP	Confidence Interval	
			2.50%	97.50%
ASC	2 Light bulbs	-7625.431	-14362.677	-2423.132
Type2	2 Light bulbs + TV	2895.954	-2920.348	8990.763
Type3	2 Light bulbs + TV+ Fan	14064.443	8763.809	20565.493
Type4	2 Light bulbs + TV+ Fan + Fridge	21800.878	16091.552	29344.518
Type5	2 Light bulbs + TV + Fan + Fridge + Iron	26649.631	20672.263	34827.262

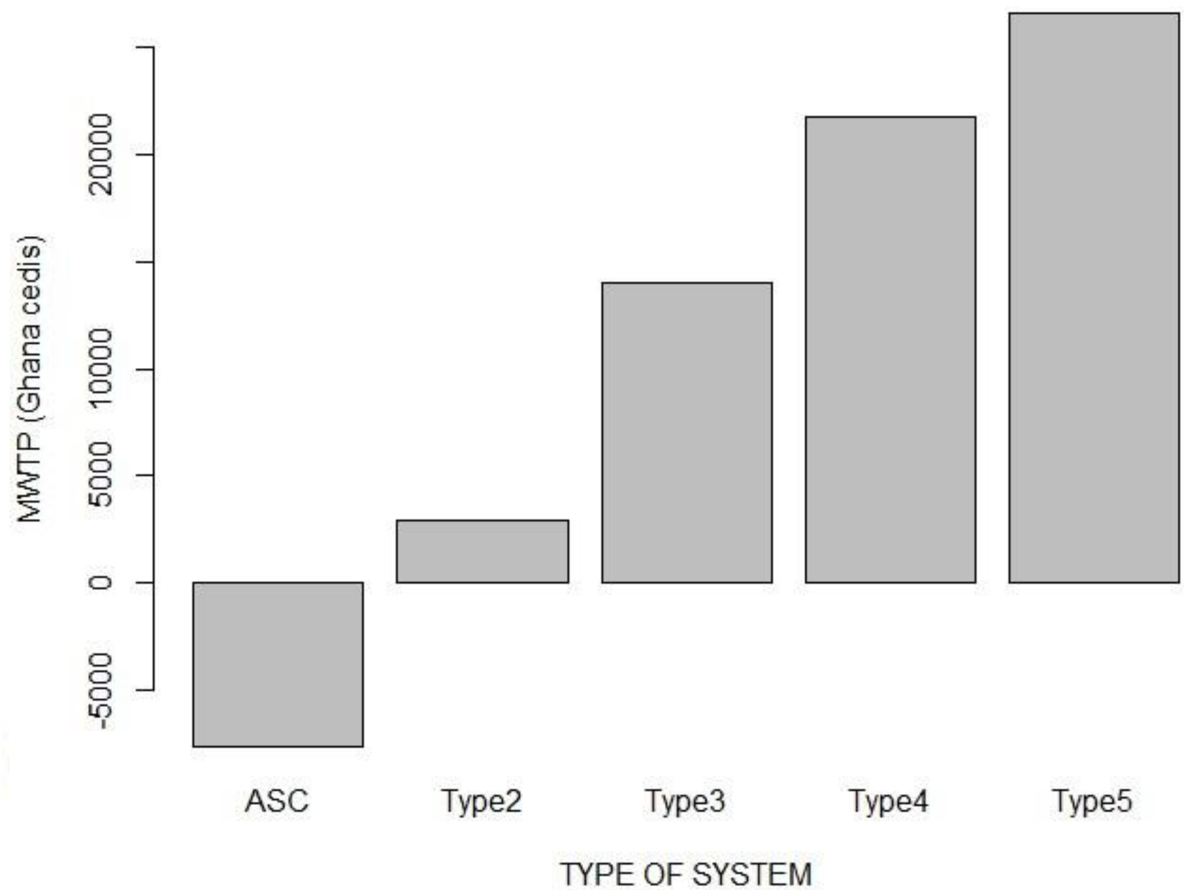

Figure 4.1: Willingness to pay estimates and 95% confidence interval for solar photovoltaic systems for households in Kumasi.

The results show that compared with type 1, the respondents' willingness to pay for type 1, type 2, type 3, type 4 and type 5 are -7625.431 GH cedis, 2895.954 GH cedis, 14064.443 GH cedis, 21800.878 GH cedis and 26649.631 GH cedis respectively. Although the willingness to pay for type 1 is significantly negative, those for type 3, type 4 and type 5 are significantly positive whiles that of type 2 does not differ significantly from zero at the 0.5 significance level.

4.3 DISCUSSION

The aim of the research was to determine the economic viability of solar photovoltaic systems in households in Kumasi. In view of this, the study sought to assess the effect of prices of solar photovoltaic systems on respondent choices and to determine the willingness of respondents to pay for different types of solar photovoltaic systems.

4.3.1. Effect of price of solar photovoltaic systems on the choice of respondents

Generally, respondents preferred solar photovoltaic systems that could power as many of their household appliances whiles paying the minimum price practically attainable. Regardless of the appliances, higher price margins did not appeal to respondent's consumer satisfaction.

The prices of the solar photovoltaic systems had a negative impact on the choices of respondents. Prospective customers preferred the cheapest of the choice sets with respect to the appliances. Further observations revealed that respondents had a predetermined price margin which they considered acceptable and therefore were unwilling to pay anything beyond.

Respondents had a negative reaction to type 1 solar photovoltaic system for two reasons; the immediate cause being that powering only one type of appliance in this case, only light bulbs was undesirable. Albeit this reason, respondent considered prices unaffordable. Respondents could spend between 4200 GH cedis and 16800 GH cedis on type one solar photovoltaic system which they perceived relatively costly to the other types of solar photovoltaic systems. This served to reenforce their deterrence.

The effect of the prices of type 2, type 3, type 4 and type 5 solar photovoltaic systems on the choices made by respondents followed a positive trend but with increasing degrees of acceptance respectively. Respondents preferred photovoltaic systems that powered higher number of appliances compared to those that powered relatively less appliances and were willing to pay additional charges for every appliance added. For instance, the majority of respondents preferred type 5 solar photovoltaic systems to type 4 solar photovoltaic systems resulting from one additional appliance, iron but preferred it at a relatively lower price. This was evident in all types of solar photovoltaic systems. Respondents preferred type 4 to type 3, type 3 to type 2 and type 2 to type 1.

4.3.2. The willingness of households to pay for different types of solar photovoltaic systems

Observations showed that, respondents were unwilling to pay for solar photovoltaic systems that powered only one type of appliance in this case, 2 light bulbs but were willing to pay for one that powered more than one appliance. Hence, they preferred to use solar for other purposes other than just lighting. They were also unwilling to pay for type 2 solar photovoltaic systems though they preferred it to type 1. This could be due to the fact that type 2 seem relatively costly than types 3, 4 and 5 and they would also appreciate it if provision was made by other bodies like government. They were however willing to pay more for type 3, type 4 and type 5. This is evident in their increasing marginal willingness to pay for these three types of solar photovoltaic system considering their various components. The higher the number of appliances powered by the system, the more their preference for it. Therefore in the order of type 1 to type 5, respondents mostly preferred type 5 to the others.

However, due to preconceived acceptable charges for each additional appliance, prices deemed beyond a certain threshold sometimes served as a deterrent to choosing higher number of appliances. These preconceived charges are directly related to the original criterion of costing based on the wattage of the various appliances where every additional appliance had a relatively higher wattage than the previous. The original prices of the solar photovoltaic systems were estimated based on the costs of solar panel, solar battery, charge controller, solar inverter, panel structure, battery bank stand, 10 millimeter square cable, wiring accessories and labour. The cost of labour differed for all the types of systems and this increased with each additional appliance. Again, the difference between type 1 and type 2 solar photovoltaic systems was only the battery cost. Between type 2 and type 3, all the costs of the various components varied at a relatively wider margin. The different costs of inverters in type 3 and type 4 resulted in their relatively low difference compared to that between type 2 and type 3. Lastly, the difference in cost of type 4 and 5 was their various costs of inverters. This resulted in the higher cost-effectiveness of solar photovoltaic systems with more appliances compared to fewer ones. Analysis revealed that prospective respondent choices were more biased towards systems with higher number of appliances except in the few cases where marginal cost of a specific appliance far exceeded this preconceived threshold.

From observation, the choice experiment's technique of presenting different choice sets derived from the original prices of solar photovoltaic systems in few cases led to very wide price differences between two successive types of solar photovoltaic systems. In such cases, respondents opted for solar photovoltaic systems with relatively fewer appliances. This is evident in the instance where some respondents preferred type 4 costing GH cedis 13,500 GH cedis to type 2 and type 3 costing 5200 and 15,700 respectively.

This research finding proves the random utility theory that when individuals are presented with options to choose from, they would prefer options that maximize their utility. Hence, it is clearly seen in this study that, households in Kumasi prefer solar photovoltaic systems that would meet all their needs at affordable prices. That is powering as many household appliances as possible. Also, when they are presented with solar systems that powered the same types and number of appliance at different costs, they preferred those with comparatively cheap prices. The study also proves the literature that, the initial capital of solar photovoltaic is very high and this has led to its minimal contribution to global energy consumption since its deployment is very low especially in developing communities like Ghana. However, with the increasing reduction in the cost of solar components, the technology will contribute greatly to energy production in coming years.

The study contradicts the economic viability study conducted by Li et al. (2011) on domestic application of solar photovoltaic systems in Ireland whose findings revealed that the domestic solar photovoltaic system is not economically viable under current conditions in Ireland and still do not look promising even if better financial support is given. The deployment of solar photovoltaic systems is economically viable in Kumasi though prices seem unaffordable currently. With the intervention of financial assistance, the technology can be deployed greatly in the city.

The study however corresponds to that which was conducted by Kumi and Brew- Hammond (2013) on the design, technical and economic analysis of a 1MW grid-connected solar photovoltaic system for Kwame Nkrumah University of Science and Technology, Kumasi. This study proved viable and is a confirmation to this study that solar photovoltaic systems are economically viable in the city since Kwame University of Science and Technology is also located in Kumasi.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Introduction

This chapter contains the major findings of the research, conclusion and recommendation

5.1.1 Major findings

The prices of the different types of solar photovoltaic systems had a negative impact on the respondents' choices.

Respondents preferred solar photovoltaic systems that powered most of their appliances and not light bulbs only since the price of system for only one appliance was relatively costly compared to the others.

They were unwilling to pay for solar that powered only light bulbs and though they had preference for a system that powered two appliances, respondents were unwilling to pay for it. They would accept it though if provided by an external source.

Respondent's willingness to pay for solar systems increased with every appliance added. Thus Type 5, Type 4, Type 3, Type 2 and Type 1 were preferred in decreasing order.

5.1.2 Conclusion

Generally, respondents preferred solar photovoltaic systems that could power as many of their household appliances whiles paying the minimum price practically attainable. Regardless of the appliances, higher price margins did not appeal to respondent's consumer satisfaction.

Observations revealed, a willingness of prospective customers to pay for each new appliance added. However, due to preconceived acceptable charges for each additional appliance, prices deemed beyond a certain threshold sometimes served as a deterrent to choosing higher number of appliances.

5.2. Recommendation

On the whole, the experiment was successful as the results obtained were a fair reflection of consumer choices, however a larger sample base for Kumasi, will be a better representative of the prospective customer preferences. Furthermore, since no work has been done to test the economic viability of solar photovoltaic systems in the entire country, further work in this regard will help immensely.

The future of solar photovoltaic systems has a good measure of economic viability however higher prices deter households from purchasing it. Government and investors may offer subsidies and loan facilities to individual households to enable access to solar photovoltaic systems to boost productivity nationwide.

The relatively higher prices of solar systems discouraged households from paying for the systems. However, if the systems could be made available to the households to be paid in installments, the deployment of the technology will be boosted in the country.

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APPENDICES

Appendix 1: Types of solar systems and their constituent appliances

Type 1	Type 2	Type 3	Type 4	Type 5

2 bulbs	2 bulbs Television	2 bulbs Television Fan	2 bulbs Television Fan Fridge	2 bulbs Television Fan Fridge Iron

Appendix 2: Appliances, their quantity, wattage and hours of usage per day

Appliance	Quantity	Wattage (KW)	Hours/Day
Bulb	2	11	12
Television	1	80	5
Fan	1	70	12
Fridge	1	200	12
Iron	1	1000	0.33

Appendix 3: Output for discrete choice questionnaire

```
Block 1

Question
      alt.1   alt.2   alt.3
NA.   "Type1" "Type2" "Type3"
NA..1 "4200"  "5200"  "13500"
 Question 2        alt.1
alt.2   alt.3   NA.   "Type2"
"Type3" "Type4"
NA..1 "16800" "4200"  "5200"
Question
      alt.1   alt.2   alt.3
NA.   "Type3" "Type4" "Type5"
NA..1 "4200"  "5200"  "13500"
 Question 4        alt.1
alt.2   alt.3   NA.   "Type1"
"Type2" "Type3"
NA..1 "16800" "4200"  "5200"
Question
      alt.1   alt.2   alt.3
NA.   "Type2" "Type3" "Type4"
NA..1 "4200"  "5200"  "13500"

Block 2
 Question 1        alt.1
alt.2   alt.3   NA.   "Type3"
"Type4" "Type5"
NA..1 "16800" "4200"  "5200"
Question
      alt.1   alt.2   alt.3
NA.   "Type2" "Type3" "Type4"
NA..1 "5200"  "13500" "15700"

Question
      alt.1   alt.2   alt.3
NA.   "Type5" "Type1" "Type2"
NA..1 "4200"  "5200"  "13500"

Question
      alt.1   alt.2   alt.3
NA.   "Type5" "Type1" "Type2"
NA..1 "5200"  "13500" "15700"

Question
      alt.1   alt.2   alt.3
NA.   "Type4" "Type5" "Type1"
NA..1 "4200"  "5200"  "13500"

Block 3
```

```
 Question 1         alt.1
alt.2   alt.3   NA.    "Type5"
"Type1" "Type2"
NA..1 "16800" "4200"  "5200"

Question 2
      alt.1   alt.2   alt.3
NA.   "Type5" "Type1" "Type2"
NA..1 "15700" "16800" "4200"
 Question 3         alt.1
alt.2   alt.3   NA.    "Type3"
"Type4" "Type5"
NA..1 "15700" "16800" "4200"
Question
      alt.1   alt.2   alt.
NA.   "Type1" "Type2" "Type3"
NA..1 "5200"  "13500" "15700"

Question
      alt.1   alt.2   alt.3
NA.   "Type4" "Type5" "Type1"
NA..1 "5200"  "13500" "15700"

Block 4

Question
      alt.1   alt.2   alt.3
NA.   "Type3" "Type4" "Type5"
NA..1 "5200"  "13500" "15700"
 Question 2         alt.1
alt.2   alt.3   NA.    "Type4"
"Type5" "Type1"
NA..1 "16800" "4200"  "5200"
Question
      alt.1   alt.2   alt.3
NA.   "Type5" "Type1" "Type2"
NA..1 "13500" "15700" "16800"

Question
      alt.1   alt.2   alt.3
NA.   "Type4" "Type5" "Type1"
NA..1 "13500" "15700" "16800"

Question
      alt.1   alt.2   alt.3
NA.   "Type3" "Type4" "Type5"
NA..1 "13500" "15700" "16800"

Block 5

Question
      alt.1   alt.2   alt.3
```

```
NA.    "Type2" "Type3" "Type4"
NA..1 "13500" "15700" "16800"

Question
      alt.1   alt.2   alt.3
NA.    "Type1" "Type2" "Type3"
NA..1 "13500" "15700" "16800"
 Question 3        alt.1
alt.2   alt.3   NA.    "Type1"
"Type2" "Type3"
NA..1 "15700" "16800" "4200"

Question 4
      alt.1   alt.2   alt.3
NA.    "Type4" "Type5" "Type1"
NA..1 "15700" "16800" "4200"
 Question 5        alt.1
alt.2   alt.3   NA.    "Type2"
"Type3" "Type4"
NA..1 "15700" "16800" "4200"
```

Appendix 4: Samples of questionnaire

Block 1

QUESTIONNAIRE

By this questionnaire I would like to try and understand the type of solar photovoltaic system you would like to purchase. This will be done by presenting to you five different solar photovoltaic systems and asking you to tell which one you prefer. Each system has its own appliances it can power. Warranty in the questionnaire refers to the life-span of the solar photovoltaic system which is 25 years. If the system is well maintained, its efficiency will not be below 90% before the 25 years.

Demographic Information

This section requires some information about you. Please select one of the options.

1. Sex: [ ] Male [ ] Female Age: …………..
2. Location in Kumasi: [ ] Residential Area [ ] Non-residential Area
3. Occupation: …………………………………..
4. Job Specification: [ ] Private [ ] Government
5. Income: [ ] below 1000 [ ] 1000-2000 [ ] 2000-3000 [ ] above 3000
6. Do you use these appliances at home (you can select more than one appliance)

   [ ] Light bulbs [ ] Television [ ] Fan [ ] Fridge [ ] Iron

   Others please list: ………………………………………………………………………
7. Do you know about solar systems? [ ] Yes [ ] No

8. Have you heard about energy efficiency? [ ] Yes [ ] No
9. If yes, do you practice it? [ ] Yes [ ] No

QUESTION 1

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light Bulbs	2 Light bulbs + TV	2 Light bulbs + TV + Fan
Price (GH₵)	4200	5200	13500
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 2

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + TV	2 Light bulbs + TV + Fan	2 Light bulbs + TV + Fan + Fridge
Price (GH₵)	16800	4200	5200
Warranty	25 Years	25 Years	25 Years

2 Light bulbs + + Fan	2 Light bulbs + TV + Fan + Fridge	2 Light bulbs + TV + Fan + Fridge + Iron
4200	5200	13500
25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 3

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance			

Price (GH₵)

Warranty

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 4

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light Bu	2 Light bulbs	2 Light bulbs + TV + Fan
Price (GH₵)	16800	4200	5200
Warranty	25 Year	25 Year	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 5

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light Bulb	2 Light bulbs + Fan	2 Light bulbs + TV + Fan + Fridge
Price (GH₵)	4200	5200	13500
Warranty	25 Year	25 Yea	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

Block 2

QUESTIONNAIRE

By this questionnaire I would like to try and understand the type of solar photovoltaic system you would like to purchase. This will be done by presenting to you five different solar photovoltaic systems and asking you to tell which one you prefer. Each system has its own appliances it can power. Warranty in the questionnaire refers to the life-span of the solar photovoltaic system which is 25 years. If the system is well maintained, its efficiency will not be below 90% before the 25 years.

Demographic Information

This section requires some information about you. Please select one of the options.

1. Sex: [ ] Male [ ] Female Age: …………..
2. Location in Kumasi: [ ] Residential Area [ ] Non-residential Area
3. Occupation: …………………………………..
4. Job Specification: [ ] Private [ ] Government
5. Income: [ ] below 1000 [ ] 1000-2000 [ ] 2000-3000 [ ] above 3000
6. Do you use these appliances at home (you can select more than one appliance)

   [ ] Light bulbs [ ] Television [ ] Fan [ ] Fridge [ ] Iron

   Others please list: ………………………………………………………………….
7. Do you know about solar systems? [ ] Yes [ ] No
8. Have you heard about energy efficiency? [ ] Yes [ ] No
9. If yes, do you practice it? [ ] Yes [ ] No

QUESTION 1

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + Fan	2 Light bulbs + TV + Fan + Fridge	2 Light bulbs + TV + Fan + Fridge + Iron
Price (GH₵)	16800	4200	5200
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 2

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + TV	2 Light bulbs + TV + Fan	2 Light bulbs + TV + Fan + Fridge
Price (GH₵)	5200	13500	15700
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 3

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**

Appliance	2 Light bulbs + + Fan + Fridge +	2 Light bulbs	2 Light bulbs + TV
Price (GH₵)	4200	5200	13500
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 4

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs Fan + Fridge	2 Light bu	2 Light bulbs + TV
Price (GH₵)	5200	13500	15700
Warranty	25 Year	25 Yea	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 5

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + Fan + Fr	2 Light bulbs Fan + Fridge	2 Light bulbs
Price (GH₵)	4200	5200	13500
Warranty	25 Year	25 Yea	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

Block 3

QUESTIONNAIRE

By this questionnaire I would like to try and understand the type of solar photovoltaic system you would like to purchase. This will be done by presenting to you five different solar photovoltaic systems and asking you to tell which one you prefer. Each system has its own appliances it can power. Warranty in the questionnaire refers to the life-span of the solar photovoltaic system which is 25 years. If the system is well maintained, its efficiency will not be below 90% before the 25 years.

Demographic Information

This section requires some information about you. Please select one of the options.

1. Sex: [ ] Male [ ] Female Age: …………..
2. Location in Kumasi: [ ] Residential Area [ ] Non-residential Area
3. Occupation: …………………………………..
4. Job Specification: [ ] Private [ ] Government
5. Income: [ ] below 1000 [ ] 1000-2000 [ ] 2000-3000 [ ] above 3000
6. Do you use these appliances at home (you can select more than one appliance)

   [ ] Light bulbs [ ] Television [ ] Fan [ ] Fridge [ ] Iron

   Others please list: …………………………………………………………………
7. Do you know about solar systems? [ ] Yes [ ] No
8. Have you heard about energy efficiency? [ ] Yes [ ] No
9. If yes, do you practice it? [ ] Yes [ ] No

QUESTION 1

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulb + Fan + Fridg	2 Light bu	2 Light bulbs + TV
Price (GH₵)	16800	4200	5200
Warranty	25 Yea	25 Year	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 2

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + TV + Fan + Fridge + Iron	2 Light bulbs	2 Light bulbs + TV
Price (GH₵)	15700	16800	4200
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 3

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + + Fan	2 Light bulbs + TV + Fan + Fridge	2 Light bulbs + TV + Fan + Fridge + Iron
Price (GH₵)	15700	16800	4200
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 4

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bu	2 Light bulbs	2 Light bulbs + TV + Fan
Price (GH₵)	5200	13500	15700
Warranty	25 Year	25 Year	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 5

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + TV + Fan + Fridge	2 L Fa	2 Light bulbs
Price (GH₵)	5200		15700
Warranty	25 Years		25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

Block 4

QUESTIONNAIRE

By this questionnaire I would like to try and understand the type of solar photovoltaic system you would like to purchase. This will be done by presenting to you five different solar photovoltaic systems and asking you to tell which one you prefer. Each system has its own appliances it can power. Warranty in the questionnaire refers to the life-span of the solar photovoltaic system which is 25 years. If the system is well maintained, its efficiency will not be below 90% before the 25 years.

Demographic Information

This section requires some information about you. Please select one of the options.

1. Sex: [ ] Male [ ] Female Age: …………..
2. Location in Kumasi: [ ] Residential Area [ ] Non-residential Area
3. Occupation : …………………………………..
4. Job Specification: [ ] Private [ ] Government
5. Income: [ ] below 1000 [ ] 1000-2000 [ ] 2000-3000 [ ] above 3000
6. Do you use these appliances at home (you can select more than one appliance)

   [ ] Light bulbs [ ] Television [ ] Fan [ ] Fridge [ ] Iron

   Others please list: ……………………………………………………………………
7. Do you know about solar systems? [ ] Yes [ ] No
8. Have you heard about energy efficiency? [ ] Yes [ ] No
9. If yes, do you practice it? [ ] Yes [ ] No

QUESTION 1

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**

Appliance	2 Light bulbs + + Fan	2 Light bulbs + TV + Fan + Fridge	2 Light bulbs + TV + Fan + Fridge + Iron
Price (GH₵)	5200	13500	15700
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 2

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs + TV + Fan + Fridge	2 Light bulbs + TV + Fan + Fridge + Iron	2 Light bulbs
Price (GH₵)	16800	4200	5200
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 3

	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3

Appliance	2 Light bulbs + + Fan + Fridge +	2 Light bulbs	2 Light bulbs + TV
Price (GH₵)	13500	15700	16800
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 4

	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
Appliance	2 Light bulbs + Fan + Fr	2 Light bulbs Fan + Fridge	2 Light bulbs
Price (GH₵)	13500	15700	16800
Warranty	25 Year	25 Year	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 5

	ALTERNATIVE 1	**ALTERNATIVE 2**		**ALTERNATIVE 3**
Appliance	2 Light bulbs + TV + Fan	2 L +	2 Light bulbs + TV + Fan + Fridge + Iron	
Price (GH₵)	13500		16800	
Warranty	25 Years		2 Years	

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

Block 5

QUESTIONNAIRE

By this questionnaire I would like to try and understand the type of solar photovoltaic system you would like to purchase. This will be done by presenting to you five different solar photovoltaic systems and asking you to tell which one you prefer. Each system has its own appliances it can power. Warranty in the questionnaire refers to the life-span of the solar photovoltaic system which is 25 years. If the system is well maintained, its efficiency will not be below 90% before the 25 years.

Demographic Information

This section requires some information about you. Please select one of the options.

1. Sex: [ ] Male [ ] Female Age: …………..
2. Location in Kumasi: [ ] Residential Area [ ] Non-residential Area
3. Occupation : …………………………………..
4. Job Specification: [ ] Private [ ] Government
5. Income: [ ] below 1000 [ ] 1000-2000 [ ] 2000-3000 [ ] above 3000
6. Do you use these appliances at home (you can select more than one appliance)

   [ ] Light bulbs [ ] Television [ ] Fan [ ] Fridge [ ] Iron

   Others please list: …………………………………………………………………
7. Do you know about solar systems? [ ] Yes [ ] No
8. Have you heard about energy efficiency? [ ] Yes [ ] No
9. If yes, do you practice it? [ ] Yes [ ] No

QUESTION 1

	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3

Appliance	2 Light bulbs +	2 Light bulbs + TV + Fan	2 Light bulbs + TV + Fan + Fridge
Price (GH₵)	13500	15700	16800
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 2

	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
Appliance	2 Light bulbs	2 Light bulbs + TV	2 Light bulbs + TV + Fan
Price (GH₵)	13500	15700	16800
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 3

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulbs	2 Light bulbs + TV	2 Light bulbs + TV + Fan
Price (GH₵)	15700	16800	4200
Warranty	25 Years	25 Years	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 4

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**

Appliance	2 Light bulbs + Fan + Fr	2 Light bulbs Fan + Fridge	2 Light bulbs
Price (GH₵)	15700	16800	4200
Warranty	25 Year	25 Year	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

QUESTION 5

	ALTERNATIVE 1	**ALTERNATIVE 2**	**ALTERNATIVE 3**
Appliance	2 Light bulb	2 Light bulbs Fan	2 Light bulbs + TV + Fan + Fridge
Price (GH₵)	1570(	16800	4200
Warranty	25 Yea	25 Yea	25 Years

[ ] I will like to purchase Alternative 1

[ ] I will like to purchase Alternative 2

[ ] I will like to purchase Alternative 3

[ ] I will like to purchase none of these

Appendix 5: Data from Questionnaire

	ID	BLOCK		Q1	Q2	Q3	Q4	Q5
1	1	1		1	1	1	1	1
2	2	2		3	4	1	1	2
3	3	3		3	1	3	1	1
4	4	4		4	4	4	4	4
5	5	5		3	4	3	2	3
6	6	1		2	3	2	3	2
7	7	2		3	4	1	1	1
8	8	3		1	1	3	3	1
9	9	4		3	2	1	1	1
10	10	5		3	3	3	2	3
11	11	1		3	3	3	2	3
12	12	2		3	3	1	1	1
13	13	3		1	1	1	3	2
14	14	4		1	4	4	4	4
15	15	5		3	3	3	1	3
16	16	1		4	3	2	4	4
17	17	2		3	4	1	1	1
18	18	3		4	4	4	4	4
19	19	4		3	2	1	2	3
20	20	5		3	4	3	2	3
21	21	1		4	3	2	4	4
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24	24	4		4	2	2	4	4
25	25	5		3	3	3	2	3
26	26	1		2	2	2	3	2
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28	28	3		1	1	3	4	1
29	29	4		2	2	1	1	3
30	30	5		4	3	1	2	4
31	31	1		4	3	2	4	4
32	32	2		3	3	1	1	1

33	33	3		1	1	2	3	2
34	34	4		3	2	1	2	3
35	35	5		4	4	4	2	3
36	36	1		4	3	2	4	4
37	37	2		3	1	1	1	2
38	38	3		1	1	3	4	2
39	39	4		3	2	1	2	3
40	40	5		4	4	3	4	3
41	41	1		3	4	2	2	3
42	42	2		3	4	1	1	2
43	43	3		4	4	3	4	4
44	44	4		1	2	1	1	1
45	45	5		3	4	3	4	3
46	46	1		1	2	1	2	1
47	47	2		3	3	1	1	2
48	48	3		1	1	4	1	1
49	49	4		4	2	4	4	4
50	50	5		4	4	4	4	3
51	51	1		4	3	2	4	3
52	52	2		3	3	1	1	2
53	53	3		1	1	3	4	1
54	54	4		1	2	1	1	4
55	55	5		3	3	2	1	3
56	56	1		4	3	1	3	2
57	57	2		3	3	1	1	2
58	58	3		4	4	3	4	4
59	59	4		4	4	4	4	4
60	60	5		3	4	1	2	3
61	61	1		4	3	2	3	2
62	62	2		3	3	1	1	2
63	63	3		4	4	2	3	2
64	64	4		1	2	4	4	4
65	65	5		4	4	3	4	3

66	66	1		4	4	4	4	4
67	67	2		2	1	1	1	2
68	68	3		4	4	3	4	1
69	69	4		4	4	4	4	4
70	70	5		4	4	4	4	4
71	71	1		4	3	2	4	4
72	72	2		2	3	1	1	2
73	73	3		1	4	3	4	2
74	74	4		1	2	4	4	4
75	75	5		3	3	3	2	3
76	76	1		3	3	2	3	4
77	77	2		3	4	1	1	2
78	78	3		4	4	3	4	1
79	79	4		3	2	1	2	3
80	80	5		3	4	3	2	3
81	81	1		3	3	3	3	3
82	82	2		3	4	1	1	2
83	83	3		4	4	3	4	4
84	84	4		3	2	1	2	2
85	85	5		2	3	3	4	3
86	86	1		3	3	3	3	3
87	87	2		3	3	3	3	3
88	88	3		4	3	3	2	1
89	89	4		1	2	4	4	4
90	90	5		3	3	3	2	3
91	91	1		4	3	2	3	3
92	92	2		3	1	2	1	2
93	93	3		4	4	4	4	1
94	94	4		1	2	4	4	4
95	95	5		1	4	4	1	4
96	96	1		4	2	1	4	4
97	97	2		3	3	1	1	2
98	98	3		1	1	2	3	2
99	99	4		3	2	1	2	3

100	100	5		3	4	1	2	3