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REVIEW ON SOLAR UTILIZATION IN GHANA

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ABSTRACT

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The objective of the study was to review the barriers of the implementation of solar energy and solar home systems (SHS) in Ghana. This research focused on using financial mechanism such as subsidy as a means of promoting SHS and use the payback period to explore into off-grid solar home system (SHS) as an alternative source of energy.
The research method included both literature review and case analysis of a householder in Ghana. The study investigated the role of financing mechanism such as subsidy in making SHS more affordable. In this particular work a load requirements of all electrical appliances from a household leaving in Dawenya a suburb of Tema in Greater Accra Region, with the help of solar radiation database on PVGIS was used to determine the payback period. A sensitivity analysis was further carried out and the result revealed that a modest subsidy of 10% would be result in a payback period of about 12 years.

Keywords Renewable energy, Ghana, barriers, solar financing, solar home system.

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1 INTRODUCTION

The word energy was extracted from the Greek word 'energeia' and it certainly appeared for the first time in the word of Aristotle, in the 4th century. The idea of energy originated from living force and is defined as the product of the mass of an object and its velocity squared. In addition, every living things or organism depends on an external source of energy and therefore the radiation of the sun, so as every fast growing economy of a country depends on energy./1/ The Sun is very reliable and is also non-polluting, inexhaustible and always renewed by nature. With the increase in energy prices, pollutions over the environment, depletion of resources and environment degradation and limited resources is on the rise and it needs critical attention.

The utilization of fossil fuels causes greenhouse effect and is a main contributor to global warming experienced on the earth today, the burning of fossil fuels also emits of carbon-dioxide (CO_2) and sulphur dioxide that creates acid rain. , . /2/ Natural gas causes unpleasant odor and pose some problems with its transportation, and crude oil also causes environmental hazards, such as it spillage, and it also contains toxic chemicals which render air pollutants when combusted.

Due to the negative effect on the environment and other related problems associated with fossil fuel it has forced many countries like Germany, USA, Spain etc. to change into environmental friendly alternatives that are renewable to sustain the rising energy demand, /3/ therefore solar energy is the way forward with the least negative effect on the environment. Photovoltaic as name implies is a means of converting sunlight directly into electricity./4/. Producing electricity by means of solar panels causes no threat to the environment and it has no rotating parts and causes no material depletion. Photovoltaic can be used in diverse ways, e.g. to operate water pumps, household's electrical gadgets, equipment and appliances and also communication equipment. It can also be used in urban and rural electrifications and also use to power industries and also for commercial purposes. Despite the potential of PV in proving access to electricity, there is less usage in Ghana.

1.1 Research Objectives

The aim of thesis was to review the solar energy utilization in Ghana and the barriers associated with the solar energy usage in Ghana.

Ghana's energy supply depends largely on hydropower and dual fired power plant. Yet deprived communities and villages do not have access to the national grid mean while there is a huge range of solar energy potential that can supply electricity to the remote areas by off-grid connection. , In this regards this thesis is to reveal the current solar usage as already stated, also deep into the barriers that is hindering the usage of solar energy in Ghana.

1.2 Research Questions

This research question will critically look into the current usage and the barriers preventing solar energy usage in Ghana. The research questions utilized were:

1. What is the current level of PV solar energy usage in Ghana?

2. What are the barriers in PV solar energy usage in Ghana?

3. What is the role of financing in the promotion of solar home systems in Ghana?

1.3 Methodology of the Research

The study on solar energy utilization in Ghana is based on desktop research and literature review, and a case study of a householder in Ghana.

1.4 Limitations of the Research

This research was limited to desk top research and literature review due to lack of financial resources to conduct a large scale survey of households in Ghana.

1.5 Outline of the Study

Chapter 2 describes the literature review stating the theoretical aspect of the thesis by gathering information from existing articles, with a brief description on the review of renewable energy sources. It also provides a review on solar energy, its

usage and barriers generally and finally a literature review on a current level of solar energy utilization in Ghana and also the barriers preventing its usage in Ghana.

Chapter 3 describes barriers of implementing renewable energy, and highlights on framework for promoting RE. The role of financing in promotion of solar home system is presented in Chapter 4 with an analysis on the payback period of a solar home system. Conclusions and recommendations are presented in Chapter 5.

2 REVIEW OF RENEWABLE ENERGY SOURCES

This chapter describes the review of renewable energy sources. As of now the demand for energy is at its peak due to the expansion of economy and also an increase in population. As a result of this it will further increase in the near future if nothing is done to curb this problem by seeking an alternative.

Renewable energy is made of resources that are replenished naturally, like wind, solar, geothermal, biomass, and hydropower. It is also known as clean energy or green power because it does not pollute air or water. The types of renewable energy sources that can be harnessed in different ways are: solar energy, wind energy, biomass energy, hydropower and geothermal energy.

2.1 Solar Energy

Solar energy is the conversion of sunlight directly into electricity which can be used to power industries, even for cooling for our homes and business, light and heating of hot water, which is actually operated by connecting the PV modules to a battery and the battery to the load so during the day light hours the module charges the battery which can be used in the evening .The battery supplies power to the load whenever needed. An electrical device known as charge controller is incorporated to the system to ensure that the battery is properly charged and also assists in prolonging the life by protecting the battery from over charging./4/ The advantages of solar energy presented in Table 1.

Table 1.Advantatages of solar energy./3/

It does not contribute to the emission of greenhouse gas(particularly CO2,NOx or toxic gases like (SO2, particulates)
It also reduces the use of lengthy transmission lines from the electricity grids
It enhances quality of water resources
Increase of regional/national energy supply
Diversification and security of energy supply
Faster rate of rural electrification in developing countries.
Changing of degraded land

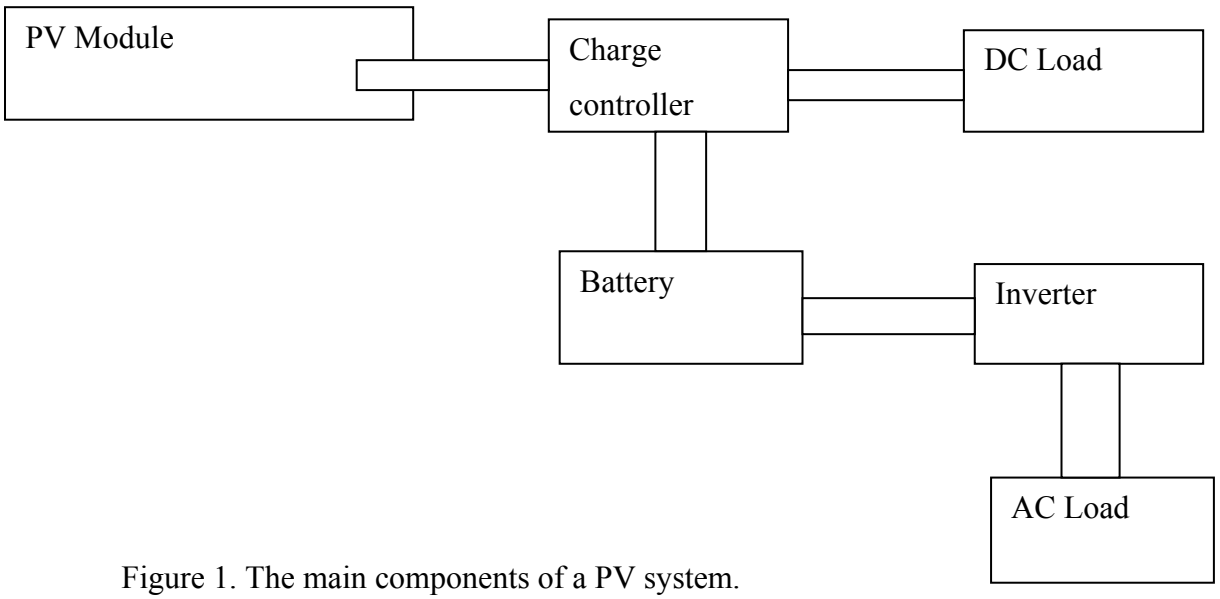

Figure 1. The main components of a PV system.

The inverter converts the DC electricity produced by the solar modules into alternative current (AC) since most of the electrical appliances and equipment run on

AC electricity and is also synchronized with utility power whenever the electrical grid is distributing electricity.

A battery-stores energy when there is an access coming in and distributes it back out when there is a demand. Meanwhile the PV panels always ensure that the batteries are maintained and charged every day. The utility meter is automatically provided to at night and during the day when the demand exceeds your solar electric production. A charge controller prevents the battery from overcharging and thus prolongs the service life of the battery of the PV system. The sample of solar power cell is presented in Figure 2.

Figure 2.Sample of solar cell. /21/

Due to the effects about the climate change, and a rise in energy consumption rate it is the concern of the international agreement to mitigate the greenhouse gas emissions and also to think about the alternative ways substitute the conventional energy with solar energy. , Countries all around the world are establishing national goals to generate electricity from renewable sources and trying to implement diverse solar energy policies in various countries.

This thesis focuses on Solar Home System (SHS). SHS (see Figure .3 below) is a stand-alone photovoltaic cell that supplies power for lighting and households appliances. It is generally used in a remote areas or rural areas where there is no

access to the grid ., The solar home system is designed in a way that it can meet the household's electrical demand and withstand basic electrical needs. SHS has variations in which it operates like 12V direct current which provides adequate low power to electrical gadgets such as lights, televisions, radio and CD player for a maximum of five hours a day. The solar home systems in a wide perspective enhances improvement in the standard of living by mitigating indoor air pollution and increases health standard as they replace kerosene lamps, and therefore it also helps to study in our homes with the solar light. The SHS enhances the possibility for working at night and also giving us accessibility to information and communication through radio, mobile phones charging, television and more. The solar home system does not contribute to greenhouse emissions and it helps to reduce the usage of kerosene, gas, diesel generators that produce electricity and dry cell batteries which are mainly from conventional energy resources. A stand-alone photovoltaic system can be used for a variety of purposes such as supplying electricity for health centers to work at night and also operate they refrigerator for vaccines and medicines to better serve the community. A sample of the solar home system is presented in Figure 3.

Figure 3.Solar panel on the roof.

2.2 Wind Energy

Wind has been with us since the inception of the world and it has been harnessed for hundreds of years. Wind energy uses the wind turbines to convert the mechanical energy through the movement of the wind into electrical energy by turning a turbine which is coupled to generator. , Wind energy is one of the cleanest energy sources; it does not contribute to global warming and is always abundant. It can be used for pumping water, powering industries, lights for our homes, grinding grains or communications. , Wind turbine formally called wind mills use the wind's energy to produce electricity .Wind turbine are mounted on a tower so as to capture the energy from the wind, with the tower height of at least-30meters (100 feet) from the ground and it can be even more than that, with the intention to take advantage of faster and less turbulence wind. Wind turbines come with two or three blades which are fixed onto a shaft to form a rotor. The turbine catches the wind as it blows and thus pulls the blade towards it which causes the rotor to turn which try to lift it, the lifting force being greater than that of the winds force against the front side of the blade which results in dragging. Therefore the lift and drag in collaboration force the rotor to turn. The rotor is a coupled to shaft which turbine inside a generator to produce electricity. This is presented in Figure 4.

Figure 4. Wind turbines./5/

2.3 Bioenergy

Bio-energy is an energy derived from biomass which includes woods, energy crops, agriculture residues, food waste, or industrial waste and by-products to produce electricity, fuel, and gas. It can be used in producing heat through the process of bio heat: , combined use of bio heat and power is used to produce electricity for industrial, commercial and cooling purposes through the use biomass. Bio -energy is increasingly attractive choice due to high fossil fuel price, and also due to national energy independence, concerns about the use of conventional energy and global climate change. Bio-energy is one of renewable energies or clean energies because its production does not contribute to environmental pollution or emission of CO_2. The biomass is presented in Figure 5.

Figure 5 Bio-mass in a form trees and plants./5/

2.4 Hydropower

Hydropower is renewable energy where the flow of water turns a turbine which is coupled to a generator to produce electricity. , It is a reliable energy source and is environmentally friendly: energy from hydropower has been exploited for centuries. It is a cheap way to generate electricity, its source is free and clean fuel that is renewed by snow or rain. Its power can be harnessed in three methods:

1. By storage is water stored in reservoir is released to a dam to turn a turbine to produce electricity.

2. A pumped storage Is a procedure where in the case of low electricity price the water is pumped into a higher reservoir for storage, and pumped back to lower reservoir to turn a turbine to produce power when the electricity price is on the hike.

3. A run-of –river: This is done as a natural flow of a river to drive a turbine to produce electricity.

2.5 Geothermal Energy

Geothermal is simply heat from the earth converted into steam to produce electricity, it can be made in large scale to power industries and also the smaller scale to supply electricity to residential or rural areas, and it also applicable for home heating. , It is very reliable, cost effective and environmentally friendly and it does not need fuel to operate./5/

2.6 Benefits of Renewable Energy

Because of the global concern to reduce air pollution, and in order to improve public health, renewable energy, such as solar energy and wind energy as an alternative has been welcomed around the world. Renewable energy has numerous benefits which are described below.

Environmental benefits

Renewable energy come from sources that do not need the use of fossil fuel so they do not give out carbon dioxide, a byproduct of burning coal and gas. , Therefore, the more we stop burning fossil fuels the more we are reducing the environmental pollution and harmful chemicals.

Economic benefits

Renewable energy is economic for the reason that renewable energy does not need transmission lines for serving users with power. Nevertheless, transmission lines a are very expensive part of the power system. Therefore renewable energy is al-

ways connected to the distribution network and therefore nearer to the load which results in saving cost and reducing power loss.

2.7 Power Quality and Reliability

Renewable energy allows the operators to have absolute control on the system voltage because it is always made closer to the load centers. Renewable energy comes from the sun's heat, the amount of heat that is being emitted by the sun, is is high enough to replace fossil fuels such as coal, gas and oil. Solar energy can be harnessed through the use of photovoltaic solar panels at a farm or on a roof top, therefore because they are renewable they protect and extend the life of the limited sources.

Human health

Flue gases emitted by combustion of fossil fuels pollute the atmospheres which result in diseases, such as asthma and even cancer. , With the use of renewable we can do always with these harmful substances in the air.

Cost and Supply

Renewable sources are virtually free after the initial costs, after wind turbines has been erected a and solar panels are installed. /6/

2.8 Problems Related to the Use of Conventional Energy Sources

The section describes the emission of CO_2.

Figure 6. Power plant using conventional energy source.

The problems associated with the use of fossil fuels are::

a). Environmental Hazard: This mainly refers to pollution due to the use of fossil fuels, emission of carbon dioxide, rise in temperature of the earth, which causes melting of polar ice caps.

b) Rising prices: As because fossil fuels are exhaustible source they will one day run out. , Therefore, OPEC always monitors the volume of oil consumed and position itself to its production in order to maintain the barrel price which always results in price fluctuations, according to the U.S. Department of Energy.

c) Acid Rain: Burning of fossil fuels always emit sulphur dioxide gas which causes acidic rain. This destroys lands, crops, marbles and water bodies. There is a threat to aquatic life due to the transportation crude oil which at times causes spillage over the sea.

d) Threat to human health: Burning of fossil fuels destroys causes the ozone layer to thin as a result of the emission of greenhouse gases. The hole in the ozone layer allows the harmful UV rays come directly to the earth surface. This causes diseases, e.g. skin cancer.

The threat mentioned above have forced many countries to formulate policies to search for an alternative source which will not deplete the ozone layer, emit carbon dioxide, sulphur dioxide and are environmentally friendly. , Below is the example of the emissions from conventional energy (Figure 6)./7/

Figure 7. Emission of CO_2.

3 REVIEW ON SOLAR ENERGY USAGE.

Solar energy an alternative source which is clean and also in abundance and can be harnessed in so many ways. This chapter will look at its usage globally. Solar energy, being the cleanest source of energy that does not contribute to environmental pollution or global warming, is the radiant heat and light energy emitted by the sun that is converted into electricity. , The earth receives 175 petawatt (PW) of solar radiation and even at the upper part of atmosphere at least 30% is reflected back to the air and most of it is absorbed by the clouds. The total amount of sunlight getting to the earth surface is more abundant and so vast in one year, it will be as double as much as will ever be acquired from all the earth's non-renewable resources, such as coal, oil, natural gas and mined uranium put together. 2010 BP Statistical Energy Survey shows that the world cumulative installed capacity of solar energy was 22928.9MW as at 2009, which made up an increase of 46.9% compared to 2008./8/

As from 2007 United State of America has increased it solar energy capacity by 17% making a total capacity of 8775megawatts (MW). , The USA has also installed another 342 photovoltaic panels (PV) of 139 thermal megawatts (MW) of solar heating, 762 MWTh of pool heating, and 21MWTh of solar space heating and cooling. /10/

At the end of 2007 Germany's installed solar PV capacity was 3.8GW, making Germany the world leader in solar installation. Spain has also been another country with abundant solar radiation, and in 2008 its solar energy installed capacity was 3500MW, compared to France has solar energy capacity of 100 MW and pledged to multiply it by 400 WM in 12 years' time./9/

China also been a country with a lot of sun shine and has installed solar energy capacity of 5GW targets to 70GW by 2015. Pakistan also has installed capacity of 23000MW with daily solar insulation of 5-7kwh/m^2/day. The potential solar of Europe is presented in Figure 8./11/

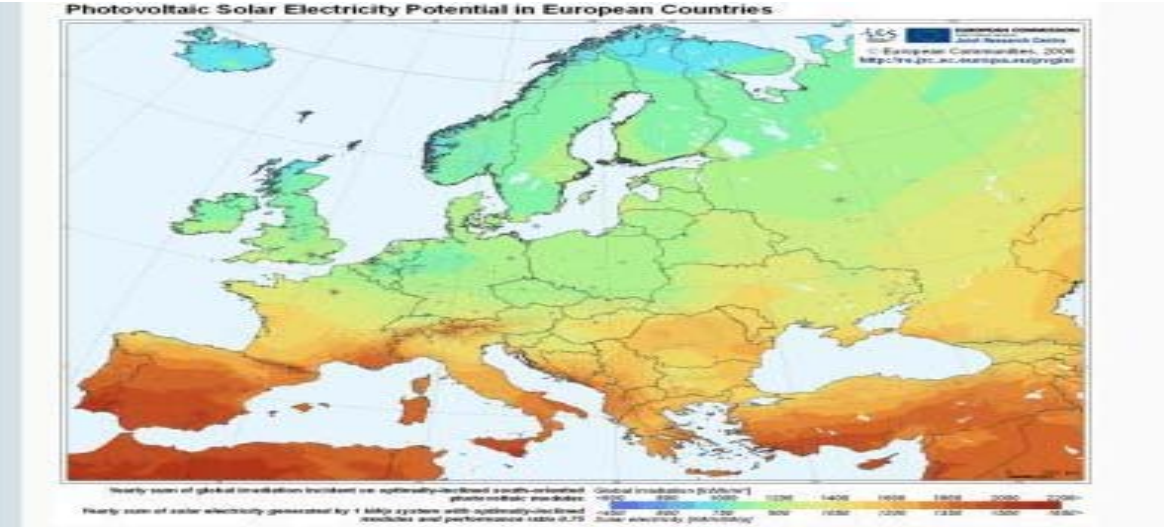

Figure 8. PV solar electrical potential in European countries.

The map shows the photovoltaic solar electricity potential in European countries. It is clearly see that the solar energy potential is high enough. A research shows that European countries are doing extremely well with the solar energy thus reducing the emission of CO^2.

The Installed Solar (PV) Capacities in various countries in Europe Countries from 2000-2010 are presented below in Figure 8.

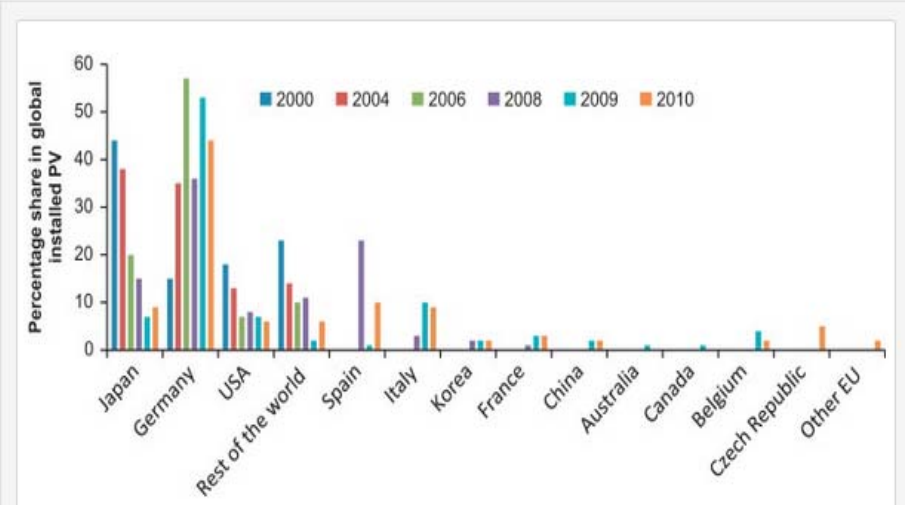

Figure 9. Installed solar capacities in Europe.

The above chart shows different EU and Asian countries and their cumulative installed capacity of photovoltaic from 2000-2010. In 2000 Japan shows a significant improvement and was the leader in the world in the of photovoltaic installation before United States and Germany. It has then jumped to second place with 35% .Germany is still in the lead in 2010 followed by Spain, Italy, Japan, the USA. It is clear that some of the European countries have embraced the solar energy technology as a way of combating the emission of greenhouse gases occurrences in the near future. Below is the yearly sum of solar irradiation in Africa (see Figure 9)./12/

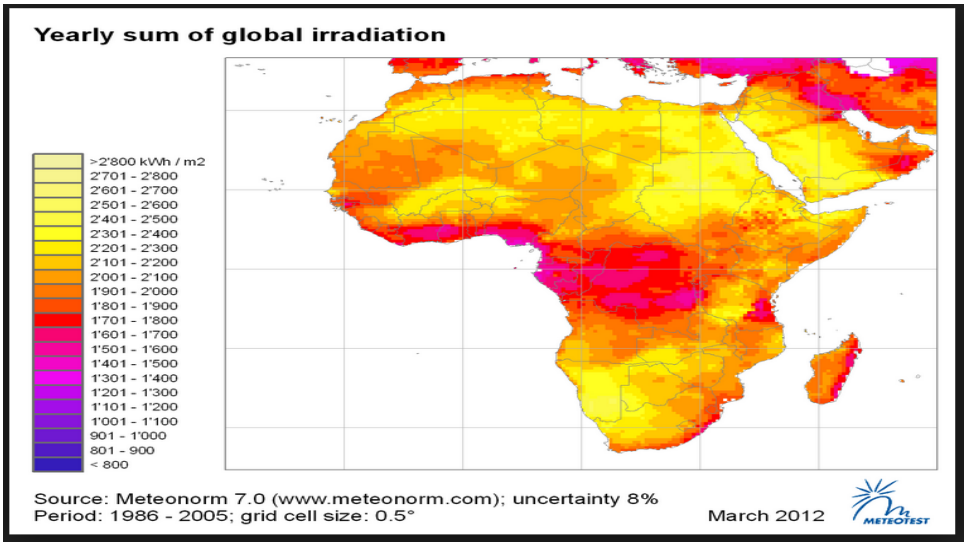

Figure 10. Solar radiation in Africa.

African has enormous solar radiation which can be harnessed in many ways to solve their energy crisis and stop relying on fossil fuels. Based on the country level, Africa's share of globally installed capacity of PV is less than 1%, meanwhile the world solar map clearly reveals that the African continent receives the highest amounts of solar radiation between 300 and 350 W/m2 annually. This even shows that Africa continent is suitable for solar energy projects. In spite of all this high solar potential, the continent makes the least in the usage of solar energy, thus referred to as the Dark Continent. Kenya and South Africa were in the lead with barely 150,000 installed PV systems each, followed by Zimbabwe. The graph below shows the usage of PV systems in South Africa, Kenya and Zimbabwe and the rest of the Africa countries (see Figure 10).

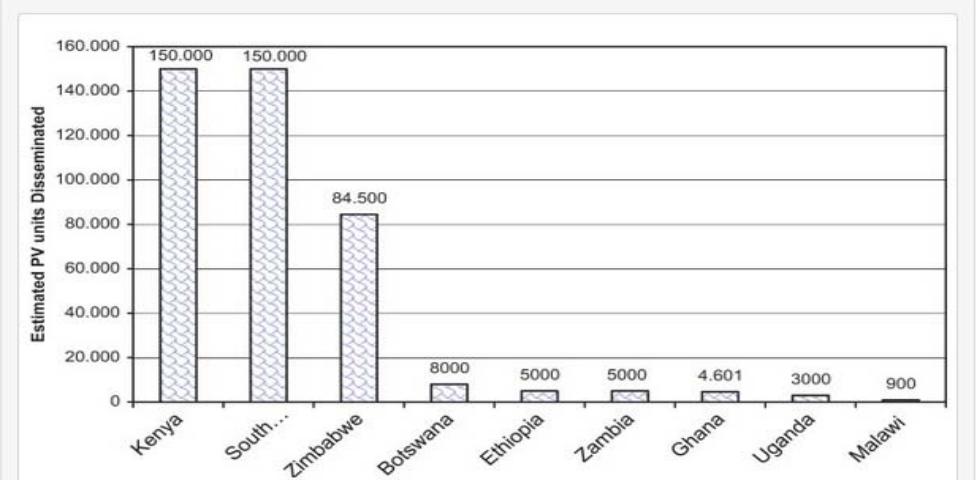

Figure 11. Distribution of PV system in Africa.

The table above illustrates that Kenya and Zimbabwe are doing better economically on the PV development than Ghana. Ghana's PV industry moved into PV development during the 1990s, while Kenya and Zimbabwe took off quickly in the 1960s and 1970s. Through the mid- 1980s in Ghana the growth of solar energy development was unstable./13/

3.1 Barriers of Implementing Renewable Energy.

The main barriers preventing renewable energy from expanding are high initial cost, technical, economic and market institutional and also the size of the cost of RE technologies. The growth of renewable energy may also come as a result of Governmental policies and support, at least those that decline investment costs. , Governmental policies and risks are the main obstacles hunting the future growth in world renewable energy use. Getting electricity from RE energy largely depends on the commercialization of a large-scale solar energy technologies that will bring down the investment costs and risks., Generating large quantity of energy from RE for future use also largely depends on Governmental climate change policies, and research, development and demonstration by private and public sectors interventions. Costs and pricing are other barriers for renewable energy. Many people seem to think that renewable energy costs more than other energy sources and this is seen in cost-driven decisions and policies that reject renewable energy. In the other circumstances it is the fact that initial capital cost of a re-

newable energy technology are always higher on a cost-per-unit base as $/kw, therefore allowing public subsidies may eventually reduce the costs of competing fuels.

Numerous policies try to compensate for cost related barriers by giving out additional subsidies to assists renewable energy to expand, such as tax credits or incentives, and also implementing policies for special pricing and power purchasing rules and lastly reducing transaction costs. Subsidies for competing fuels where bigger institutions, such as World Bank and the International Energy Agency have given fossil fuels more attention by putting global annual subsidies on conventional energy sources(fossil fuels), as much as $1 trillion in buying of fossil fuels annually. So giving large public subsidies on fossil fuels reduces final energy price thus putting renewable energy under disadvantage if it is not also treated equally. High initial capital costs is also underpinning the growth of renewable energy which makes it unable to give high installed capacity to the initial dollar invested compared to the conventional energy sources. It is therefore clear that renewable energy in its entirety needs more finance for the same capacity of conventional energy sources. /14/

3.2 Barriers in Solar Energy Usage.

Solar energy technology is gaining less popularity due to some certain barriers, therefore this section will highlight on the overview of the barriers contributing to its usage in developing countries.

3.2.1 Barriers in Solar Energy Usage in Nigeria

This section will highlight the barriers affecting solar energy usage in Nigeria. Nigeria is one of the biggest countries located in West Africa, with annual daily average solar radiation estimated to vary from about 12.6MJ/m2/day (3.2kwh/m2/day- 25.2MI/m2/day (7.0kwh/m2/day) . , A series of barriers underpinning the expansion of solar energy include:

- Variability and intermittency of radiation: ; the minimum duration of sunshine in the southern part and northern part of the country is estimated to

vary from 4h to 9hrs/day , therefore the availability of sunshine fluctuate and also not consistent.

- Grid unreliability: this poses a serious threat to solar energy because as of now the transmission grid in Nigeria operates at a maximum of 132 and 330KV.
- Lack of awareness and information: the information about the development and benefit of PV are inadequate.
- High initial investment cost: this is one of the barriers that underpin the development of PV in a developing country like Nigeria, and there are no incentives on the import of PV devices for the local manufacturers in the country.
- Operation and maintenance costs: as a result of inadequate technical skilled personnel the operation and maintenance cost is appreciably high.
- Government policy and incentives: policies implemented by the government on energy favored only conventional energy sources by supporting them with subsidies leading to a low patronage in PV system.
- Cost reduction measures: development of solar energy in Nigeria is possible but the finance of the project is not available. Financial institutions can be made to grant loan to retailers at a low rates so as to enable them to develop the solar energy technology.
- Competition with land uses: land issues are very critical for PV projects as land owners or the communities are preventing the release of their lands for fear of total destruction of the heritage.
- Consistent awareness creation: solar energy can be implemented successfully in a large scale with the support of public./23/

3.2.2 Barriers in Solar Energy Usage in China

China has solar energy in abundance in the north western area which occupies approximately 2/3 of the territory. This solar energy can be amounted to 1,7 x 10-6 million tons of coal equivalent, but the barriers which prevent solar energy form expanding includes:

- ✓ Lack of market base: proper stable market must be established for the PV which cannot be disturbed be improper actions.
- ✓ The unbalanced development of regional economy: as a result of excessive emphasis on the economy benefit, a series of regional development has become urgent.
- ✓ The scale barrier of renewable industry: due to a low feed-in tariff the power generation from PV has declined, which adversely affects the manufacturers to develop solar energy.
- ✓ The lagged construction of power grid: the lagged construction of the power grid has made it extremely difficult to interregional trade and transmission which prevents the implementation of PV./24/

3.2.3 Barriers for Solar Energy Usage in Hong Kong

Hong Kong has enormous solar energy potential which is estimated to be 5944GWh per year and can be equated as 16% of the annual electricity consumption, . However the average solar radiation available on the horizontal surface is estimated to 1.28MWh/m2. The barriers underpinning the development of solar PV are presented below;

- o Long payback period: this is considered as the second biggest barrier to development to use of solar system, and also the high cost of the raw material, for example the pure silicon, and the fabrication product contributed to the long duration of the payback period.
- o High initial and repair costs: this has to do with PV panels, mounting hardware, circuit breakers and inverters and cables.
- o Inadequate installation space and service infrastructure: In Hong Kong 50% of the electricity is consumed by air condition during the summer time, however the installation and positioning of PV panel have to face the south and north hemisphere at an angle equivalent to the latitude of the location, therefore due to anomalies a solar system cannot be installed in the building in Hong Kong.

- Lack of stakeholder/community participation in energy choices: incentives given to private sector and utility companies are very small; this leads to low development of the PV system.
- Legal and regulation constrains: clearer legislation is needed concerning the various impacts, for example, possible direct/ indirect ,short-/ long term reversible effects of using solar energy./25/

In summary, the barriers for solar energy usage can be described as follows:

- High initial cost is the main barrier to PV
- Difficult to finance, the system needs easy accessibility and approach to financing.
- Lack of training: more qualified experts will be needed for the installation of the PV system.
- Inadequate communication, the prospective consumer must be given the adequate information about the advantage in using PV system.
- Lack of credibility: the PV system must be given a full credible endorsement so that consumers can have confidence in it.
- Failure to account for full value: value for PV must be emphasized, for example, value for homes with PV, status and environmental value.
- Insufficient governmental support for the purchase of solar power.
- Relatively there is more abundance of conventional energy sources.
- Assurance of credit is being given to the export of conventional energy.
- Consumers are unaware of PV system
- Inability to get on board energy providers in PV deployment.
- Subsidies supporting conventional energy interests, meanwhile solar PV does not have equal assistance.
- Lack of marketing: manufacturers lack of the necessary market about the solar PV and also lack the nonfinancial benefit of PV. /26/

3.3 Framework for Promoting Renewable Energy

This section will highlight on framework conditions for promoting renewable energy. It will therefore be suggested that policy and legal framework,

energy sector competition and bias, market performance, and financing are the critical factors required to promote renewable energy technologies such as the solar home system. The framework is presented below in Table 2.

Table 2.Framework condition on renewable energy./31/

Framework-conditions	Policy and Legal Framework	➢ Independent power producers may be unable to sell into common power grids. ➢ Transmission access and pricing rules may penalize smaller and /or intermittent renewable energy sources, Utilities and set burdensome interconnection requirements. ➢ Permitting requirements and siting restrictions may be excessive. ➢ Requirements for liability insurance may be excessive.
	Energy Sector Competition and Bias	➢ Low cost of energy from conventional sources. ➢ Price distortions from existing subsidies and unequal tax burdens between renewables and other energy sources.
	Market Performance	➢ Failure of the market to value the public benefits of renewables. ➢ Lack of environmental externality cost in the current price of fossil fuels ➢ Market barriers such as inadequate information
	Financing	➢ RE unfamiliar to financiers due to lack of information ➢ RE often considered not attractive, because high risk without adequate risk compensation in form of risk coverage instruments or higher returns. ➢ Financing hardly available for projects and customers due to lack of funds and/or lack of instruments.

Policy and legal Framework: It will be important that putting in place implementation of policy and legal frame will allow renewable energy to grow and compete with the conventional energy sources, in fact without these policies, it will be difficult for investors like Independence Power Producers to go into renewable energy and thereby sell their power to the grid or a third party under the auspices of power purchase agreement. This situation creates a lot discomfort for project developers to plan and finance projects. Transmission access is one of

the key factors of renewable energy producers as the power produce must be transmitted or distributed to the end consumer which more or less depends on the location and which utilities disallows transmission access to renewable energy producers or charged high prices for this.

Energy sector competition and bias: Low cost of conventional sources are made possible because more attention is paid to fossil fuels than renewable energy sources because of large public subsidies such as direct budgetary transfer, tax incentives, research and development spending, liability insurance, leases, land right way and waste disposal are the assurances given to fossil fuels to reduce projecting finances. , As renewable energy does not have access to these incentives, it has a competitive disadvantage.

Market performance: Lack of information on renewable energy makes difficult for project developers to source finance from the banks because it is unknown whether the utilities will allow long term power purchase agreements to buy the power.

Financing: Due to high risks associated with renewable projects without any available compensation it scares financiers to invest into because renewable energy is considered to be unattractive to consumers it depends on the country, for example, in the United States loans are made available for all sectors, and it has a low interest rate is also given for renewable energy to promote it.

In this study, the focus is on SHS, and thus it is explored how financing can be used to promote the use of solar home system in Ghana. The next chapter describes the energy usage in Ghana and the expected role of solar SHS./31/

4 ENERGY USAGE IN GHANA

Ghana is a West African country bordering on the Gulf of Guinea, bounded by Cote d'Ivoire to the west, Burkina Faso to the north, Togo to the east with Atlantic Ocean to the south. It is a country with a population of 25, 241, 99, birth rate of 26,999/1000, infant mortality rate of 47, 26/1000, with the growth rate of 1.787%, Land area of 88,881 square mile (see Figure.11).

The map of Ghana is presented in Figure 11. Below.

Figure 1 Geographical map of Ghana.

Below is the installed electricity generation capacity since 2004. Even though Akosombo hydroelectric power plant has the highest installed capacity of 1038 MW with a electricity generation of 4404 GWh followed by Kpong Hydroelectric power plant with 876GWh with overall total of 1748MW and 6038GWh yet the country is in energy crisis. , Solar energy is yet to be developed to produce maximum power to support the energy system. Therefore, below is the installed electricity generation capacity is presented in Table 3. /15/

Table 3. Installed electrical generation capacity since 2004./17/

	Installed capacity in MW	Electricity generation in GWh
Akosombo Hydroelectric Power Plant	1038	4404
Kpong Hydroelectric Power Plant	160	876
TAPCO THERMAL Power Plan (Takoradi Power Company)	330	636
TICO Thermal Power Plant TICO=Takoradi Power company	220	222
TOTAL	1748	6038

The potential of the renewable energy resources in Ghana is presented in Table 4 below. Much needs to be done to tap these useful resources.

Table 4. Energy resources in Ghana./16/

Resources	Value	Units	Rank	Period	Sources
Wind Potential	1,124	Area(km2) Class 3-7 Wind at 50m	59	1990	NREL
Solar Potential	706,055,035	MWh/year	73	2008	NREL
Coal Reserves	Unavailable	Million Short Tons	N/A	2008	EIA
Natural Gas Reserves	22,650,000,000	Cubic Meters (cu m)	76	2010	CIA World Factbook
Oil Reserves	15,000,000	Barrels(bbl)	87	2010	CIA World Factbook

Source: Energy commission (year 2010) /17/

Ghana has been experiencing a series of power crises for more than two decades because of the over reliance on hydroelectric power which mainly depends on rain fall pattern of the country. Studies shown by Energy Commission of Ghana 2006, show, that grid electricity demand will go up about 6,900GWh between 2000 and 2015 and is also likely to increase again to 24,000GWh by the end of 2020. For the country to ensure stable power supply by the year 2020, an additional source must be tapped to generate electricity to assist the existing. Ghana government has targeted 10% energy generation from renewable energy which will mainly come from solar energy. /16/

4.1 Solar Potential in Ghana

This section presents the potential of solar energy in Ghana. The solar radiation map is presented in Figure 12. The red part is the three northern regions, namely Northern region, Upper east and Upper west which the most solar energy potential

is followed by Greater Accra region with a lot of solar possibilities but not as much as the three northern regions. The deep yellow and the light yellow represent the region with least solar energy possibilities (See Figure 12).

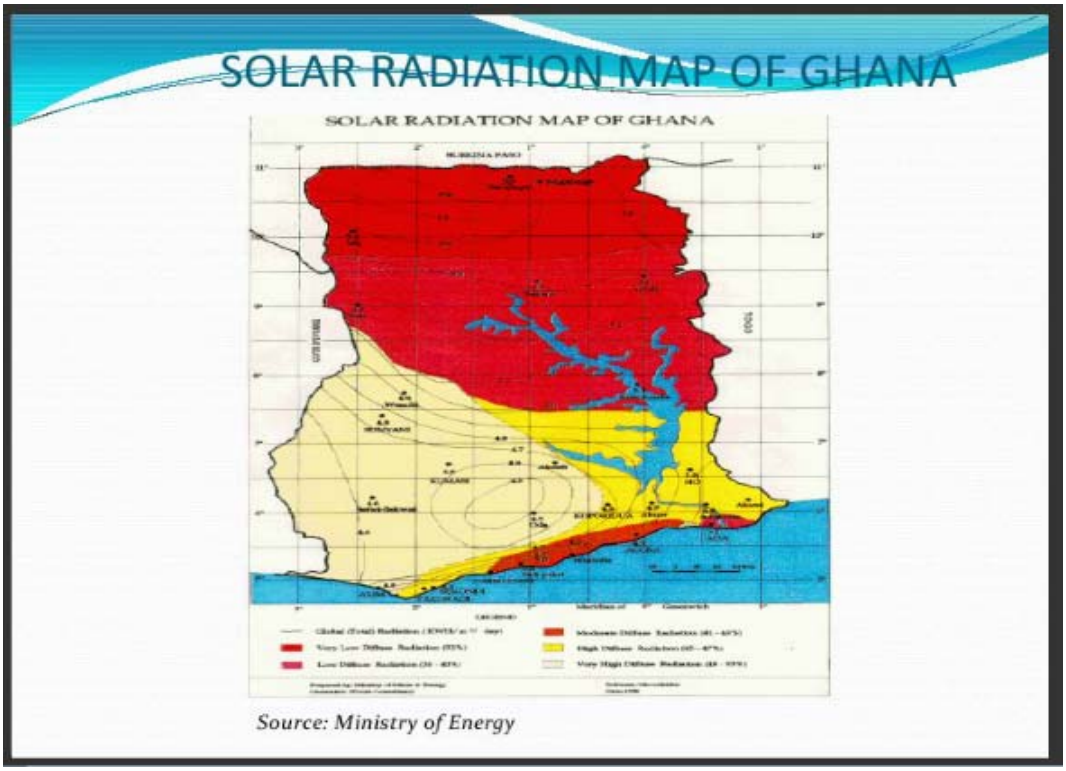

Figure 13. Solar map of Ghana.

Solar energy resource is potentially high in Ghana with 4.5kwh/m2-5.6kwh/m^2 of daily solar irradiation range with sunshine duration of between 1,800 and 3,000 hours per annum. Below is the solar energy intensity in Ghana is presented in the table below (See table 5)./17/

Table 5. Solar intensity in Ghana. /17/

SOLAR INTENSITIES OF AGRO-CLIMATIC ZONES IN GHANA

Agro-climatic Zone	Region	Intensity (kWh/m²-day)[1]
Savannah (close to the Sahel)	Upper East, Upper West , Northern, upper parts of Brong-Ahafo & Volta Regions	4.0 – 6.5 kWh/m²-day
Middle Forest Zone	Ashanti, Eastern, Western and parts of Central, Brong-Ahafo , Volta Regions	3.1 – 5.8 kWh/m²-day
Savannah (Coastal belt)	Greater Accra, coastal parts of Central & Volta Regions	4.0 – 6.0 kWh/m²-day

4.2 Current Level of Solar Energy Usage in Ghana.

Ghana is endowed with many resources, both conventional and renewable energy sources, yet the country has been facing a power crisis for over a decade. The above information clearly illustrates that Ghana has enormous solar potential. This chapter will describe the current level of solar energy usage in Ghana.

It is estimated that over 4,000 off-grid photovoltaic systems (PV) have been installed country wide. In 2000 the installed capacity was 1MW. In table below the photovoltaic installations carried out are shown.

Table 6.Solar installations and their capacities./17/

Solar Capacity	Location
4kwp	Kwame Nkrumah University of Science and Technology.
4kwp	Energy Commission
50kwp	Ministry of Energy
155MW	Nzemaa District(Aiwaiso)
2MW	Navrongo

4.3 Barriers in Promoting Solar Energy in Ghana

The literature highlighted various barriers preventing the implementation and use of solar energy in various developing countries. Similarly, solar energy developers and installers are facing the same problem in Ghana. The main problems that prevent the use of solar energy in Ghana are presented below:

- High cost components, leading to high system cost.
- Lack of financing for consumers.
- Lack of financing for service providers and installers.
- Perception of high cost of solar PV by the public.
- Unresponsiveness of potential market groups: for example the real estate industry.
- Awareness creation; another barrier that has underpinned the development of PV in Ghana. At least consumer demands will increase once the awareness is built up and PV market will also grow: The low level of education on PV is due to over dependence on the national grid.
- Government policy direction on energy: There are numerous barriers preventing expansion of solar energy usage: The government of Ghana's ex-

penditure on the national grid over the years has been more or less considerably compared to PV. grid extension to rural areas is one of the prime drivers of low wide spread of PV as compare to another developing countries./29/

4.4 Financing of Solar Home System

There is a very high potential of solar energy in Ghana but little is done to tap this energy into use. As of now there is no financial aid for PV development. In developed countries such as United States, Germany etc., there are subsidies for PV but the government of Ghana has not provided any subsidies for this enormous system. Also the interest rates are very high as a result the local financial institutions feeling reluctant to offer loans to project developer. The great public also thinks that the PV technology is immature. International financial bodies like World Solar Programme and Global Environmental Facility are yet to be established in Ghana. It will be in the best interest that financing of this system is carried out in two ways: by financing the end consumer as a way of enabling the system to be more affordable and secondly financing the retailers and also the service providers to boost their activities. The cash price for a fundamental DC SHS is between 500 USD to 1200 USD, which actually depends on the size, and also the quality of the components. Taking into account the taxes and duties of that country, the cost of installation for a SHS domestic system is from 7 USD. In certain countries, (for example in Indonesia, 1994) to 26 USD. (For example in Kenya, 1993). The cost of PV module has decreased from 20 USD.wp-1as in 1980 to the current price of 5 USD.wp and it is expected to reduce more as a result of economies of scale.

Of course PV technology is known to be maintenance free, but the operational cost of the SHS over the life time is made to be added to the purchase price. , Typically, a monthly payment of 5 USD to 10 USD is made to by the consumer. In comparing the SHS and conventional grid extension in economy wise, the price of transmission line to the rural community is approximately 10000 USD.kw, and also the traditional energy sources, for example kerosene and candles causes a lot smoke which is not good for human health. It is therefore clear the SHS stands

economical for the purpose of rural areas, meanwhile the cost of grid extension electricity on a small scale is amounted between 2 USD.kw to 10 USD.kw, whilst PV electricity to the rural community cost between 1 USD .kw to 3 USD.kw.

4.5 Financing SHS

The target group for SHS in the study is a per-urban and rural household. Studies have shown that these households have different incomes that can affect the purchase of solar home systems. For example, Photovoltaic Power Systems Program stated the factors influencing the willingness to pay for SHS as:

Operational problems: Although operational problems exist in large numbers, consumers have realized in a short period that the SHS system is not maintenance free. Balance of system (BOS), for example battery and fluorescent lamps (with electronic ballast), and also BUC, are the main problems of the SHS system. The earlier failure of the battery can be addressed by efficient information on its life span which also has to do with for example, the type, the size, the brand and also the quality of it usage pattern and required maintenance. , For the BCU and the fluorescent lamps, it has not come to the notice of the consumer but its poor performance has become recently known is due to absent of technical standard which has not checked systematically. As a matter of fact the major challenge to the SHS for the future is the battery, BCU and the fluorescent is due to its quality that is not assured, which deter the public from accepting the SHS. Of course high quality comes with durability and high price, so the consumers have to choose whether to buy low quality with a cheap product or choosing to go with the one that is expensive and durable./30/

Awareness of system´s capacity: Another issue that to do with the consumer's knowledge is the awareness the limited capacity of the SHS he/ she owns. The limitation of electricity supply of the installed SHS may be regarded as second class power, but the issue of limiting the consumer SHS is actually easier said than done: , electrical appliances are made in a precision to the consumer expectation and choices and not the other way round. The expected generating capacity of the SHS needs from the consumer a more or less static consumption behavior , not

adding extra loads to the system when required. The expansion of the SHS needs additional panels which come with additional investment and operational costs.

Electricity consumption in a newly electrified community for the first month after grid connection is between $0.5kwh^{-1}$.0kwh per day per household, consumption cannot be satisfied with this type of standard SHS installed.

Political disincentives: Political disincentive has been one of the major draw-backs into a low credit recovery, and is due to how the credit services are ruined and managed. So in the case of SHS the government has been the major stake-holder and to a large extent shows how the credit are established, so the intervention of the government in this sector illustrates the direct target of the programmes on regional terms. In normal circumstances a huge chunk of funds stem from government sources and come with special conditions, and at every time with direct subsidies to utilities, or intermediaries or at time directly subsidizing the SHS consumers. As the consumer became aware that the government has to bear the total costs of installation of the SHS, . So in short special incentives has to be implemented so as to enable the public to patronize the use of solar energy which intend can enhance the increase of the SHS. /30/

Subsidies: Subsidies has always been the issue for SHS. The difference is made between good, bad, smart, and bad subsidies. Subsidies are very much important for banks, dealers and private sector manufacturers who are trying to enter into PV business. Other benefits that subsidies have are as follows: employment effects, education of banks and political decision makers, training of technician of dealers and utilities. ./30/

4.6 Case: Role of Financing in Promoting of Solar Home System

The financial analysis of Solar Home System is carried out based on the information gathered from a household in Dawenya a suburb of Tema in Greater Accra region. The cost of this system is taken from the investment point of view and also yearly stand point and how the provision of subsidy can influence the purchase

and payback period of SHS. Below is the financial indicator which is used to look into the potential of the solar home system.

b) The Payback Period
c) Net Present value

Payback period- is the time at which the initial cash flow of an investment is made to recover from the cash inflows generated by the investment excluding debt payment, therefore the formula to calculate the payback period is presented below. : In this thesis the focus will be specifically on the payback,

Payback Period = Initial investment

Cash Inflow per period

Net present value is simply the sum of the present values of the individual cash flows. The mathematical expression is presented below:

NPV = Total present value of the net

Amount to be invested

We consider only the payback period in this study. The starting cost of the solar home system has to do with knowing the number of electrical gadgets and taking note of their wattages and quantify all to see it equivalent in solar system, also purchasing of solar equipment and installation, and other related cost like miscellaneous items. Below is the initial cost breakdown of 1KW solar home system with their prices (see table 7).

Table 7. Breakdown of a solar home system./19/

ITEMS	PRICE

Solar Panel Pma x 1080w	$ 06-0.8 per watt
Inverter output 1000W	$ 89.00
Charge controller 48V, 30A	$ 133.00
Battery capacity 48V, 400AH	$ 13-19.00

This section is high lighting the calculation of monthly and annual saving on SHS. Below is the Load Requirement based on an interview with a household living in Dawenya-Ghana, see Table 8. Table 8 should the daily consumption of the householder and the electricity bill paid. A proposed SHS of 1kW is to be purchased by the householder. A 1kW solar system presented in Table 9 consists of load requirement of a household.

Table 8. Cost of solar components parts./19/

Solar Component	Cost
Solar Panels	$ 829.6
Inverter	$ 31.52
Charge controller	$ 31.5
Battery	$ 94.7

Table 9. Load requirement of a household.

LOAD REQUIREMENTS				
APPLIANCES	QUANTITY	WATTAGES	HOURS USED	TOTAL KWH

Television	1	300	3	900
Fridge	1	200	24	4800
CD player/ radio	1	120	24	4800
Cell phones	3	5	2	30
Electric iron	1	1600	1	1600
Standing fan	1	65	2	260
Ceiling fan	1	120	8	960
Electric stove	1	1500	1	1500
Bathroom bulb	1	15	1	15
Washroom bulb	1	15	1	15
Kitchen bulb	1	10	5	50
Outside bulbs	3	34	5	510
Bedroom bulb	1	5	4	20
Corridor bulbs	2	5	4	40
TOTAL				15500
Amount paid/month (electricity bill)				Ghc 160.00

The payback period of a PV solar home system is presented in the steps below.

STEP 1: Determine the monthly electricity bill. This amount was obtained from the electricity bill of the householder, in this case, GHc 160.00.

STEP 2: Determine the kilowatt used by the householder. Kilowatt hours per month is 465kwh, which is the daily consumption of 15.5 multiplied by 30 days and is expressed below:

15.5*30 = 465 kilowatt-hours per month.

STEP 3: Determine the output of the proposed solar home system. The monthly output of the proposed PV system is 122KW/month, according to the satellite PVGIS estimation of 1KW PV solar home system electricity generation for a given system in Dawenya of Greater Accra region. See PVGIS information in Figure 13.

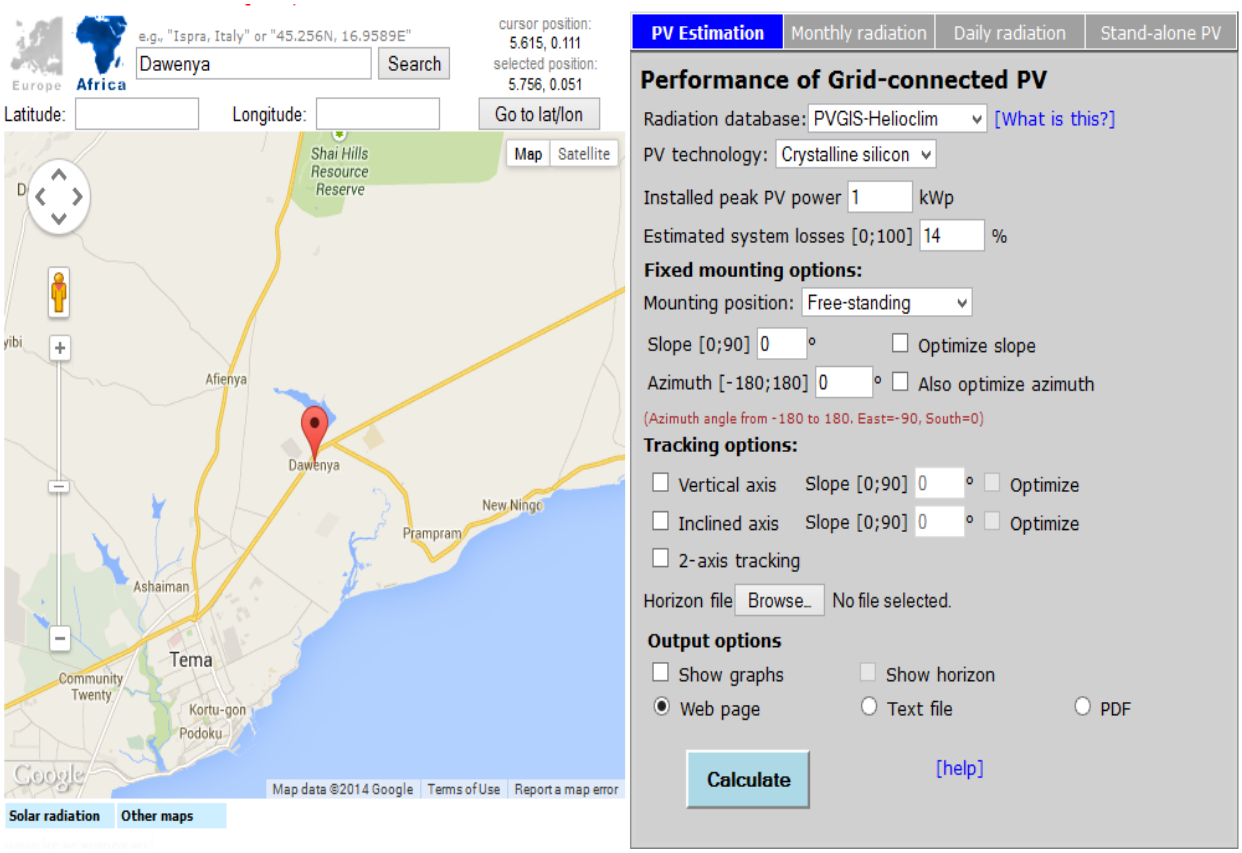

Figure 14.Photovoltaic Geographical information system.

The figure below is the solar radiation used by the PVGIS to calculate the average sunshine for a particular area used in this thesis, See Figure 14./18/

Solar radiation database used: PVGIS-helioclim

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 13.0% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 2.5%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 27.0%

Fixed system: inclination=0°, orientation=0°				
Month	E_d	E_m	H_d	H_m
Jan	4.55	141	6.25	194
Feb	4.60	129	6.36	178
Mar	4.39	136	6.10	189
Apr	4.33	130	6.06	182
May	3.75	116	5.16	160
Jun	3.18	95.5	4.34	130
Jul	3.65	113	5.00	155
Aug	3.60	112	4.94	153
Sep	3.51	105	4.80	144
Oct	4.04	125	5.53	172
Nov	4.15	125	5.70	171
Dec	4.28	133	5.87	182
Yearly average	**4.00**	**122**	**5.50**	**167**
Total for year		**1460**		**2010**

E_d: Average daily electricity production from the given system (kWh)
E_m: Average monthly electricity production from the given system (kWh)
H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Figure 15.Performance of grid connected PV system. /18/

STEP 4: Determine the adjusted amount. The adjusted estimate of the real solar condition is estimated to be 20%, taking into consideration cloudy days, rains and any other things that may reduce its peak performance. Therefore, we subtract 20% from 122 kWh being the monthly use out of the proposed system according to the PVGIS. This is expressed mathematically below:

122 kwh/month x .8 = 97.6 kilowatt hours per month.

STEP 5: The adjusted hours of the proposed system will divided by the actual average monthly use on the electricity bill to determine what percentage of the electricity bill the PV system will support.

The adjusted hours output = 97.6 kwh/month

The actual average month kilowatt hours used per month = 465 kwh/month, expressed mathematically below:

97.6 / 465 = 0.20 or 20%, so now it is expected that the 1kw PV system will cover 20% of the electricity needs.

STEP 6: Determine monthly and annual savings. To determine monthly and annual savings, multiply the average monthly electricity bill (Ghc 160) by the percentage (0.20) that would be supported by the PV solar home system. So we firstly multiply the kilowatt hours charged in Ghana by the monthly bill: , 160.00*.20 = Ghc 32 per month. We therefore multiply Ghc 32 by 12 months to save Ghc 384 annually.

4.7 Payback Period with No Subsidy

The section will present the payback period of 1kW SHS proposed to the householder at Dawenya, and how the subsidies would affect the purchase of SHS. Currently, there are no subsidies in the purchase of SHS in Ghana. The initial investment cost of 1kW SHS is GHc 7632. The study did not consider maintenance costs and replacement cost for the inverter. Table 10 shows the payback period without subsidies.

Table 10. Payback period with no subsidies

CSF	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Year	0	1	2	3	4	5	6	7	8	9	10
Initial cost	-7632										
Annual savings		384	384	384	384	384	384	384	384	384	384
Cummulative annual saving		383	768	1154	1526	1920	2304	2688	3072	3456	3830
Simple Payback Period		-7248	-6864	-6478	-6096	-5712	-5175	-4766	-4560	-4176	-3802

CSF	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Year	11	12	13	14	15	16	17	18	19	20
Initial cost	-7632									
Annual savings		384	384	384	384	384	384	384	384	384
Cummulative annual saving	4224	4608	4992	5376	5760	6144	6528	6912	7296	7680
Simple Payback Period	-3408	-3024	-2640	-2256	-1872	-1488	-1104	-720	-336	48

Note: CSF: denotes cash flow savings.

As seen in Table 10 above, the payback period is about 20 years. Table 11 shows the payback period with a subsidy of 5%

Table 11. Payback Period with 5% subsidy

CSF	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Year	0	1	2	3	4	5	6	7	8	9	10
Initial cost	-7250										
Annual savings		384	384	384	384	384	384	384	384	384	384
Cummulative annual saving		384	768	1152	1536	1920	2304	2688	3072	3456	3840
Simple Payback Period		-6866	-6482	-6096	-5714	-5330	-4946	-4562	-4178	-3794	-3410

CSF	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Year	11	12	13	14	15	16	17	18	19	20
Initial cost	-7256									
Annual savings	384	384	384	384	384	384	384	384	384	384
Cummulative annual saving	4224	4608	4992	5376	5760	6144	6528	6912	7296	7680
Simple Payback Period	-3026	-2642	-2258	-1874	-1490	-1106	-722	-338	46	430

As seen in the Table 11 above, the payback period is above 19 years. Table 12 shows a subsidy of 10%

Table 12. Payback Period with 10% subsidy

CSF	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Year	0	1	2	3	4	5	6	7	8	9	10
Initial cost	-6868										
Annual savings		384	384	384	384	384	384	384	384	384	384
Cummulative annual saving		384	768	1152	1536	1920	2304	2688	3072	3456	3840
Simple Payback Period		-6484	-6100	-5716	-5332	-4948	-4564	-4180	-3796	-3412	-3028

CSF	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Year	11	12	13	14	15	16	17	18	19	20
Initial cost	-6868									
Annual savings		384	384	384	384	384	384	384	384	384
Cummulative annual saving	4224	4608	4992	5376	5760	6144	6528	6912	7296	7680
Simple Payback Period	-2644	-2260	-1878	-1492	-1108	-724	-340	44	428	812

The payback period shown in Table 12 has also started from year 18 because the investment cost has further reduced by 10%. Of course it will be of more advantage if the government will review their renewable energy policy by providing direct subsidies to the purchase of SHS. Another approach could be ensuring adequate sales taxes and duties on the importation of solar generation systems so as to encourage the public to choose renewable energy and solar energy as an alternative source.

5 CONCLUSION AND RECOMMENDATION

Ghana has enormous solar radiation capacity that can be harnessed to assists the already existing power generation plants but at the time of the research little has been done to utilize this solar potential. I was t is also realized that there are some barriers which are underpinning the promotion of solar energy utilization in the Ghana , governmental support, country's energy policies, insufficient information and awareness creation and so on and which those things must critically looked at.

This study demonstrates how financial mechanism such as the use of subsidies can be used as an incentive to promote solar home systems. Financial evaluation of a solar home system was used to calculate the monthly and annual saving from a PV solar home system which also involves calculating of a payback and the annual saving. Our analysis shows that when the initial investment cost was Ghc 7632 the payback starting from year 20. When the investment cost is then reduced by 5% the payback starts to be positive from year 18. If the investment cost is further reduced by 10% and the payback started from year 10: , It will be of a great help for off-grid power producers and the public if the Government will subsidies the solar packages; people will be able to recover their investment cost within the shortest possible time.

A potential benefit of using SHS system would that the householder might be shielded from a possible blackout. Our analysis revealed that implementing 1kW SHS might contribute to 20% of electricity requirements of the householder.

From the financial evaluation of the PV solar home system above it is recommended by the researcher that the Government should be able to give tax incentives and rebates for solar energy. This would in the initial investment cost and also shorten the payback time of the system. It is essential that the Government addresses these barriers especially the financial mechanism to ensure affordability by peri-urban and rural household in Ghana. International donors and the Government can also assist micro finance institutions in Ghana to assist in paying upfront cost for householders interested in purchasing the SHS. A more pragmatic

approach and more relevant solar widespread strategy need to be adopted to assist the current power crisis the country is facing. It will also be of more use to implement motivations towards solar energy promotion from a long term focused sustainability point of view rather than from a default option associated with the need to expand the country's electrical capacities. It will also be of importance to implement a stable and legal framework which is complete and transparent before a long term investment can be attracted. , Barriers hindering the expansion of solar energy should be identified and dealt with, solar market should be structured or designed so as to determine the wide dissemination of small scale installation. , The development of local manufacturing industries should be one way or the other be supported by a strong political will.

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