William Apotogse Oduro

Financing options for solar photovoltaic deliverables in developing countries

Case study: Ghana

School of Technology and Innovation…
Master's thesis in Industrial Management

Vaasa 2021

UNIVERSITY OF VAASA
School of Technology and Innovation
Author: William Apotogse Oduro
Title of the Thesis: Financing options for solar photovoltaic deliverables in developing countries: Case study: Ghana
Degree: Master of Science in Economics and Business Administration
Programme: Industrial Management
Supervisor: Dr. Emmanuel Ndzibah
Year: 2021 Number of pages: 62

ABSTRACT:

The increases in electricity tariffs as well as the unreliability of the supply of electricity have brought untold hardship to the populace in Ghana. However, Ghana's geographic location creates an opportunity for an alternative solution from the use of the solar photovoltaic unit (solar PV). Nonetheless, the very expensive initial cost of acquiring a solar PV unit is of concern. This thesis seeks to explore various financing options for solar PV deliverables in developing countries with a focus on Ghana.

The research question set forth to investigate these options is: *what are the financing options available for solar photovoltaic deliverables in developing countries with Ghana as a case study?*

The objectives of the study include identifying the types of financing options available in Ghana and analyzing the merits and demits of the options available in Ghana. More so, identifying the best option(s) suitable for the financing of solar PV in Ghana, and detecting barriers to implementing the best option(s) in Ghana.

The method utilized includes collecting relevant data from 96 solar PV companies as well as 100 business and household customers. The questionnaire was sent via google forms. These questionnaires were to help understand the various financing options available and in use by solar PV companies in Ghana in promoting the acquisition of solar PV deliverables in Ghana and to understand the best options viable for adoption going forward.

The response rate was as follows; 71 responses from the 96 solar PV companies while out of 100 businesses and household customers, some 52 responded

From the results, it was obvious that solar companies in Ghana were aware and to some extent uses some financing options like *green loans, leasing, revolving funds, credit co-operative, personal installment*, and bank loans. Nonetheless, the popularity of personal installments presented itself as the best option for consideration. This research also, discovered that despite the popularity of that option, frequent defaults on payment made it unattractive to the solar PV businesses thus their preference for outright payment. Green loans are also a preferred and viable option.

The research also established that for the popular financing option in Ghana to work effectively, there was the need to include a net-metering system for off-grid solutions to facilitate strict adherence to a pay-as-you-use approach.

KEYWORDS: Photovoltaic, financing options, developing countries, Ghana

Acknowledgments

First and foremost my biggest thanks goes to the Almighty God Jehovah for giving me the strength and wisdom to complete this research work. I am really grateful.

My second thanks goes to Dr. Emmaunel Ndzibah who is also my supervisor. He has always been there for me and I owe him a very big thanks. I admire his professionalism and always on my neck to see to it that I complete this research work as early as possible, thank you sir and you really made me work hard. May Jehovah continue to give you wisdom and understanding.

I also want to thank Tenure Track Professor Ahm Shamsuzzoha, for reviewing my work as the second evaluator. Your hardwork and inciteful comments were very helpful.

Thanks to Associate Professor Adebayo Agbejule of Vaasa University of Applied Sciences for giving me prior insight into the field of renewable energy during my bachelor`s program , Sir I am forever grateful.

My sincere gratitude also goes to my wife Regina Amihere-Oduro and daughter Keren Amihere-Oduro for your continues support both spiritual and emotionally during this period. I really appreciate.

Finally, my sincere thanks goes to Mrs. Sakeena Twumasi Dodzi for accepting to do the field work for me and also to my brother Benjamin Oduro and sister Asibi Apotogse for your continue supports. Thank you all

Contents

Figures

Tables

Abbreviations

BDT	Bangladesh Taka
BOG	Bank of Ghana
BOOT	Build-Operate-Own and Transfer
CEC	Clean Energy Council
EPC	Engineering Procurement and Construction
GDP	Gross Domestic Product
GEC	Ghana Energy Commission
GSC	Ghana Stock Exchange
HDI	Human Development Index
IEA	International Energy Agency
IMF	International Monentary Fund
MPC	Monetary Policy Committee
MPR	Monetary Policy Rate
NIC	National Insurance Commission
PURC	Public Utility Regulation Commission
PV	Photovoltaic
SUNREF	Sustainable Use of Natural Resources and And Energy Finance
SWERA	Solar and Wind Energy Resource Assessment

1 Introduction

1.1 Background of the study

Energy has become one of the major determinants of the economic prosperity of any country. It plays a very important role in undertaking daily activities such as cooking and lighting also powering machines in the industrial sector (Pirlogea Corina & Cicea Claudia, 2012). Whiles energy plays a significant role in our daily life, the international energy agency in 2020 reported that about 590 million people in Africa still do not have access to energy and Ghana is no exception. The energy commission of Ghana in its reports on the 2020 energy outlook reported that Ghana has a total installed generation capacity of 5171.6 megawatts which consists of 3410 megawatts coming from thermal plants whiles the rest comes from hydropower and renewable. Thermal power plants which are the highest generating source of energy use three types of fuels to operate and these fuels are so expensive that it was reported in Ghana`s energy commission outlook, 2020 that the expected delivery fuel price for the thermal plants will be 721.4 million dollars and this has made a relatively high end-user tariff increase to Ghp57.3Kwh even though currently Ghana has a demand of only 2612.6 megawatts.

As the population of the world grows and there is a growing demand to reduce greenhouse gas emissions and also improve energy efficiency, renewable energy will be an effective way to manage this situation and also improve environmental protection, however, the situation in Ghana looks different, out of the 5171.6 megawatts installed capacity its only 42.6 megawatts of installed capacity coming from renewable energy resources(Ghana Energy Commission, 2020) even though studies from (SWERA, 2017) suggest that Ghana`s geographical location around the equatorial sunbelt is very strategic for her to exploit the abundant solar energy resources and economically viable, about 82.4 percent of the population have access to electricity (World Bank, 2018).

Now electricity tariff in Ghana continues to increase because the fuels used to power the thermal plants are becoming expensive (PURC, 2019)and government have no option but to distribute the cost among the end-users, coupled with many people still not having access to electricity and the option that Ghana has the potential to explore solar energy as an alternative but the initial cost very expensive, it is the aim of this thesis to consider the various financing options for solar photovoltaic deliverables in Ghana

1.2 Research gap, questions, and objectives

There have been many studies conducted on how renewable energy particularly solar photovoltaics should be financed and the table 1 below will explain what the researcher found after using certain key phrases

Table 1 key words used to find research gap

Key phrases	Range	Type of database	Number of hits	Core parameters, scope, and gap
Financing options for solar PV	2017-2021	Science Direct	1260	Most of the articles were just analyzing some of the financing options available but did not give a clear recommendation as to the one suitable for especially developing countries.
Financing options for solar PV	2017-2021	Scopus	2	These two articles only talk about how government can finance solar PV but did not even explore the various financing options to see which one will be suitable for espe-

				cially developing countries
Financing options for solar PV in developing countries	2017-2021	Science Direct	2413	Most of the articles were not even focused on the various financing options available and even those articles that were focused on the financing options did not give a clear recommendation as to which one will be suitable in developing countries
Financing options for solar PV in developing countries		Scopus	No article	With this kind of keyphrase, no article was found in this database.

After using the phrases the results I got indicate that even though there has been a lot of research done on solar photovoltaic financing there has not been a clear-cut view of the best way to finance solar photovoltaics, especially the standalone type and that is why so independent researcher like Ndzibah, 2013 proposed a study that will explore the various types of financing options in promoting photovoltaic deliverables and recommend the best options, therefore the main objective of this research is to explore in details the various financing options in promoting photovoltaic systems in Ghana.

The research question for this study is stated *what are the financing options available for promoting solar photovoltaic deliverables in developing countries with Ghana as a case study?*

But to answer this research question the following objectives are useful

- Identify the types of financing options available in Ghana
- Analyze the merits and demerits of the options available in Ghana
- Identify the best option(s) suitable for the financing of solar PV in Ghana
- Identify barriers in implementing the best option(s) in Ghana.

1.3 Definitions and Limitations

This part of the research will define some keywords and give some limitations of the research. This is going to help the reader understand the meaning of those keywords in terms of this research. These keywords are:

Photovoltaic

This is defined as an installation of components such as an inverter, solar panels, batteries, and electrical cables which are connected in a way that converts energy gotten from the sun into electrical energy for domestic usage and even stores the surplus electricity in the battery for future use (Clean Energy Council, 2008). There are two types of solar photovoltaic systems, and these are stand-alone and grid-connected (CEC, 2008) but for this research, the concentration will be on the stand-alone type.

Developing countries

Sheffrin (2003), defines a developing country as a country that has a less industrial base and a low human development index (HDI). Developing countries tend to have low levels of access to drinking water, energy poverty, and generally poor infrastructure (O"Sullivan & Sheffrin, 2003). In this research, the limitation will be Ghana and all examples will be based in Ghana.

Financing option

In this research, the definition of financing option is financing already made products of photovoltaic deliverables and the financing option that will be investigated include revolving funds, crowdfunding, credit co-operative, leasing, and green loans (Ndzibah, 2013).

Ghana

Ghana is a developing country which is situated on the west coast of Africa. It is surrounded by Burkina Faso in the north, to the eastern border is Togo, to the west cote d`ivoire whiles to the south is the Gulf of Guinea. Ghana was formally called Gold Coast until 1957 6th of march when it had its independence from the United Kingdom (Ghana web, 2014).

This research will be based in Ghana and all examples will be from Ghana but since the researcher cannot travel to all the sixteen regions in Ghana, his examples will be based on companies situated in the Greater Accra Region specifically around the main capital city and peripheral towns.

1.4 Research design

The main aim of this research is to explore in detail the various financing option for promoting photovoltaic deliverables in Ghana. This research is going to use the qualitative method accompanied by a questionnaire and an interview with some industry players. With the issue of data collection, the approach will be a survey, interview, energy reports, scientific articles, and observation.

The survey will be done in Ghana and those to be interviewed will be both households and business solar PV users. These groups of people will be gotten from the solar companies based in Accra.

Primary data such as interviews will be used, these interviews will be with solar photovoltaic companies in Accra. GEC, 2021 has about 50 registered solar photovoltaic companies, but out of that 3 are based in Kumasi whiles 1 is based in the Eastern Region, therefore this research will be based on at least 25 of the 46 companies in Accra. The idea is to understand the current system being put in place for financing solar photovoltaic deliverables in Ghana. This will help to identify some barriers to financing solar photovoltaic deliverables in Ghana.

The secondary data will be energy reports. These reports will be taken from the institutions in Ghana that are responsible for photovoltaic development, especially GEC. The researcher does not need to go to those institutions since those reports will be available on the internet. Articles on photovoltaic deliverables and financing options will be used in this research.

1.5 Structure of the study

Chapter one of this research will discuss the background of the study, the research gap, and the research question as well as the objective of the research. It will also discuss the limitations and define some keywords and then the research design.

Chapter two will also deal with the background of the case country as well as the energy infrastructure and the types of financial institutions and credit setups in Ghana.

Chapter three will be the literature review. This will deal with the configuration and components of the photovoltaic unit and the various financing options for solar photovoltaic deliverables. it will also describe developing countries and the parameter to determine developing countries.
Chapter four will be the methodology which includes the data collection and analysis and the results. it will also talk about the reliability and validity of the study.

Chapter five will be the theoretical methodology and findings. It will also include the conclusion and further research.

2 Case country background

This chapter will present the political, historical as well as economic history of Ghana after attaining independence from Britain. The chapter continues with an overview of the types of financial institutions and credit setups in Ghana.

2.1 Historical, political, and economic history of Ghana

Ghana gained its independence on the 6th of March 1957 from its colonial masters the British. Ghana sits on the Atlantic Ocean and shares a border with Togo on the east, Cote d'Ivoire, and Burkina Faso on the west and north respectively (World Bank, 2021). Ghana has a population of 30.07 million according to data available to GSS, 2021 with the capital city Accra being the most populated in the country.

Ghana in the past two decades has taken major strides toward democracy under a multiparty system while its judiciary gaining public trust and was ranked by the world bank in 2021 as among the top three African countries where freedom of speech and press freedom is high and has strong broadcast media with radio being the medium in which people are reached most, these have provided Ghana with a solid social capital.

Ghana's economy contracted by 3.2% and 1% in the second and third quarters of 2020 respectively sending the country`s economy into recession for the first time in thirty-eight years (World Bank, 2021). Ghana's economy is ranked as the 89th best in the world according to the 2022 index of economic freedom making it the 9th among 47 countries in the sub-Saharan African region (Economic Freedom Score, 2022). Ghana's economic history has been quite stronger over the past three decades during which the country pursued market-led economic policies and programs with minimal involvement of government in direct economic activities (Alagidede et al., 2013).

The World Bank 2010, in its annual report on the country's economy, reported that Ghana recorded about 5.2% annual average growth between (1984 and 2010) and be-

came a lower middle-income country after the national accounts were rebased in 2010 making the country's annual average growth to 8.3% between 2007-2012. Ghana, in 2011 started the production of oil in commercial quantity. This development contributed about 5.5% points(oil-GDP) to the 15.0% real GDP growth in that same year making Ghana one of the fasters growing economies in the world that year (World Bank, 2010).

The 2021 budget statement read by the finance minister estimated a real gross domestic product(GDP) growth rate of 5.1% in 2021 and 6.7% for non-oil and in the first quarter of 2021, overall growth in GDP of 3.1% and non-oil growth rate of 4.6% was reported by the Ghana statistical service (Bank of Ghana Annual Report, 2021). The 2021 mid-year budget review on Ghanas key economic sectors had the agricultural sector having the highest growth rate of 4.3% which is followed by the services sector with a growth rate of 4.0% whiles industry grew at 1.3%, but in 2020 the highest growth rate was recorded by the service sector at 12.3%, followed by the agricultural sector of the growth rate of 10.2% and industry sector 1.4% (Bank of Ghana Monetary Policy Report, 2021).

The recent economic development outlook of the world bank 2022, states that Ghana's economic rapid growth of 7% per year from (2017-2019) came to stand still of the recent covid-19 pandemic, the lockdown in March 2020, and a sharp decline in commodity exports. This slowdown of the economy had a very significant impact on households making the poverty rate slightly increase from 25% to 25.5% in 2021 (World Bank, 2022). Ghana's inflation had risen to 31.7% in July 2022 from 12.6% at the end of 2021 but despite these macroeconomic headwinds, the banking sector performance has remained stronger making the non-performing loan ratio moved to 14.1% in June 2022 from 17% in June 2021 (*Bank of Ghana Monetary Policy Report*, 2021).

In terms of interest rate in march 2020, the monetary policy committee(MPC) lowed the monetary policy rate(MPR) from 16% to 14.5%. This was maintained throughout 2020 and to the first quarter of 2021. The MPC in May 2021 reduced the monetary

policy rate to 13.5% and was maintained until September 2021. This helped in easing financing conditions and boosting lending and growth and the average commercial banks lending rate remained comparatively higher throughout 2020 (NIC Report, 2020).

The Ghanaian foreign exchange market was relatively stable with the country's currency performing better as compared to 2019 and this was because of the reserve build up by the Eurobond issuance of US$3.0 billion, the COCOBOD loan of US$1 billion International monetary fund(IMF) rapid credit facility (Bank of Ghana Annual Report, 2021).

2.2 Types of financial institutions and credit setups in Ghana

The world bank 2019 in its economic update for Ghana indicated that with the usage of innovative technology and approaches, Ghana can attain universal financial access, however, in their fourth economic update for Ghana the report indicates that even though the financial sector has grown rapidly since 2010, access to finance across regions and demographics is still low, especially among women, poor and rural areas.

PricewaterhouseCoopers Ghana classifies Ghana`s financial sector into three main categories. They are the banking sector, the insurance, and the capital markets sector (PricewaterhouseCoopers, 2021).

The banking sector is the most dominant financial services sector and is made up of traditional banks, asset management companies, microfinance institutions, and rural banks. The banking institution in Ghana is regulated by the central bank (Bank of Ghana, 2021). The Bank of Ghana (BOG) formulate and implemented a monetary policy to achieve price stability and ensure a sound payment system.

During the first half of 2021, the sector continues to grow stronger in terms of assets, deposits, and investments but the growth of credit remains sluggish due to the effect of the covid-19 pandemic. In the Bank of Ghana, monetary policy report 2021 the total assets of the banking sector increased by 17.2 percent year-on-year to 162.9 billion

Ghana cedis at the end of June 2021 as compared to 23.2 percent growth at the end of June 2020. As of the end of June 2021 investments in bills, securities and equity remained the biggest component of the total assets (Bank of Ghana Monetary Policy Report, 2021). According to the Bank Of Ghana monetary policy report 2021, the total borrowing in June 2021 increased by 5% as compared with the 10.9% growth in the previous year and this was due to the higher increase in deposits.

Despite some achievement within the banking sector on August 14^{th,} 2017, the BOG in its press release to the public announced the taking over of two indigenous banks by Ghana Commercial Bank as a result, their operational licenses were taken from them and just a year later five other indigenous banks were consolidated to form one new bank and BOG sited corporate governance,non-performing loans, credit risk, and regulatory lapses as the result of the collapsing of these seven local banks (Bank of Ghana Annual Report, 2017).

The insurance institution in Ghana is regulated by the National Insurance Commission (NIC) and is made up of 27 non-life companies,23 life companies, and 80 broking companies as of 2021 (National Insurance Commission, 2019). The sector is governed by the Insurance Act 2006, Act 724. In NIC's annual report in 2019, the total estimated number of people employed in the industry is about 12000 and the total profit made was 196 million Ghana cedis.

The sector in its 2020 annual report, reported that due to the effect of covid-19 sales particularly life insurance has been low due to the new culture of social distancing. In terms of growth and performance of the insurance sector, the gross premiums increased by 21% from 3.5billion Ghana cedis in 2019 to 4.2billion Ghana cedis in 2020. The life insurance premiums increased from 1.65billion Ghana cedis in 2019 to 2.02billion Ghana cedis in 2020 whiles the non-life premiums increased from 1.8billion Ghana to 2.2billion Ghana cedis in 2020 (NIC Report, 2020). The total assets for both the life and the non-life sectors over the past five financial years ie between 2016-2020

have seen a more than doubled growth rate of 107% and 114% respectively and the total assets of the five non-life insurers are made up of 52% of the non-life insurance sectors total assets whiles in terms of total assets of five life insurers is made up of about 75% of the sectors total assets (NIC Report, 2020).

The insurance industry over the past few years has experience underwriting losses in both life and non-life insurance and these losses are brought about as a result of higher management expenses incurred by the regulated entities. The industry has increased its total profit from 196 million Ghana cedis in 2019 to 293 million Ghana cedis in 2020 with the life insurance sector contributing about 219million Ghana cedis with represent 75% of the total compared to a contribution of 69% of the total profit made after tax in 2019 whiles the non-life insurance sector contributed about 74million Ghana cedis in the same year(2020) which represents 25% of the total (NIC Report, 2020).

The insurance industry according to the NIC report 2020, faced a new challenge as the covid -19 pandemic did not allow people to meet face-to-face making the premium reduced from 61% of the gross premium in 2019 to 42% in 2020 but insurance companies were able to put in structures like digital channels where customers can still make use of it.

The capital market in Ghana began to develop with the establishment of the Ghana stock exchange in 1990 with associated institutions such as broker-dealers, investment advisors, and fund managers (Ghana Capital Market Masterplan, 2020). The capital market is regulated by the Securities and Exchange Commission (SEC) and they set rules and laws to create a level playing ground for investors, brokerage firms, and listed companies on the Ghana Stock Exchange (GSC). There are about 21 listed companies,10 brokerage firms,5 mutual funds, and 1 unit trust company listed on the Ghana Stock Exchange (Ghana Stock Exchange, 2021).

The capital market in Ghana over the past two decades has made very remarkable strides in its development but is still small compared to the emerging market. It is dominated by government domestic debt with a total value of 115 billion Ghana cedis as of December 2019 which represents 33% of the gross domestic product (Ghana Capital Market Masterplan, 2020). According to the Ghana capital masterplan report 2020, the total market capitalisation over the past five years has remained relatively flat but the total market capitalisation to gross domestic product(GDP) was approximately 32% in 2015 to approximately 16% in 2019 whiles the domestic market capitalisation to GDP has increased marginally from 6.2% in 2015 to 6.5% in 2019.

3 Literature review

3.1 Description of developing countries

The United Nations (UN) defines developing countries as a country that has their living standard as low and has their industrial bases are underdeveloped and a low human development index.

Developing countries are sometimes known as underdeveloped countries and generally have some characteristics in common. For instance, Ahuja, 2016 has this to say about the common characteristics of developing countries are that most developing countries have low living standards, high illiteracy rates, low access to finance and unemployment rate is high, and a lack of good governance (Ahuja, 2016). Developing countries sometimes known as underdeveloped countries are in a hurry to develop their economy by making use of their resources but they are lagging in the race for development and instability (Ahuja, 2016).

3.1.1 Parameters for determining the status of developing country

In determining the status of a developing country, the real per capita income of a developing country is very low compared to a developed country. This indicates that the average person in a developing country cannot save or invest because the income is not sufficient (Todaro & Smith, 2009). Another parameter for the status of a developing country Ahuja,2016 is the rate of unemployment is high. This unemployment comes about due to a lack of proper utilization of natural resources and a lack of planning. Todora, et al, 2009 also gave high population growth as one of the parameters for determining the status of a developing country attributing it to a lack of proper family planning education.

Todora, et al, 2009 mentioned that low productivity can also be a factor in determining the status of a developing country. This comes about when there is the absence of capital and managerial skills for getting innovative technologies, and policies and managing them efficiently.

Ahuja, 2009 also proposed that lack of infrastructure can also be one determining factor for a status of a developing country in that developing countries lack infrastructures like roads, financial institutions, power, transportation, communication, etc and this has made living conditions in developing countries more difficult.

3.1.2 Parameters that classify Ghana as a developing country

Ghana has a market-based economy with relatively few policy barriers to trade and investment in comparison with other countries in the region, and Ghana is endowed with natural resources. Ghana's economy was strengthened by a quarter-century of relatively sound management, a competitive business environment, and sustained reductions in poverty levels, but in recent years has suffered the consequences of loose fiscal policy, high budget and current account deficits, and a depreciating currency (World Economic Outlook, 2018).

Agriculture accounts for about 20% of GDP and employs more than half of the workforce, mainly small landholders. Gold, oil, and cocoa exports, and individual remittances, are major sources of foreign exchange. Expansion of Ghana’s nascent oil industry has boosted economic growth, but the fall in oil prices since 2015 reduced half of Ghana’s oil revenue. Production at Jubilee, Ghana's first commercial offshore oilfield, began in mid-December 2010. Production from two more fields, TEN and Sankofa, started in 2016 and 2017 respectively. The country’s first gas processing plant at Atuabo is also producing natural gas from the Jubilee field, providing power to several of Ghana’s thermal power plants (World Economic Outlook, 2018).

3.2 Configuration and components of the photovoltaic unit

Solar PV over the years has gained a lot of popularity and there has been an increase in installation of the product whiles the unit cost has reduced rapidly. (Whitaker et al, 2008).Clean energy council defines a solar photovoltaic unit as an installation of several components such as the inverter, battery, solar panels, electrical cables, etc which are connected in a way to convert the energy gotten from the sun into electrical energy. Solar PV is normally set up on the roof or other structures and generally, they are flat panels.

In this thesis, the emphasis will be on the stand-alone type of solar photovoltaic.

Photovoltaic panels

Photovoltaic panels also known as photovoltaic modules produce electricity from solar radiation and are semiconductors, but the modules that are available in the market only produce 5-25% of electricity from input solar radiation whiles the rest of the radiation produces heat in the solar photovoltaic panels (Hosenuzzaman et al., 2015).

Photovoltaic panels are made up of a different number of individual cells which are connected to produce the desired voltage of electricity and most photovoltaic panels are made up of crystalline silicon and the heat generation in solar photovoltaic panels raises its operating temperature, which in effect affects its electrical performance, its life span (Manwell, 2004).

The material of the photovoltaic panel, the intensity of solar irradiance, surface temperature, azimuthal angle, and the panel inclination angle are some of the factors that determine the efficiency of the solar panels and monocrystalline and polycrystalline silicon are the two most common photovoltaic cells with 40% average annual growth (Goodrich et al., 2013).

The monocrystalline silicon photovoltaic are the most efficient solar cells and with the highest conversion efficiency between 17%-24% whiles, whereas the polycrystalline silicon photovoltaic cell is made from a large block of silicon and is less efficient as compared to the monocrystalline type (Redarc, 2011). The efficiency and reliability of the photovoltaic depend on the factors such as location, environment, and the type of solar PV panels being used (Boeing et al., 2022)

Photovoltaic Charge Controller

This is the heart of the solar photovoltaic system, and it prevents the photovoltaic panels from overcharging the battery and prevents excessive water loss and the reduction of the life span of the battery (Ndzibah, 2013). The charge controller usually charges the battery with the use of a multi-stage charging approach where the battery is efficiently charged without destroying the battery produced by extreme charge overheating and gassing (Apeh et al., 2021).

There are different types of charge controllers which include shunt controls, single-stage controls, multistage controls, etc. (Zhang & Ruzhu, 2019)

Photovoltaic inverters

The photovoltaic inverters change the direct current (DC) gotten from the solar photovoltaic modules or the batteries into an alternating current (AC) to power the appliances (Ndzibah, 2013). Normally, the required standard for an alternating current in most developing countries is 220v even though the output of individual batteries varies between 3v-48v and beyond.

Solar inverters can be classified as stand-alone, grid-tie, battery backup inverters, and intelligent hybrid inverters and normally uses the maximum power tracking (MPPT) to get the highest possible power from the photovoltaic array (Tiantian & Ruzhu, 2019).

Inverters that are used standalone can operate independently from a utility grip and uses the internal frequency generator to get the current output frequency which is (50/60) Hz" however when it comes to grid-connected its different (Hill & Pearsall, 2001).

Most inverters have frequencies ranging between 90-96% for full load whiles 85-95% for 10% load, particularly for the load that needs surge voltage(Hill & Pearsall, 2001; Ndzibah, 2013). The modified sine wave (MSW) and pure sine wave (PSW) inverters are the two types of inverters that we have whiles the pure sine wave with the total harmonic distortion can be used to operate electronic devices which are sensitive and needed for cleaning, the modified sine wave was designed to satisfy the efficiency of a photovoltaic system at a very low cost compared to pure sine wave inverter (Wilson D, 2011).

Battery

The purpose of the battery for photovoltaic systems is to store the electrical current been generated by the solar cells and these electrical currents act as backup power when there is electricity disruption or when the systems a hybrid system (Hill & Pearsall, 2001; Ndzibah, 2013).

Lead-acid and lithium-ion battery technology are the ones mostly used in the solar home system. Batteries normally lose energy when it is been charged and their efficiency also falls when it gets old or has been misused (Schmid & Behrendt, 2021). A battery life span is usually connected or linked to the depth -of-discharge (Dunlop J & Farhi B, 2001) the battery capacity is measured in amp-hour (Ah) at a given voltage.

Zeman (2014) has some factors needed to be taken into account when buying a battery for use in the photovoltaic system. These are:

- It should have its operating temperature between (eg -15 to 50 degrees Celsius
- Self-discharge rate (% per month)

- Resistance to overcharging
- Cost
- Charge efficiency from 20% discharged

There are two kinds of batteries used in photovoltaic systems and these are lead-acid batteries and alkaline batteries. Alkaline batteries are often used when there are extreme climate conditions according to Dunlop &Farhi (2001). There are two types of alkaline batteries which are mostly used, and these are nickel-cadmium and nickel-metal-hydride, but they are very costly because it's very scared (Meed-ved Dusan & Michal Kolcun, 2011).

3.3 Financing options for solar photovoltaic deliverables

This part will discuss the various options for financing a photovoltaic system in devel-oping countries.

3.3.1 Revolving funds

In this type of financing option, a fund is created, and money is lent into the fund by any willing individuals or organization. The fund can be borrowed by any member of the community to acquire a basic solar photovoltaic system and the interest charged to the borrower covers the cost of running the fund (Derrick, 1998; Ndzibah, 2013). Some countries like Namibia have a similar policy where the ministry of mines and energy is the sole administrator for the fund called the solar revolving fund. This fund is a credit facility to stimulate demand for the utilization of solar energy technologies in rural are-as, especially those living in off-grid areas (IEA, 2015)

3.3.2 Leasing

Leasing is an innovative way of financing photovoltaic systems for self-consumption by an external investor. This involves an agreement of monthly fees being made available by a utility service provider for the use of a photovoltaic system (Derrick, 1998;

Ndzibah, 2013). In this type of financing the amount of electricity generated is irrelevant in the lease arrangement and the leasing can either be a finance lease or an operating lease, wherein the finance lease, an opportunity is given to the customer to buy the solar photovoltaic equipment when the lease term is due whiles in operating lease the solar photovoltaic equipment returns to the lessor at the end term. Kapa solar in Kenya practice this kind of financing method which they use for lighting, charging mobile phones, and powering televisions (Munyak & Mwasaria, 2019).

When Kapa solar lease a solar photovoltaic system to a customer, that customer is required to make an upfront payment between 10-12.5% of the gross price of the leased product, and then the balance remaining is made on a pay-As-You-basis that is a customer is required to make a lease payment of between 0.5 to 2USD daily in 400-600 instalment depending on the product until the remaining lease amount is paid but if the customer fails to pay the system will automatically shut off preventing any further usage of the system until the payment is settled (Munyak & Mwasaria, 2019).

3.3.3 Credit co-operative

This type of financing option is usually a fund where those going to use the solar photovoltaic system create and those monies are borrowed from this same fund to cover the cost of the system (Derrick, 1998; Ndzibah, 2013). Normally since the individual stakeholders who borrow from the funds are familiar with each other there is a high rate of success and low-rate default (Ndzibah, 2013).

3.3.4 Crowdfunding

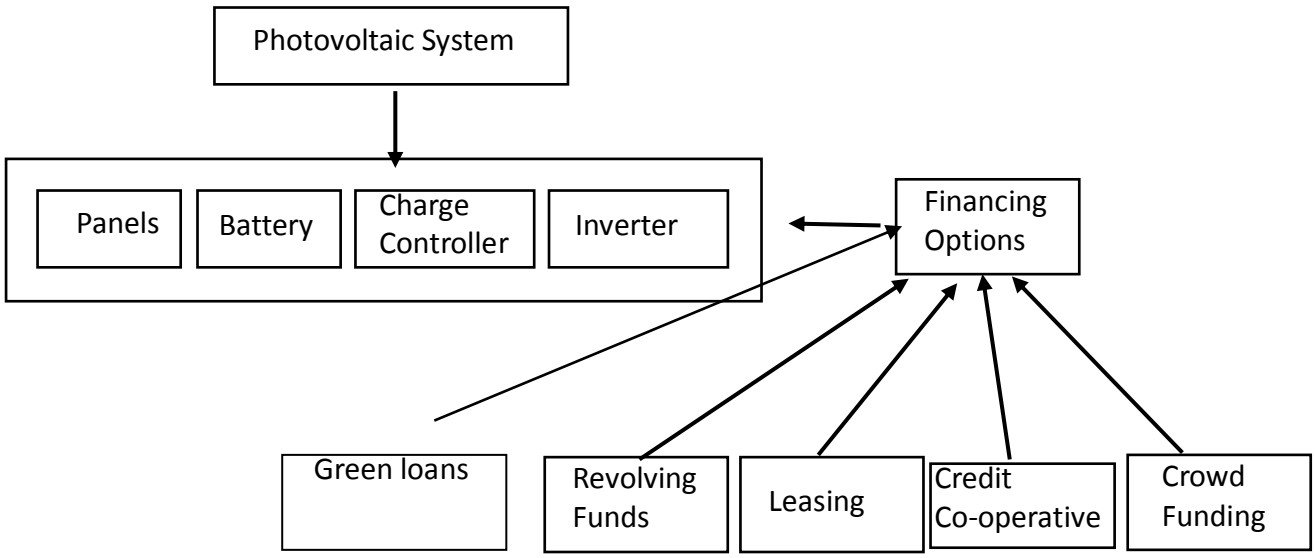
Crowdfunding is an effort made by various individuals or groups of people to generate funds for the project by collecting small contributions from a large group of individuals using the internet and without the intervention of any financial intermediaries (Lu et al., 2018).

Crowdfunding normally involves two-sided market dynamics where the platform for the crowdfunding will bring two different types of groups of customers together where the platform could be either a website or a broker who will be able to connect both the investors and the investees (Osterwalder A & Pigneur Y, 2010). The models of crowd-funding currently in the market are either non-financial or financial funding (Lu et al., 2018). Non-financial crowdfunding depends on funders who do not expect financial returns (Mollick, 2014) whiles financial crowdfunding comprises models like lending - base, equity-based, and royalty-based(Lu et al., 2018).

3.3.5 Green loan

The world bank, 2021 defines green loans as a form of financing that allows a borrower to go ahead to exclusively fund projects that make environmentally friendly. Products such as panels, batteries, and hot water systems can be used purchased through green loans. Green loans generally have interest rates that are lower as compared to personal loans therefore if one cannot pay outright cash for a solar photovoltaic system green loans are the best options (Ndzibah, 2013). Some financial institutions will only finance approved solar products and will only approve loans to persons who have a very good credit score. In Bangladeshi green loans has being increasing and for instancI in 2018 Green loans in Bangladeshi banks had increased from 24.2billion Bangladesh Taka(BDT) to 94.1 billion Bangladesh Taka (DBT) after the central bank in Bangladeshi set a mini-mum target for banks and other financial institutions to allocate 5% of their total loan disbursement and investments to green financing.

3.4 The theoretical framework of the photovoltaic system and the various financing options



The main product of the photovoltaic unit under discussion includes the panels, the battery, the charge controller, and the inverter.

Ghana has abundant solar energy resources but the financial capacity of various individuals who wish to use solar PV but cannot afford it since the initial cost of purchasing solar PV is high. The PV companies try to use instalment basis which is the most dominant in Ghana but there have been a lot of challenges to this method and therefore this thesis is exploring some financing options that will make it possible for renewable energy companies in Ghana to adopt. The various financing options for promoting photovoltaic deliverables such as revolving funds, leasing, credit co-operative, crowdfunding, and green loans are the ones this study would focus attention on. The discussion of the various financing options in the study would help various renewable energy companies to look at the best option to implement

4 Methodology of the study

This chapter will discuss the procedure involved in gathering the data and the analysis of the data. It will also discuss the reliability and validity of the data gathered.

Fischler (2014), defines research as the process whereby data or information is gathered to increase the understanding of a particular topic. Qualitative and quantitative research has a different procedure and therefore both methods can be said to be incompatible due to the difference in emphasis and objectives of the study (Ghauri P & Gronhaug, 2005).

According to(Creswell J W, 1994) qualitative research is inductive and therefore it makes things easier for the researchers to even create or develop hypotheses, concepts, or theories. This helps in answering the “what”, where” and “when” questions.(Creswell J W, 1994) whiles (Bryman Alan, 2012) defines quantitative research as a research strategy that centers on quantifying the collection and analysis of the data. It is from the deductive approach where importance is given to the testing of the theory (Bryman Alan, 2012).

In this research, both qualitative and quantitative data were used. To gather the quantitative data, a questionnaire type was created using Google Forms and the questionnaire was in English for the respondents to answer. A questionnaire is a list of questions given to a group of people(respondents) to answer for themselves (Creswell J W, 1994) suggested that this type of approach to gathering data is very suitable.

In this thesis, the main research question is *what are the financing options available for solar photovoltaic deliverables in developing countries with Ghana as a case study?* The following objectives of the study will help in identifying the various financing options available for solar photovoltaic deliverables in developing countries such as Ghana.

- Identify the types of financing options available in Ghana
- Analyze the merits and demits and demerits of the options available in Ghana
- Identify the best option(s) suitable for the financing of solar PV in Ghana
- Identify barriers in implementing the best option(s) in Ghana

4.1 Data collection

The data used for this study are both primary and secondary. The secondary data was mainly on reports from state institutions like the Bank of Ghana, the Energy Commission of Ghana, the Public utility regulation commission, etc while the other source was the primary source the researcher decided to collect fresh data through surveys (questionnaires).

The researcher identified 46 registered solar energy companies through the energy commission of Ghana website but unfortunately, it was difficult for the researcher to get responses from them, the researcher did not give up so he then found an expert who has been in the industry for long and decided to let her know my challenges. She then advised me to give the questionnaires to her both the customers' own and the companies' own so that she can do the fieldwork for the researcher. The researcher then found out that apart from the 46 registered solar companies in Ghana there are about 50 more companies that are not registered with the energy commission. So a total of 96 questionnaires for the solar companies and 100 questionnaires were sent to the expert to conduct the fieldwork and the researcher only tabulated the responses.
To ascertain the sample size of the solar companies in Ghana a confidence level of 95% was used, a margin of error of 5% a population proportion of 50%, and 96 population sizes were used and a sample size of 77 was gotten and out of the 77 sample size the researcher had 71 respondents.

In the case of the customers both household and business, the researcher focused only on those who are based in the capital city Accra and to ascertain the sample size a con-

fidence level of 95% was used whiles a 5% margin of error, 50% population proportion and population size of 100 were used and a sample size of 80 was attained. The data then were collected and analyzed using Google Forms.

After the questionnaires were answered an interview was conducted with some companies to see how the various financing options in Ghana are implemented. The results of the questionnaire are analyzed in the next chapter

4.2 Data analysis and results

This chapter wills analyze the research data found during the survey. First of all the questionnaire had two different types of questions, one for solar business companies and the other for customers and business companies using solar PV systems, and also an interview from some companies who have the various financing options.

The researcher decided to provide two different questionnaires to two different groups of people(solar companies and individuals and companies using solar PV) and this is because the researcher wants to ascertain, first of all, the solar companies, to know the kind of financing options they have put in place to attract customers and also to ascertain in their option which of the financing options that have been discussed will they recommend and some of the problems they face when implementing those financing options and also to the individuals and business that uses the solar PV to ascertain is they are also happy with terms and conditions been put in place by the solar companies to attract them and also see if they are aware of various financing options available with the solar companies.

The researcher also went further to interview some of the solar companies that use the various financing options being discussed to also see how they also implement their financing options.

In the case of the questionnaire for the solar companies here are the responses.

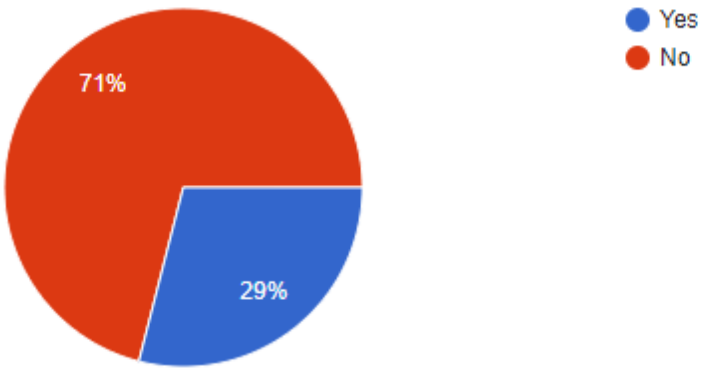


Figure 1. Whether customers pay outright cash for PV systems or not

On the question of whether customers pay outright cash for the PV system, the response is shown in figure 1 above.

From figure 1, 71% said No whiles 29% said yes. So based on the result it can be concluded that most customers in Ghana do not pay outright cash for solar PV. Knowing that majority of the customers do not pay outright cash to the solar companies for purchasing solar PV means that customers have other means of paying for the solar PV system. The figure below will then show what other means the customers use in buying the solar PV system if not outright paying.

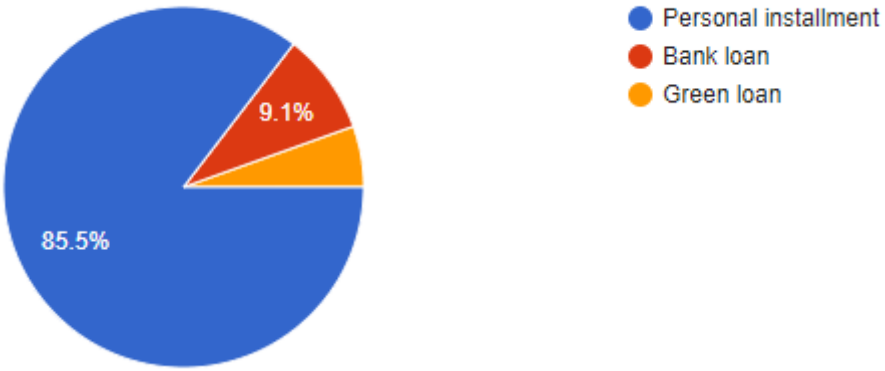


Figure 2. How customers pay for their PV systems from the PV companies

The figure shows that 85.5% of the companies that responded said their customers use personal installment whiles 9.1% said their customers take bank loans to pay whiles 5.5% of the companies said their customers pay through green loans. This shows that a lot of customers pay through personal installment making it difficult for customers since some of the installment agreements would be that you pay 70% of the overall price of the PV system then the rest is spread over a short period. This made the researcher go on to ask the companies if they were familiar with the various financing options discussed in the research and if they are not included in the list they should indicate which other option(s) are they familiar with.

Table 2 below shows how the companies responded in terms of familiarity with the financing option

Table 2. List of financing options companies are familiar with

Number of companies that are familiar with the various financing options	Types of the financing options
69	Personal savings/ installment
56	Green loans
53	leasing
29	Credit co-operative
17	Revolving funds
8	crowdfunding
1	SUNREF
1	Bank loans
1	Pay-As-You-Go
1	Build, own, operate, and transfer(BOOT)

17 companies indicated that they are familiar with revolving funds whiles 53 companies said leasing. In terms of credit co-operative 29 said they are familiar with whiles 8 and 56 said they are familiar with crowdfunding and green loans respectively but 69 companies said they are familiar with personal savings/ installment.

The researcher also found out that 4 additional financing options were added which the company said they were familiar with and in each of them only one from the company said they are familiar with. These additional ones are Bank loans, Pay-As-You-Go, BOOT(Build, Own, Operate, and Transfer), and SUNREF(Sustainable Use of Natural Resources and Energy Finance).

These answers from the company then helped the researcher to ask them which of those financing options is or are they using in promoting solar PV. When the question

of which of the financing options the companies use to promote their solar PV the table below indicates their response.

Table 3. Financing options that companies use in promoting solar PV

Type of financing options in promoting solar PV	Number of companies that use it to promote solar PV
Personal installment/savings	65
Leasing	36
Outright payment	22
Credit co-operative	6
Green loans	5
Revolving funds	2
Bank loans	1
BOOT	1
crowdfunding	0

36 companies said they use leasing in promoting their solar PV system whiles 22 companies said they do not have any financing options in promoting PV but they only demand outright payment for the system when it is installed. In terms of green loans,5 companies said they use that to promote their PV system whiles 2 said they use revolving funds.6 companies use credit co-operative whiles 65 companies indicated that they use either personal savings or installment and demand that customers pay 70% of the entire cost and then the rest is spread within some short period. In terms of BOOT and bank loans, only 1 company indicated that they use them. The researcher also notice that with crowdfunding no company indicated that they use it to promote solar PV. With this, the researcher can know which type of financing options most companies in Ghana use, and it will help the researcher in finding out his research question, that is, *what are the financing options available for promoting solar photovoltaic deliverables in developing countries with Ghana as a case study*. The information on this question

also helped the researcher to go further to ask which component(s) they have the option on.

Below are the responses the researcher got from the various companies when they were asked which component they have the financing option on

Table 4 Which components the financing options is used on.

Components of solar PV	Number of companies using financing options to promote the part
Battery only	12
The whole package(ie battery,panels,inverter and charge controller)	10
Inverter only	10
Panel only	3
Charge controller only	0

A critical look at the table above shows that most companies would prefer to have the financing option on either the battery only or the whole package. This helped the researcher to see which components of solar PV companies prefer to give financing options and probably because those parts are very expensive so PV companies want to take some burden off the customer. Knowing which components the companies prefer to give financing options made the researcher ask if they have problems with the financing options they are using to promote solar PV. The figure below indicates their responses to the question.

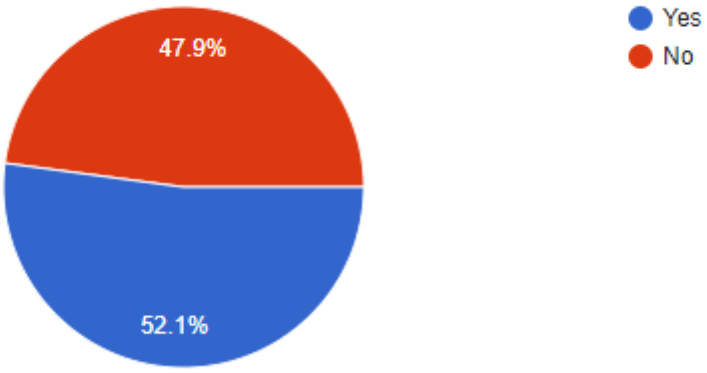


Figure 3. Whether companies face problems in using the financing options

A careful look at the results obtained indicated that most companies experience problems in implementing the various financing options as 52.1% said yes they encounter problems while the other representing 47.9% said no they do not. This made the researcher ask those companies to list the problems they encounter and this will help the research objective of identifying the barriers in implementing the financing options. So when companies were asked to list the problems they face in implementing the various financing options. The table below indicates some of the problems been face by the companies in implementing the financing options.

Table 5. Problems faced by companies when implementing the financing options

Number of companies	Types of problems
Too many defaults/inconsistencies in the payment plan	48
Bad cheques	12
Poor credit system	20
Delayed payment	34
High inventory cost	4
Inconsistencies in the exchange rate	32

A critical look at table 5 indicates that many companies have too many defaults payment when they try to implement the financing options as high as 48 companies shared the same problem. Since most companies indicated these problems it helped the researcher to ask the companies which of the financing options will they recommend. Table 6 below indicates their responses when asked to recommend which financing options .

Table 6. Which Financing option is the best

Number of companies	Financing options
8	Leasing
33	Green loans
4	Credit co-operative
4	Personal installment
33	Outright payment
0	Revolving fund
0	crowdfunding

From table 6 above, none of the companies would even recommend revolving funds or crowdfunding but rather companies will recommend either outright payment or green loan. Most companies said that they are recommending green loans because for an individual or business to be granted a green loan it has to go through due diligence before a person or company can be granted a green loan and with the outright payment the solar companies are always secured.

In the case of the questionnaires for the customers using solar PV in the Greater Accra region below are their responses:

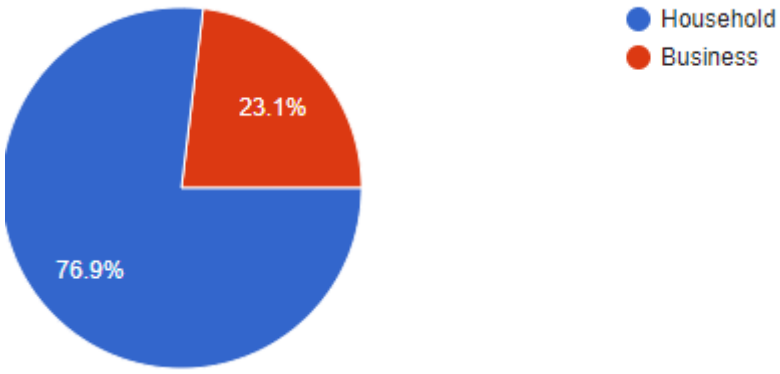


Figure 4. Categories of customers

Figure 4 shows the category of customers who responded to the questions. Out of the 52 respondents, 40 were household that uses solar PV representing 76.9% whiles 12 were business that uses solar PV representing 23.1%. This means that solar companies have a lot of customers who are households than the customer that are businesses and this makes it more difficult if the solar companies do have any financing options for these household customers because they may not be having ready cash to purchase the solar PV system. This information also helped the researcher to further ask the customers how they do they pay for their solar PV package whether through personal installment, bank loan, or outright payment.

The figure below indicates their responses

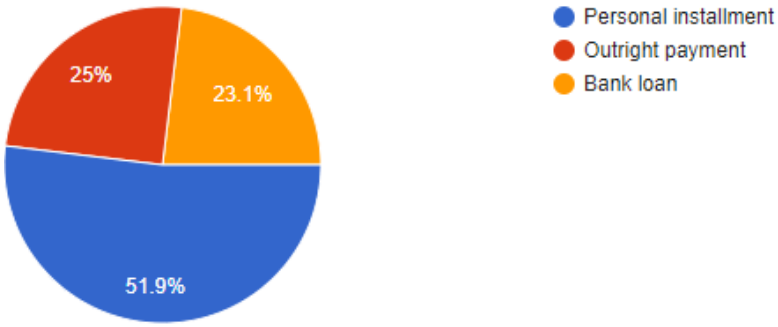


Figure 5 How customers pay for their solar PV system

Out of the 52 respondents, 13 customers said they paid outright representing 25% whiles 12 customers said through bank loans representing 23.1% while the rest which is 27 customers through personal installments represented 51.9%. This means that more customers pay through personal installments. For these personal installments, most solar companies will initially let the customers pay 75% of the total cost of the package, and the rest is spread within a short period but with the outright payment, a lot of customers find it difficult to raise the amount and with the bank loan it's also difficult to get and if you will get it the interest rate is very high.

Customers were then asked if they are paying outright cash for solar PV do they find it difficult in raising the money.

The figure below indicates how they responded

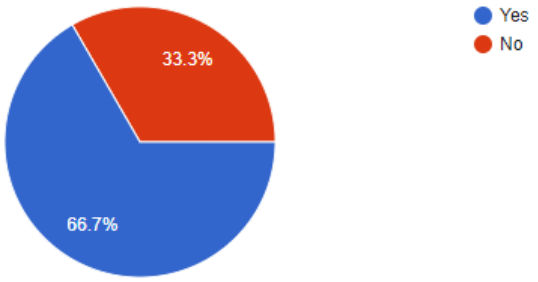


Figure 6. How customers respond if it was difficult to pay outright cash for solar PV

Out of the 15 respondents who said it was difficult they pay outright cash for solar PV, 66.7% said it was difficult in raising the money which represents 10 customers whiles 33.3% said it wasn't difficult for them to raise the money representing 5 customers. This means that paying for solar PV systems outright with cash becomes difficult for customers and therefore there was a need to see if there is any other alternative that customers can use in getting the PV system. The researcher then asked the 27 customers who said they purchase the PV system through personal installment if they were happy with the terms and conditions that the PV companies are given them. The figure below will indicate how the customers responded.

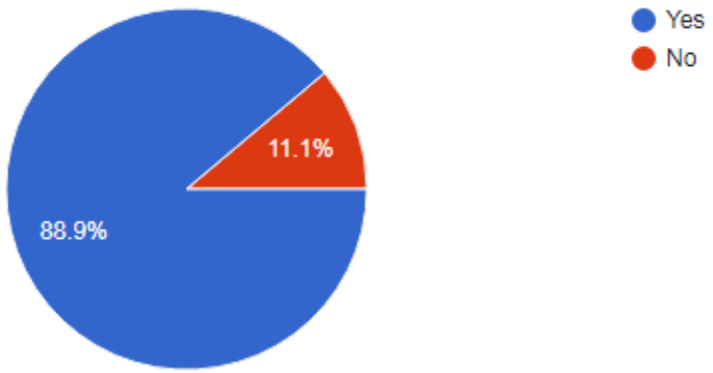


Figure 7. How customers responded whether they are happy with the terms and conditions of the solar companies

Out of the 27 who indicated that they buy the solar PV by installment,24 people were happy with the terms and conditions representing 88.9% whiles 3 people said no they are not happy representing 11.1%. This will help the researcher to see if customers are happy with the terms and conditions PV companies give to them, but with those customers how said they pay for the PV system through a bank loans, the figure below indicates their answers when they were asked if the loan has a higher interest or lower interest or interest-free

Figure 8. Customers respond on whether the bank loan has a high or low-interest rate

All the customers (12) indicated that the bank loan was having high interest and this affect them financially. Knowing that customers get a high-interest rate in securing the

loan helped the researcher to now ask the customers whether the company they bought the PV system from has any financing options for promoting the PV system. The figure below shows their responses.

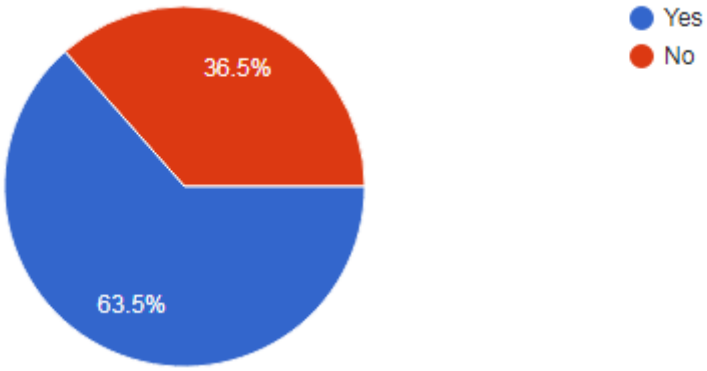


Figure 9. Customers respond on whether the PV company has any financing in promoting solar PV

Out of the 52 respondents, 19 said No representing 36.5% whiles 33 customers said Yes representing 63.5%. Knowing that a lot of companies have various financing options for promoting solar PV would help them in identifying the kind of financing options being given to the customers. The researcher then went further to ask those customers(33) who indicated that the companies that sold the PV system to them had financing options where ask to state those options. The figure below indicates how they responded.

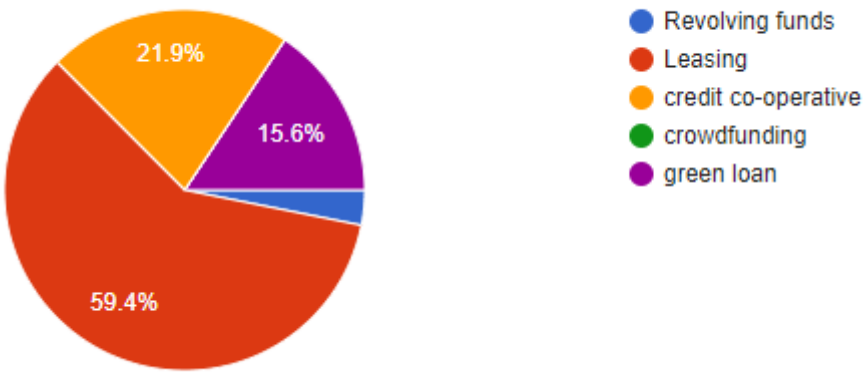


Figure 10. Customers respond on which financing option the company used

Out of the 33 customers who indicated that the company that sold the PV system to them have various financing options in promoting PV system, 32 responded to the question of specifying which financing options the PV companies uses, and out of the 32 respondents leasing has the highest representing 59.4%, followed by credit co-operative, then green loans and revolving fund. No customer was able to state any company using crowdfunding. These results will then help the researcher to see which financing options are customers familiar with.

In the part of the personal interview, the researcher wanted to know how the PV companies in Ghana carry out the various forms of financing options in promoting PV systems to see. Below are what the researcher got from the PV companies.

For *green loans* this is how it's done in Ghana for the Grid-tied system, For an institution or a client of an RE company to be accepted and approved by a financier for whom a loan facility like a green loan is to be given, the following requirements are to be met by both the RE company and the client

RE Company due diligence to be accepted by Financers

1. Company Registration documents

2 Operation License from Energy commission (Installation & Maintenance, Importation, and Solar product)

3. Value Added Tax Certificate from GRA

4. Yearly Audited Financial Statement

5. Company Insurance (on solar products or components and warranty)

6. Root of Company Directors

7. Company's Credibility

8. Employer and Employee's contract

9. Technical Capabilities (qualified Engineers)

10. Office location and ownership documents

Criteria for a customer's project to Qualify for a Green loan from Financers

1. Financial standing (3 years Audited Report)

2. Company Registration documents

3. Board of directors background

4. Signatories to Company's Account

5. Office location and ownership documents

6. Purpose of Grid-Tied System project

Cross-boundary Energy Ghana Ltd, Daystar Financial Group, M-Power New Energy, Ecoligo Ghana, Ewia Green Investment, etc are some few Renewable Energy Financers in Ghana. They Finance projects for bulk customers (Commercial and Industrial) whose power demand or consumption for Grid-Tied solar systems is around 500KVA and above, which is regulated and requires PPA- Power Purchase Agreement from the Energy commission.

Financers package are in two main folds for the renewable energy advisors or company

1. Project Developers

2. Engineering Procurement & Construction. (EPC)

Project Developers are more of marketing agents to get solar Grid-Tied installation deals whilst Engineering Procurement & Construction. (EPC) are those who conduct an energy assessment, design, and installation. However, a RE Company can be either of the above or both, once a deal is closed and the project proforma invoice is presented to the Financers, they compare to their available financial models (lease to own or higher purchase), add some interest then spread over 10years duration. An MoU is signed between the financer and customer before installation is carried out. The Financers pay for the cost of solar system components and services (installation & labor) to the RE Company but the maintenance and operation of the system are different contracts priced separately. The monthly installment could be either fixed or Variable Amounts.

Risks or difficulties involved

1. To sign a contract for Grid-Tied solar system takes 2years because you need to get a Power Purchasing Agreement from the Energy commission which is mandatory

2. It's difficult to get bulk customers whose power demand is around 500KVA.

3. Most of the commercial and industrial owners only want to purchase the power but are not ready to own the solar system hence avoiding operations and maintenance cost

4. Most commercial and industrial owners avoid bookkeeping of the system on their financial records

For green loan off-grid this is what is involved SUNREF Ghana is established and managed by Energy Commission to facilitate access to affordable sustainable energy, acquire higher quality equipment, make cost savings and become more competitive by managing energy more efficiently while respecting the environment.

This innovative program by SUNREF is part of a worldwide initiative developed by Agence Francaise DE Development (AFD) to mobilise public and private banks to finance private sector investments involving green technologies and sustainable energy. In addition, the EU is supporting the Programme by financing the technical assistance component, as well as providing an investment grant to eligible projects. Together with local partner banks like Calbank, Stanbic, Absa and GCB Bank, SUNREF Ghana offers businesses, organisations and households an opportunity to access financing for sustainable energy projects, and assistance in structuring green investments.

The Energy Commission licenses renewable energy service providers and maintains a list of registered RE companies that install and maintain renewable energy products and services to households and businesses including SMEs in Ghana. The Association of Ghana Industry, AGI-Energy Service Centre also maintains a continuously updated list of renewable energy service providers and advisory services for the business community including SMEs in Ghana.

Sourcing the RE system

When the customers contacts the RE companies for off-grid solar solutions, they are directed to SUNREF who then presents a list of registered license RE service providers and banks for a preferred choice.

SUNREF follows up with the preferred RE service provider who can assess client energy needs, recommend suitable RE products and proforma invoice or quote which includes operation & maintenance cost. SUNREF receives RE invoice or quote from installer and present to the preferred bank . The bank also goes ahead to make further checks on both Client and RE installer.

Banks Requirements for an RE client to qualify for off-grid solar solutions support:

1. Proof of ID i.e National Identity Card, valid passport or current valid driving license

2. Latest payslip (in case you receive variable income, e.g., monthly commissions, then we shall need your 12 months' payslips)
3. Three months bank statement, where your salary is being credited
4. Pro Forma Invoice/ Quotation from green equipment supplier

Banks Requirements for RE installer:

Review and verify their certifications, licenses, track record and reputation on the market. The warranty for installed system is between 15 to 25 years which ordinarily covers total failure or leakages in the system but excludes any wear and tear over time. For the revolving fund this is what the researcher got from how some companies does it. The RE installers market SUNREF off-grid solar funding program to mostly organisation such as churches, institutions, banks whose branches can be found in other regions or at least has five.For instance in case of the church, the churches will come together and contribute and their contribution is used to build solar PV For one church. When that is done they continue to make another contribution for the next church till the last one.

4.3 Reliability and validity of the study

According to (Rosenthal R & Rosnow R.L, 1991), Reliability forms a major concern when a psychological test is used to measure some attribute or behavior. Reliability in scientific research means that one can get the same results and conclusion if another researcher uses the same procedures the other researcher used (Yin R & K, 2003). In research, reliability is vital when one wants to measure and test its attributes and this is because data acquired during research are affected by random or systematic errors of measurement (Rosenthal R & Rosnow R.L, 1991).

In this research, questionnaires were sent to an expert in the industry to the various respondents and if another.

(Maylor H & Blackmon K, 2005) defines validity as the precise way of conducting research. It shows the underlying truth of a situation so as not to mislead others to avoid research errors (Ndzibah, 2013).

The secondary data collection was taken from highly respectable scientific journals and publications like science direct and also some respectable websites from Ghana institutions like the Energy Commission, PURC, the World Bank, etc

In this research, questionnaires were sent to solar companies in Ghana. To make the research more reliable the questionnaires were given to an expert who has been in the industry for a long after identifying the various companies through the Ghana Energy Commission website and the expert also conducted interviews with some PV companies. If another researcher follows this same process, similar results ought to be obtained and therefore this research can be said to have relatively high reliability. Another question was given to the various customers (both businesses and individuals) using solar PV to answer. This was to help the researcher know what is the problems with the customers regarding purchasing the solar PV.

(Saunders et al., 2007) defends the validity of the study as the ability of a method to accurately measure what it is supposed to measure. According to (Yin R, 2003) Validity can be seen from both internal and external perspective whiles the internal validity means both the researcher and those responding have a very good understanding of what the research is about whiles the external refers to the level to which a research finding can be generalized and to prove the validity data was retrieved from different sources.

5 Summary and conclusion

Chapter one of this research started by looking at the current energy situation in developing countries, especially Ghana. It was found out that even though the population in Ghana is increasing and there is an energy demand, Ghana has not been able to utilize its potential in exploring the abundance of solar energy resources. It was also found that electricity traffic continues to increase because the fuel used to power the thermal plants is becoming more expensive.

Chapter one continues with the research gap the research questions and the objectives. With the research gap, it was found out that there have been various studies conducted on how PV systems should be financed but there has not been a clear-cut view of the best way to finance the PV system, particularly the standalone type, therefore this research was to explore the various financing options in Ghana and recommend the best option.

The research question for this thesis is what are the various financing options for promoting solar deliverables in developing countries with Ghana as a case study? But to answer this research question the main objectives of the research were:

- Identify the types of financing options available in Ghana
- Analyze the merits and demits of the options available in Ghana
- Identify the best options(s) suitable for the financing of solar PV in Ghana
- Identify the barriers to implementing the best option(s) in Ghana

The chapter ends with definitions of some keywords and limitations

Chapter 2 of this thesis was about the historical and political history of the case country and also the various types of financial institutions in Ghana. Chapter 3 which is the literature review described the parameters for determining the status of a developing country. It also gave a brief description of why Ghana is described as a developing

country. It also talks about the configuration and components of the photovoltaic unit. The various components that make up the solar photovoltaic unit were discussed and the various financing options were also discussed. Finally, in chapter 3 a theoretical framework for photovoltaic systems and the various financing options available for the photovoltaic system were discussed.

Chapter 4 dealt with the methodology of the study which used both primary and secondary data. The primary data was a questionnaire given to solar companies to answer whiles another questionnaire was given to customers using solar PV (individuals and businesses).

5.1 Theoretical methodology and findings

In terms of the solar companies, 71 responded and the research reveals that most of their customers do not pay outright cash to purchase solar PV but rather would pay through personal installment. A critical look at the data reveals that at least 85.5% of the customers would pay through personal installment. Since the most popular financing option among the solar companies is personal installment/personal savings, it was found that most solar companies in Ghana use personal installment rather than the discussed financing options that the researcher discussed. It was revealed that out of the 71 respondents 65 said they use personal installment options.

The research also revealed that the most popular financing option for promoting solar PV in Ghana that most solar companies are familiar with is personal installment which was not part of the options that the researcher discussed in the research and in terms of the financing options that were discussed in the research, it was revealed that the most popular among them is green loan.

It was also noticed that companies face a lot of problems implementing the financing options that they are familiar with ie personal installment, therefore, most companies

would prefer either a green loan or outright payment since with the personal installment most customer default payment.

For the solar PV customers it was revealed that most of the customers are individuals (households) as out of 52 respondents 40 were individuals (households) whiles 12 were businesses.

In terms of how customers pay for their solar PV systems, the research shows that a lot of customers pay through personal installments whiles the rest would pay through either bank loans or outright payment. The outcome of the research revealed that customers find it difficult to pay outright cash for solar PV but also it was found that most customers that pay through personal installment are happy with the terms and conditions that the solar companies have arranged with them.

On the customer's side, it was found that more individuals have solar photovoltaic deliverables than companies. Also, it was found out that a lot of customers pay for their solar PV package through personal installment but with those customers paying outright the researcher found out that raising money was difficult for the customers.

A critical look at the data from the research indicates that customers that go for bank loans suffer high-interest rates from the banks and from the research data it can be said that customers are aware that if they cannot purchase the solar PV with outright cash there are various financing options available for them through the solar companies.

With regards to the research question about *what are the financing options available for solar deliverables in developing countries with Ghana as a case study* the outcome of the research shows that the financing options available for promoting solar deliverables in Ghana are green loans, leasing, revolving funds, credit co-operative, personal installment,Build,Own ,Operate and Transfer(BOOT), and bank loan.

5.2 Conclusion and further research

The goal of the research was to identify the various financing options for promoting solar PV in Ghana since energy is becoming expensive and Ghana has abundant solar energy resources but the initial cost is very expensive. The research findings were conclusive that, yes most solar companies in Ghana have various financing options to promote solar PVs (green loans, leasing, revolving funds, credit-cooperative, personal installment, BOOT, and bank loans), but the most popular one is personal installment basis which most customers have been defaulting payment, therefore solar companies would rather prefer outright payment or green loan. Because of this, it is the view of the researcher that since most PV companies are willing to give the PV system on an installment basis but customers default on the payment and this brings a big problem to the PV companies, then the PV companies should rather negotiate with financial institutions in Ghana to provide soft loans for their customers so that customers will be paying the installment to the financial institution.

Most companies purchase the solar package in foreign currency (dollars or euros) and the inconsistencies in the exchange rate have become one of the major problems the PV companies face, therefore if Ghana wants to promote it is the view of the researcher that prizes of the PV system should be in foreign currency to avoid any future problems about the price of the PV system.

Even though the research was to see if there are financing options available for promoting PV systems in Ghana, the researcher found out that if the popular financing option in Ghana which is the personal installment would work effectively in Ghana then in the researcher`s option the net- metering system for off-grid should be encouraged. This is because in Ghana the net–metering system is not working and if that was working, customers will be willing to get the PV system at a high price since they know that when they generate the excess energy they don’t need they can add it to the national grid to get money and that money can be used to offset some of the installment

payment. Given this, the researcher suggests that research should be conducted to see how best the net-metering system can be implemented in Ghana even though on paper it has been documented that, only renewable energy generators with a capacity of up to 200kw will be able to benefit from the net metering support according to IRENA (International renewable energy agency)

References

Ahuja, H. L. (2016). *Advanced Economic Theory*. S Chand and Company Limited.

Alagidede, P., Baah-Boateng, W., & Nketiah-Amponsah, E. (2013). *The Ghanian economy: an overview The Ghanaian economy: an overview*.

Apeh, O. O., Meyer, E. L., & Overen, O. K. (2021). Modeling and experimental analysis of battery charge controllers for comparing three off-grid photovoltaic power plants. *Heliyon*, *7*(11), e08331. https://doi.org/10.1016/J.HELIYON.2021.E08331

Bank of Ghana. (2021). *Bank of Ghana*. Bank of Ghana Website Retrived from Https://Www.Bog.Gov.Gh/.

Bank of Ghana Annual Report. (2021). Retrived from Https://Www.Bog.Gov.Gh/Wp-Content/Uploads/2022/06/AnnRep-2021.Pdf.

Bank of Ghana Monetary Policy Report. (2021). Retrived from Https://Www.Bog.Gov.Gh/Mpc_press_release/Banking-Sector-Developments-Report-September-2021/?Jsf=jet-Engine&pagenum=5.

Bryman Alan. (2012). *Social Research methods*. oxford university Press.

Clean Energy Council. (2008). *Electricity from the sun; Solar Pv systems explained*. 4.

Creswell J W. (1994). *Research design:Qualitative and quantitative approaches*. Thousand Oak,CA :Sage Publicatios.

Derrick, A. (1998). Financing mechanisms for renewable energy. *Renewable Energy*, *15*(1–4), 211–214. https://doi.org/10.1016/S0960-1481(98)00159-1

DunloP J, & Farhi B. (2001). *a review of lessons learned. Florida solar energy center.Proceedingof forum 2001.Solar Energy:The power to choose*. 21–25.

Economic Freedom Score . (2022). Retrived from Https://Www.Heritage.Org/Index/Country/Ghana.

Ghana capital market masterplan. (2020). Retrived from Https://Sec.Gov.Gh/Wp-Content/Uploads/Press-Release/SEC_CMMP.Pdf.

Ghana Energy Commission. (2020). *Energy outlook for Ghana 2020*. Retrieved from Http://Www.Energycom.Gov.Gh/Planning/Data-Center/Energy-Outlook-for-Ghana?Download=105:Energy-Outlook-for-Ghana-2020-Final-Draft.

Ghana Stock Exchange. (2021). *Ghana Stock Exchange* . Ghana Stock Exchange Website Retrieved from Https://Gse.Com.Gh/Listed-Companies/.

Ghana web. (2014). *Ghana web*.

Ghauri P, & Gronhaug, K. (2005). *Research methods in business studies: A pratical guide.Essex: Prentice hall Europe*.

Goodrich, A., Hacke, P., Wang, Q., Sopori, B., Margolis, R., James, T. L., & Woodhouse, M. (2013). A wafer-based monocrystalline silicon photovoltaics road map: Utilizing known technology improvement opportunities for further reductions in manufacturing costs. *Solar Energy Materials and Solar Cells*, *114*, 110–135. https://doi.org/10.1016/J.SOLMAT.2013.01.030

Hill, & Pearsall. (2001). *Photovoltaic modules systems and applications .Northumbria photovoltaic applications centre,* .

Hosenuzzaman, M., Rahim, N. A., Selvaraj, J., Hasanuzzaman, M., Malek, A. B. M. A., & Nahar, A. (2015). Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation. *Renewable and Sustainable Energy Reviews*, *41*, 284–297. https://doi.org/10.1016/J.RSER.2014.08.046

Lu, Y., Chang, R., & Lim, S. (2018). Crowdfunding for solar photovoltaics development: A review and forecast. *Renewable and Sustainable Energy Reviews*, *93*, 439–450. https://doi.org/10.1016/J.RSER.2018.05.049

Manwell, J. F. (2004). Hybrid Energy Systems. *Encyclopedia of Energy*, 215–229. https://doi.org/10.1016/B0-12-176480-X/00360-0

Maylor H, & Blackmon K. (2005). *Researching bussiness and management*. Palgrave Macmillan.

Meedved Dusan, & Michal Kolcun. (2011). *Importance of Batteries for photovoltaic system*.

Mollick, E. (2014). The dynamics of crowdfunding: An exploratory study. *Journal of Business Venturing*, *29*(1), 1–16. https://doi.org/10.1016/J.JBUSVENT.2013.06.005

Munyak, P., & Mwasaria, M. (2019). *Leasing of photovoltaic system in kenya Retrived from https://www.roedl.com/insights/leasing-solar-photovoltaic-systems-pv-kenya*.

National Insurance Commission. (2019). *National insurance commission Report retreived from https://nicgh.org/wp-content/uploads/2020/10/2019-NIC-Annual-Report.pdf*.

Ndzibah, E. (2013). *Marketing mechanisms for photovoltaic technology in developing countries*. University of Vaasa.

NIC Report. (2020). Retrived from Https://Nicgh.Org/Wp-Content/Uploads/2022/09/2020-NIC-Annual-Report.Pdf.

Osterwalder A, & Pigneur Y. (2010). *Business model generation: A handbook for visionaries,game changers, and challengers*. John Wiley and Sons.

O''Sullivan, A., & Sheffrin, S. (2003). *Economic: Principles in action*. Pearson Prentice.

Pirlogea Corina, & Cicea Claudia. (2012). *Econometric perspective of the energy consumption and economic growth relation in European Union*. 5716–5726.

PURC. (2019). *Public Utilities regulatory commission Report*. Retrieved from Https://Www.Purc.Com.Gh/Attachment/515595-20210602120604.Pdf. .

Redarc. (2011). *Monocrystalline solar panels DOC389, Version 2. Redarc Electronics Pty Ltd*. Available Https://Delibra.Bg.Polsl.Pl/Content/32281/BCPS_36005_-_Monocrystalline-Sili_0000.Pdf.

Rosenthal R, & Rosnow R.L. (1991). *Essentials of Behavioral Research:Methods and Data Analysis* (Second Edition). McGraw-Hill Publishing Company.

Saunders, M., Lewis, P., & Thornhill, A. (2007). *Research methods for Business students* (4th ed.). Edinburgh. Pearson Education Ltd.

Schmid, F., & Behrendt, F. (2021). Optimal sizing of Solar Home Systems: Charge controller technology and its influence on system design. *Sustainable Energy Technologies and Assessments*, *45*, 101198. https://doi.org/10.1016/J.SETA.2021.101198

SWERA. (2017). *SWERA Report* . Retrieved from Https://Www.Dlr.de/Tt/Portaldata/41/Resources/Dokumente/Institut/System/Publications/SWERA_10km_solar_finalreport_by_DLR.Pdf.

Tiantian, Z., & Ruzhu, wanj. (2019). *High efficiency plants and building intergrated renewable energy systems*. 441–595.

Todaro, M. P., & Smith, S. C. (2009). *Economic Development*. Pearson Education.

Wilson D. (2011). *Sine Wave vs.Modified Sine wave: which is better?.The inside story, Xantrex Technology USA*. Available Files/Powerelectronics.Com/Files/Archive/Powerelectronics.Com/Mag/608PET21.p.

World Bank. (2018). *World Bank Report*. Retrieved from Https://Openknowledge.Worldbank.Org/Bitstream/Handle/10986/30326/9781464812965.Pdf?Sequence=3&isAllowed=y.

World Bank. (2021). *world bank* . Retrived from Https://Www.Worldbank.Org/En/Country/Ghana.

World Economic Outlook. (2018). *World Economic Outlook Report reterived from https://www.imf.org/-/media/Files/Publications/WEO/2018/October/English/main-report/Text.ashx*.

Yin R. (2003). *Case study research:Design and methods*. Sage publication Inc, 5,11.

Yin R, & K. (2003). *Case study research;Desgin and methods*.

Appendices

Appendix 1: PV companies Questionnaire

Dear sir/Madam

Please I would be glad if you can spend about 10min or less of your time answering the sample questions below. This questionnaire forms part of my master's thesis at the University of Vaasa, Finland.

This study aims to explore in detail the various financing options in promoting Photovoltaic (PV) systems in Ghana. The results of these questionnaires will help me identify the various types of financing options available in Ghana for the Pv system. Furthermore, the results will help address the merit and demerit, the best option(s), and the barriers in promoting the solar Pv system in Ghana.

The outcome of this study will be useful for policymakers, investors, and renewable energy companies. Your contribution to this questionnaire is warmly welcomed and will be treated with the strictest confidentiality.

Yours faithfully,

Oduro William Apotogse

School of Technology and innovations

University of Vaasa, Finland

Email: a111650@student.uwasa.fi

Supervised by: Dr. Emmanuel Ndzibah

Email: emmanuel.ndzibah@uwasa.fi

1. Do your customers always pay outright cash for the PV system
   ( ) yes ( ) No
2. If not, how is the payment done
   ( ) Personal instalment ( ) bank loan ( ) Green loan
3. Which of the following financing options in promoting solar PV are you familiar with? Tick as many as you are you know or specify if not included in the list

( ) Revolving funds ( ) leasing ( ) credit co-operative ( ) crowdfunding ( ) green loans

Please specify……

4. Which of them is/are the company using now?
   Please specify…….

5. Does the company have financing options in promoting some Pv components?
   ( ) Yes ( ) No

6. If yes which component(s)
   ( ) Battery ( ) panels ( ) charge controller ( ) Inverter

7. Is there any problem with the option(s) you are using?

   ( ) Yes ( ) No

   If yes, please what is the problem(s)

8 In your opinion which of the financing options will you recommend.

   Please specify…….

Appendix 2: PV customer`s Questionnaire

Dear sir/Madam

Please I would be glad if you can spend about 10min or less of your time answering the sample questions below. This questionnaire forms part of my master's thesis at the University of Vaasa, Finland.

This study aims to explore in detail the various financing options in promoting Photovoltaic (PV) systems in Ghana. The results of these questionnaires will help me identify the various types of financing options available in Ghana for the Pv system. Furthermore, the results will help address the merit and demerit, the best option(s), and the barriers in promoting the solar Pv system in Ghana.

The outcome of this study will be useful for policymakers, investors, and renewable energy companies. Your contribution to this questionnaire is warmly welcomed and will be treated with the strictest confidentiality.

Yours faithfully,

Oduro William Apotogse

School of Technology and innovations

University of Vaasa, Finland

Email: a111650@student.uwasa.fi

Supervised by: Dr. Emmanuel Ndzibah

Email: emmanuel.ndzibah@uwasa.fi

1. Please indicate which category you belong to
   ( ) Household
   ( ) Business

2 . How did you pay for the solar PV package

( ) personal instalment

( ) outright payment

( ) Bank loan

3 . If it was outright payment, did you find it difficult in raising the money

( ) Yes

( ) No

4. If it was a personal instalment, were you happy with the terms and conditions that were given by the company.

( ) Yes

( ) No

5. If it was a bank loan how was the interest.

( ) Low interest

( ) high interest

( ) interest free

6 . Did the company selling the PV product have financing option in promoting the product?

( ) Yes

( ) No

7. If yes ,which of the following do they have ,and please specify if none of the above

( ) Revolving funds

( ) Leasing

( ) credit co-operative

( ) crowdfunding

( ) green loan