IMPACT ASSESSMENT OF THE NATIONAL ROOFTOP SOLAR PROGRAMME (NRSP) ON RESIDENTIAL HOMES-A CASE STUDY OF BENEFICIARIES IN ACCRA-GHANA

BY

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A Thesis Submitted to the Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi in Partial Fulfilment of Requirement for the Award of

MASTER OF SCIENCE

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DECLARATION

I hereby declare that this submission is my own work towards the award of Masters of Science in Project Management and that, to the best of my knowledge it contains no material previously published by another person(s), not 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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ABSTRACT

Worldwide attention has been drawn towards renewable energy especially in the sphere of solar energy in a bid to tackle global energy deficit and environmental crises such as global warming, air and water pollution. Solar energy offers an encouraging solution to this search as it is a less polluting renewable energy resource and can be easily converted into electricity through the use of Photovoltaic (PV) systems. Solar PV systems provide electric energy by absorbing and converting sunlight into electricity. It achieves this by an arrangement of several components known as the Balance of System (BoS) and solar panels. PV systems range from small, rooftop mounted or building integrated systems with capacities from a few to several tens of kilowatts (kW), to large utility scale power stations of hundreds of megawatts. In 2007, Ghana was faced with drastic energy crisis and this lasted till the year 2016, though it is not permanently solved in the country. There were persistent, regular and unpredictable electric power outages. This satirically birthed the term “Dumsor” literally meaning “off-on” to represent the worsening power crisis the country was plagued with. In a bid for the government to solve this challenge, the Government of Ghana (GoG), under the auspices of the Energy Commission of Ghana (EC) began an implementation of a Capital Subsidy Scheme where free rooftop solar panels up to a maximum capacity of 500 Watts peak to residential beneficiaries. This study therefore sought to assess the impact of the rooftop PV solar systems on beneficiaries in Accra since its implementation and to forecast its expected benefits or otherwise in the long term for Ghana. Results showed from the study revealed that, there was very low patronage of the programme by the citizenry. Only about 0.10% (2,449/2,270,000) of the total population of the people in Accra applied to benefit from the project. There was a further reduced number of beneficiaries (727) who actually got the solar systems to be installed in their homes. The mean expenditure on power and consumption levels of beneficiaries before and after installation of the rooftop solar PV systems was significantly reduced. Results showed that every reduction in consumption level was accompanied by almost two times reduction in cost of electricity. However, the major challenge beneficiaries had faced with the rooftop solar PV systems were the batteries. In effect, the project was a good programme and should be continued.

DEDICATION

I dedicate this research to the Almighty God for His love and protection throughout the trying moments of this coursework and also to my family for their love and support.

ACKNOWLEDGEMENT

My first Gratitude goes to the Almighty Father for bringing me this far, for keeping me and granting me all the strength I needed for this research work. If not for Him this work would not have been a success.

I wish also to express my profound gratitude to my supervisor, Dr. Godwin Acquah who took time to read, correct and make necessary recommendations to enable me complete this study successfully. I am very grateful for all his assistance and pray that God continues to make his life fruitful.

Also, to my parents, Mr and Mrs Benjamin Ardayfio for their love, fiscal support, prayers and encouragement as well as inspiring me throughout my academic endeavours till now. I wish to acknowledge Energy Commission for the material resources made available to assist in this research as well as respondents who are mainly in the energy sector for providing me with all the necessary information needed for this study.

Thank you to Mr John Bambio, Madam Gladys Akyea- Mensah Frimpong, Mr Frederick Kenneth and Mr Julius Nkansah Nyarko for your words of encouragement and advice. God bless richly bless you all.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	**Alternating Current**
BoS	**Balance of System**
CAN	**Canada**
EC	**Energy Commission**
ECG	**Electricity Company of Ghana**
DC	**Direct Current**
PURC	**Public Utilities Regulatory Commission**
CAGR	**Compound Annual Growth Rate**
HP	**Hydro Power**
GoG	**Government of Ghana**
PV	**Photovoltaic**
GSA	**Ghana Standards Authority**
Kw	**Kilowatts**
NRSP	**National Rooftop Solar Project**
REN21	**Renewable Energy Policy Network for the 21st century**
ROW	**Rest of the World**
USA	**United States of America**

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

In the span past three decades, the power generation landscape around the globe has changed significantly. The availability of fossil fuels and other non-renewable sources of energy are declining (Whisnant et al., 2003). The demand and consumption of power exceeds the supply. Renewable energy sources offer the potential for alternate sources of energy in the world today. Renewable energy is energy from sources that are naturally replenishing. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit time (Brower et al., 2014). The major types of renewable energy sources are solar, wind, geothermal and biomass (Kumar, 2014).Worldwide attention has been drawn towards renewable energy especially in the sphere of solar energy in a bid to tackle global energy deficit and environmental crises such as global warming, air and water pollution. Solar energy offers an optimistic antidote to this search as it is an eco-friendly renewable energy resource and can be simply transmuted into electricity with the help of Photovoltaic (PV) systems.

PV systems provide electric energy by absorbing and converting sunlight into electricity (Brower, 2014, Datta, 2010). It achieves this by an arrangement of several components known as the Balance of System (BoS) and solar panels. PV systems range from small, rooftop mounted or building integrated systems with capacities from a few to several tens of kilowatts (kW), to large utility scale power stations of hundreds of megawatts. Some PV systems can be connected to the national power grid of some countries through a net metering module or can be connected as standalone systems or off grid systems (Al-Karaghouli, 2010).

Photovoltaic (PV) energy is the fastest growing sustainable energy source and it’s interest has catapulted to extreme attention (Kong, 2018). It also has a fast-emerging market. The Compound Annual Growth Rate (CAGR) of PV installations was 24% between years 2010 to 2017. Concerning PV module production in 2017, China & Taiwan hold the lead with a share of 70%, followed by Rest of Asia-Pacific & Central Asia (ROAP/CA) with 14.8%. Europe contributed with a share of 3.1% (compared to 4% in 2016); USA/CAN contributed 3.7%.

In 2017, Europe’s contribution to the total cumulative PV installations amounted to 28% (compared to 33% in 2016). In contrast, installations in China accounted for 32% (compared to 26% in 2016). Si-wafer based PV technology accounted for about 95% of the total production in 2017. The share of multi-crystalline technology is now about 62% of total production. In 2017, the market share of all thin film technologies amounted to about 5% of the total annual production. In 2017, Germany accounted for about 10% (42.4 GWp) of the cumulative PV capacity installed worldwide (415 GWp) with about 1.6 million PV systems installed in Germany. In 2017 the newly installed capacity in Germany was about 1.7 GWp; in 2016 it was 1.5 GWp. PV covered about 7% of Germany’s electricity demand in 2017.

Renewable sources delivered about 38% of the total net power consumption in 2017 in Germany. In 2017 about 19 Mio. t CO_2 emissions have been avoided due to 38.4 TWh electrical energy generated by PV in Germany. PV system performance has strongly improved. Before 2000 the typical performance ratio was about 70%, while today it is in the range of 80% to 90% (Philips, 2018).

The cost of PV is declining speedily with a rapid increase in development accompanied by the following reasons; the economic benefits and the solar system's modularity, low maintenance, low noise level, long life and non-emission of greenhouse gases (Al-Karaghouli, 2010).

In 2007, Ghana was faced with drastic energy crisis and this lasted till the year 2016, though it is not permanently solved in the country. The entire electricity demand of the Country in 2015 was between 14,000 GWh to 16,400 GWh whiles the available supply was around 15,000 GWh. This led to persistent, regular and unpredictable electric power outages. This satirically birthed the term "Dumsor" literally meaning "off-on" to represent the worsening power crisis the country was plagued with. The term gradually evolved into "Dum Dum" which means "off-off" to describe the increase in the prevalence of the power outages. Dumsor has now been inscribed in the political history books of Ghana because of its consistency and magnitude worldwide attention. This crisis was due to power supply shortage. The country's generating capacity is currently 400-600 MW which is less than the demand.

In 2015, the national grid stabilized with the introduction of solar minigrid plants as well as a two (2) power Barges of a total of 450 MW owned by Kapowership, private Independent Power Producer (IPP) to supplement the national grid.

These power generators had a negative impact on the country's finances with a major contributor being the commercial losses as a result of theft of electricity and the inability of the country's power distributor, Electricity Company of Ghana (ECG) to collect its revenue from consumers.

In a bid for the government to reduce the dependency on the national grid, the Government of Ghana (GoG), under the auspices an agency of the then Ministry of Power (now Ministry of Energy), Energy Commission of Ghana (EC) began an implementation of a Capital Subsidy Scheme where free solar panels up to a maximum capacity of 500 Watts peak to residential beneficiaries. The aim of this capital subsidy programme was to help take the residential lighting load off the grid with the use of solar PV technology. The pilot project was to give 2000 homes in Accra 200 households in the Kwahu East district rooftop solar PV technology. Ghana's National Energy Policy aims at targeting 10% coverage of electricity production in the country with solar energy by 2020. It further aims at increasing electricity power generation capacity from 2,6 GW to 5,5 GW by 2026 (Bellini, 2017).

This study therefore seeks to assess the impact of the rooftop PV solar systems on beneficiaries in Accra since its implementation and to present its expected benefits or otherwise in the long term for Ghana.

1.2 PROBLEM STATEMENT

Ghana's electricity supply has faced some challenges as electricity demand grows. Notable amongst the challenges include inadequate reserve margin, low water levels in the HP dams, erratic natural gas supply, intermittent dysfunction of thermal power plants etc. This has had some negative impact on our industries, private businesses and domestic consumers as well. Many industries and companies were collapsing due to the inconsistency in the power supply, some industries and private businesses had to lay off some of their workers to adjust for the cost of running their industries and businesses on alternative power. Many homes had their electronic equipment and appliances damaged and refrigerated foods regularly went bad. Health and safety needs were also compromised as some hospitals and health facilities having no electricity could not provide healthcare.

The institute of Statistical, Social and Economic Research (ISSER), stated that Ghana lost about 1 billion dollars in 2014 alone to dumsor (www.isser.org).

There was the need to consider desperately the use of renewable energy in the country, particularly, solar energy. Ghana is amongst the countries located in the tropical climate of the world and thus is endowed with a lot of sunlight throughout the year. Figure 1.1 shows the solar irradiation map of Ghana. The figure shows that the country receives adequate amounts of sunlight throughout the year and this energy can be tapped for renewable energy sources. The northern parts of the country receives the most sunlight (Figure 1.1).

One way to mitigate our energy crisis is to consider the utilization of solar PV systems in our industries, private businesses and residence. However, one key barrier to the uptake of solar PV technology is the high initial investment cost involved.

The National Rooftop Solar Programme (NRSP) has been initiated to help address the issue. The programme is a Capital Subsidy Scheme under which beneficiaries are given capital subsidy to cover the cost of the solar panel component of a solar PV system. The objective of the programme is to install 200,000 solar PV systems on rooftops in the country to reduce peak load (lighting load and critical loads) up to 200MW in the medium term. The beneficiaries of the programme will include homes, offices, industries, small and medium enterprises (SMEs). Rooftop PVs would represent a massively resilient energy source for the country.

In as much the programme was to relieve the grid off a certain demand capacity, it is an action plan of the GoG's target policy to increase the portion of renewable energy in the total energy generation mix from 0.3% to 10% by the end of 2020 (Energy Commission, 2006).

The implementation of the National Rooftop Solar Programme begun on 8th February, 2016. This current study seeks to assess the impact of the National Rooftop Solar Programme thus far on beneficiaries since its implementation in the country.

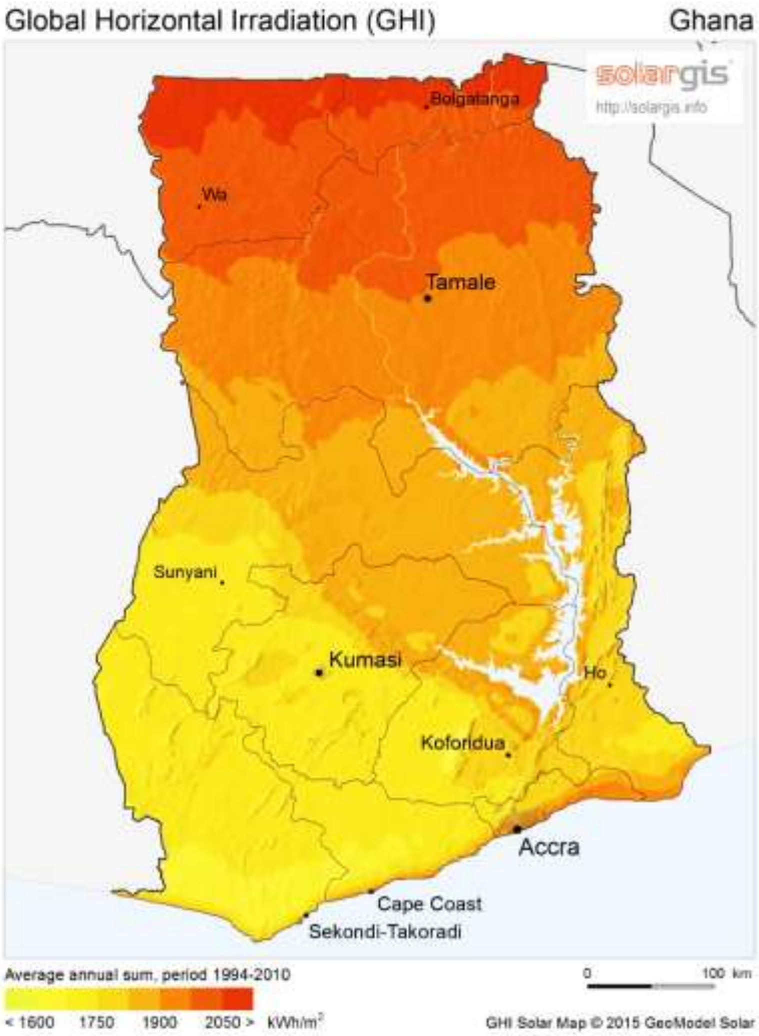

Figure 1.1 Solar irradiation map of Ghana.

Source: https://solargis.info

1.3 RESEARCH QUESTIONS

1. What has been the effectiveness of the National Rooftop Solar Programme (NRSP) policy since its implementation?
2. What benefits in terms of cost effectiveness has the rooftop solar PV systems brought to beneficiaries?
3. How is the sustenance of the rooftop solar PV systems installed in the residence of the beneficiaries?

1.4 OBJECTIVES OF THE STUDY

1.4.1 Aim

- To assess the impact of the rooftop solar PV systems on residential homes of beneficiaries of the National Rooftop Solar Programme in Ghana

1.4.2 Specific objectives

The following are the specific objectives outlined to be achieved during the project:

- To assess the National Rooftop Solar Programme (NRSP) policy;
- To assess the cost effectiveness of the rooftop solar PV systems; and
- To assess the sustenance of the rooftop solar PV systems installed in the residence of the beneficiaries.

1.5 AN OVERVIEW OF RESEARCH METHODOLOGY

The current was descriptive research targeted at shedding light on the current status of the NRSP policy in Ghana and among its beneficiaries. The survey approach methodology was employed to collect data for the study. A structured questionnaire was used to collect information from the study participants. Study participants included beneficiaries of the rooftop solar PV systems since its implementation. Thus far, according to data from the EC of Ghana, a total of 869 rooftop solar PV systems have been installed to beneficiaries in Accra, Ghana. Hence, all these beneficiaries were sampled in the current study. Data was analyzed using SPSS according to study objectives. Results were presented in figures, graphs, charts and tables where appropriate.

1.6 SCOPE OF STUDY

This study sought to assess the impact of the NRSP policy in Ghana since its implementation. However, only beneficiaries in Accra were sampled for this study. It involved beneficiaries in Accra having functioning solar PV systems installed in their homes. Cost effectiveness of the solar PV systems since its installation in their homes compared to the conventional meters from the ECG was assessed. Further, the sustenance of the solar PV systems in terms of maintenance and services was also assessed from beneficiaries since installation in their homes.

1.7 SIGNIFICANCE OF STUDY

This current study is timely and essential as it will provide a current status report on the National Rooftop Solar Programme in the country. It will also help in evaluating the performance of the solar PV panels supplied by the country to the beneficiaries. An appraisal also of some solar PV installers in the country will be ascertained. Consequently, the overall output of the NRSP will be determined.

1.8 LIMITATION OF THE STUDY

The major challenge to the research will be assess to study participants. Possible challenges will include: inaccurate or wrong home address, inaccurate or wrong work address, inaccurate or wrong telephone numbers, inaccurate or wrong mobile phone numbers, no response when called, loss of mobile phone and travel. There could also be the unwillingness of study participants to respond appropriately to questionnaire. A lot of money will also be spent in reaching out to study participants in terms of call costs and travel expenses to their homes or offices.

1.9 ORGANIZATION OF THE STUDY

The study was organized into five chapters. Chapter one presented the overview and background to the study. It introduced renewable energy with special emphasis on solar PV systems. It further outlined the NRSP policy in Ghana and its current status. It discussed the statement of the problem, the objectives of the study obtained from the statement of the problem, the research questions, an overview of the methodology that was be used in the study, the scope of this current study and its limitations as far as the study is concerned. Chapter two reviewed literature related to the study under various considerations. Chapter three looked at the study design and proposed methodology in answering the study objectives. Specific statistical analysis was applied to the data collected to obtain appropriate inferences in relation to the study objectives. Chapter four presented the observed results and findings from the data collected. Results was organized into tables and charts where appropriate. Chapter five reflected on the summary of the findings with appropriate discussions from related literature. Conclusions were presented and suitable recommendations were formulated for interventions.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

A literature review is and can be defined as a methodical and critical analysis of the most significant academic literature published on a particular subject (Jesson, 2011). This chapter thus presents and reviews related literature on the empirical and theoretical studies on renewable energy with emphasis on the Photovoltaic systems also called PV systems or solar power systems.

2.2 RENEWABLE ENERGY

Electric energy security is essential, yet the high cost and limited sources of fossil fuels and other non-renewable sources of energy, in addition to the need to reduce greenhouse gasses emission, have made renewable energy resources attractive in world economies. The potential for renewable energy resources is enormous because they can, in principle, exponentially exceed the world's energy demand. Renewable energies are energy sources that are continually replenished by nature. Some sources are directly derived from the sun. These include; thermal, photo-chemical, and photo-electric. Those indirectly derived from the sun include hydropower, photosynthetic energy stored in biomass and wind. The rest are obtained from other natural movements and mechanisms of the environment such as geothermal and tidal energy (Ellaban et al., 2014). Figure 2.1 displays an overview of the various available renewable energy resources.

Renewable energy technologies on the other hand refer to machines, gadgets, devices and systems that convert these natural energy sources mentioned above into usable forms of energy namely electricity, heat and fuels (Brown et al., 2011).

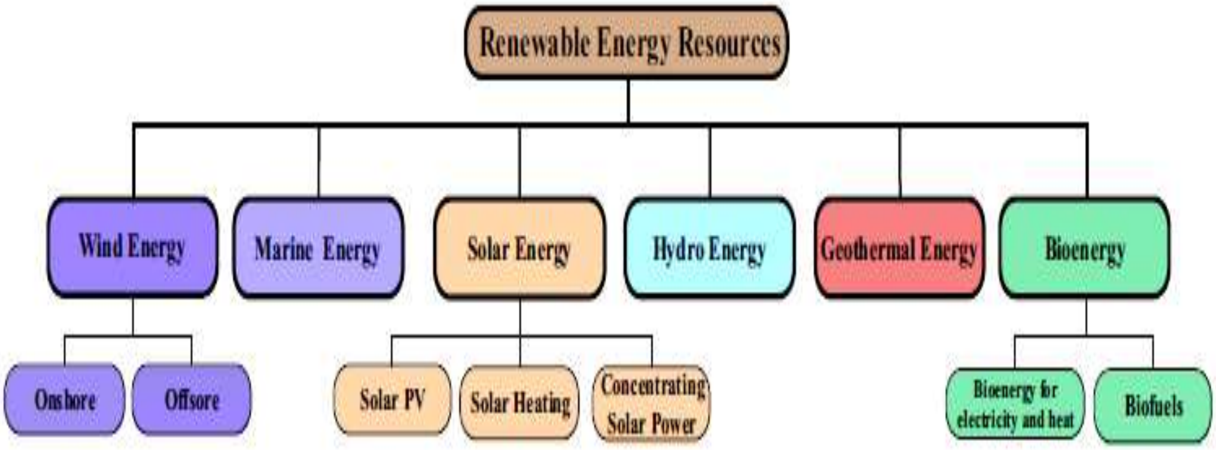

Figure 2.1: Examples of renewable energy resources

Source: Ellaban et al.,(2014)

From REN21 2017 report, renewable energy contributed to 19.3% of global energy consumption and 24.5% to their generation of electricity in 2015 and 2016 respectively. This was divided as 8.9% coming from Biomass, 4.2% as solar energy, 3.9% as hydro power and 2.2% from indirect renewable forms of energy. Also, worldwide investments in renewable energy technologies in countries like China, USA and Germany amounted to more than US$286 billion in 2015.

2.3 PHOTOVOLTAIC SYSTEM

Solar energy generation involves the application of the sun's energy to produce hot water through the use of solar thermal systems or electricity via Solar Photovoltaic (PV) and Concentrating Solar Power (CSP) systems.

A photovoltaic (PV) system is a power system designed to supply usable solar power by means of photovoltaic. Photovoltaics convert the sun's radiation into usable electricity (Ellaban et al., 2014). It consists of an arrangement of several components which include the solar panels and Balance of System components (BoS) to install a complete working system.

The basic building unit of a PV system is the PV cell, which is a semi-conductor device that converts solar energy into direct- current electricity. PV cells are interconnected to form a PV module or panel ranging from capacities as low as 8W to 280W. The solar PV modules, combined with a set of additional application- dependent system components comprising the inverters, deep-cycled batteries, electrical components known as the Balance of System (BoS) and mounting platforms form a Solar PV system. PV systems are highly modular, i.e., modules can be linked together to provide power ranging from a few watts to tens of megawatts. The most established solar PV technologies are silicon-based systems. More recently, thin film modules, which consist of non-silicon semi-conductor material, have become highly essential. The price per unit capacity of thin films are lower although they are of a lower efficiency than silicon modules. Concentrating PV, where sunlight is focused onto a smaller area, is on the edge of entering full market deployment. Concentrating PV cells have very high efficiencies of up to 40% (Bhuiyan et al., 2012, Marks et al., 2012).

Photovoltaic (PV) installations are classified under two major categories namely; the off-grid and grid-connected applications.

2.3.1 OFF-GRID PV SYSTEMS

Off-grid PV systems have a significant opportunity for economic application in non-electrified areas of developing countries, and off-grid centralized PV mini-grid systems have become a reliable alternative for village electrification over the last few years.

2.3.2 GRID CONNECTED PV SYSTEMS

Grid connected PV systems use an inverter to convert electricity from DC to AC and then supply the generated electricity to the electric grid. Compared to an off-grid installation, grid connected systems costs are cheaper since no energy storage in the form of deep-cycled batteries are not required because the grid is used as a buffer. Grid-connected PV systems are further classified into two types of applications namely; distributed and centralized application.

Grid-connected distributed PV systems are installed to provide power to a grid-connected customer or directly to the electric network with the use of multiple 3-phase string inverters for sub arrays of solar PV panels. Since the system is installed at the point reducing distribution losses along the cable network. Also the acquisition of extra land surface and mounting structures are not required reducing the cost of installation where in certain scenarios, the system is mounted on an existing structure such as roofs of buildings, car park canopies. The photovoltaic array in its nature can be used as a cladding or roofing material and facades of buildings known as Building-integrated PV (BIPV). Typical grid connected sizes vary from 1 to 4kW for residential systems, and 10 kW to several MW for rooftops on public and industrial buildings (Brankera et al., 2011). In the case of the centralized application or architecture, a single inverter is used for the photovoltaic installation.

Solar PV has two advantages being; module manufacturing can be done in large plants, which allows for economies of scale. On the other hand, PV is a very modular technology. Compared to concentrating solar power (CSP), PV has the advantage that it uses not only direct sunlight but also the diffuse component of sunlight, i.e., solar PV produces power even if the sky is not completely clear. This capability allows the effective deployment in many more regions in the world than for CSP (Marks et al., 2012). The initial investment of a PV plant requires a high financial input but has a limited running cost provided quality and efficient components are used: the fuel which is natural and available at no cost and the maintenance costs are limited since, in majority of cases, there are no moving parts in the system. These costs are estimated to be about from 1 to 2% of the cost of the plant per year and include the charges for the replacement of the inverter in the 10th-12th year and an insurance policy against theft and adverse atmospheric conditions which might damage the installation (Kumar, 2015).

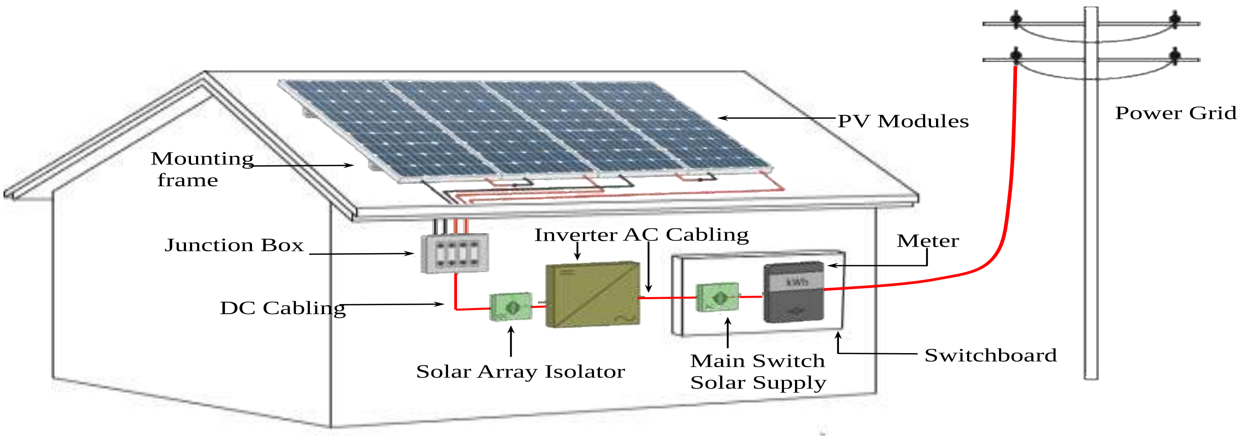

Figure 2.2: Solar PV system setup in a residential home

Source: Ellaban et al., (2014)

2.4 PV MARKET IN THE WORLD

Photovoltaics (PV) is a fast-emerging market. The Compound Annual Growth Rate (CAGR) of PV installations was 24% between year 2010 to 2017. Concerning PV module production in 2017, China & Taiwan hold the lead with a share of 70%, followed by Rest of Asia-Pacific & Central Asia (ROAP/CA) with 14.8%. Europe contributed with a share of 3.1% (compared to 4% in 2016); USA/CAN contributed 3.7%. Europe’s contribution to the total cumulative PV installations as recorded in 2017 amounted to 28% (compared to 33% in 2016). In contrast, installations in China accounted for 32% (compared to 26% in 2016). Si-wafer based PV technology accounted for about 95% of the total production in 2017. The share of multi-crystalline technology is now about 62% of total production. In 2017, the market share of all thin film technologies amounted to about 5% of the total annual production.

In 2017, Germany accounted for about 10% (42.4 GWp) of the cumulative PV capacity installed worldwide (415 GWp) with about 1.6 million PV systems installed in Germany. In 2017 the newly installed capacity in Germany was about 1.7 GWp; in 2016 it was 1.5 GWp. PV covered about 7% of Germany’s electricity demand in 2017.

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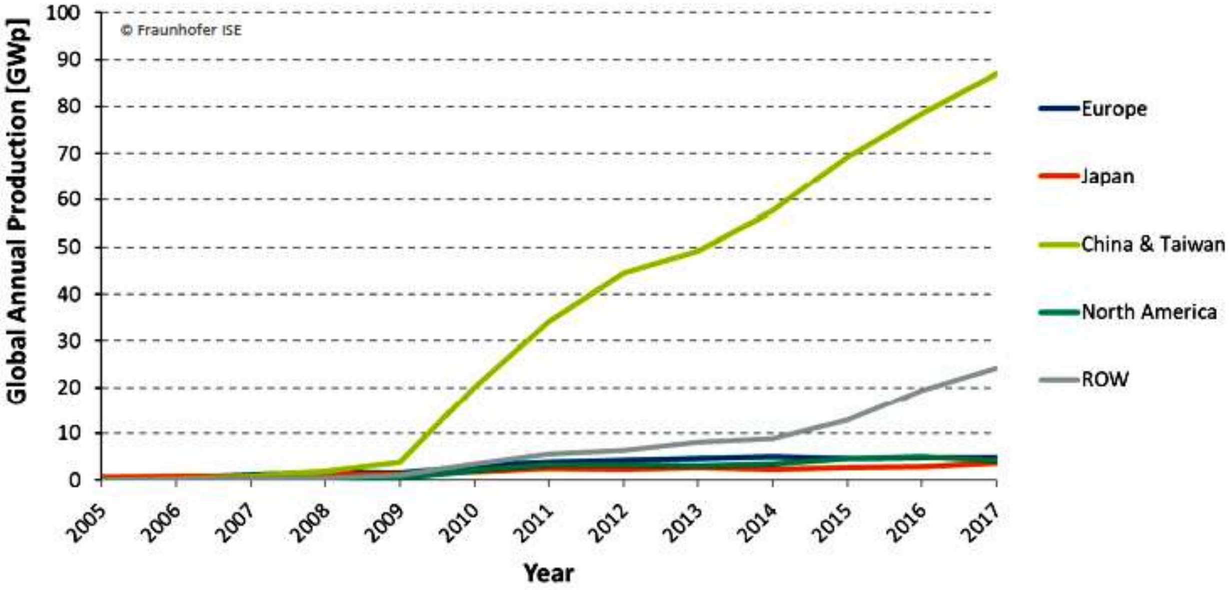

Figure 2.2: PV production by region 2005 to 2017

Source: Philips, (2018)

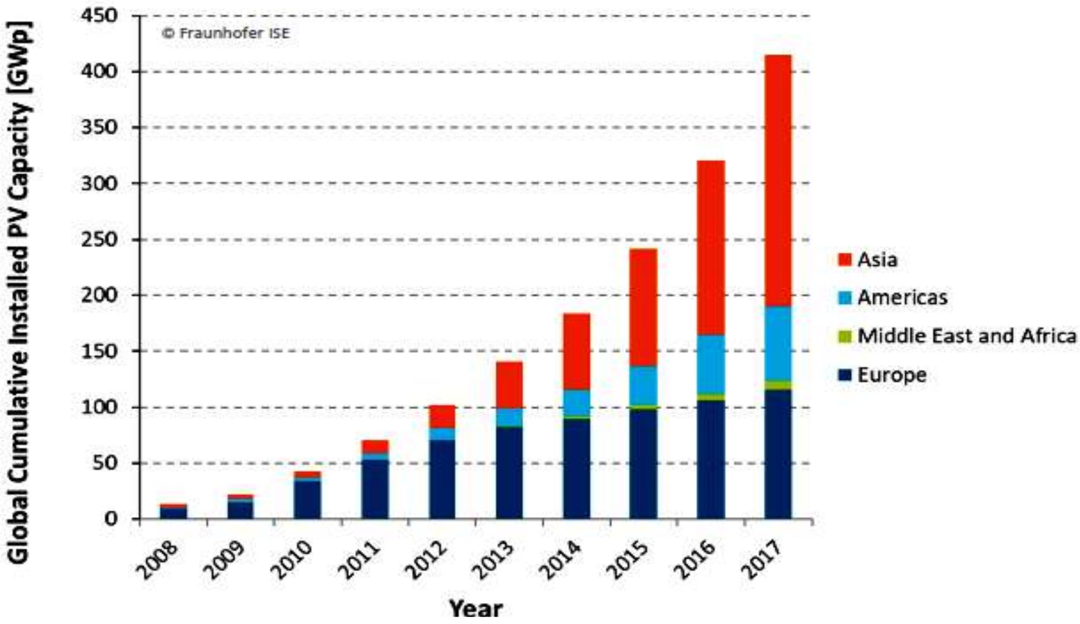

Figure 2.3: Global PV installation until 2017

Source: Philips,(2018)

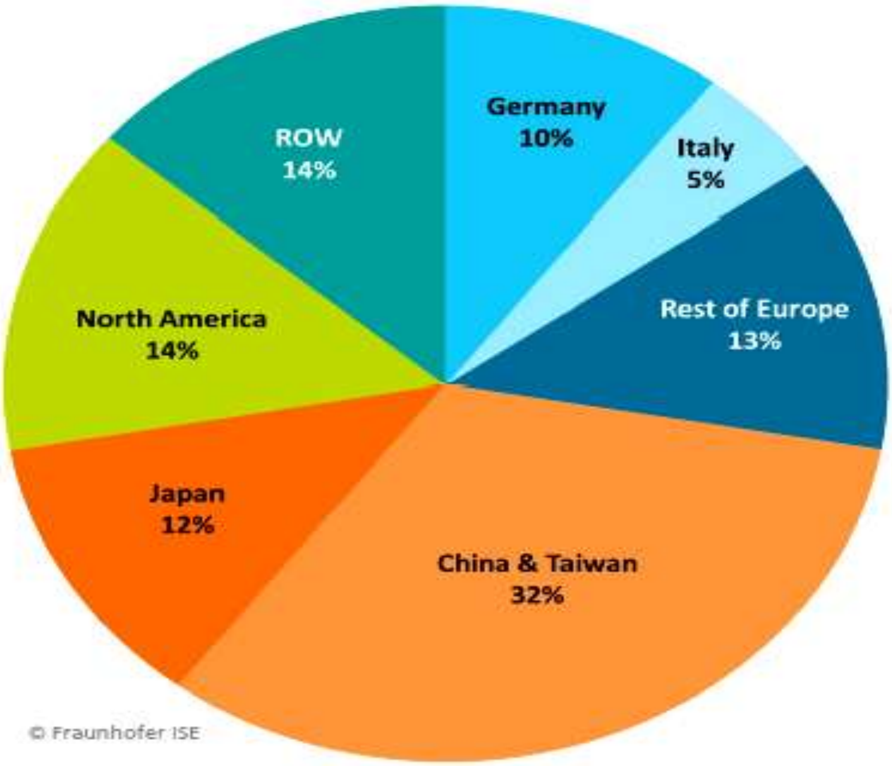

Figure 2.4: Global PV installation by country, 2017 status

Source: Philips, (2018)

2.5 PV SYSTEMS IN GHANA

Currently, plans are underway to install 200 MW of rooftop PV energy capacity using the roof of residential homes in the country. The Ministry of Power (now Ministry of Energy), through the Energy Commission, is implementing a Rooftop Solar Photovoltaic (PV) Programme in the country. The programme is in fulfilment of the President's Rooftop and the Energy Commission has been tasked to facilitate the installation of 20,000 rooftop solar PV systems in residential facilities (homes). The schedule under the programme was to grant a capital subsidy to beneficiaries by the distribution of actual solar panels provided the beneficiary has fulfilled the requirements demanded which were to have purchased and installed the standard Balance of System (BoS) made up of the inverter, charge controllers and deep cycled batteries connected with standard cables and the necessary switch breakers. The maximum capacity of 500 Watts (W) peak solar panels that will be granted each beneficiary under the programme and installed by a selected solar vendor selected by the beneficiaries themselves with this being limited to only Residential Facilities (Homes).

Prospective beneficiaries had to meet the following requirements in order to qualify for the 500Wp solar PV panels:

- Change all lighting points in the home to Light Emitting Diode (LED) ;
- Potential beneficiaries should be ready to acquire the BoS and other components from licensed solar PV vendors;
- Agree on the term that the installation of the BoS will be completed before the supply and installation of the solar PV panels from the Programme by a licensed solar PV vendor selected by the beneficiaries themselves;
- Install only deep cycle batteries that meets the minimum standards set by Ghana Standards Authority (GSA) designed for solar PV systems; and
- Engage the installation services of licensed solar PV vendors by the Energy Commission (Bellini, 2017)

Figure 2.5: Logo of the NRSP

Interest shown in the programme thus far as at March 2017 reveal that, 2,449 home owners have applied to benefit from the programme. The Energy Commission (EC) has given approval to 1,273 applicants (mostly in Accra) who do not have BoS to purchase and install the requisite BoS. 727 applicants have been given the maximum 500 Wp solar panels. Figure 2.5 shows the status of the NRSP in Ghana.

Some banks have expressed the interest to grant loan facilities for applicants who meet their requirements (e.g. UMB, UNIBANK, Afb, etc.). 105 Licensed solar vendors have signed agreements with the EC to supply and install systems. EC has given permission to the banks and solar vendors to use EC's logo to advertise their products under the programme (www.energycom.gov.gh).

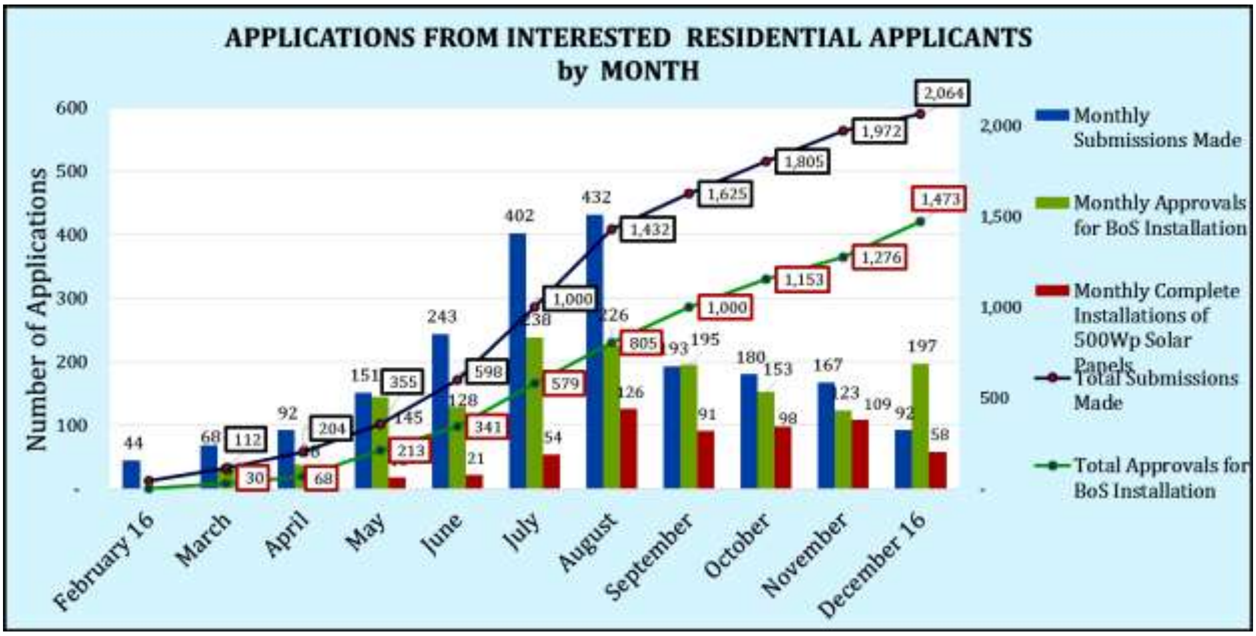

Figure 2.6: Status of the NRSP in Ghana

Source: www.energycom.gov.gh

2.5.1 CHALLENGES TO GHANA'S NRSP

1. Logistical challenges for approval inspection resulting in low number of inspections per day.
2. Financial constraint on the part of some of the beneficiaries – "expensive BoS"
3. Competing needs/use of the Energy Fund
4. Remoteness of the location of some of the residential facilities.
5. Incomplete application forms & wrong and information provided by applicants (e.g. wrong contact numbers, etc.)
6. Changing of choice of solar vendors with applicant, hence delays in the approval process.

Failure on the parts of some installers to understand the terms and conditions stipulated under the contract agreement.

Source: www.energycom.gov.gh

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter described how the study was conducted and the methods that were employed to achieve the study's aims and objectives. The chapter discusses the research design, study population, sample size, data collection methods and techniques of data processing and analysis that were adopted.

3.2 RESEARCH DESIGN

The descriptive research method was used for this study. Descriptive research methodology aims at describing characteristics of a sample population. It describes current issues or problems through a process of data collection that reports on the particular situation vividly (Fox and Bayat, 2007). Descriptive studies are used to describe various aspects of a phenomenon. The type of descriptive research method that will be used in this study is the survey research method. The survey research method allows participants to answer questions administered through questionnaire guides and interviews sessions. After participants answer the questions, researchers describe the responses given according to the study objectives (Jackson, 2009). The descriptive research method was employed in this study to be able to ascertain the current status of the NRSP through the use of interview sessions.

Beneficiaries of the NRSP served as study participants for the survey research. Interview sessions were adopted to solicit responses from the study participants according to the study's objectives. SPSS was used to analyse the data accordingly. Results were presented in figures, plates, charts and tables where appropriate.

3.3 STUDY POPULATION

Determining a study population for any research is an integral component to answering the study objectives. It is not enough to claim an intervention or counter effect was effective or otherwise without describing the types of participants on which the intervention was used or tested upon. This description is the specification of criteria for eligibility (Freidman et al., 2010). It is the subset of the general population with the conditions or characteristics of interest.

The study population for this study comprised beneficiaries of the NRSP in Accra who had functioning solar PV systems installed in their homes. A total of 150 beneficiaries were sampled.

3.4 SAMPLING TECHNIQUE

Purposive sampling was used to include study participants in this current research. Purposive sampling also known as judgment, selective or subjective sampling is a non-probability sampling method and it occurs when elements selected for the sample are chosen by the judgment of the researcher. In purposive sampling personal judgment needs to be used to choose cases that help answer research questions or achieve the research objectives (Saunders et al., 2012). Beneficiaries of the NRSP in Accra who had functioning solar PV systems installed in their homes were purposely selected for the study.

3.5 DATA COLLECTION INSTRUMENT

The data collecting instrument used for the study was interview sessions. Interviews are research data instruments consisting of a series of questions for the purpose of gathering information from study participants (Freidman, 2010). They provide a relatively efficient way and means to sample a large number of people to obtain relevant large amount of information. Interviews are a major data collection tool applied in qualitative research. They are most often than used as a research scheme to accumulate information about participants' perspectives, views and experiences concerning a specific research question or phenomenon of interest (Lambert and Loiselle, 2007). Sandelowski (2002) also purports that one-to-one interviews are the most commonly used data collection tools in qualitative research.

The semi-standardized or the semi-structured interview method was used in this study. Semi-standardized or semi-structured interviews offer a more flexible approach to the interview process. While they may use an interview schedule for predetermined topics, they allow for unanticipated responses and issues to emerge through the use of open-ended questioning (Tod, 2006). The flexibility of the semi-standardized interview allows the interviewer to pursue a series of less structured questioning and also permits the exploration of spontaneous issues raised by the interviewee to be explored. The wording of questions is flexible and facilitates different levels of language to be used and clarifications to be made by the interviewer (Berg, 2009). The semi-standardized facilitates the collection of richer more textured data from the interviewee or participant than that obtained through formally structured scheduled questions.

Interview questions were divided into two parts. Part A were question items designed to assess how cost effective the rooftop solar PV been since its installation in their homes. Question items included the details of the installed solar PV systems in their homes, the amount they bought the BoS the electrical appliances and gadgets connected to the installed solar PV system and the average amount of money they spent monthly on electricity before the installation of the solar systems and the average amount they spend currently after the installation of the solar PV systems. Part B comprised question items to assess the sustenance of the rooftop solar PV systems among beneficiaries since its installation. Some question items included challenges or otherwise they had encountered during the period they have used the solar systems, their general impressions thus far on the solar PV systems and any recommendations they would propose to enhance the program and policy in the long term.

3.6 DATA ANALYSIS

Data was analyzed with SPSS version 23 to answer the research objectives. The completed interview questions were first coded into SPSS after which they were cleaned for consistency. Results were presented and summarized with figures, plates and tables to depict the indicators where necessary according to the study objectives.

CHAPTER FOUR

PRESENTATION OF DATA ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results from the data collected from the field survey. It describes and analyses the data gathered for the purpose of the study. Results are presented in sections according to the study objectives. The use of tables and charts were employed with the presentation of the results. Discussion and implications of the study are also presented in this chapter.

4.2 ASSESSMENT OF THE NATIONAL ROOFTOP SOLAR PROGRAMME (NRSP) POLICY.

The Ministry of Power (now Ministry of Energy) under the auspices of the Energy Commission is implementing a Rooftop Solar Photovoltaic (PV) Programme in the country under a Capital Subsidy Scheme in 2016 as a fulfilment of the President's Rooftop Solar Initiative declared in 2015. The prime motive of the programme is to provide 200MW peak load relief on the national grid through solar PV technology in the interim. In a bid to execute the actual implementation of the programme, the Energy Commission has been tasked to facilitate the installation of 20,000 rooftop solar PV systems in residential facilities (homes). The schedule under the programme was to grant a capital subsidy to beneficiaries by the distribution of actual solar panels provided the beneficiary has fulfilled the requirements demanded which were to have purchased and installed the standard Balance of System (BoS) made up of the inverter, charge controllers and deep cycled batteries connected with standard cables and the necessary switch breakers. The maximum capacity of 500 Watts (W) peak solar panels that will be granted each beneficiary under the programme and installed by a selected solar vendor selected by the beneficiaries themselves with this being limited to only Residential Facilities (Homes).

Prospective beneficiaries would have to fulfill certain conditions listed below:

- Change all lighting points in the home to Light Emitting Diode (LED) ;
- Potential beneficiaries should be ready to acquire the BoS and other components from licensed solar PV vendors;
- Agree on the term that the installation of the BoS will be completed before the supply and installation of the solar PV panels from the Programme b y a licensed solar PV vendor selected by the beneficiaries themselves;
- Install only deep cycle batteries that meets the minimum standards set by Ghana Standards Authority (GSA) designed for solar PV systems; and
- Engage the installation services of licensed solar PV vendors by the Energy Commission.

The prospective beneficiary must put in an application. The application form can be picked from the EC office and completed or completed online and submitted automatically via the online application portal. Upon success of the applicant and necessary requirements are met, an EC inspector will then call the applicant and arrange for an inspection of the applicant's home. After the inspection, the EC issues a letter of approval to the chosen licensed solar vendor to integrate the approved solar panels (a maximum subsidy of 500Wp) to the installed BoS.

The vendor then goes ahead to install the approved solar panels for the applicant. The informs the EC of the complete installation of the solar panels and fills out the installation data sheet and submits to EC with the required invoice and photographs.

The EC then undertakes random monitoring of the installed system to validate completion of installation of the solar systems.

The implementation of the National Rooftop Solar programme begun on the 8th February, 2016.

Interest shown in the programme thus far as at March 2017 reveal that, 2,449 home owners had applied to benefit from the programme. The Energy Commission (EC) had given approval to 1,273 applicants (mostly in Accra) who do not have BoS to purchase and install the requisite BoS. 727 applicants had been given the maximum 500 Watts peak solar panels. Figure 4.1 shows the status of the NRSP in Ghana. 105 Licensed solar vendors had signed agreements with the EC to supply and install systems. Some banks also expressed the interest to grant loan facilities for applicants who meet their requirements (e.g. UMB, UNIBANK, Afb, etc.). EC had given permission to the banks and solar vendors to use EC's logo to advertise their products under the programme.

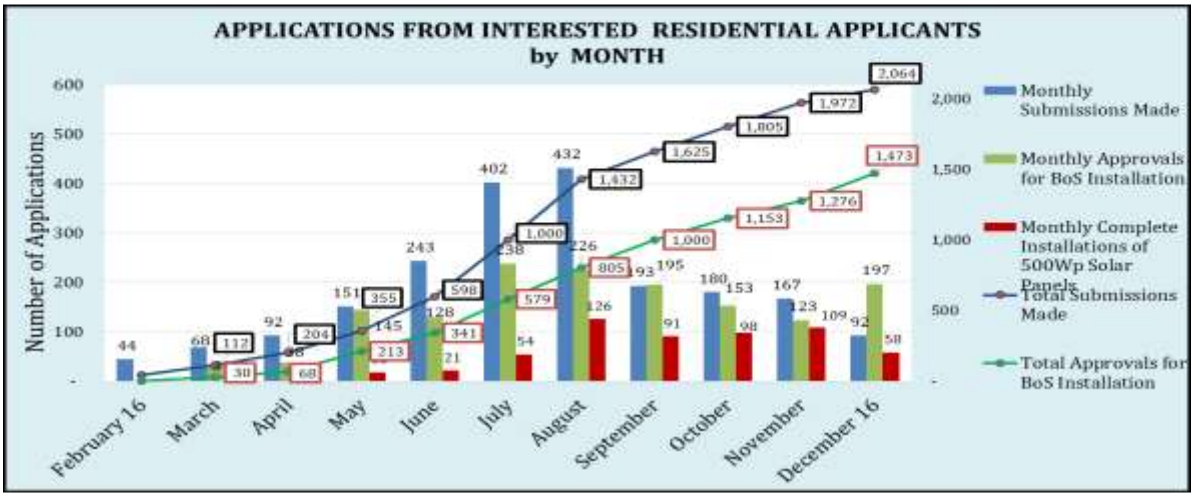

Figure 4.1: Status of the NRSP in Ghana

Source: www.energycom.gov.gh

Table 4.1: Status of the NRSP in Ghana

Status	***n***
Applications submitted	2,449
Applications approved	1,273
Solar systems installed	727

n – Frequency

Figure 4.2 shows a trend analysis of the monthly submissions made, approvals for BoS installation and monthly complete installations of 500Wp solar panels for the period understudy.

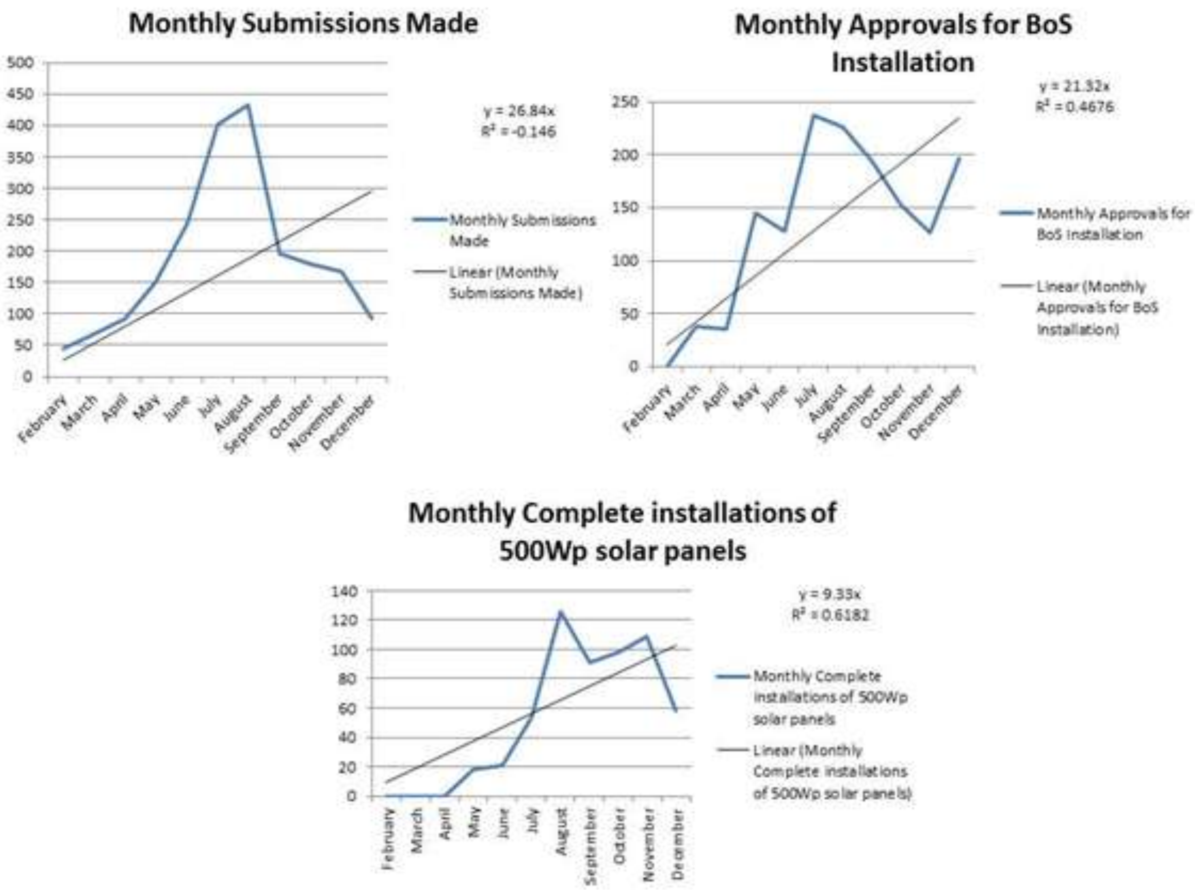

Figure 4.2: Trend analysis of monthly applications, monthly approvals and monthly complete installations of the NRSP in Ghana.

The trend lines show increasing trends for monthly submissions, monthly approvals and monthly complete installations. However, the gradient of the slopes reveal that although monthly submissions and monthly approvals for BoS installations consecutively increased about 26 times $(y = 26.84x)$ and 21 times $(y = 21.32x)$ respectively, monthly complete installations of solar panels increased only 9 times $(y = 9.33x)$ every month. This means that the rate of monthly submissions and monthly approvals for BoS installation were almost 3 times and 2 times respectively more than monthly complete installations.

This reflects delay in meeting demands for solar panel installations. This inadequacy can be attributed to the number of vendors and installers licensed for the programme and delay in reimbursement of the cost of panels by the Energy Commission to the licensed solar PV vendors for works completed. The gap shows that the installers were not apt in meeting up with the demand for the monthly approvals. This establishes the fact that there is the lack of skilled expertise in solar PV technology in Ghana. More locally skilled engineers and technicians need to be trained in the assembly, installation and maintenance of the solar PV systems in the country. This situation reflects the same report by Adeyemo (2013) in Nigeria who also showed that there is little trained manpower for the solar PV technology in Nigeria. They reported that, there is the lack of technical know-how in the installation, operation and maintenance of solar energy systems in the country. They further stated that, these challenges delay the ability to quickly notice basic problems in the setups. These problems persist for long and they eventually make the projects a failure.

Additionally, the number of applications submitted within the period demonstrate very little participation in the programme. From the graph it could be seen that about 0.10% (2,449/2,270,000) of the population of Accra applied to the benefit from the programme showing the lack of awareness creation in order to build the interest of the project among the citizenry evident on the graph representing the monthly submissions made showing a downward dive in the latter part of the year.

The public advertisement was limited and though it was a GoG project, there was little committment from the government. Also, intense education ought to be enhanced among the citizenry on the benefits of the solar powered projects so it is embraced. This is consistent with Adeyemo (2013), who also found out that there is no political motivation and full government participation and support in awareness creation on the subject of solar PV technology. Also, commercial activities related to the sale and operation of solar PV technology plunged into the minimum region posing as challenges to solar energy projects to which the country Ghana has to overcome before it comes into the limelight as a torch bearer of renewable energy particularly Solar.

4.3 COST EFFECTIVENESS OF THE ROOFTOP SOLAR PV SYSTEMS INSTALLED IN HOMES OF BENEFICIARIES

A paired sample T-test was conducted to compare the expenditure on bills (in GH₵) of beneficiaries before and after installation of the rooftop solar PV system. Consumption levels (in kWh) with the help of the ECG gazetted Reckoner (2016 & 2018) and gazetted tariff structure published by the PURC, the right consumption units were derived based on the units of electricity purchased were additionally compared before and after installation.

Table 4.2 below shows the mean expenditure on power and consumption levels of beneficiaries before and after installation of the rooftop solar PV systems. The table shows an average cost reduction of GHC 135.76 (45.31%) in electricity bills after installation of the systems. This was accompanied by an 84.78kWh (23.70%) reduction in consumption levels over the period understudy (Table 4.2). This shows that every reduction in consumption level is accompanied by almost two times reduction in cost of electricity. The result confirms a proposition by Branker et al (2011) on the advantages of the solar PV systems over main stream source of electricity. Their research revealed that continual decline in installation costs coupled with increasing cost of grid electricity will make solar PV systems a beneficial source of electricity over other sources. This is due to the fact that every beneficiary seeks to maximize utility (satisfaction) at a minimal cost.

Table 4.2 Average cost and consumption levels before and after installation of solar PV systems among beneficiaries

		Average	Mean difference (%)	*n*
Cost (GH¢)	**Before installation**	299.60	135.76 (45.31%)	150
	After installation	163.84		150
Consumption (kWh)	**Before installation**	357.67	84.78 (23.70%)	150
	After installation	272.89		150

n=Sample size

Source: Field data 2018

Further, Table 4.3 provides information of significance of reduction in cost and consumption level before and after the installation of the rooftop solar PA systems. Results from the table indicates significant reduction ($p<0.00$) in cost and consumption levels after the installation. Thus, the results substantiate the GHC135.76 (45.31%) and 84.78kWh (23.70%) reductions in cost on electricity bill and consumption respectively. This proves that beneficiaries of the rooftop solar PV system can save close to half of the amount they continually spend for regular source of electricity. This greatly cuts down on their expenditure on utility bills.

As confirmed by Ali et al., (2017), rooftop PV has the potential of generating huge volumes of electricity. As a result, it has a significant likelihood of reducing the use of other sources of electricity and minimizing cost on energy generation (Numbi and Malinga, 2016). This again proves that the rooftop solar PV system is an economically viable technology choice that must be part of energy strategies. There is also the progressive technological advancements and speedy decrease in costs of production and installations of the solar PV systems across the world making this technology a preferred choice of alternative energy source (Griffith and Mills, 2015).

Table 4.3: Significance difference in cost and consumption levels by beneficiaries

	95% Confidence Interval of the difference		t	Df	Sig.
	Lower	Upper			
Cost	106.05977	165.45539	9.03	149	**0.00**
Consumption	57.14607	112.41823	6.06	149	**0.00**

Source: Field data 2018

4.4 SUSTENANCE OF THE NATIONAL ROOFTOP SOLAR PROGRAMME

Beneficiaries of the project were asked on their impression of the project so far. They were asked to outline the challenges they had faced so far with the systems. They were also asked to state some recommendations they would propose towards the project.

All the respondents 100% (150/150) agreed that the batteries were the major challenge with the system. They said that determining the size or number of batteries needed for the systems in their homes was a problem and also the batteries die out very fast. They argued that, additionally, the efficiency of the batteries reduces after 2 years.

Table 4.4 shows the factors for the sustenance of the National Rooftop Solar Programme. Altogether, Majority of the beneficiaries, 23% (35/150) agreed that the project is a good program and should be brought to the door step of the ordinary Ghanaian. There should be more effort from the EC to advertise this service so many more Ghanaians can apply for the solar since it will significantly reduce the burden on the national grid and serve as a cleaner and more efficient way of power supply.

Table 4.4: Factors for the sustenance of the National Rooftop Solar Programme (NRSP)

	n	*freq*	*%*
1. Capacity of solar panel offered is highly inadequate to make any significant impact. Thus, government should increase the capacity of the panels.	150	24	16
2. The program is a good program and should be brought to the door step of the ordinary Ghanaian. There should be more effort from the EC to advertise this service so many more Ghanaians can apply for. This will significantly reduce the burden on the national grid and serve as a cleaner and more efficient way of power supply.	150	35	23
3. Government should provide meters that will enable us to feed excess power into the grid for money. We will also become mi producers and get value for our money.	150	10	6
4. The cost of the BoS is way too expensive. The energy commission should license dealers who can provid at a much cheaper cost.	150	11	7
5. The Government should implement solar PV systems at all Public offices	150	28	18
6. Energy Commission should be more proactive in providing support for customer applications for service. The lead time for approval of application through to installation is just too lengthy.	150	30	20
7. The program should be continued and extended to the rural areas of the country.	150	12	8

n – sample size

Source: Field data(2018)

Based on the findings of this work, the following recommendations are made:

1. Solar energy projects must be noticed and embraced as a better option to fixing the country's energy prevalent crises. There should be the proper planning of the entire solar energy projects in the country. Proper and quality planning of the entire projects from the planning stage to the execution state is highly crucial hence great time should be invested in drawing important and sustainable in the area of solar energy. The NRSP project was a good project and therefore should be properly planned, implemented and consciously supervised. Review stages or milestones should be set accordingly in monitoring the project.
2. There should be intense education, publicity, greater awareness and emphasis on the solar energy projects and its advantages. The education and training can be done through the local government departments, the understanding of what a PV system is and how to operate it will become a possibility to every Tom, Dick and Harry. This will cause the citizenry and the whole nation to embrace the project.
3. More solar energy vendors and installers should be trained in the country. A lot of engineers and technicians should delve into the field of solar energy projects and PV systems as this is a viable area for exploitation in the country.
4. The use of the LED energy saving bulbs should be intensified as a must in all homes, public offices and private organizations in the country. These bulbs are energy efficient hence consume lesser amount of energy hence people will save money on their consumption of electricity.
5. Further, Ghana should learn from the way solar energy projects have being approached or are being handled and executed in advanced countries across

the globe. Countries such as the USA, Finland, Germany, China, and Japan just to mention but a few should be used as learning field for the country and understand their approach on how they developed their solar capacity in their country. Such countries should be yardstick for solar projects from which processes can be learnt and applied back home on current projects and future developmental projects.

CHAPTER FIVE

CONCLUSION

5.1 INTRODUCTION

This chapter presents the summary of this research. It outlines appropriate conclusions obtained from the dataset analyzed per this research. It then formulates practical recommendations based on the findings.

5.2 CONCLUSION

The study assessed the impact of the rooftop solar PV systems in Ghana based on the GoG programme of the National Rooftop Solar Programme (NRSP) initiative in the country. The implementation of the National Rooftop Solar programme begun on the 8th February, 2016.

Interest shown in the programme as at March 2017 revealed that, 2,449 home owners had applied to benefit from the programme. The Energy Commission (EC) had given approval to 1,273 applicants (mostly in Accra) who do not have BoS to purchase and install the requisite BoS. 727 applicants had been given the maximum 500 Wp solar PV panels. 105 Licensed solar vendors had signed agreements with the EC to supply and install the solar systems.

The specific objectives of the study were therefore:

- To assess the National Rooftop Solar Programme (NRSP) policy.
- To assess the cost effectiveness of the rooftop solar PV systems among beneficiaries; and
- To assess the sustenance of the rooftop solar PV systems among beneficiaries.

With respect to the NRSP policy based on the views and recommendations received from beneficiaries, it could be seen that the policy is laudable and must be continued with since Ghana is aimed at going green and increasing the percentage of renewable energy in the energy mix. Also the solar PV systems installed proved to be cost effective and beneficiaries had value for their money though the initial capital was intensive having the system reduced their electricity bills as well as their consumption by a reasonable margin.

In all, there was very low patronage of the programme by the citizenry with about 0.10% (2,449/2,270,000) of the total population of the people in Accra applied to benefit from the project. There was a further reduced number of beneficiaries (727) who actually got the solar systems to be installed in their homes. Generally, there was the lack of awareness and the lack of interest in the project among the citizenry. There was also very little awareness created for this project. The public advertisement was limited and though it was a GoG project, there was little motivation from the government.

The mean expenditure on power and consumption levels of beneficiaries before and after installation of the rooftop solar PV systems was assessed. The results showed an average cost reduction of GH¢135.76 (45.31%) in electricity bills after installation of the systems. This was accompanied by an 84.78kWh (23.70%) reduction in consumption levels over the period understudy. This shows that every reduction in consumption level is accompanied by almost two times reduction in cost of electricity.

However, a major challenge the programme faced was in the area of financing the payment of solar panels installed by the vendors for the beneficiaries. As reported by

Graphic Online, it was revealed that the Energy Commission was unable to raise an amount of GH¢533 million required to fully implement the programme to subsidise rooftop solar panels for homes. This resulted in the reluctance of the solar PV vendors from carrying out other approved installations for new beneficiaries.

Another challenges beneficiaries had faced with the rooftop solar PV systems were the batteries. They said that determining the size or number of batteries needed for the systems in their homes was a problem and also the batteries die out very fast. They argued that, additionally, the efficiency of the batteries reduces after 2 years. The cardinal recommendations proposed among the beneficiaries was that the project was a good program and should be brought to the door step of the ordinary Ghanaian. There should be more effort from the EC to advertise this service so many more Ghanaians can apply for. This will significantly reduce the burden on the national grid and serve as a cleaner and more efficient way of power supply. The least number of beneficiaries also said that the government should provide meters that will enable them to feed excess power into the national grid for money. This will make them become mini producers of electricity and get value for their money.

Furthermore, it can be concluded that there has been a constant supply of electricity across the country as a result of the programme which acted as a relief measure to stabilize the grid.

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APENDIX