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SUPPLY CHAIN DEVELOPMENT OF PHOTOVOLTAIC ENERGY SYSTEMS: A Critical Analysis of the Consumer's Role

Case Study Ghana

Master's Thesis in
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Vaasa

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ABBREVIATIONS

GEC	Ghana Energy Commission
GSS	Ghana Statistical Service
CEC	Clean Energy Council
EMA	Energy Market Authority
BPA	Bui Power Authority
GNA	Ghana News Agency
REW	Renewable Energy World
IEA	International Energy Agency
SCM	Supply Chain Management
VRA	Volta River Authority
MoEP	Ministry of Energy and Petroleum
PURCG	Public Utilities Regulatory Commission of Ghana
GoG	Government of Ghana
NG	Natural Gas
UNIDO	United Nations Industrial Development Organisation
UNEP	United Nations Economic Programme
GDP	Gross Domestic Product
RE	Renewable Energy
VALCO	Volta Aluminum Company
IPP	Independent Power Producers

ECG	Electricity Company of Ghana
TICO	Takoradi International Company
LPG	Liquefied Petroleum Gas
SNEP	Strategic National Energy Plan
EPC	Enclave Power Company
PV	Photovoltaic
DC	Direct Current
AC	Alternating Current

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ABSTRACT

The rising energy problems in Ghana and the need for solutions called for this research. The alternative solution to this problem is renewable energy such as solar photovoltaic systems. Although solar PV systems are in the country its adoption process is slower due to several reasons. This research contributes to a pool of solution by looking at the supply chain of PV systems through the eyes of the consumer, hence the topic; *Supply chain development of photovoltaic energy systems: A critical analysis of the consumer's role – Case study Ghana*.

The method used for this research was a case study. First a survey was conducted among some solar PV businesses in Ghana to identify the existing supply chain for PV systems and their challenges. Secondly, another survey was conducted among consumers to identify their preferences in solar PV supply chain development. The consumer questionnaires revolved around the *four P's of marketing* and *supply chain models*.

The results of the research revealed that the major challenges faced by solar PV business in Ghana were; *government policies and finance*. On the consumer side, the major challenges faced by them were; *finance, education, information awareness and availability of PV's*. The positive side is that consumers want the supply chain to be designed in such a way that PV's will be available in the nearest retail and distribution centres. Consumers also want PV maintenance specialist centres be established in their communities and education and information to be readily available.

In conclusion solar PV businesses have good future prospects in Ghana, only that most consumers are not fully aware of the benefits and prospects of this technology. Secondly, this research recommends that government policies on PV's be amended to facilitate business. Government and business in Renewable energy industry should co-operate to bring education and to promote consumer awareness. Finally, government should provide incentives on behalf of consumers and businesses for banks and financial institutions to grant soft loans for PV purchases to help solve the energy crisis.

KEYWORDS

Photovoltaic systems, supply chain, consumers, renewable energy, Ghana

1 INTRODUCTION

1.1 Background

Energy is very paramount for the development of every country in the world. Most of the major developmental sectors in a country's economy are dependent on energy, so it can be said that constant supply of energy is the life blood of any performing economy in the world. Research has shown the correlation between rates of economic growth based on demand and supply of energy. (World Economic Forum, 2012; Pirlogea, C., Cicea, C. (2012)

The economy of Ghana is highly dependent on energy for a lot of productivity, "the rate of growth of Ghana's Gross Domestic Products (GDP) since 1985 has been between 3.5 -6 percent, yet over the same period the demand for electricity had grown at the rate of 10 – 14 percent per annum" (Ghana Energy Commission 2014). The Ghana Energy Commission has projected that the demand for electrical energy in Ghana will grow from 6,900 Gigawatt-hour in the year 2000 to about 18,000 Gigawatt-hour by 2015, reaching about 24, 000 Gigawatt - hour by 2020 (Ghana Energy Commission 2014).

For the past 52 years, Ghana has relied heavily on its hydroelectric dam and thermal plants which currently have a capacity of 2,936MW (GEC 2014) to supply electricity to its citizens and industries. The generating facilities are state owned enterprises, there have been some few additions of power plants over the years, and currently there is a construction of a new hydroelectric dam at Bui which is to add 400MW of electricity to the National grid, but still will not be enough to meet the market demand in Ghana's economy. (BPA 2014)

The Akosombo hydroelectric dam, which is the largest source of power generation in Ghana, about 60 percent, was made for a population of 6 million at the time of construction. Currently, the population of Ghana is about 24.6 million (GSS 2010), which exceeds the initial capacity of the hydro dam. The government has not been able

to meet up with infrastructural development in the areas of power generation with the rapid population growth. This has actually created electricity crisis for the second time in the history of Ghana. There has been a lot of power rationing from one locality to the other in recent times and this has affected a lot businesses and their productivity. Failure of some consumers also to pay their electricity bills on time made the Electricity Company of Ghana to lose 12.40% of their annual revenue. And also the ECG lost 10.97% of their annual revenue to frequent network breakdown and associated power outages (GNA 2014; Boateng A. Kojo 2014; Mensah Mary 2014).

In view of the above energy crisis, there is a need for an alternative source of energy to help with the power crisis in Ghana. Renewable energy; photovoltaic, is one good source of energy for the republic of Ghana. Some citizens have already started using photovoltaic systems, but majority of the population are not making use of this alternative source of energy, even though they are handy and can be controlled from one's home. Some of the challenges associated with the slow diffusion of photovoltaic's in Ghana are; high cost of energy delivery from photovoltaic, unregulated market for photovoltaic, institutional set-up, political influence on grid extension (Wisdom A. Togobo 2014; GNA 2014).

Ghana is located in the tropical region of Africa and it has 12 hours of sunshine in a day and throughout the year. So in view of this there is a need for more research in solar photovoltaic supply chain development in Ghana, since the running cost of photovoltaic's are not so expensive. There have been some photovoltaic distributors in Ghana already, but the demand for photovoltaic systems is not high as a result of lack of awareness, which calls for a research into that problem. According to the (GEC 2006), electricity generated from solar photovoltaic systems in Ghana is 0.1 percent of the total national grid, which is very small. There may be some challenges hence the need for this research; "Supply chain development of photovoltaic energy systems - A critical analysis of the consumers role" with Ghana as the case country.

The main idea is to find out the best way to distribute photovoltaic energy technologies in Ghana at affordable prices. And also to find out which supply chain network type will be suitable for Ghana. The research seeks to find out the best possible way the

technology can reach consumers and meet their needs. There are many forms of renewable energy such as; wind, solar, tidal, geothermal, bioenergy, ocean energy etc, but for this research the focus will be on solar photovoltaic energy technologies. (REW 2014)

1.2 Research gap, Objectives and Questions

There are so many studies that have been conducted about supply chain development in some business areas and also in renewable energy business in the world. But these researches on renewable energy are not so much on the continent of Africa. There are some researches on renewable energy in Africa, but these studies are not enough to help both consumers and investors. Some of the reputable and recognized bodies that conduct research on energy on the African continent are ESI-Africa. ESI-Africa usually provides news and events about energy development on the continent. They showcase what the governments on the continent are doing about the energy issues and situations. Usually, these kinds of researches and reports are too generalized and not detailed enough to exert the right impact necessary for rapid development. However, they don't provide enough academic research about energy development and energy mix and the way forward. There have been some good research conducted by independent researchers on the continent on renewable energy; examples are (Ndzibah 2013; Bedzo 2013; Bugaje 2006). These independent researchers tackle some aspects of the energy issues on the continent and also Ghana in particular. For example, (Ndzibah 2013), researched on marketing mechanisms for photovoltaic technology in developing countries using Ghana as a case study, the goal of that research was to find out suitable marketing mechanisms for photovoltaics in Ghana. As part of the research, he proposed a new principle called the "Robin Hood and Donkey", which can be very suitable for the Ghanaian environment if policy makers apply it .On similar topic, (Bedzo 2013), also researched on a market entry plan for a solar product manufacturing company that wanted to enter the Ghanaian renewable energy business. And as part of his research also he proposed four different market entry plans for the company. (Bugaje 2006), also

researched on “Renewable energy for sustainable development in Africa; a review” He analyzed the national energy policies of the following countries South Africa, Egypt, Nigeria and Mali to see the areas that needs improvement to achieve sustainability.

The goal of this research is to add up to what others have done in the renewable energy management research. This research is focused on “the role of the consumer in the supply chain development of solar photovoltaic energy in Ghana”. The main objectives of this research are;

- *To investigate consumers expectations of photovoltaic energy technologies efficiency, reliability and affordability*.
- *To develop a supply chain network for solar photovoltaic systems in Ghana*

To get to the bottom of this research, two key research questions are going to be the guide;

- *What are the existing supply chain networks for photovoltaic systems in Ghana?*
- *What are the challenges and expectations of consumers of photovoltaic energy system in Ghana?*

The rationales for choosing these particular questions are; first to understand the existing supply network, study and analyse the shortcomings of the network. And propose an improved network which will help both consumers and businesses.

Secondly, to know specifically the challenges that consumers are facing and also to know their expectations in terms of easy access, price, location, efficiency of the technology.

1.3 Research Design

Research Philosophy

The aim of this research is to find out the role the consumer plays in the development of the supply chain for photovoltaic systems in Ghana. This research satisfies academic, scientific, policy issues and addresses stakeholders in the RE industry thus the philosophy adopted for this thesis; *pragmatism.* According to pragmatism in the management research, ideas and practices are evaluated in terms of their usefulness, workability and practicality (Saunders 2009). Hence the contributions of this research are going to be evaluated based on its scientific, practicability and the workability.

The approach to this research is *inductive*; it gives the researcher the flexibility to alter the intended path based on new findings. An inductive approach develops a theory or a way of thinking as a result of data analysis (Saunders 2009). Understanding of the role of the consumer in the supply chain is gained by using grounded theories in supply chain management, marketing and consumer behaviorism, since these are the key areas serving as the theoretical backbone of the research. Due to the nature of inductive research and the research philosophy (pragmatism), the researcher cannot develop a hypothesis in this thesis (Sarmad 2009). Usually, an inductive approach along with pragmatism philosophy uses research questions to narrow down the scope of the thesis.

This study uses multiple research methods; both *qualitative* and *quantitative* methods by conducting field surveys and also in depth interviews with entrepreneurs and businesses in the RE industry. Multi-methods would be employed and it allows the use of different data collection methods in one study to ensure the reliability and validity of the research. For the *time horizon*, this study is a *cross sectional* study; different segments within the consumers and the businesses in photovoltaics will be studied.

With regards to the data collection techniques for this research, five main approaches are going to be used for this research. These are; survey, interviews, energy reports, scientific articles and observations. Figure 1 below shows the techniques of data collection.

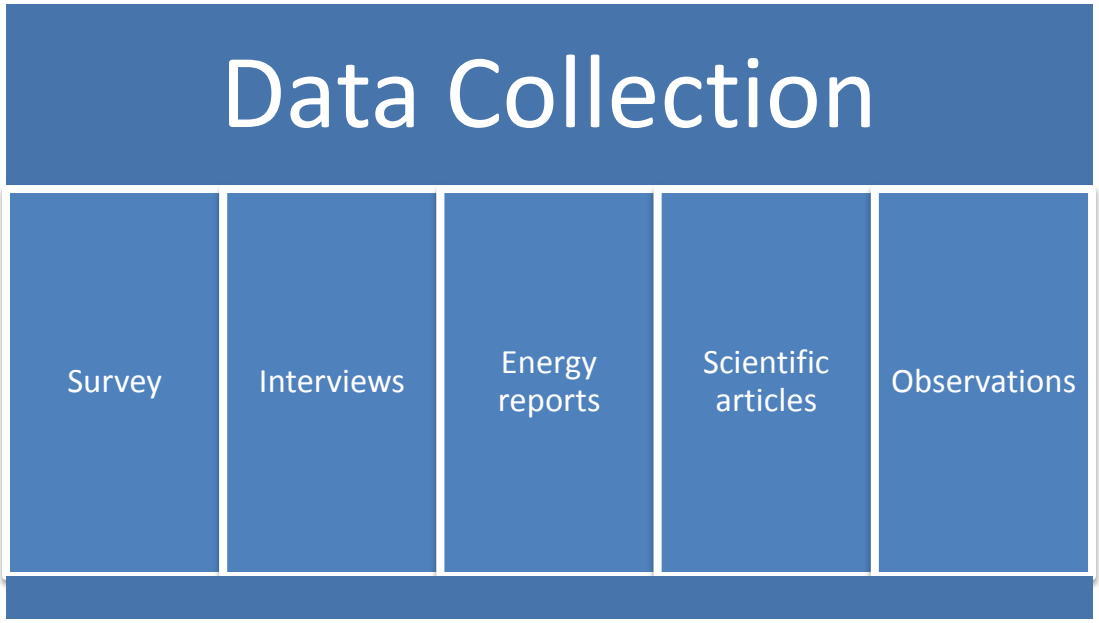


Figure 1 Techniques of data Collection

First and foremost, energy outlook reports of the government of Ghana will be reviewed to see the roadmap for RE and photovoltaic systems in Ghana and also to analyse the current policies if they promote or facilitate RE and photovoltaics development. This will be a desktop research, because most of the energy reports are available on the internet at the website of the Ghana Energy Commission.

Secondly, a survey will be conducted in Ghana and the target group will be users of photovoltaic systems, house owners, tenants, businesses and companies. The target number for this survey will be in the range of 200-500 people; this will be a field survey. A tailored made questionnaire will be used for this survey, the questionnaire captures most of the major issues related to supply chain development and the role played by the consumer.

Thirdly, an interview will be conducted, the target group for the interview are businesses and companies in the field of RE and photovoltaic systems in Ghana. The main idea for this interview is to study and understand the current supply chain network for the photovoltaic systems in Ghana and also to investigate some of the challenges faced in the existing supply chain.

Fourthly, scientific articles on photovoltaic systems, supply chain development and consumer behaviorism will be used. These will also be a desk research and literature reviews. Finally, observations and judgment of the researcher will also be applied as part of the analysis of the research process.

1.4 Definitions and Limitations

Definitions

This part defines and provides limitations for the research. Some key terms in this research that will be repeated over and over, and these terms needs to be defined and explained at this stage of the research so that the reader understands the meaning of those terms in the context of this research. Some of the terms have already revealed themselves in the title of the study, the purpose statement, research questions, research objectives, literature review and the method section. These are;

Supply chain management

There are so many definitions for Supply chain management (SCM) such as; the process for designing, developing, optimizing and managing the internal and external components of the supply system, including material supply, transforming materials and distributing finished products or services to customers, that is consistent with the overall objectives and strategies (Spekman et.al 1998).

Mentzer et.al (2001 p 4), also defined supply chain management as a "set of three or more organizations directly linked by one or more of the upstream and downstream flows of products, services, finances, and information from a source to a customer". However, the definition of supply chain management for this research is the one proposed by Lambert et.al (1998; p 1); "*as the integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders".* The research will be

concerned with physical products, services, information, customers, stakeholders and added value.

The main products are photovoltaic panels. Information is also very important; and it encompasses knowledge about the photovoltaic cells, where to purchase, where to maintain, technical advice etc. Stakeholders include all the key people or persons, organizations and institutions involved for the supply chain network to work effectively. The value expected from the supply chain and the photovoltaic systems are affordable photovoltaic panels at the right place and constant supply of electricity at the right time and the right quantity for the consumer.

Photovoltaic System

A photovoltaic system is an installation of several electrical components, such as solar panels, an inverter, batteries, electrical cables, etc, connected in such a way to convert the direct energy from the sun into electrical energy (Kagkarakis 1992; CEC 2008). The solar PV's are mounted to face the sun's rays, and the PV's absorbs the rays and convert it into electrical energy. Solar modules are generally flat panels mounted on roof tops or other structures. In simple language, a solar PV system uses sunlight to generate electricity for domestic use, stores excess electricity in batteries for later use or feed in to the electricity grid. There are two types of solar photovoltaic systems installation; these are *stand-alone* and *grid-connected* (CEC 2008; EMA 2010). And for this research the emphasis is on stand-alone systems.

Renewable Energy

"Renewable energy is energy derived from natural processes (e.g. sunlight and wind) that are replenished at a higher rate than they are consumed" (International Energy Agency 2014). There are other sources of renewable energy such as geothermal, hydropower, bioenergy and ocean power are sources of renewable energy. The roles of Renewables have increased in recent years in the areas of electricity, heating, cooling, transport etc. But for this research the kind of renewable energy that is going to be studied is solar photovoltaic panels.

Consumer and consumer behavior

For this research it is very important to identify the consumers and their behavior in relation to photovoltaic systems. "*Consumers are individuals who buy products or services for personal consumption"* (Jobber et.al 2013). Organisations can also be consumers; they buy products and services for use in the organization's activities. A consumer has the power to make a decision whether to purchase an item at the store or supermarket. They can be influenced by marketing and advertisement. The main consumer groups for this particular research are house owners, tenants, and businesses. *Consumer behavior,* on the other hand is defined by Kotler et.al 2009 as "*the study of how individuals or groups buy, use and dispose of goods, services, ideas or experiences to satisfy their needs and wants".* The needs and wants of consumers varies across cultures, situations and individual characteristics and therefore it is important to study the behavior of the consumers in Ghana in relation to the supply chain development for the photovoltaic systems.

Limitations

For most research studies there are some limitations associated or encountered during the process. For this research the limitations are; survey sample size, financial issues and geographical reasons, all interconnected with each other. For the sample size, the estimated number is 200-500 people in Ghana. It would have been better to get small proportions of the participants from each region in Ghana to get a good reflection of the results, but due to financial reasons and geographical distances the researcher will not be able to distribute questionnaires in all the ten regions of Ghana. But rather the questionnaires will be distributed in four out of ten regions which may affect the results.

1.5 Structure of the study

The chapter one gives a general overview of the energy situation in Ghana and the need for this research. The chapter throws light on the research gap, and provides the objectives and research questions for the research. It also highlights the importance of this research to all stakeholders involved. The chapter also defines key issues and limitations of the parameters under investigation.

Chapter two, starts with the case country background, it evaluates the historical, political and technical Administration of energy systems in Ghana. It examines the electricity management in Ghana, the types of energy mix, future forecast and the overall installed capacity of Ghana in relation to the market demand. The Renewable energy policy of Ghana is also highlighted in this chapter. Furthermore, the supply chain network for photovoltaic systems in Ghana is identified and examined in relation to consumer preference.

Chapter three reviews key literatures for the research; it discusses the supply chain model in relation to the role played by consumers in the supply chain. It analyses important factors such as; consumer buying behavior, consumer decision making process and types of buying decision behavior. In addition, it examines distribution channels and types, and how to select the right channel. The supply chain performance measurement criterion is also evaluated in this chapter.

The Chapter four defines solar photovoltaic technology, its uses, benefits and challenges experienced by consumers. Furthermore, it analyses the solar photovoltaic supply chain and also the expectations of consumers on the technology.

Chapter five gives more information about the research methodology, the data collection process, the analysis of the research results, the validity and reliability of the research process.

Chapter six summarizes the outcome of the research questions and tries to look at what can be improved in the existing supply chain for photovoltaics in Ghana. It also provides necessary recommendations and suggestions based on the outcome of the

research. The limitations of this research and future research possibilities in this area are highlighted in this chapter.

2 CASE COUNTRY BACKGROUND

The case study location of this research is in the Republic of Ghana. Ghana is located on the west coast of Africa, and it shares boarders in the north with Burkina Faso, to the west with Ivory Coast, to the east with Togo and in the south with the Gulf of Guinea or the Atlantic Ocean. Ghana has an estimated population of 24.6 million (GSS 2010), and the official language is English language. This chapter throws more light on the Energy Administration, electricity management, the installed capacities and the renewable energy policies.

2.1 Historical, political and technical Administration of energy systems in Ghana

Ghana gained its political independence from the British on 6th March 1957. Ghana has had different forms of political leadership since independence. But for the past 22 years Ghana has been practicing unitary presidential constitutional democracy. Ghana is a stable country conducive for business and investment. (Government of Ghana 2014)

The first energy system after Ghana's political independence was the Akosombo hydro electric dam. It was started in 1961 and commissioned on 1965. The hydro dam has a total surface area of 8,502 square kilometers making it the largest man-made lake in the world. It had an initial power output of 912 MW, which was later upgraded to 1,020 MW in a retrofit project which was completed in 2006 (Volta River Authority 2014). The Akosombo hydro dam project was financed by the government of Ghana in collaboration with Kaiser Aluminum of America operated by Volta Aluminum Company (VALCO). The original plan of this project was to supply electrical power to the Aluminum smelting production in Tema Industrial area. However, it was extended to include the energy demand of the general population of the country. The electrical energy provided by the hydro dam after post independence was adequate for the demand at that time, because the population at that time was estimated to be 6 million (GSS 2010) and also the industrializations at that time wasn't so much to demand greater electrical energy. On the other hand, with the passing of time and population

growth in relation to industrialization growth in the mining sectors and other sector, the demand for electrical power has actually overshadowed the production of electrical power. The current population of Ghana is 24.6 million (GSS 2010). There have been some other additional power plants constructed over the years by the government, but they are still not able to meet the energy demand which calls for a more quick response and adoption of other flexible alternative source of power, renewable energy technologies. According to a research conducted recently by the ministry of energy, Ghana will need about 200MW power additions every year to match up with the rate of population growth and electricity demand (MoEP 2013).

2.2 Electricity management in Ghana

In Ghana, there are about 6 regulatory bodies responsible for the production, distribution, promotion and management of electricity. Each body has its own duties, and the services of these regulatory bodies comes together to bring power to the consumer.

First and foremost is the Ministry of Energy; responsible for energy policy formulation and also the representative for the government (MoEP 2013). Second is the Energy Commission; they serve as the government energy policy adviser by making national energy policy recommendations to the ministry of energy, they also provide planning, technical regulations and monitoring. The energy commission is also responsible for granting licenses to public utilities for the transmission, wholesale supply, distribution and sale of electricity and natural gas in Ghana (MoEP 2013). The third body is "PURC", Public Utilities Regulatory Commission; this body is responsible for regulation of utility services by public utilities to consumers in Ghana. In addition, PURC approves rates chargeable by public utilities, ensures that there is fare competition among public utilities, monitors standards of public utility service provision and ensures the protection of consumer rights. The PURC is also a regulatory body working hand in hand with the energy commission (PURCG 2013). Fourth body is Volta River Authority (VRA); responsible for electricity generation and transmission.

This is done by the hydropower dam on the Volta River at Akosombo. However, the transmission aspects of the VRA have been cut off by the Volta River Development Act, 2005 (Act 692). This was an amendment and part of the government's reformation of the energy sector. The transmission aspects have been handed over to a privately owned Company called GRIDCO. Under the current law only one entity can hold the transmission license at any given time and GRIDCO is the current holder. (Volta River Authority 2013)

The generation and distribution aspects are open to competition, and this has given Independent Power Producers (IPP) the chance to compete. The Volta River Authority (VRA) is the largest power producer or generation firm. They have the following assets; the Akosombo Dam, Bui Dam, the Kpong Dam, the Aboadze thermal plant, and 10% share in the Takoradi International Company (TICO). The remaining 90% stake in TICO is owned by a subsidiary of UAE investment firm TAQA. As of January 2013, some IPP's were in the process of starting operations in Ghana; Sunon Asogli Thermal Plant (200MW) and CENT thermal plant (100MW). The passage of the Renewable Energy Act has also facilitated the interest of IPP's in investing in Renewable energy technology especially solar technology.

The fifth body is on the distribution. On the distribution aspects, there are three Companies at the moment in Ghana. These are the Electricity Company of Ghana (ECG); ECG oversees the southern sector which includes the Greater Accra, Ashanti, Eastern, Western, Central and Volta Regions, the Northern Electricity Company (NEDCO), (wholly owned subsidiary of the VRA); NEDCO takes care of the northern sector starting from the Brong Ahafo, Northern, Upper East and Upper West Regions. The Enclave Power Company (EPC) is the third distribution Company.

The sixth body is the energy foundation; they are responsible for promotion of energy efficiency and conservation in Ghana.

2.2.1 Types of Energy systems, capacity and future forecast

According to the (Ghana Energy Commission 2014), the energy sector of Ghana is divided into two parts; the demand and supply sector. The demand sector consist of residential (household), commercial & services, agriculture & fisheries, industry and transport. The energy supply sector consist of electricity, petroleum, wood fuels and renewable. The table and bar chart below gives a good overview of the general energy mix in Ghana and their capacities.

Table 1 Total Final Energy Consumed (ktoe)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Electricity	596.8	614.7	587.2	450.7	455.7	512.8	633.0	553.8	620.8	640.8	715.2	789.9	796.0	910.0
Petroleum	1,535.3	1,537.0	1,633.6	1,573.5	1,800.0	1,817.6	1,872.6	2,126.6	2,071.3	2,597.7	2,491.1	2,826.6	3,303.1	3,300.1
Biomass	3,432.4	3,237.8	3,081.8	2,924.7	2,839.0	2,745.2	2,671.3	2,593.7	2,517.8	2,493.3	2,463.9	2,575.6	2,588.8	2,676.0
Total	5,564.5	5,389.4	5,302.6	4,948.9	5,094.6	5,075.7	5,176.9	5,274.1	5,209.8	5,731.7	5,670.2	6,192.1	6,687.9	6,886.0

Source: Ghana Energy Statistics 2014

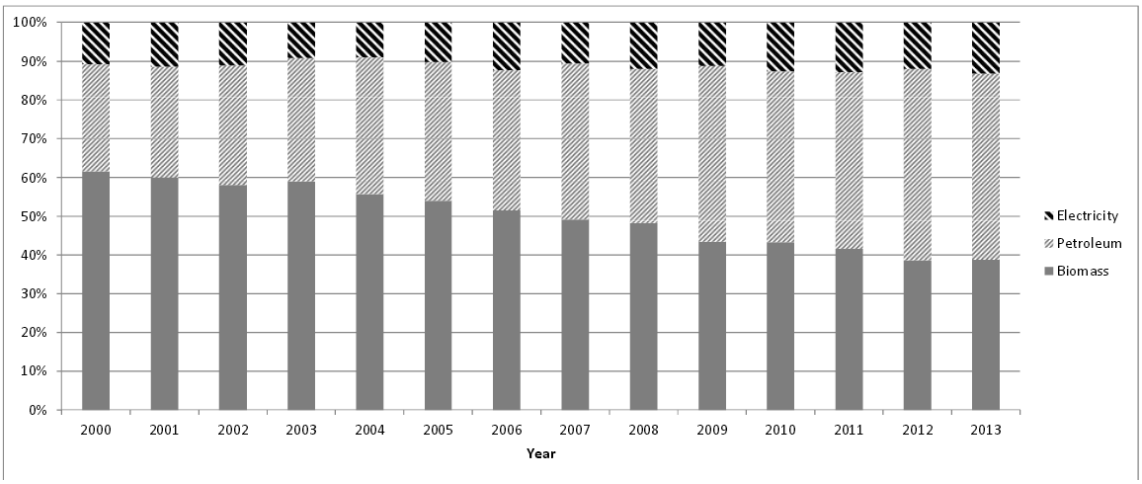


Figure 2. Trend in Final Energy Consumed

Source: Ghana Energy Statistics 2014

From table 1 and figure 2 above, it can be seen that from the year 2000 to 2013 the dominant energy use in Ghana has been biomass, on the other hand it can be seen that its usage has reduced consistently over this period and electricity and petroleum products have increased. Biomass, more specifically charcoal has been the traditional energy used in Ghana, and it has many applications in the lives of both rural and urban communities in Ghana. It is used for domestic activities such as cooking, bread baking, processing of oil palm, brewing of local drinks, traditional soap making, fish smoking and for commercial purposes such as traditional textiles (tie and dye batik) etc.

Wood fuel or charcoal production involves fire wood collection and charcoal burning; it is a greater source of income for rural communities. However, this is not sustainable, even though it is a renewable form of energy. Government control programs for re-afforestation are not adequate to control the depletion of the forest after the trees have been cut for firewood; this causes desertification to replace the ever green rainforest in Ghana, hence the need for other forms of alternative energy. On the other hand its usage has declined gradually over the years due to several factors.

As can be seen from figure and table, second highest energy type used is Petroleum; the demand for petroleum has been on the ascendency. Petroleum is generally used for fuelling automobiles, power plants, industries, generators and for domestic uses in Ghana. The third type of energy used is electricity, it doesn't mean it is not important, it is important but the current demand has actually exceeded the supply. Electricity in Ghana is used for many purposes, the basic and the general uses are for lighting at night and for other domestic uses such as ironing, cooking, etc. However, it is also used for industrial purposes such as mining, aluminum smelting etc. There is a need for more power plant constructions to meet the current and future demand for electrical power in Ghana.

In 2013, the total grid electricity generated in Ghana was 12,874 Gigawatt-hours (GWh), 6% more than in 2012. It is estimated that the total electricity demand for 2014 will be in the range of 15,725 -16,500 GWh. In 2013, the peak load of Ghana on the transmission grid was 1,791 Megawatts (MW); 2.7% more than in 2012 and the total system peak on transmission was 1,943 MW; 3.8% more than in 2012. The energy

commission estimates that, in 2014, the peak load for Ghana would be in the range of 1,900-2,200MW and the peak on the grid transmission will be in the range of 2,200-2,300MW. (Ghana Energy Commission 2014)

According to the Energy Commission, the potential drivers for energy consumption in Ghana are the following factors; First and foremost is VALCO's aluminum production; if VALCO expand operations then the demand for electricity is going to be high. This is because at the moment VALCO's operations are consuming about 320MW of electricity everyday and about 2,900GWh per year. Second is the mining sector, largely influenced by gold prices and production. When the demand for gold in the world market increases, the need for more gold production, hence the higher need for more electricity. According to (Ghana Energy Commission 2015), the electricity demand for surface mining in Ghana is about 8-.9GWh per tonne of gold whilst underground mining requires 28-29 GWh per tonne of gold. The third factor is the other industries, at the end of the year 2013; the other industries consumed 23% of the total electricity generated in the country besides VALCO and the mining sector.

The fourth driving factor is the national electrification scheme; the more new communities are connected to the national grid, the more additional need for more electricity generation. According to MoEP 2014, at the end of the year 2013, about 1,400 communities were connected to the national grid, making the total communities connected nationally to be 6,857 covering a population of about 19 million. It has been projected that about 1000 communities will be connected to the national grid by the end of 2014.And also it is estimated that about 100 – 300 GWh rise in energy for 2014, as a result of the national electrification program. (Ghana Energy Commission 2015)

The installed grid electricity capacity of Ghana at the end of the year 2013 was about 2,936 Megawatts (MW). Table 2 below gives the electrical energy mix in Ghana in accordance with their installed capacities.

Table 2. Installed Grid Electricity Capacity of Ghana, December 2013

GENERATION PLANT	FUEL TYPE	INSTALLED CAPACITY (MW)	PERCENTAGE SHARE
Hydro Power Plants			
Akosombo	Hydro	1,020	
Bui	Hydro	400	
Kpong	Hydro	160	
	Sub-Total	**1,580**	**53.8%**
Thermal Power Plants			
Takoradi Power Company (TAPCO)	LCO/NG/DIESEL	330	
Takoradi International Company (TICO)	LCO/NG/DIESEL	220	
Sunon- Asogli Power	NG	200	
Tema Thermal Plant 1(TT1P)	LCO/NG/DIESEL	126	
Tema Thermal Plant 2(TT2P)	NG/DIESEL	49.6	
CENIT Energy Ltd (CEL)	LCO/NG	126	
Takoradi T3	NG	132	
Mines Reserve Plant	DIESEL/NG	40	
Osagyefo Power Barge	NG	125	
	Sub-Total	**1,348.5**	**45.9%**
RENEWABLES			
VRA Solar	Solar	2.5	
	Sub-Total	**2.5%**	**0.1%**
Embedded Generation			
Genser Power	LPG	5	
	Sub-Total	**5**	**0.2%**
TOTAL		**2,936**	

Source: Ghana Energy Commission 2014

From table 2 above, it can be seen that Ghana's dominant source of electricity generation is the hydro power plants at Akosombo and Bui, followed by the thermal plants and the renewable energy. There are not so much varieties in the electricity generation mix. There haven't been so much investment and development in the renewable energy sector with the exception of the hydro dams which have seen huge sums of money and investments over the years. It is just recently that VRA developed their solar farm which is connected to the national grid. The output capacity of this solar farm is 2.5MW which is not much in comparison with other forms of electricity generation in Ghana. More of these solar farms can be developed in addition to other forms of energy such as wind energy, bio energy, tidal etc.

The Energy Commission estimates that, the annual electricity capacity short fall is in the range of 200-250MW. The major challenge facing Ghana is to constantly secure adequate supply of gas which is a less expensive fuel for the production of electricity at affordable prices for consumers.

It is estimated that the grid electricity consumption of Ghana will rise from about 6,900 Gigawatt-hour in the year 2000 to about 18,000 Gigawatt-hour by the year 2015, reaching about 24,000 Gigawatt-hour by the year 2020 (Ghana Energy Commission 2015). This quantum jump in demand will affect Ghana's balance of payment, since Ghana imports crude oil and gas to fuel its power plants. The existing power generation infrastructure needs to be multiplied to meet the future demand. The total energy cost is also projected to be in the ranges of US$5.2 – 5.6 billion, 8-9% of GDP by the year 2020. The total capital investment is projected to reach US$4.3 – 5.4 billion for the period 2006 – 2020, with the investment in the electricity sector being the highest about 70% of the total. (Ghana EC 2009; 22-24)

Furthermore, with regards to the future, it is the strategic plan of the government of Ghana to achieve 10% of installed renewable energy capacity by the year 2020 and also to achieve 30% electrification of rural areas using renewable energy technology. In addition, the government has designed three different road maps to achieve energy sustainability in Ghana. And in all these roadmaps, renewable energy is included in the energy mix (Ghana EC 2009, 44). The table 3 below shows the roadmaps.

Table 3. Generation mix of the expansion options by installed capacity

ENERGY TYPE	OPTION 1	OPTION 2	OPTION 3
Hydropower	39 - 41%	46 – 49%	44 – 46%
Thermal	51%	43 – 46%	41 – 43%
Nuclear	0%	0%	3 – 8%
Renewables	8 – 10%	5 – 11%	7 – 8%

Source :(Ghana EC 2015)

Ghana has the potential for wind energy, according to the ministry of energy; Ghana has about 5600MW of electric power potential, representing about 1,128km2. And most of these sites are located along the coastal belt of Ghana (MoEP 2013).

Furthermore, Ghana has the potential for solar energy, because solar energy resource is spread throughout the country. It is estimated that the daily solar radiation level ranges from 4kWh/m2 to 6kWh/m2. The areas with the highest radiation levels are the northern part of Ghana representing about 60% of the landmass. It is estimated that, the annual sunshine duration ranges between 1800 to 3000 hours, making it a very good potential for grid connected and off grid connected applications. Over 6,000 photovoltaic systems have been installed for off grid applications having a total capacity of 3.2MW (MoEP 2013). Figure 3 below shows the solar energy potential of Ghana and the key locations.

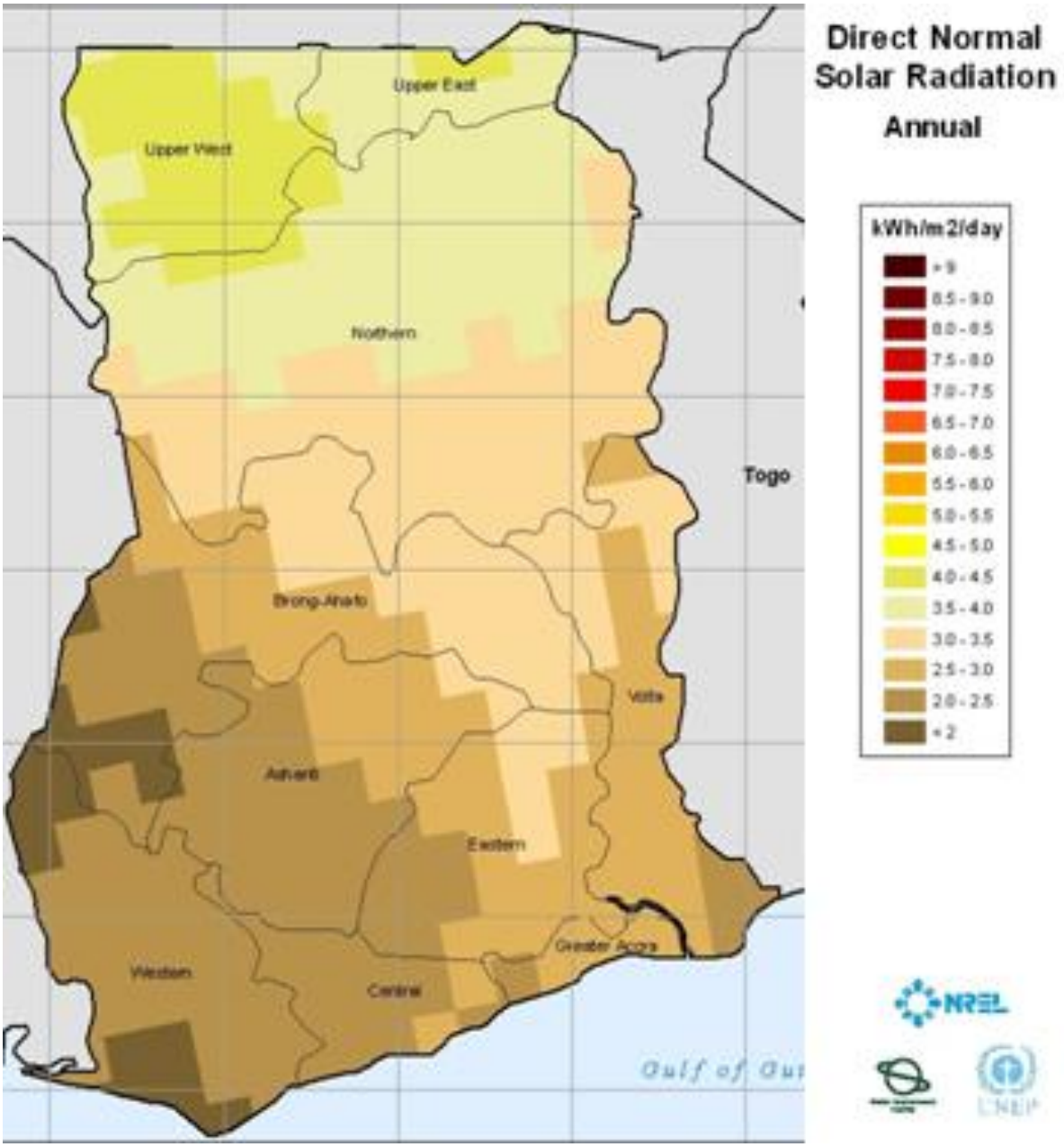


Figure 3 Solar Radiation Map of Ghana

Source: www.unido.it

2.2.2 Renewable energy policy and regulations in Ghana

According to the report created by the Energy Commission of Ghana, primary energy uses are about 90-95% wood fuel (biomass), 5-10% hydro energy and less than 1% photovoltaic energy. The use of renewable energy in Ghana by the government and the households are very small and the statistics on renewable usage are not well updated. The government has developed a strategic national energy plan for 2006-2020 (henceforth SNEP), that outlines the energy needs of the country. According to the report, some of the major challenges facing the government are the expansion of generation capacities and increasing accessibility of electricity to consumers. (Ghana Energy Commission 2009; EC 2006)

Some of the key objectives of the SNEP include, diversifying sources of energy supply, easy access for private sector investment in energy infrastructure development and services delivery, and the facilitation of the development and usage of renewable energy efficiency technologies (Ghana Energy Commission 2009; EC 2006). To realize these objectives, the government and the ministry of energy have putting in place measures to make public-private sector collaboration lucrative. A key measure is to secure private sector investments that seek to expand electricity generation capacities, expansion of transmission and distribution networks etc. The government also plans to increase the efficiency in the management of the existing infrastructure by restructuring the public sector to attract private sector investment. Furthermore, the government plans to speed up the development and usage of renewable energy and efficiency technology to realize the goal of 10% renewable energy usage in Ghana by the year 2020. (Ghana Energy Commission 2009; EC 2006)

These policies show the interest of the government in the development of renewable energy technologies. The renewable energy will come from small and mini hydro plants, photovoltaic systems, wind, and biomass and community solid waste. In addition, the government plans to strengthen the existing regulatory bodies such as the Energy Commission (EC) and the Public Utility Regulatory Commission (PURC) to improve their functionalities. Some of the plans include the supporting of training of Ghanaians in various fields of energy development and power sector reforms.

The government has also developed policies for the commercial and service sector with regards to *energy efficiency* and *conservation measures.* Some of the practical steps taken in line with this policy are promotion of pre-paid meters in government buildings and offices, the setting up of electricity consumption limit for ministries of government. According to this policy any government institution that goes beyond the limit of consumption will pay for the extra from their budget. (Ghana Energy Commission 2009; EC 2006)

For the energy supply sector, the government has policies to help the development of alternative energy sources. These sources are renewable energy for power generation and mini-grid systems for cost reduction in terms of supplying power to remote and rural communities. The practical steps include the creation of incentives to entice private sector investment. Some of these are loans, financial instruments, guarantees and grants for infrastructural investment. Furthermore, the government plans are to open up the electricity generation market for both local and international investors to participate in the infrastructural development. This gives the chances for businesses and entrepreneurs to invest in the photovoltaic energy market, because there are tax incentives on all equipment imported for the generation of renewable energy. It is also the policy of the government to keep to its promise of 100% electrification of the whole country by the year 2020. (Ghana Energy Commission 2009; EC 2006; Bojnec and Papler 2011)

3 LITERATURE REVIEW

3.1 What is supply chain management?

Supply chain management can be defined "*as the integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders"* (Lambert et.al 1998; p 1). A supply chain network can be bigger or smaller depending on the nature of the business, suppliers, manufactures, stakeholders and customers involved in the network. For this research two accepted models of supply chain network will be adopted as the backbone in analyzing the hypothesis. One of the models gives a very big picture and more details of a complex supply chain network whiles the other model gives a simplified view of a supply chain network which makes it easier to understand. The first model is the one proposed by (Lambert 1998) and the second one by (Beamon 1998). The main emphasis will be on the simplified model.

3.1.1 Douglas Lambert's model of Supply Chain Management

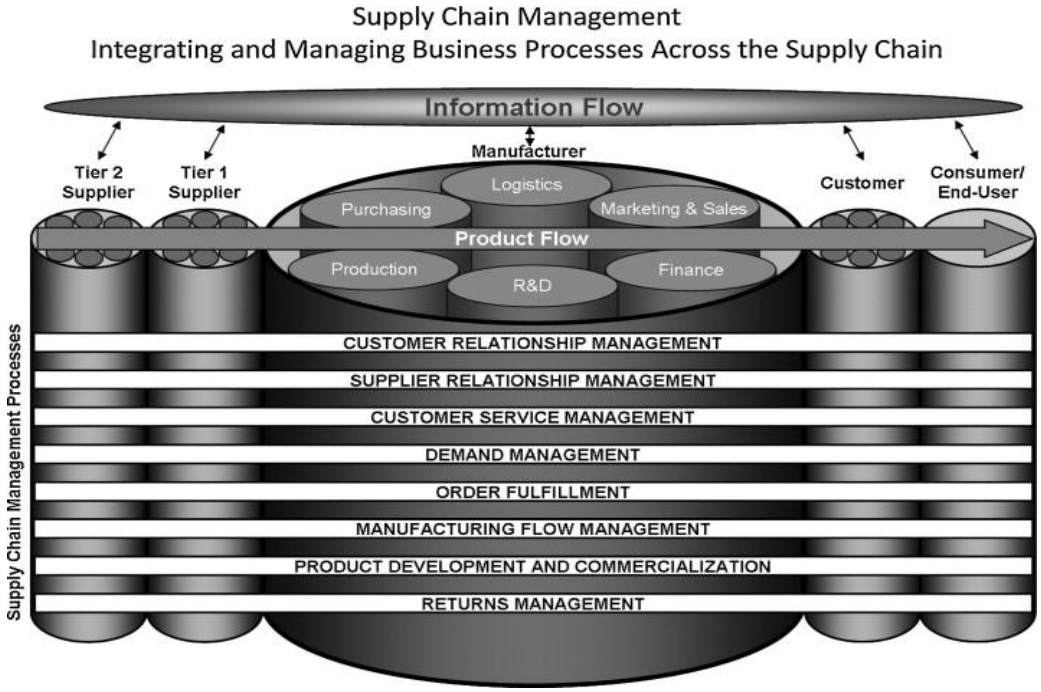


Figure 4. Douglas Lamberts Model of Supply Chain Management

Source: (Lambert 2008, p8.)

From figure 4 above, it can be seen that it is a complex supply chain network which takes into consideration all the business processes necessary to consolidate the supply network to make it functionable. This kind of model is more applicable in bigger and medium sized firms whereby there are a lot of business processes and suppliers behind the scenes.

3.1.2 B. M. Beamon Model of Supply Chain Management

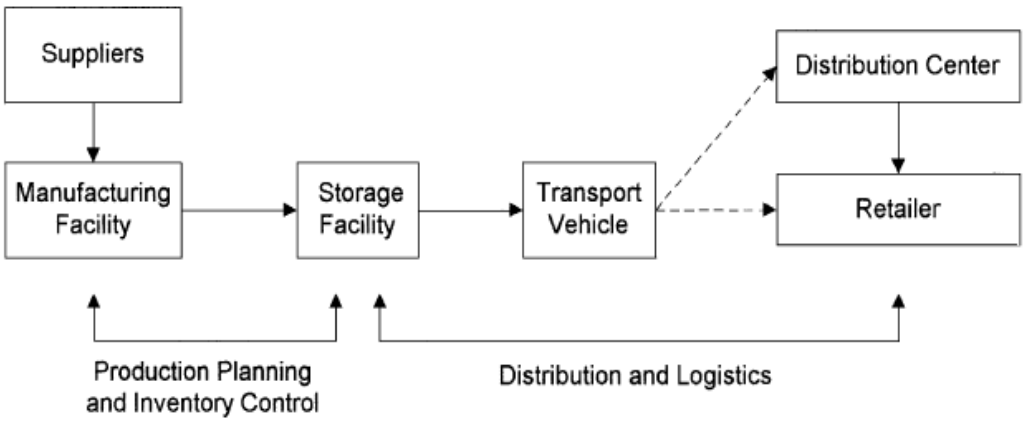


Figure 5. The Supply chain Process Beamon's model

(Beamon 1998, pg 281-294)

The (Beamon 1998) model looks at the supply chain network in a simplified way by considering some key relevant points in the network. The model classified the network into two areas; production planning and inventory control, distribution and logistics. The production planning and inventory control process starts from suppliers to manufacturing facility to storage facility. And the distribution and logistics process also starts from the storage facility to transportation through distribution centre to the retailer. This model can further be narrowed down to address the role of consumers in the supply chain. Figure 6 shows a modified model.

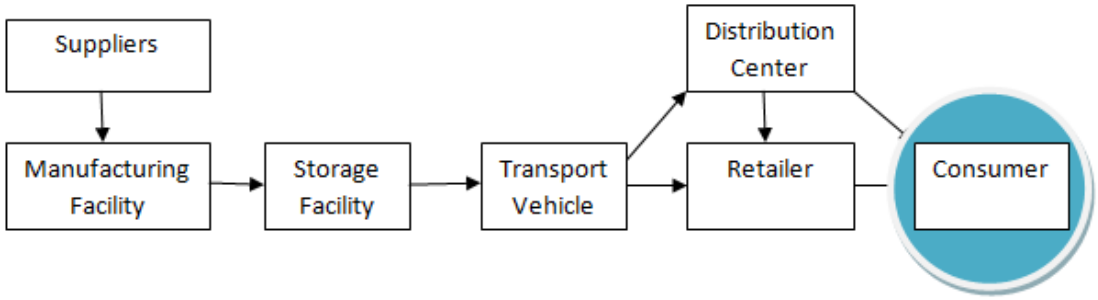


Figure 6. Modified supply chain model

Source: Adapted from (Beamon 1998)

3.2 The Role of the consumer in the supply chain

According to (Godsell & Harrison 2002), the field of supply chain management is changing into consumer value driven chain management where there are lots of improvements in supply chain efficiency and lots of emphasis placed on consumer needs and values. These have become keys for competition and distinctiveness in the chain (Godsell & Harrison, 2002; Christopher, 2005; Womack & Jones, 2005). It is not only the product that needs attention, but the whole chain of business activities needs to be managed well right from the raw materials through to the final point of consumption so that, the consumer value requirements can be achieved. Hence, it is prudent to use one supply chain model that could successfully address consumer requirements, step by step analyzing the value proposition at each level, identifying the misalignment with the consumer value and meticulously transforming the products and processes to deliver those requirements.

The consumer is the first and the last end of the business supply chain process. Without identifying consumer's needs and how to serve them, the whole supply chain will be useless (McEachern & Warnaby, 2005; Tarrant, 1998; Pickernel & Hermyt, 1999). In the ideal situation, all business activities within the chain that adds value to the product should have the same knowledge of what consumer requirements are based on good market research and communication along the chain. However research have shown that

other sectors of the chain don't have the same understanding of what consumers values are and this can lead to clashing practices and poor consumer satisfaction (Zokaei & Hines 2007). Consumer values and needs are best understood by consumers themselves, and it shouldn't be the responsibilities of businesses to assume what the consumer need (Hauser and Clausing, 1988). Many methods within the marketing circles have been developed to identify the consumer values and needs such as focus group research (Floyd et al, 1993). This thesis will utilize some of the methods by conducting field survey to capture the consumer needs, values and requirements in the areas of photovoltaic systems supply chain development. But to be able to do this effectively, we have to delve a little deeper into areas such as consumer buying behavior, the consumer's decision making process, characteristics affecting the consumer's behavior etc, so that the right survey questionnaire can be developed to capture the consumer's value.

3.2.1 Consumer buying behavior

"Consumer behavior is the study of how individuals or groups buy, use and dispose of goods, services, ideas or experiences to satisfy their needs and wants" (Simonson et al 2001). The needs and wants of consumers usually vary across different cultures, situations and individual characteristics. Consumer behavior is dynamic, involves interactions, and involves exchanges (Peter & Olson 2010). Consumers take a lot of buying decisions and these have interested many companies and institutions to conduct research to understand the rationale behind consumer's decisions; they try to understand questions such as; what consumers buy, where they buy, how and how much they buy, when they buy and why they buy. Sometimes, it is not easy to understand *why* consumers buy; it is usually unpredictable because it is based on many variables. The starting point in trying to understand consumers is by the application of the stimulus-response model of buyer behavior. Figure 7 below shows the stimulus-response model of buyer behavior. From the figure 7, marketing stimuli consist of the four Ps; product, price, place and promotion. Other factors that motivates the buyer are forces and events in the buyers environment; economic, technological, political, and cultural. These

become inputs that enter the brain of the buyer and are processed to give out observable outcomes such as product type, dealer type, brand preferred, purchase timing and purchase amounts (Kotler & Armstrong, 2001).

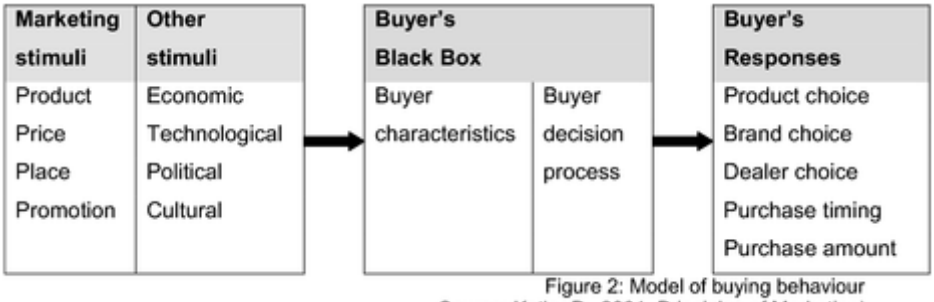


Figure 2: Model of buying behaviour
Source: Kotler P., 2001, Principles of Marketing)

Figure 7. Stimulus-response model of buyer behavior

Consumer Behavior towards Electricity and Photovoltaics

A research conducted in Goa state of India revealed that electricity consumption among consumers varies with demography and annual income. In rural communities the consumption was found to be lower due to low or no industrialized equipments and also fewer domestic electrical appliances, whereas in urban and bigger cities the electricity consumption was very high due to more industrialized equipments and also migration of people to the bigger cities. It was also found that when consumer's income increases that also affects electricity consumption in the sense that, they buy a lot of electrical appliances to their homes which consumes more electricity (Manjunath et al 2014).

Tsantopoulos et al (2014) conducted a research on the public attitude towards photovoltaic developments in Greece and the outcome of the research was positive. The research revealed that out of 1068 respondents, half had knowledge about the use of photovoltaic systems for generating electricity. Secondly, half of the respondents were ready to invest in PV systems for domestic use. The research revealed that the motivating factors contributing to the use of photovoltaic systems were; environmental, financial and social. Finally, the research revealed that those who were more motivated

to invest in PV for residential use were university graduates and technical school graduates.

In Japan, a research was conducted in Iida city to find out consumers behavior after installation of PV systems in their homes. The research revealed that in households where there is a PV system and the family members have knowledge about the importance of the system, they tend to show more positive behavior towards the environment. The research outcome also suggest that the installation of residential PV systems affects consumers concerns and norms related to energy and the environment, hence influencing the behavior of people (Hondo & Baba 2009).

The demography of Ghana can be classified into three groups according to income level; higher earners, middle income and lower income earners. Most of the higher and middle income earners live in urban centers and the majority of the lower income earners also live in the rural communities. The electricity needs for the urban centres in Ghana are very high as compared to the rural communities. These are as a result of higher Industrialization and higher income level among urban dwellers. Those with higher income level in the urban centers would like to have a comfortable life, therefore, they will purchase a lot of electrical appliances ranging from electrical bulbs, TV's, laptops, cooker, electric irons, washing machines etc. thereby increasing the electricity needs of the urban centre.

With regards to the recent electricity problems in Ghana, I think the introduction of PV systems in Ghana will be a very good idea and would be welcomed by businesses and many people who are affected by the power fluctuations. I think the elite group and the majority of the young graduates will embrace it in the urban centers. And in the rural communities, PV systems can be used to power their street lights and market squares at night, and also some rich individuals in the rural communities can also purchase and use it for both domestics and business use. In Ghana, some people view it as a higher social status to use PV systems to generate electricity. And this comes with a lot of prestige and respect as some in the society evaluate them as rich. However, some of the middle class also would prefer to use PV systems so that they could also be seen as belonging to the upper class of the society. Some small and medium sized companies may also use

PV systems for their businesses. There are some solar PV companies already in Ghana, but it seems the usage of PV's to generate electricity is not widely used. This could be due to several factors such as; finance, availability, government policies, etc. Education can also be a major factor affecting the usage of PV systems in Ghana. This is because only the elite and some of those who have received formal education are aware of this technology. The majority of the population may not have adequate knowledge and information about this technology. I think if the education and information awareness on PV systems increases, the patronage will be higher.

3.2.2 Characteristics affecting consumer behavior

There are many factors that can affect consumers buying behavior. These characteristics can be grouped into four categories; cultural, social, personal and psychological factors, as shown in figure 8. It is noteworthy that marketers can take notice of those factors, but they cannot change those factors. Marketers can only understand them and use it to their benefit. (Kotler et al 2001)

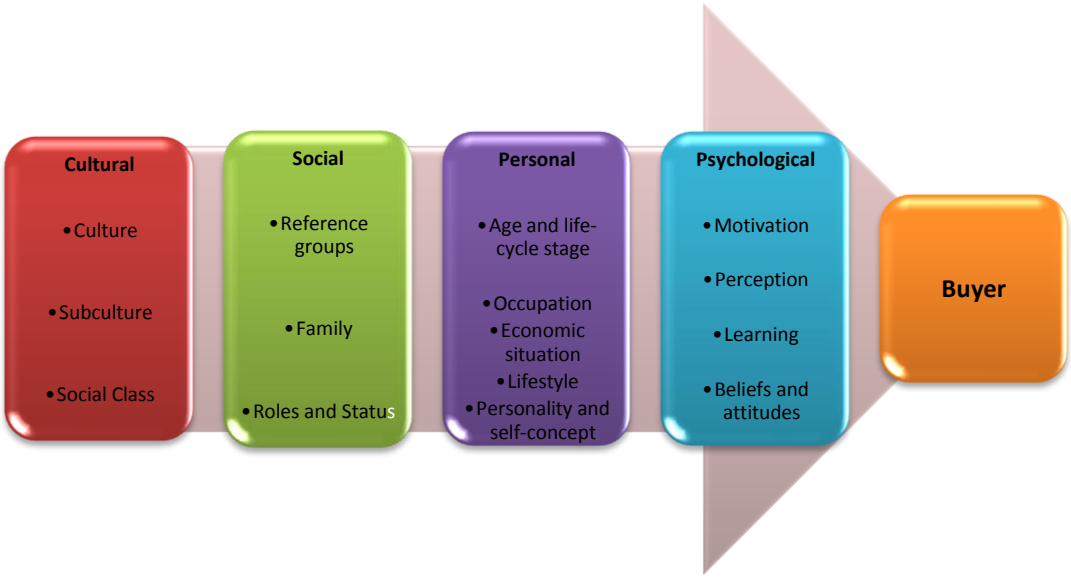


Figure 8. Characteristics affecting consumer behavior Source: Kotler 2001, Principles of market

Culture

Culture can be explained as the complex whole which includes knowledge, arts, beliefs, morals, laws, customs and any other habits and capabilities acquired by man as a member of a particular society (Avruch 1998). Cultural influences are very strong and affect us on the kind of choices that we make as consumers. These powerful influences vary from one geographical area to the other. Every geographical area and their preferences towards things such as; food, clothing, housing, education, entertainment, politics etc. Cultural influence also determines how consumers react towards marketing; it is therefore prudent for an organization to understand a particular culture before engaging in any marketing campaign.

For example a research conducted by Kacen et al (2002), on "the influence of culture on consumer impulsive buying behavior", it was a multi-country survey (Australia, United States, Hong Kong, Singapore and Malaysia). The results revealed that both regional level factors (individualism-collectivism) and individual cultural difference factors (independent – interdependent self-concept) all influence impulsive buying behavior. Another research conducted to find out on how both collective and individualistic societies respond to embarrassing service failure. The results revealed that, in individualistic societies if there is a service failure and even if it doesn't cause any embarrassing situation, consumers will complain. On the other hand in collective societies, consumers complain more only when there is an embarrassing situation associated with the service failure. These researches give more insight about cross-cultural consumer behavior and also provide rich managerial implications (Wan 2011).

In the case of Ghana, it is a collective society. The whole community identifies themselves as one group even though they are seen as individuals and families. The individuals who make up the community discuss a lot about different topics at different places; at the bus station, in the bus, at the hospital, at school, at work etc. They discuss about both good and bad topics, so the adoption of PV systems in Ghana can be very quick if the technology proves to be good and efficient. The good news about the PV system will spread quickly through the word of mouth. On the other hand if the

technology fails to deliver as promised, the adoption rate will be badly affected or very slower.

Social

Social factors such as small groups, family, social roles and status in the society also influence consumer's behavior. A person's buying behavior can be influenced by so many small groups either directly or indirectly. For instance, if a person belongs to an organized religion, there is a higher probability that, the individual dresses in formal clothing to church every Sunday which under normal circumstances the individual will not do. Some people's profession doesn't require formal dressing, but belonging to an organized religion compels the individual to get formal clothing in order to fit into the group. Group impact differs across products and brands; it becomes stronger when a product is visibly used by a respected person in the society. In view of this marketers usually try to market some specific products by the use of opinion leaders, respected persons, famous sportsmen etc. (Kotler et al 2001; Axsen et al 2013)

Family is another influential force on the behavior of consumers. There are nuclear and extended family members, all of them exert their own force either directly or indirectly towards a consumer's behavior. For example in the nuclear family, the buying roles of husband and wife, traditionally in most cultures around the world women are the ones who buy household things such as food, clothing for children, room decorations like flowers, curtains etc. And men are known to be the ones who purchase hardware stuffs for the house. Children also influence their parents to buy certain brands for some products. Marketers take cognizance of these influences and strategically direct their marketing for some specific products towards specific members of the family (Kotler et al 2001)

A person may belong to different bodies; family, clubs, organizations etc. The position of the person in the groups can be defined in terms of role and status. And the higher the position, the higher the status and the corresponding behavior, for example if an individual is a manager in an organization, because of the status associated with the position, the person is expected to behave in accordance with the position in terms of clothing style, car, housing etc. So the role and status actually influences the person's

buying behavior, something which under the normal circumstance the person wouldn't have done. In recent times, social media website such as facebook, twitter, google plus, watssup, viber, tumbler etc. have a greater influence on consumers purchasing behavior. There are a lot of discussions on various topics going on social media platforms with regards to many products and brands, marketers are aware of the influence of these mediums and are making good use of it (Kotler et al 2001; Cetina et al 2012; Park and Kim 2014).

With regards to the case country Ghana, social influence is very high when it comes to the adoption of a new product. So many people belong to smaller groups such as the golf club, women's union, workers union, churches, etc, and are influenced directly or indirectly by the group. For instance, in the case of the PV systems if one member belonging to a particular group adopts PV systems and it works very well. That individual will recommend to the rest of the group. Secondly, the extended family system is very strong in Ghana. In most cases people's decisions are influenced by their families and in the case of PV systems, families can influence it for good or bad depending on the experience of the first person in that family to use. The use of social media to spread information is on the ascendency in Ghana, especially the brands facebook and whatsapp. Consumers used it to share both positive and negative news and can be used in this case by consumers to facilitate the adoption of PV systems.

Personal

A consumer's buying decision can be influenced by personal characteristics such as *age* and *life-cycle stage, occupation, economic situation, lifestyle, personality and self-concept.*

Age and life-cycle stage; as consumers advance in years, their choices in life changes with regards to goods and services. Choices in food, furniture, clothing, automobile, recreation etc are often age related. Marketers are often very clear about their focus group with regards to their life-cycle stage and design right products and marketing strategies for each stage. In the past, family life cycle stages included singles and

married couples with children, but in recent times this have evolved to include other groups to the life cycle stages; these are unmarried couples, late married couples, childless couples, same sex couples, single parents and extended families. Marketers do well to capture the attention of all these groups (Kotler &Armstrong 2001; Lee et al 2013). In the case of photovoltaics and Ghana, the age group may have greater influence in the adoption process, the young adults whom majority are formally educated would be more enticed to try out this technology to solve the electricity problems.

A person's occupation can have greater effect on the choices made on goods and services. For example white collar workers may prefer more formal clothing such as suits and tie, whereas blue collar workers may prefer casual clothing. A computer programmer may make different programmes for an accountant, engineer, manager and other different professional groups to suit their working environment. Marketers recognize these differences and designs product to match each group.

Economic situation is another influential factor on a consumer's buying behavior. Usually, when people have good income, they tend to purchase more expensive things and when the income level is also lower they buy things within their range of income. And marketers take notice of these variations in income and design products to suit higher earners, middle incomes earners and lower income earners. The income level for many professions in Ghana has increased and also there have been many financial institutions and banks in Ghana that are facilitating the lives of people by offering some soft loans. In view of these packages many people are able to afford homes, cars and other properties. And if photovoltaics are well packaged, banks and other institutions may help consumers purchase PV's.

Lifestyle can also influence a consumers buying behavior. Lifestyle can be explained as a person's way of living with regards to attitudes and tastes. This involves measuring a consumer's major activities, interests and opinions to create a profile of an individual. This goes beyond an individual's social class or personality and it reveals how the person interacts with the world around them (Kotler et al 2001)

Personality and self concept are other influential factors on consumer's buying behavior. Personality can be explained as the sum total of the physical, mental,

emotional, and social characteristics of an individual, these are unique traits that distinguish one person from another person and can be manifested in the forms such as self-confidence, dominance, sociability, autonomy, defensiveness, adaptability and aggressiveness. Marketers recognize these differences and design products to meet their needs. Marketers also make good use of another concept called *self-concept* or *self-image*, the basis of this concept is that, people's identities are tied to their possessions; thus "we are what we have". This implies, for the marketer to understand the consumer's behavior, he or she must comprehend the correlation between consumer self concept and property ownership (Kotler et al 2001; Sarker et al 2013). In the Ghanaian society, some of the elite class may also want to be associated with their possessions. They want to be seen as the first to adopt PV systems in that locality or the house that has constant electricity even when the grid goes off and this actually boost the confidence of some notable persons in the Ghanaian society.

Psychological

Research reveals that a person's buying preferences can be influenced by four psychological factors: motivation, perception, learning, beliefs and attitudes (Kotler & Armstrong 2001).

There are many motivational theories, but this research will take some few points from the works of Abraham Maslow on motivation. According to Abraham Maslow's hierarchy of needs, human needs are arranged in order of priority: *physiological needs*, *safety needs*, *social needs*, *esteem needs* and *self-actualization needs* (Kotler & Armstrong 2001). A person tries to satisfy the most important need first, and when that is accomplished, it no longer becomes a motivator. The individual tries to fulfill the next pressing need. For example, a starving person will first think of finding food before thinking about where to sleep, the kind of car to buy or the kind of cloths to purchase. So always the pressing need first followed by the next most pressing need (Kotler & Armstrong 2001; Ostinelli 2014). The fulfillments of these needs are in accordance with the increase of the income level of the individual. In the case of Ghana, some of the urban dwellers with good jobs and increment in salaries have higher chances of

satisfying the next need in their lives, which may be electricity problems; by purchasing PV systems to solve the problem.

A motivated person is ready to act on his/her perception of the stimuli received. *Perception* is the process by which an individual chooses, organize, and interpret information to form a meaningful picture of the things around him/her. We all acquire knowledge by means of our senses: sight, hearing, smell, touch and taste. But different people react to the same stimuli in a different way based on their perception of the stimuli. Marketers try very much to attract the attention of consumers (Kotler & Armstrong 2001; Lee & Yun 2014). In like manner for the photovoltaic systems, a motivated person based on the advertisement well presented by marketers will make the decision to buy the PV systems. They can see the advert on TV, listen to it on radio, and if possible physically go to see for him / herself how the system functions.

When a motivated person acts based on his/her perceptions, the person learns in the process. *Learning* explains changes in a person's behavior as a result of experience. Some experts say that most human behaviors are learned. Learning takes place through factors such as drives, stimuli, cues, responses and reinforcement. The practical value of learning theory for marketers is that they can design a product which could be associated with strong desires applying motivating cues, and providing positive reinforcement (Kotler & Armstrong 2001). After the consumer choosing the PV systems, the person begins to use the system and it becomes a learning curve for the consumer. The person comes to understand how the system functions, how to service and maintain it etc.

Actions and learning process creates *beliefs and attitudes* in people which in turn influence their buying behavior. A belief is a strong thought that a person has about something. Beliefs may be based on experience, facts, knowledge, opinion or faith, and it may or may not carry an emotional charge. The beliefs that consumers create behind products and services are the things that interest marketing experts because they are some of the motivating factors for buyers buying behavior. Consumers create attitude towards things such as cloths, food, music, automobiles, houses and almost everything. *Attitude describes a person's manner, disposition, feeling, position etc, with regard to a*

thing or a person; tendency or orientation, especially of the mind (Dictionary.com 2014). Attitude makes people have a certain frame of mind towards some things, and this can be positive or negative. People may like something and draw near it or may dislike and move away from it. Some may have the attitude of trying to buy always the most expensive, the cheapest or the best in all things (Kotler & Armstrong 2001; Liu et al 2013). In the case of the PV systems in Ghana, marketers can help design packages that will create the right attitude in the minds of consumers in Ghana. The packages should be based on facts, past experiences of PV systems user's reviews, knowledge, education etc, to create strong beliefs in the consumers and that is what will motivate them to purchase the product. They can design a package for the high earners, middle income and another package to target the low income earners as well. And also advertise about the advantages of having PV systems.

3.2.3 Types of buying decision behavior

According to (Kotler & Armstrong 2011), there are about four types of consumer buying behavior; *complex buying behavior, dissonance reducing buying behavior*, *habitual buying behavior, and variety seeking buying behavior.* Figure 9, below shows the types of buying decision behavior.

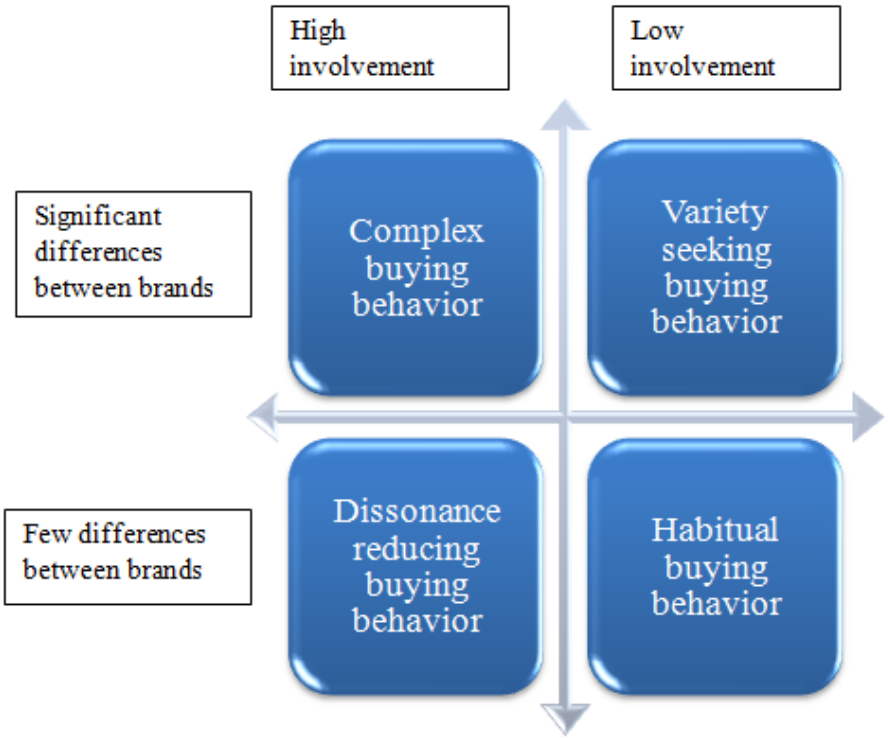


Figure 9. Types of buying decision behavior

Source: Adapted from Kotler & Armstrong 2001 p 191.

Dissonance-reducing buying behavior takes place when consumers are more involved with an expensive, seldom, risky purchase, but realizes little differences among competing brands. This implies the consumer can purchase any product without taking serious considerations to brands (Kotler & Armstrong 2001).

Habitual buying behavior happens under conditions of low consumer involvement and little importance is placed on brand difference. Such kind of behavior takes place when consumers buy low cost and frequently purchased products such as sugar, salt, bread; milk etc. requires low consumer involvement and doesn't demand significant brand differences. With this behavior type, consumers buy products because of their familiarity and not because of brand loyalty (Kotler & Armstrong 2001).

Consumers undertake *variety-seeking buying behavior* in situations associated with low consumer involvement but *greater brand differences*. In this situation, consumers usually do a lot of brand switching. For example, the purchase of soaps, detergent, shoes, shirts etc. consumers try to use different brands of such products because they want to check variety (Kotler & Armstrong 2001).

Complex buying behaviors are usually undertaken by consumers when they are more involved in a purchase and realize greater differences between brands. For example such decision takes place when the consumer is buying something more expensive, riskier and seldom bought things such as a new car from factory, a new house, new computer etc. To make a final decision, the consumer seeks a lot of information through the print media, internet and other sources to learn more about the product's features, attributes, quality, durability, reliability etc. This helps the consumer to develop some special belief and attitude towards the product. The consumer makes the final decision when satisfied with the information gotten. Therefore, it is more prudent for marketers of high end products to make the information about their products and companies easily accessible and also should make clear differentiation of their product from competitors (Kotler & Armstrong 2001).

The focus of this research will be on *complex buying behavior* because the product PV systems are new products to consumers in Ghana and also are products that are seldom bought in Ghana. In addition, there are greater differences between PV systems and the grid connection; in the sense that for the PV systems the consumer has greater autonomy about the electricity generated whereas the grid electricity is been controlled from somewhere. Secondly, with the PV systems there are higher chances of electricity been delivered to the consumer whereas at the moment the grid electricity cannot be relied on all the time due to inadequate power generation which leads to load shedding among communities. On the other hand, the initial costs of PV systems investment in Ghana are quite expensive as compared to the initial cost for connecting to the national electricity grid. In view of this, consumers who are new to this technology and do not have enough knowledge and education about the long-term cost benefits of solar PV systems may view it as a riskier investment. For the consumers to be able to make good decision with regards to the PV systems in Ghana. The marketer has to be able to make

the knowledge and education about PV systems available to the consumer through the media. In Ghana, the most efficient mediums to reach consumers are through the radio, TV, newspaper, internet and social media.

Consumer decision making process and the buyer's decision process for new products

According to Kotler and Armstrong 2001, there are five stages in the buyer decision process as illustrated in figure 10 below. These are; *need recognition, information search, evaluation of alternatives, purchase decision and post purchase decision.*

Figure 10. Buyer decision process

Source: Kotler & Armstrong 2001, p193

Need recognition is the starting point of the buyer's decision process. This usually happens when the buyer identifies a problem or a need in his or her life. The buyer can easily sense differences between his or her current lifestyle and some desired lifestyle. In the case of the consumer in Ghana, the problem encountered is inadequate supply of power and power fluctuations. The need *recognized* by the buyer is alternative sources of electricity. This moves the buyer's decision making process to the second level; thus *information search* on alternative sources of electricity (Kotler & Armstrong 2001).

Information search; at this stage the buyer searches for information about all the alternative sources of electricity that are available, accessible, adaptable, portable, cost effective, practical etc, through the various channels such as newspaper, internet, radio, energy experts, TV, adverts, educational institutions, energy magazines etc. And in the

case of the buyer in Ghana, the person can come up with alternatives such as wind power, solar PV, bio energy, generator set, etc. After listing all the alternatives, the buyer moves on to the next stage of the decision making process; *evaluation of alternatives* (Kotler & Armstrong 2001).

In the *evaluation of alternative* stage, the buyer evaluates all the alternatives based on own criteria. And not all consumers subject a product through a strict criteria check, some buy on impulse. In the case of the consumer in Ghana, the buyer can evaluate all the alternatives sources of electricity based on cost, availability, functionality, portability, durability, maintenance, etc. After going through all the alternatives, the buyer may be left with two options to choose from, probably generator set and solar PV system. The buyer can do further evaluation of other factors such as cost on the long term and operational efficiency. After further considerations, the buyer may make a final decision of going for solar PV, which moves the buyer to the next stage of the decision making process, *purchase decision* (Kotler & Armstrong 2001).

At the *purchase level*, the buyer decides to buy PV systems, but that decision can be influenced by two factors; thus attitude of others and unexpected situational factors. Other people can influence the decision for good or bad depending on their own personal experiences in relation to PV systems. Unexpected situational factors such as sudden loss of job can affect ones finances which can delay the purchase or reduce the capacity of PV systems planned to be bought. It can also be any other factors in life that can affect the purchase. Let's assume the buyer finally makes the purchase. After the purchase, the buyer reacts to the product either positively or negatively, this moves the buyer to the next stage of the decision making process; *post purchase behavior* (Kotler & Armstrong 2001).

Post purchase behavior occurs after the purchase, and it can be either positive or negative depending on the products performance. If the product performs to expectation the buyer becomes satisfied and if it underperforms the buyer becomes dissatisfied. In the case of the consumer in Ghana, if the PV system performs as expected, the individual becomes satisfied and happy. And this person can recommend this technology to friends and family through oral conversation. On the other hand, if it fails

also, this same person will give negative comments about the PV system to friends and family. Therefore it is better for marketers to develop a good feedback system which takes of the after purchase behavior (Kotler & Armstrong 2001).

The buyer decision process for Photovoltaic systems

The first stage in the buyer's decision process for PV systems is *awareness* of the product. The buyer must become aware that, there is a product that can be used to generate electricity. At the awareness level, detail information may not be available, if the buyer is interested then moves on to the next stage of *information search.* The more information that becomes available to the buyer, the more the interest becomes bigger and the more curious the person becomes. After getting all the necessary information about PV systems, the buyer moves on to the next stage of *evaluation*. The person evaluates the PV systems on different criteria to see if it will actually meet his/her needs. The buyer contemplates whether to buy the new product or not. The buyer moves on to the next stage of *trial* of PV systems or demonstration of how the system works. This can be done at the premises of the organization or the business using samples of PV's for demonstration. Finally, after the trial, the consumer finally makes a decision to *adopt* the PV systems as an alternative source of electricity (Kotler & Armstrong 2001).

3.3 Distribution channels and Types

Distribution channels are set of organisations that are dependent on each other in the process of product and services creation for consumers (Louis et al 1996). These set of organizations that rely on each other become intermediaries in the channel to the final customer or consumer. Why are they necessary? The use of intermediaries brings greater results and higher efficiency in making goods and services available to the target market, than could have been achieved by a firm on their own. Intermediaries use their contacts, experience, specialization and scale of operations (Kotler & Armstrong 2001).

The distribution channels perform many functions so as to make the goods available to the final consumer. Some of these functions are:

- *Information:* They distribute and collect marketing data and knowledge about influential forces and actors in the marketing environment and use that information for strategic planning.
- *Promotion:* They develop and spread information about a products offer.
- *Contact:* Searching and contacting consumers through other means.
- *Matching:* The products offers are made to fit the requirements of the consumer. Other activities such as manufacturing, grading, assembling and packaging are also important.
- *Negotiation:* They make agreements on product's prices and terms of payment with regards to the offer so that ownership or title of deed could be transferred.
- *Physical distribution:* Transportation and sorting of goods.

(Kotler & Armstrong 2001)

Types of Distribution channels

There are about four main types of distribution channels depending on the levels of intermediaries and the amount of extra work that needs to be done on the product or service before it reaches the final consumer. For this research, the focus will be on three channels. Figure 11 below shows all the four types of channel

Channel 1

Channel 2

Channel 3

Figure 11. Types of distribution channels

Source: Adapted from (Kotler & Armstrong 2001, p 434)

From figure 11 above, channel 1 is called *direct marketing channel*, it doesn't make use of any intermediary. It is a direct transaction between businesses and consumers. For example, according to a recent article in the *Financial Times*, "Procter & Gambler" has started selling directly to US consumers online for the first time. There are many manufacturing companies and products that are sold directly to consumers without the need of an intermediary. The other channels in figure 11, uses *indirect marketing channels.* Channels 2 contain only one intermediary which is very typical of consumer

markets and are usually retailers. For example, manufacturers of cameras, television tires, furniture and other products sell their products directly to bigger retail outlets. Channel 3 contains two intermediary levels, a wholesaler and a retailer. This channel can be applicable to the supply chain of the PV systems in Ghana in the sense that, there are no PV manufacturers in Ghana and most of the PV's are coming to Ghana from Americas, Europe, Asia etc. A big wholesaler can import huge quantities of PV's to Ghana and retail it to smaller electrical appliances businesses who will then sell it directly to consumers. There can be Agents who will be mainly responsible for installations and maintenance of the systems. These Agents will co-operate with both the wholesaler and the retailers. The wholesaler can be given the right from the manufacturers to train retailers who will then train the consumers on how to use PV systems. I believe with this kind of channel more consumers can be reached with PV systems (Kotler & Armstrong 2001).

Distribution channel selection

To design a distribution channel for a product is usually a challenge for manufacturers; this is a struggle between what is fitting and what is workable. The marketing environment for a particular product varies from one geographical area to the other and as such the same distribution channel may not be applicable in all cases, the distribution channel needs to be adapted to a particular geographical market needs. And most of the time the consumer's needs are the top of the channel designing. To be able to design a suitable channel, certain factors need to be taken into consideration: *channel objectives, the need for services, anticipation of challenges and evaluation of other types of channels* (Kotler & Armstrong 2001).

First and foremost, in the channel design, *analysis of consumer service needs* is very important. The aim of the channel design is to deliver *value* to the consumer or customer, so it will be more prudent to find out what are the consumer preferences in the channel. In the case of PV systems in Ghana, a consumer research can be conducted in Ghana to find out the consumers preferences with regards to PV systems. Questions such as these could be asked to guide in the designing of the channel; do consumers

want to buy PV's from nearby locations or are they willing to go to more distant centralized places? Would they prefer to buy in person, over the phone, through the mail or the internet? Would the Ghanaian consumer prefer additional services such as (delivery, credit, installations, repairs etc) or will they look for these services somewhere else? Would they prefer faster delivery and greater assortments? Providing higher level of services is good, but it comes along with higher cost on the channel which is transferred to the consumer to pay. Therefore companies are to strike a balance between *consumer service needs* and *feasibility* and *cost.* Lower cost is very important for most Ghanaian consumers. Companies are to ensure that, the product or services meet consumer's price range preferences (Kotler & Armstrong 2001).

Second important factor to consider in the channel design is to *set channel objectives and constraints.* Channel objectives are very important and should be set right at the beginning of the channel design. The *objectives* should be clear about the desired service level of target consumers. In the case of PV's and Ghana, some of the channel service objectives could be to provide electricity to consumers, to provide PV systems installation, PV systems maintenance, PV education for consumers, expert advice etc. And some of the target consumers can be real estate developers. PV business can negotiate with real estate developers to add PV's to their housing package so that a newly constructed house comes with alternative source of power in addition to the grid. Secondly, in terms of financial security, PV businesses can target consumers who have regular monthly income such as teachers, nurses, policemen, military men etc, so that PV businesses can negotiate with the banks so as to offer these categories of consumer's soft loans to purchase PV's on credit. The goals of the channel can be impacted by the kind of products the business is dealing in, marketing style, intermediaries, environment and competition. It is therefore the decision of the business to decide which channel type to use; whether to use the same outlet that competitors use or not? Finally, unpredictable *economical conditions* and *law requirements* of a particular place can affect the channel goals and its design. In the case of Ghana, companies should investigate the law to find out the requirements for choosing a particular channel (Kotler & Armstrong 2001).

Thirdly, after making the channel objectives clear, the next step is to find out other types of intermediaries and how many will be necessary and what their duties in the channel are. A company should be able to identify channel members who are available to carry out channel work. And these can be in the form of the company's sales force, manufacture's agency, industrial distributors etc.

Three strategies can be used by companies to determine the *number of channel members* to use at each level. These are: *intensive distribution, exclusive distribution* and *selective distribution* (Kotler & Armstrong 2001). Intensive distribution strategy is mostly used for convenience products and raw materials. The aim is to make the brand very popular and provide comfort for the consumer. With this strategy, goods are stocked in many outlets as possible, they must be available where and when consumers need them. Examples of these kinds of products are toothpaste, candy, salt, sugar, etc. On the other hand, *exclusive distribution is* the opposite of intensive distribution. With exclusive distribution, the manufacturer intentionally limits the levels of intermediaries by given the right of distribution to only some few dealers. This actually helps the manufacturer to have some good amount of control over the dealer prices, promotions, credit and services. This strategy is often used in the automobile industries, alcohol industries etc. And this strategy can be applicable to PV's in Ghana, in the sense that, PV's are special products that needs some good control and supervision on its distribution channel so as to avoid intrusion of fake products. *Selective distribution* lies in between intensive distribution and exclusive distribution. With regards to this strategy, more than one, but fewer intermediaries are willing to work on a company's product. Examples are: furniture, television, electrical appliances etc. (Kotler & Armstrong 2001).

The manufacturer and intermediaries need to agree on the *terms* and *responsibilities* of each member of the channel. Important issues such as: price policies, conditions of sale, territorial rights, price list, discounts etc, should be agreed on with regards to PV systems. They should also agree on specific services perform by each member of the channel (Kotler & Armstrong 2001).

Finally, the company should *evaluate the major alternatives* after making the decision to select some channels. The evaluation can be done using economic, control and

adaptive criteria. The economic criteria help the company to evaluate the profitability, the sales and cost volume of each channel. Using intermediaries also implies that some amount of control should be given them, and companies must be ready to do so. And most of the time companies try to have the maximum amount of control. The firm must evaluate each channel to ascertain if it is flexible and adaptive to the changing marketing environment (Kotler & Armstrong 2001).

4 WHAT IS SOLAR PHOTOVOLTAIC ENERGY SYSTEM?

A solar photovoltaic energy system is an installation of several electrical components, such as solar panels, an inverter, batteries, electrical cables, etc, connected in such a way to convert the direct energy from the sun into electrical energy (Kagkarakis 1992; CEC 2008). The solar PV's are mounted to face the sun's rays, and the PV's absorbs the rays and convert it into electrical energy. Solar modules are generally flat panels mounted on roof tops or other structures. In simple language, a solar PV system uses sunlight to generate electricity for domestic use, stores excess electricity in batteries for later use or feed in to the electricity grid (CEC 2008). There are two types of solar photovoltaic systems installation; these are *stand-alone* and *grid-connected* (CEC 2008; EMA 2010). And for this research the emphasis is on stand-alone systems. Figure 12, below shows a solar panel mounted on a roof top.

Figure 12. Solar Panel Mounted on Roof Top

Source: CEC 2008

Stand-alone solar PV system is not connected to the grid electricity. The battery bank supplies electricity through the inverter to the appliances connected to the system. And the battery banks are charged with the help of the solar panels which are mounted on the roof top or outside facing the direct sun rays. If one tries to use more energy than what the battery banks can hold, you run the batteries too low and reduce their life expectancy. The number of solar modules and the battery banks can be increased to generate and store more energy (CEC 2008). Figure 13 below is a simplified stand alone home connection.

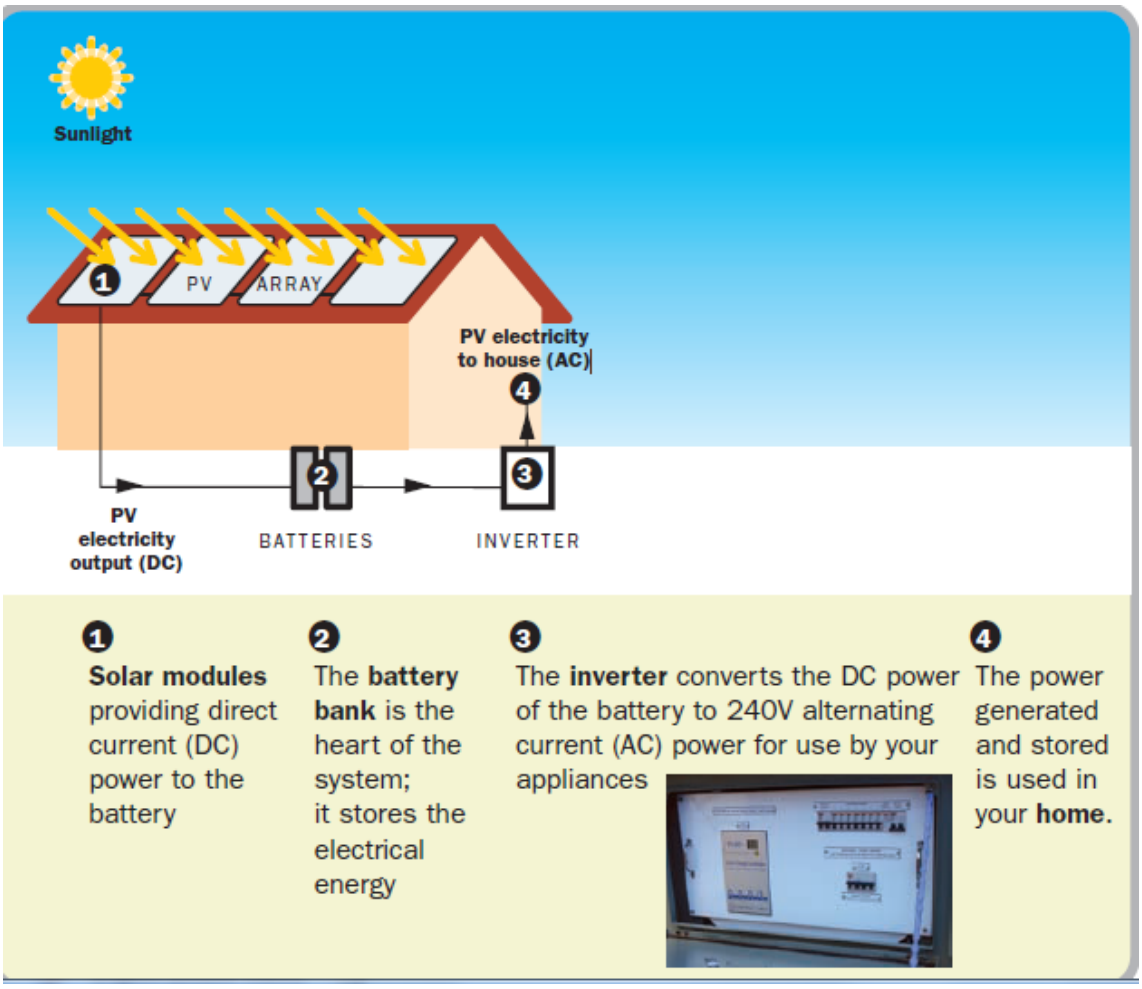


Figure 13. Standalone Connection

Source: CEC 2008

What are the main components of solar photovoltaic system?

The main components of a solar PV system are; solar module or solar panels, batteries, charge controllers and DC/AC inverter. There are other auxiliary components such as connecting cables, mounting structures and the load that will be connected to the PV system. The loads are the electrical appliances that are going to use the energy. For one to adopt solar PV system to the home, the person has to see an expert to conduct load analysis on the household appliances to find out the total energy need of the household and also to determine how many solar panels and battery banks would be needed for the total load (CEC 2008).

4.1 Uses and Benefits of photovoltaic systems

There are many applications for solar photovoltaic systems. Some of these are;

Electricity generation; It can be used to generate electricity for domestic uses such as lighting, using of domestic appliances such as TV, radio, solar water heating, etc. Not all domestic appliances can be connected to the PV systems especially those that draws a lot of current for operations such as microwave, kettle, deep freezers etc. In order for those to be used then the capacity of the PV panels and battery banks needs to be improved.

Rural Electrification; It can be used for powering remote villages that are not connected to the grid. The street lighting system of the remote village can be powered by solar street lights operated by photocells; whereby the street lights comes on at night by itself with the help of the photocell technology and also goes off during the day time. So in the day time the batteries can be charging and will be ready for use in the night when it is needed most by rural folks. The PV's can also have similar domestic applications such as using TV, radio, in the villages as the grid connection.

Water pumping and treatment system; PV's can be used as a source of power for pumping water for drinking both in rural and urban areas. It can also be used for pumping water for irrigation purposes. Water purification systems can also use PV systems as its source of power.

Health care system; Lighting in rural clinics and also for vaccine and blood storage refrigeration.

Communication; It can be used to power remote TV and radio receivers, remote weather measuring equipment, mobile radios etc.

Agriculture; It can be used for livestock watering and irrigation of farm lands.

Transportation; For traffic light systems both in urban and rural communities, lighting for runways, etc.

Security systems; Alarm systems, CCTV applications

Income generation; This can become a source of revenue generation for some people both in urban and rural communities; battery charging stations, radio, TV and video pay station, village industry power, refrigeration services.

(REW 2014)

Benefits of photovoltaic systems

There are many benefits associated with the usage of solar photovoltaic systems. Some of these are;

Generate electricity; Solar PV systems generate electricity which can be used for both domestic and industrial applications.

Cuts energy cost and long-term security planning; Once the system has been purchased, the electricity is generated from a free resource; the sun. With the use of

the grid and other sources of energy, the cost increases with the passing of time, but with PV systems, it reduces your current energy cost. It also makes your own electricity supply more secure and predictable for the future.

No greenhouse gases; Solar electricity is generated without the emission of greenhouse gases and other substances that would be harmful to the environment and the household.

Operation silent; Solar PV systems don't use any moving parts which make the operation very silent. There is no noise generations associated with the operation.

Integrated in a building; Solar PV modules can be added into a building in the form of windows, walls, roof tiles etc.

Solar electricity can be fed into the grid; In situations whereby the energy generated for the household is in excess, the excess can be fed into the grid which can be another source of revenue generation for the owner.

Additions can be made; More modules can be added later when the energy demand grows or when the budget increases.

Long - life span; Solar PV module should last 20-30 years

(CEC 2008, Bosch 2012, REW 2014)

4.2 Solar photovoltaic supply chain analysis

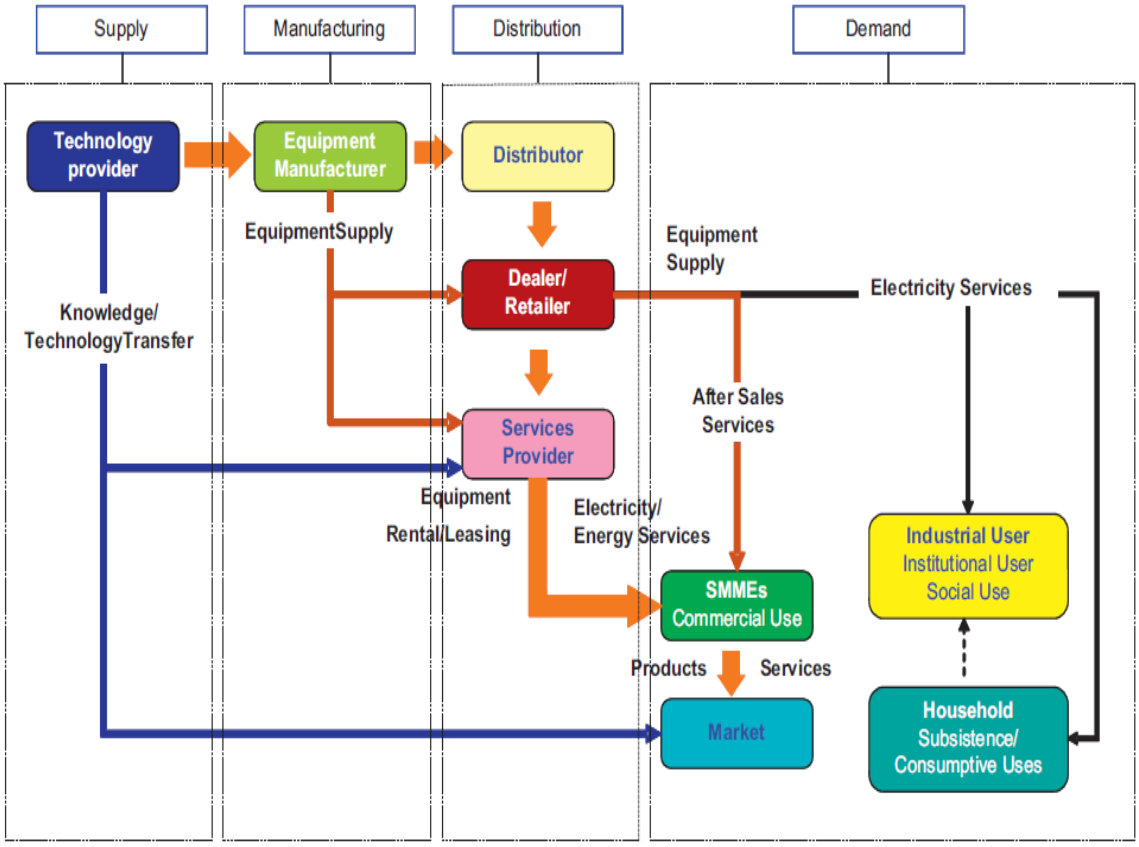


Figure 14. A pure RE supply chain chat and its actors.

Source: United Nations Development Programme 2010

Figure 14 above, is a typical supply chain flow chat of RE, and this flow chat can be applicable to the supply chain of photovoltaics, in the sense that PV's are another form of RE's.

From figure 14 above, the actors of PV supply chain can be categorized into four main groups; *supply*, *manufacturing*, *distribution and consumers*. However, there is a fifth strong actor which is not captured on the flow chat above; thus *the government*. Each member of the actors of the PV supply chain has an important role to play to make the supply chain function effectively. From the supply side, the *technology provider* is responsible for conducting research and development on PV's to improve the

technology and also to provide guidelines on its functionality, types of PV systems available and maintenance. The technology provider makes the technology available to the *equipment manufacturer*. The manufacturer has the production capabilities and the capacity to produce the PV's that have been designed by the technology provider. However, the manufacturer has other sources of suppliers who provide him with the raw materials necessary to manufacture the PV modules. The manufacturer does a lot of work by manufacturing different sizes, types, capacities and categories of PV's depending on the consumer request which is received through the supply chain. After production, the manufacture now determines which *distribution channel* type to use to reach the consumer; the manufacturer can decide either to sell directly to consumers' or through a big distributor. The consumers can buy directly from the manufacturer and also from a dealer or a retailer. Consumers can receive maintenances guidelines and services through a service provider or directly from the technology provider. The consumers also have a major role to play in the supply chain. One way is to make their preferences and their challenges that they are facing with regards to the technology be known to the manufacturer and the technology provider through the supply chain. This can be in the form of feedback and co-operating in market field research. The *government* has also a major role to play in the supply chain of PV systems. One major role is policies implementation and regulations that will facilitate the supply chain. For example in Ghana, there are tax exemptions on importation of PV systems as a complete package. However, there are higher taxes on individual components which may not be good for business. So this calls for feedback from both consumers and business to the government so that they can make the appropriate adjustments on the policies so as to facilitate PV businesses in Ghana.

4.3 Trends and Analysis of photovoltaic energy market and Investments around the world

According to a research conducted by Bloomberg &UNEP 2014, the total investment in renewable power and fuels (excluding large hydro-electric project) fell in 2013 to a figure of 214 billion US dollars worldwide, 14% lower than in 2012 and 23% below what was achieved in 2011. The decline, according to the research was as a result of a sharp fall in solar systems prices and also the effect of policy uncertainty in many countries.

Another reason that led to the sharp fall of the PV systems prices was that, in 2013 there were a lot of cost reductions and efficiency improvement programmes, which enabled a lot of wind and solar PV projects to be constructed around many locations in the world without subsidy support. Solar PV systems can compete as far as there is constant supply of sunshine and there are no cheap indigenous goals or gas feedstock. Figure 15 below shows renewable energy investment from 2004-2013. As can be seen from the bar chart in figure 15, there has been a gradual increase in the investment in renewable energy from the year 2004 to 2011, after 2011, there has been a sharp decrease in the investment due to the fall of the prices in the PV systems worldwide. (Bloomberg & UNEP 2014)

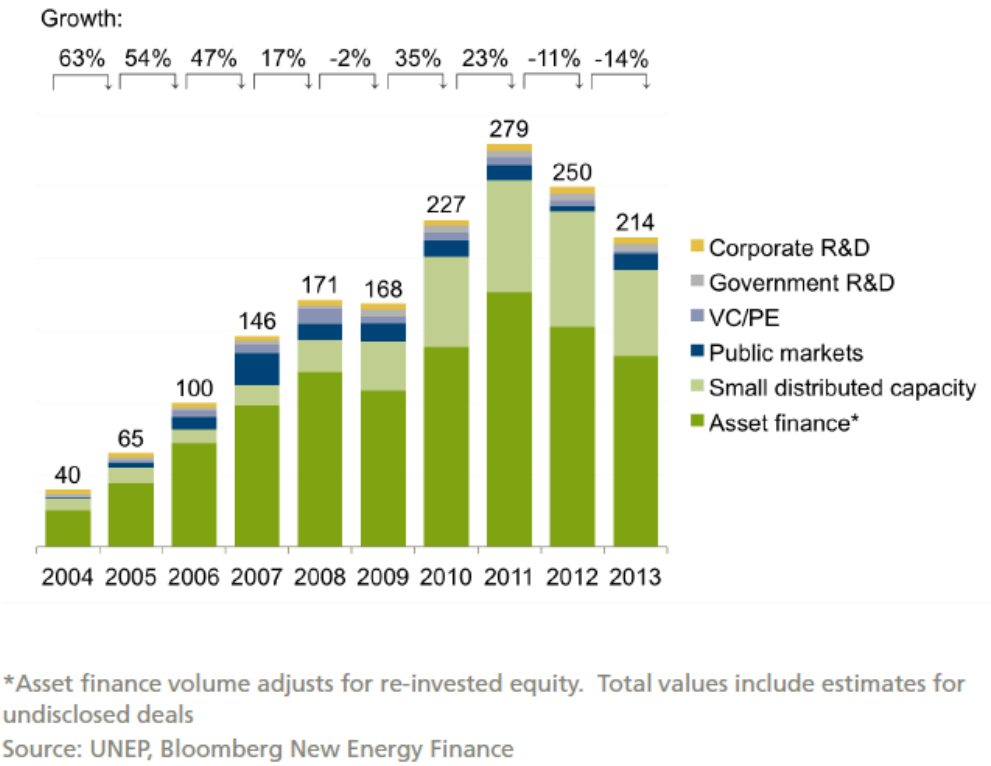
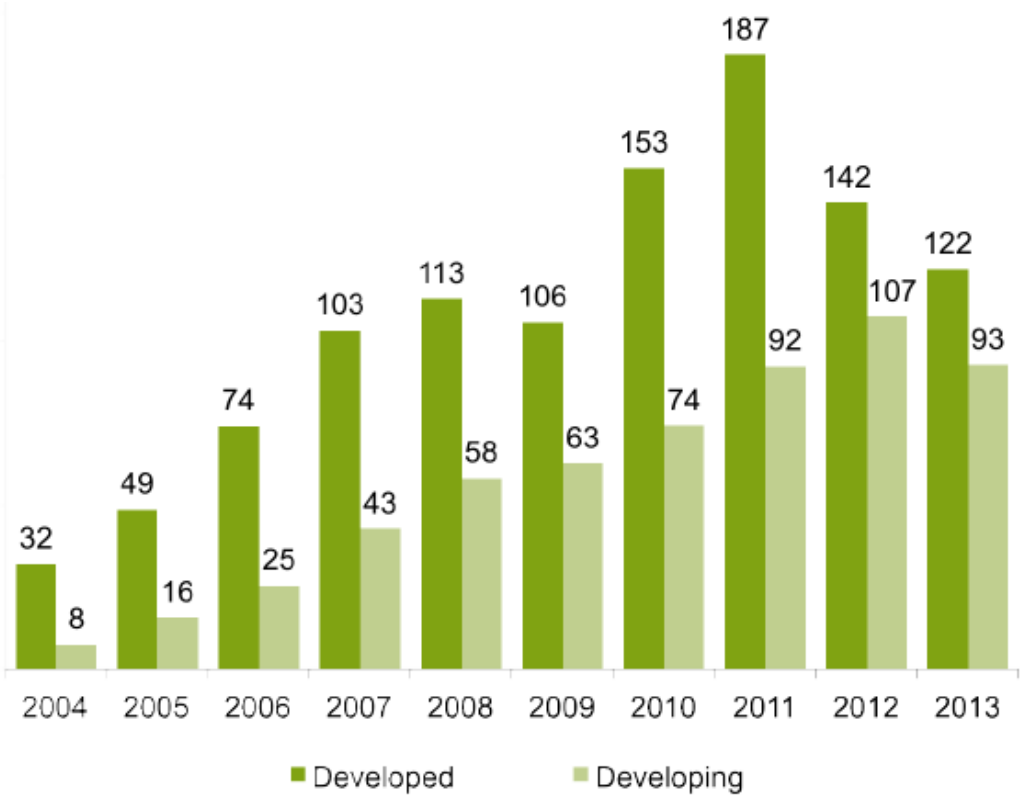


Figure 15. Global New Investment in Renewable Energy by Asset Class, 2004-2012, BN US dollars

Source: UNEP &Bloomberg 2014

Although there were some declines in renewable energy investment around the world, there were also some notable good investment and projects around the world. Many of these projects were in Latin America, Middle East and Africa. Hundreds of millions of dollars worth of investments were made without any subsidies support. Figure 16 below is a comparative bar chart, showing the investment between developed and developing countries around the world. It can be seen that both have made significant investment from 2004 to 2011. It can also be seen that in terms of amount of investments, the developed nations are having higher investment than the developing nations. However, the investments have been increasing gradually. (Bloomberg & UNEP 2014)



New investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals. Developed volumes are based on OECD countries excluding Mexico, Chile, and Turkey.

Source: UNEP, Bloomberg New Energy Finance

Figure 16. Developing and Develop Nations Energy Investment

Source: UNEP &Bloomberg 2014

Figure 17 below, shows that investment in renewable power and fuels in 2013 were dominated by solar and wind respectively. Even though both generation sources experienced a drop in their financial flows of 1% and 20%, they accounted for 90% of the investment in the Renewables excluding large hydro. These research results reveal how far the global awareness about Renewables especially *solar PV systems* has gone. Many people across the globe are gradually becoming aware of the technology, its uses and cost benefits (UNEP &Bloomberg 2014).

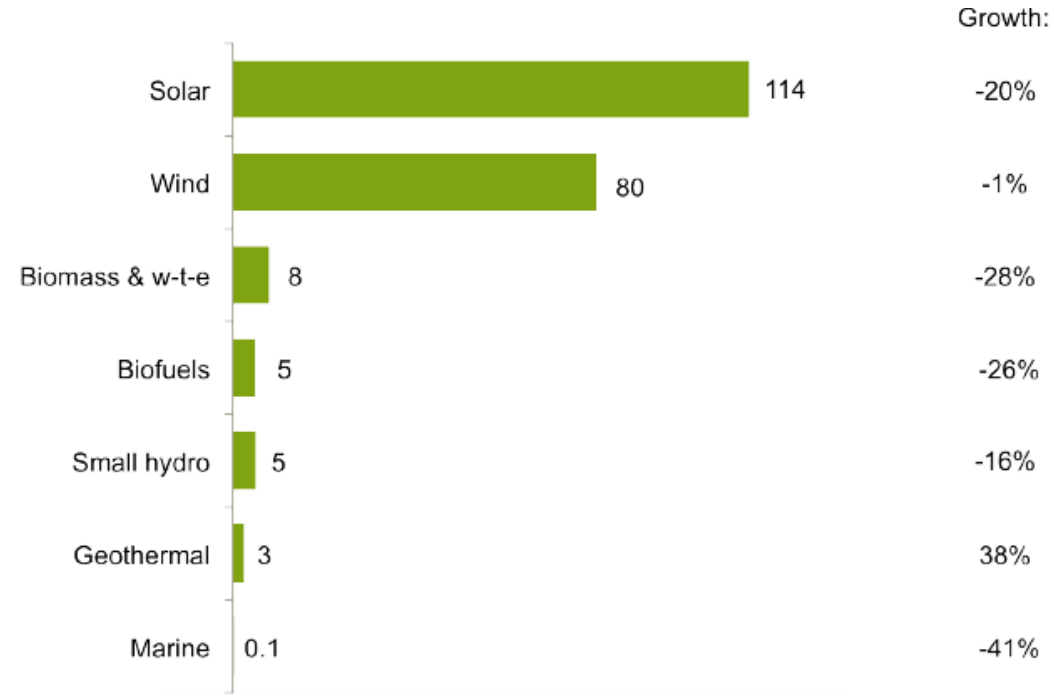


Figure 17. Global Investment in Renewable Energy by sector, 2013 and growth on 2012, BN US dollars

Source: UNEP &Bloomberg 2014

4.4 The existing Supply Chain Network for photovoltaic systems in Ghana

To identify the existing supply chain network for photovoltaic systems in Ghana, a survey was conducted in Ghana among three companies (*Deng GH Ltd, Atlas business, Milky-Way Energy Ltd*) that are in the photovoltaic business. The survey was followed by an oral interview, to try to understand the business and also the challenges facing the PV industry in Ghana. The survey looked at the following areas in the supply chain; *sources of supply, mode of transport, distribution channel, consumers, management systems and challenges.*

For the sources of the supply for PV's, the results indicated that 66.7% from Europe and 33.3% from Asia. And for the batteries, inverters and charge controllers, 66.7% are from Europe and 33.3 from Asia. For the mode of transport, the results revealed that 100% by sea transport. The oral interview of the companies indicated that, the sea transport is better considering the weight of the PV, batteries and other components in relation to the cost; they always prefer sea transport to air transport. All of them indicated that occasionally if a client needs a component that is not heavier, then they use air transport. The results revealed that, the distribution channel type used are 33.3% Assembly to consumer, 33.3% from wholesaler to retailer to consumer and 33.3% from assembly to retailers to consumers. All the three companies interviewed use all the three types of distribution channel. Basically it can be seen as they are doing everything without a well structured distribution channel. This is because consumers can come to them directly without having to go through a retailer. And secondly, through observation, PV retailer locations are not many in Ghana. Most of the companies are in the capital cities and some few bigger cities. So always the consumers have to travel to the source in Accra to purchase the PV. With regards to the consumer types, the results revealed that 66.7% are homeowners and 33.3% are institutions and companies. The management systems used frequently is the use of few suppliers which the results revealed 66.7%

The major challenges facing the supply chain were higher taxes 66.7% and finance 33.3%. During the interview, the companies were asked to throw more light on these challenges. And they revealed that, the port duties are very high on the PV systems components if they are purchased separately. However, if they come together as a complete system then the taxes are very low. But the companies indicated that, this kind of government policy doesn't support their businesses but rather it kills their businesses because it makes the prices of PV's very expensive for the consumer. The second biggest challenges for the companies were sources of finance to expand their businesses. They revealed that, the banks and financial institutions are not ready to lend money to companies to invest in the PV industry because they see it as not lucrative enough to give them returns for their investments. (*See appendix for tables and charts*)

Figure 18 below is a graphical representation of the existing supply chain network for PV's in Ghana

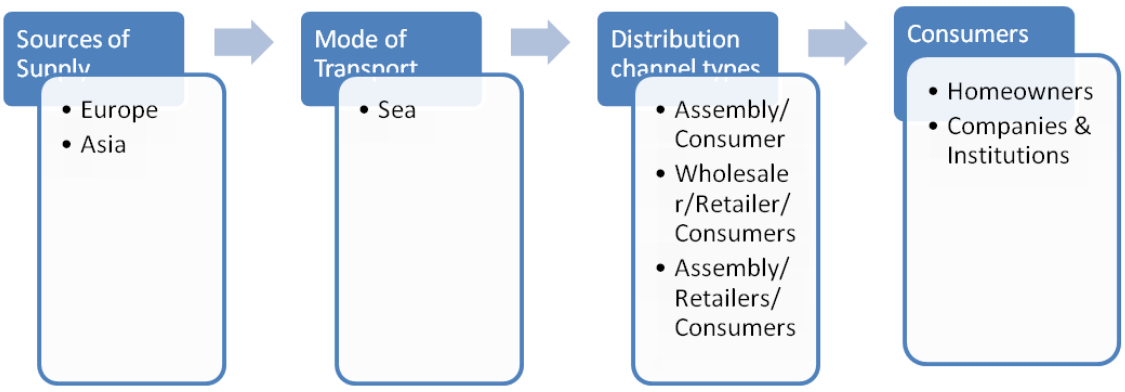


Figure 18. Graphical representation of the existing supply chain network for PV's

4.4.1 Challenges faced by Consumer's of photovoltaic systems

Consumers of photovoltaic systems expect to have constant supply of electricity whenever they need it and they also wish to have adequate knowledge, education, maintenance skills, and distribution centres of PV systems and also to be able to improve the capacity of their installations from time to time. But they are plagued with the following challenges;

a. *Higher initial capital cost and lengthy payback period;* These are cited in literature among the primary barriers of diffusion of PV technology and there are evidences from the United States, Spain, United Kingdom and Canada (Boyle et al 2003; Del Rio & Unruh 2007; Jacobsson & Johnson 2000). And in the case of Canada, a research conducted by TREC, found out that roof top "PV projects are not profitable in Ontario without a reduction in up-front cost of $3,500 – $5,000/kW, an equivalent subsidy or a substantial increase in tariff payments under Ontario standard offer contract program" (Brigham & Gipe, 2007, p4). And Ghana which is a developing country will not be an exception, if the

developed nations are having these challenges then very likely Ghana will also face this challenge, especially when the PV's are not manufactured in Ghana and it has to be transported to Ghana by sea freight. The cost of transportation and port duties will make the product very expensive for the consumer. In addition, consumers may be unable to invest large amount of money in a single transaction and to wait a longtime for a return on their investment. Government should provide subsidies on PV systems so that it can be economically attractive for consumers to buy.

b. *Consumer perceptions and values;* Consumers perceptions may be shaped by many factors and these can be inaccurate, irrational, or unrealistic. Consumers may misunderstand how the technology works; this was observed during the field study in Ghana. There was one particular consumer who misunderstood how the PV technology functions; his assumption was that, during the day time the PV system uses directly the energy from the sun to generate electricity without making use of the battery banks and as such uses the battery banks only in the night. This consumer had to be re-educated to come to understand that, whether day or night time, the system have to store the energy first into the battery banks and after that use the energy that has been stored in the battery banks to generate electricity. Consumers may also perceive the technology as risky or unproven (Bradford 2006; Cooke et al 2007). There has to be enough education on PV systems for consumers.

c. *Awareness & Availability of Information;* Potential consumers need access to information both on policy and on PV technology. PV consumers suffer from a lack of information regarding feasibility and cost of the technology, and existing subsidies. Difficulties and regulatory vagueness may dissuade potential consumers from adopting the technology. And these challenges are very common for the Ghanaian consumer with regards to information on the technology and on policies (Brown 2001; Del Rio & Unruh 2007). The government and business should make information on PV's available through the various media.

d. *Design & Installation Skills;* Proper design and installation is an important factor for all RE systems. Usually, the products are designed by experts and it

must be understood at the consumer level and the local level. This implies that the design must be simple to be understood and installation must also be easy to be done by local technicians. The major problem for developing countries such as Ghana is the installation and maintenance skills at the local level. This is because there are not enough skilled trained technicians in the solar PV business. This usually can be done at the urban centres, but in the rural areas it becomes a challenge. Therefore it is necessary for the manufacturers to make the owner/user manual available in the language of the country in which the product is to be sold (UNIDO 2014).

e. *Maintenance & after sales service;* Maintenance of PV systems are very important. Some systems require little attention on maintenance whiles others also require routine and planned maintenance to ensure proper functionality of the product. In the case of planned maintenance, monies have to be saved to carry out this kind of maintenance and usually for off grid PV systems especially in the rural areas where the income of the inhabitants are very low, it becomes a challenge for them to do the maintenance. Secondly, even when they have the money, there are no skilled technicians to do the maintenance for them. This maintenance issue can be a deterrent for possible PV adopters to move away from the system (UNIDO 2014). So the purpose of this study is to create awareness and to organize seminars and workshops in training such communities.

f. *Training;* Training is very important for PV systems and this training must be organized for the local people and the end consumers. There needs to be extensive training of the local people especially the existing electricians to be able to deal with some simple and major issues related to the PV systems. Users must also be educated on how the PV systems work and how to take good care of the system. Information sharing is also very important, it will be very good to explain what the system can do and what it cannot do. If the information sharing is enough this will help reduce over optimism of what the system can do. This was observed during the field study in Ghana when one of the clients of the company that was interviewed for this research had actually invested huge sums of money into the PV project and as such expected corresponding output of

energy. The client was over optimistic about what the system could do. He wanted the system to be able to power all the electrical appliances in the house at a goal from TV, lights, ceiling fan, 3 refrigerators, electric cooker, rice cooker etc. And the system wasn't able to do all those and somehow he was getting disappointed and he had to be re-educated about what the system could do (UNIDO 2014). Enough education about PV's should be provide for consumers.

g. *Institutional capacity building for microfinance;* Most consumers want the benefits that come with electricity especially those in rural communities in developing countries such as Ghana. But they are faced with one major problem *finance;* lack of capital to pay RE equipment and services. However, this challenge can be overcome by appropriate local credit schemes made available through the banks. In some places and rural communities in Ghana it possible for farmers to get soft loans to buy agriculture implements and chemicals to support their farms. However, there are no such schemes for farmers to buy RE equipments such as solar water pump for irrigation purposes. There is lack of low-cost, long-term financing options (UNIDO 2014).

h. *Women in development;* The role played by women in development is very notable, but in most cases they are underestimated. In the case of PV systems, if many women are given the education about the system, it will help spread the knowledge and awareness very fast. But in the case of developing countries such as Ghana, not all the women have access to formal education. And that is one setback to the dissemination of information. However, there is still a way around it; the education can be done in the local language of the people. The fact that someone has not had formal education does not mean that the person is not intelligent and cannot learn new things. More women should be trained and educated about PV systems (UNIDO 2014).

5 EMPIRICAL STUDY

This chapter discusses the method used for gathering the data and the analysis of the data. It also throws more light on the reliability and the validity of the data. The main research question for this thesis is "*the role of the consumer in the supply chain development of photovoltaic systems in Ghana".* The approach used to gather data for this research were thoroughly broken down to reflect and achieve the goal of the research. The methods used were to capture the consumer's preferences which are a key objective when it comes to their role in the supply chain development.

5.1 Data collection

The data used for this research are both primary and secondary data. The secondary data are mostly facts about the government of Ghana and reports on the energy plans and energy roadmap of the country. There are other sources also, however with regards to primary data on this particular topic of *"the role of the consumer in the supply chain development of photovoltaics in Ghana,* due to lack of adequate data on it, I decided to use this opportunity to collect fresh data and help contribute to knowledge. To get the primary data for this research, a focused group study was first undertaken followed by a field survey and an online survey.

The survey questionnaires were tested on the focused group research to see if they were relevant to the survey environment; and also to find out how the consumers are feeling about this technology, the major challenges and preferences. It was also to help restructure and modify the survey questionnaire. So a focused group discussion was conducted at Obuasi in Ghana. The participants were from various backgrounds; a mechanical engineer, electrical technician, nurse, two entrepreneurs, a driver and IT engineer. There was a very nice discussion about PV systems in relation to the research questions. Each participant was allowed to express him/herself with regards to each question. The aim of this was to find out if they all share the same or different opinions and ideas. The researcher was the modulator. Care was taken that no one person

dominated the discussion with strong opinions. The focused group discussion was audio recorded to help the research to be able to connect the ideas so as to restructure the research questionnaire and also for future references. The discussion lasted for (51) fifty one minute. In most literature, the duration for a focused group discussion is from 45 minutes-1 hour, and this research satisfied that condition.

A survey questionnaire was developed afterwards based on the responds of the focused group discussion. And also the survey questionnaires were designed with the key parameters that define a supply chain network in relation to the preferences of the consumer. The key areas that were taken into consideration are; *consumer type, availability, cost of product, PV's electrical output capacity, maintenance services, education, feedback and challenges.* The survey was conducted on two different mediums; one was on the field and the other on the internet. On the field, the survey was conducted in three regions out of the ten regions. The online survey was also conducted with the aid of an online organization called *survey monkey*. The same questions were posted to Ghanaians who are on various social media network to participate.

Next are the summary of the answers to each question from the focus group discussion.

1. ***How important is accessibility to you when choosing a place to purchase PV systems or solar panels?***

   All the participants agreed that if the accessibility is very high and also if it is closer to their vicinity that is more preferred than buying from a distant location. Factors considered includes; risks involve in transportation, time spent on transportation, cost of transport and feedback system to the dealer. They preferred that since it is a new technology to the Ghanaian environment, the agents or dealers should be closer so that they can report faults and malfunctions easily.

2. ***Would you prefer to buy solar PV systems and its components from one dealer? YES OR NO, and why?***

   They preferred one dealer for the reasons of PV components compatibility, inferior goods in the market and also the ability to trace whom to apportion blame if the system fails to work. It is easier to deal with one dealer that multiple dealers. The running cost is cost effective for one dealer than multiple dealers.

3. ***How important is price to you when choosing PV systems?***

   According to the participants, price determines the quality and capacity of the product; the higher the price the better the quality. They will prefer to have an expensive product which will last for them than a cheaper product that brings them a lot of running cost. At the same time they compared the price of solar PV system in Ghana in relation to how much they pay for the grid connection. And the solar was seen to be extremely expensive, even though they would prefer to have it as a back –up.

4. ***What factors will you consider when buying a PV system?***

   The following points came out; efficiency of the product, economical, initial cost of the product, availability of maintenance and training centres.

5. ***Where will you prefer to go for PV systems maintenance and services?***

   Dealers and to be trained how to do it.

6. ***Is education and information awareness about PV systems very important?***

   Education is very important and it must start from the highest level of the Ghanaian society to the lowest level. It must be done both in urban and rural centres. The medium suggested were; house to house campaign in the sense that people could ask all the necessary questions about the product. Second was

television and radio, because it has wider coverage in Ghana and most people get a lot of education from the TV and radio on various subjects, so it is also seen as other best means to reach consumers

7. ***What medium would you prefer to use to give feedback to your dealer?***

   Social media (Wattsapp, facebook), telephone

8. ***What are the key challenges in buying PV systems?***

   Finance – Initial capital to invest in PV systems is a problem in Ghana. Secondly, most people are tenants, so they fear that making such an investment on somebody's else's property is not worth it because it may become a challenge for them if they want to relocate to a new house. Then they have to spend money again to remove and reinstall in their new house. However, it is easier to dismantle the system without much cost.

9. ***Is there any idea or contribution that can be added further to improve the supply chain?***

   Consumers should educate their friends about PV systems through word of mouth recommendations. Alternative financing from the banks will also help the supply chain.

5.2 Analysis of the data collected

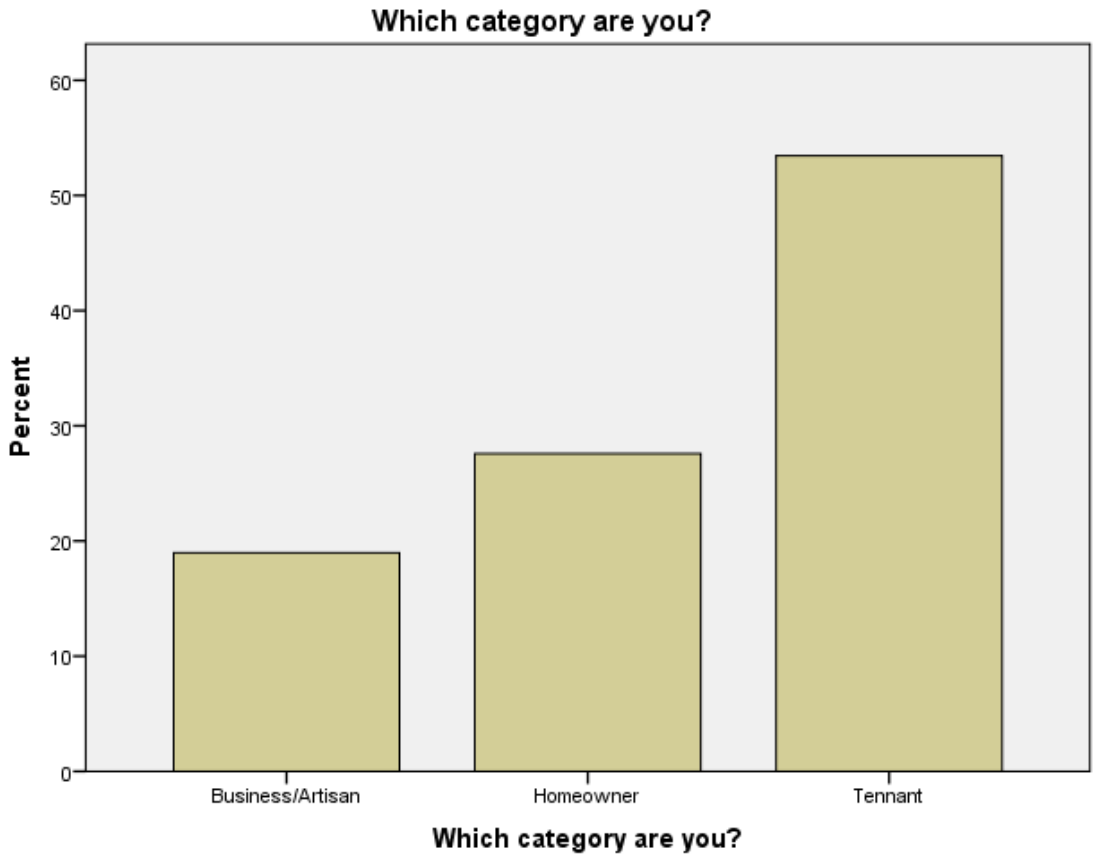


Figure 19. Categories of PV Consumers

From figure 19 above, there were three main categories that were the focus of this research; business/artisan, homeowner and tenants. The results revealed that 53.4% of the respondents were Tenants, followed by 27.3% of homeowners and 19.0% business/artisans. The reason for the higher number of tenants is because in Ghana many residents do not have their own homes; they rent apartments. So the number of tenants by default is higher than the number of homeowners and businesses.

The first question was about convenience of purchase of a PV system; the figure 20 below shows the results. The results revealed that 32.8% felt convenience was extremely important whiles 37.9% very important and 15.5% moderately important. So based on the results it can be concluded that convenience is very important for the

consumers in Ghana since half of the respondents are leaning more to extremely convenient, it suggest that the priority is that convenience is preferred with regards to PV systems.

Figure 20. Convenience results

The second question was about which place consumers will choose to buy PV systems from. The results are revealed in the table 4 below.

Table 4. Solar PV System and Components results

Which place will you choose to buy solar PV systems and its components?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Nearest Retailer	18	31,0	31,0	31,0
	Assembly/Production	12	20,7	20,7	51,7
	Distributor/Wholesaler	18	31,0	31,0	82,8
	Agent	10	17,2	17,2	100,0
	Total	58	100,0	100,0	

The results revealed that 31.0% of the consumers will prefer to buy from the nearest retailer, whiles another 31.0% will also prefer to buy from the distributor/wholesaler, 20.7% will also prefer assembly/production and 17.2% from agents. The higher percentage in the nearest retailer as choice for purchase could be as a result of higher level of convenience expected by the consumer. And also the higher percentage in distributor/wholesaler as a place for purchase could be as result of price reasons. Because in Ghana many people have this preconceived idea that distributor/wholesale level purchase is quite cheaper than at the retail level and as a result would prefer to buy from the distributor/wholesale level. However, it is noteworthy to note that not all consumer goods can be purchased at the distributor/wholesale level by the end consumer. For some products the end consumer has to buy from the retail level for business and other reasons. It can also be noted that quite a percentage of the consumers will also prefer to buy from the assembly/production level, reasons which could be due to quality issues and also closer interaction with the manufacturer in terms of education, maintenance and warranties. Some of the consumers are with the notion that to avoid buying inferior goods, it is necessary to buy from the original source that is the assembly/production.

The third question was about if consumers would prefer to buy PV systems from one dealer? The results revealed that 46, 6% extremely prefer whilst 29, 3% very preferable and 13% not preferred at all. Based on the results, it can be concluded that most consumers would prefer to buy from one dealer than from different dealers. The rationale behind this decision was explained during the focused group research and on the field study. Many consumers openly said that they would prefer to get everything from one dealer so that if something doesn't work they can hold the person responsible than with different dealers; in that case it becomes difficult isolating the problem.*(See appendices for table and chart)*

The fourth question was about the importance of price to consumers. Figure 21 below gives a picture of the results. The results revealed that 48,3% it was extremely important to them, 34.5% very important whilst 5.2% it was slightly important, so it can be concluded that price is very important to consumers and as such businesses should try to reduce the running cost of their business so that the end consumers can have the products at affordable prices. From my field experience in Ghana, many consumers that I spoke to appreciated the PV technology but at the same time lamented about the higher prices of PV products. And they expressed that if the prices were a little bit lower most of them would try the solar PV technology considering the current power outages in Ghana.

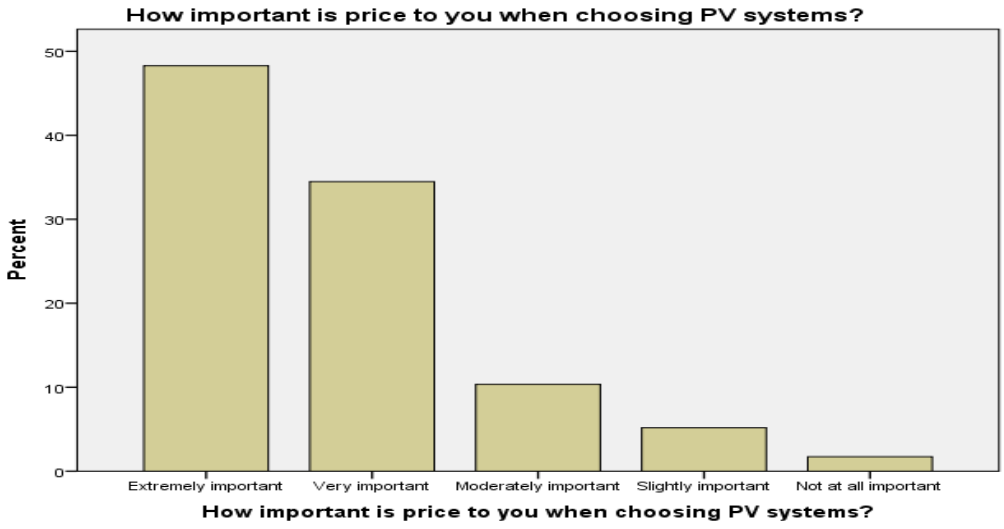


Figure 21. Results of Price

The fifth question was about output capacity level of PV systems that consumers would prefer to buy. The results revealed that 32.8% preferred very high output, 32.8% also preferred high output and 29.3 moderate output, whilst 3% low output. So in total it can be concluded that consumers prefer solar PV systems with higher electrical energy output. And the reasons for this can be seen from the availability of a lot of electronic and domestic electrical appliances in an average home in Ghana. Many consumers are using refrigerators, TV's, ceiling fans, lights, mobile phones, microwaves, audio sound systems etc. And all these demand a lot of energy. *(See appendices for table and chart)*

The sixth question was about where consumers would like to go for PV maintenance and services. The results revealed that 77.6% preferred PV maintenance specialist centre, 10.3% distributor, 1.7% PV agent. So it can be concluded that consumers would like to have their maintenance and services from PV maintenance specialist centre. The figure 22 below gives a clear picture.

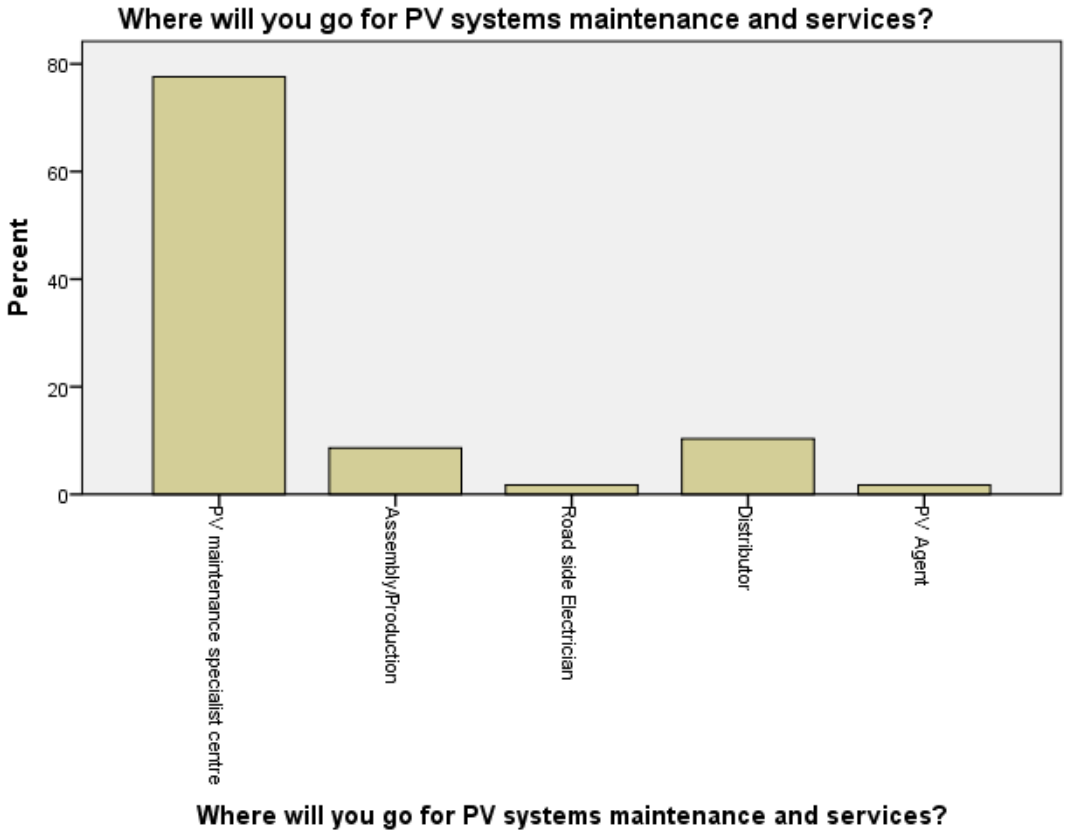


Figure 22. Results of Maintenance and Services

The seventh question was about where consumers would like to have education and information awareness on PV systems. The results revealed that the key areas that consumers would prefer to have education and information awareness were; 18% TV, 17% internet, 16.5% house to house, 11.8% schools, 11.8% radio, 9.4% social media etc. *(See appendices for table).* The results are true reflection of the Ghanaian society in terms of information and education awareness. Most people are always on the TV for news and general information, the younger generations are on the internet and social media platform, most small and medium sized business usually use radio for advertisement and as such listen to radio often for general news and other information. In Ghana, for mass sensitization information awareness and education on a specific project, the government usually uses house to house education as one of the platforms in addition to TV education. And from personal experience on the field during this research, most consumers said they prefer house to house education in the sense that, they can ask all the questions that they may have in mind concerning PV systems.

The eight questions, was about the medium of feedback to dealers. The results revealed that 60% telephone, 15.5 % emails, 15.5% personal visit, 13.8% social media and 3.4% postal services. The results are a true reflection of how Ghanaian consumers give feedback to their dealers in any other business circumstances. Usually, many prefer first to use the telephone to make their complaints and dissatisfaction about a product or service. The next method is true personal visits; usually consumers go unannounced to the premises of the dealer to complain about a service or product. And during the field study, it was observed that the use of social media in Ghana is on the ascendancy and as a result many businesses have social media page which consumers can use to give feedback on their purchases. *(See appendices for table)*

The ninth question was about the challenges that consumers may face when it comes to purchasing PV systems. Table 5 below gives a summary of the results. The results revealed that 53.3% finance, 23.3% education, 13.3% availability and 10% information. From personal experience and first hand information on the field, most consumers complain about the higher prices of PV systems in Ghana in relation to sources of

finance to purchase them. Others also expressed their views concerning the intensity of education on PV systems in Ghana as very low. Others also told me that, the products are not available in their locality, if it is available they will give it a try and through that they will get to know more about it. Others also expressed their view on the availability of information on PV systems as also very low, because they don't know even where to go for information on PV systems.

Table 5. Results of Challenges

$Challenges Frequencies

		Responses		Percent of Cases
		N	Percent	
Challenges PV[a]	Financeq9	32	53,3%	59,3%
	Informationq9	6	10,0%	11,1%
	Educationq9	14	23,3%	25,9%
	Availabilityq9	8	13,3%	14,8%
Total		60	100,0%	111,1%

5.3 Reliability and validity of the research process

Reliability in a scientific research means that the study should be able to be repeated with the same outcome and conclusion if the same procedures are followed by another researcher (Yin 2003: 37). In this research, structured interviews were conducted among photovoltaic business in Ghana. The questions were typed and forwarded to the businesses which accepted to take part in the research. The questionnaires were answered and it was followed up by an oral interview which concerns the questionnaires. The aim of this was to double check the results and also to capture things which the questionnaires failed to capture. If this same procedure is followed by another researcher, the same outcome and conclusion would be reached. Secondly, a survey was conducted among the consumers in Ghana, but before the survey, a focused group discussion was conducted to ensure that the survey questions were suitable for the survey environment. Afterwards the survey was conducted. If another researcher follows the same procedure the same results would be achieved. So with regards to reliability of this research, it can be said to be very high.

Validity means that all parts of the research are in harmony. Validity is about whether the research is measuring what is supposed to measure; does the research finding reflect the overall research objectives (Saunders et al 2007: 150). One important way to check the quality of a case research like this one is through the construct validity (Yin 2003:35). It is about establishing the correct operational measures for the concepts been researched. This implies that, the underlying features of the constructs are well understood on the same level for both the researcher and the respondents of the research. This research is on four key constructs; *supply chain, photovoltaic systems, consumers and renewable energy.* The definitions of these terms were taken from existing research, and their meanings were well understood by interviewees and survey respondents, so the construct validity in this study is very high.

Another important factor to consider in this research is *external validity.* It is about the generalization of the findings of the research (Yin 2003: 37). The data for this research were gotten from different multiple reputable institutions in Ghana such as the *energy*

commission, the ministry of energy, PURC etc. And in addition a primary data was taken through interview and survey. The survey was a sample of the population of Ghana, so therefore the results of this research can be generalized to the entire population.

6 CONCLUSIONS

This chapter gives the summary of the overall findings of this research. First and foremost a brief highlight is made to the objectives and research questions of the research, and then conclusions and recommendations are offered based on the survey's outcome. Afterwards limitations of the research will be highlighted and future research questions will also be suggested.

The objectives of this research were;

- *To investigate consumers expectations of photovoltaic energy technologies efficiency, reliability and affordability.*
- *To develop a supply chain network for solar photovoltaic systems in Ghana*

To identify the role that consumers can play in the supply chain development of PV systems in Ghana is not a straight forward thing. To be able to identify the role of the consumer, one has to be able to identify the preferences of the consumer, thereby getting to know both the direct and indirect role played by the consumer. To get to the bottom of this research, two key research questions were used as the guide;

- *What are the existing supply chain networks for photovoltaic systems in Ghana?*
- *What are the challenges and expectations of consumers of photovoltaic energy system in Ghana?*

6.1 Key Findings of the research

The research outcome revealed that, for the existing supply chain for PV systems in Ghana, the *sources of supply* are mainly from Europe and Asia, and the most used mode of *transport* is the sea. The research revealed that with the distribution channel types used in Ghana, are not clearly specified; almost all the companies that were interviewed uses all the various types of distribution channel (*wholesaling, retailing and assembling)* and as such the channel types are not stronger and efficient as compared to some other industries like soft drinks industry, cement industry, etc. During the field

work it was observed that, there were basically no retail centres for PV system in other parts of Ghana. If someone is interested in PV's, that individual has to make purchase from Accra.

The research also revealed that, most of the consumers of PV systems in Ghana were *homeowners, companies and institutions.* There were few tenants who were using this technology. Through the focus group study and discussion, it was revealed that most tenants were afraid that if they install solar PV systems on a rented apartment it may be difficult or come with additional cost if they later want to relocate to their own homes or a new apartment. Some tenants also through oral discussion also revealed that, they fear it can bring about jealousy to the landlord or landlady, especially when there are light outs and it is only the tenant who is having electricity in his/her apartment alone; that can lead to them been ejected from the place as the property owner may think otherwise. These are cultural issues related to the PV systems in Ghana.

With regards to the second research question about *the challenges and expectations of consumers*, the outcome of the research revealed that the biggest challenges for consumers in Ghana were; *finance 53.3%, education 23.3%, availability 13.3%,* and *information 10%* respectively. The expectations of the consumers were numerous, but the key ones that relate to supply chain development were; *convenience, nearest location, price very important, products output capacity and maintenance.*

Consumers expect high level of *convenience* in the supply chain development of PV systems in Ghana, reasons such as transportation cost, damages as result of long transport, quick feedback and product installation support from the distributor were mentioned as the reason for a nearest place or retailer. The results of the research revealed that *price* was very important to the Ghanaian consumers, some highlighted during oral discussion that, if the PV products are good but too expensive, they cannot buy, so they prefer a moderate price in relation to the general cost of grid electricity in Ghana. The results of the research revealed that *output capacity* is also very important for consumers, most prefer higher output capacity, because during the field survey many who took part in the research had the believe that solar PV system cannot give the same

power output as the grid, so they were a bit skeptical looking at the amount of huge monetary investment they have to make.

Finally, the results revealed that consumers prefer *PV systems maintenance specialist centre*, to be part of the supply chain development, because many highlighted the need for a maintenance centre closer to them to take care of their system on a regular interval basis.

6.2 Recommendations

There are a lot of challenges facing solar PV business and consumers in Ghana. However, the major challenges have been highlighted in this research. This section will propose some recommendations for policy makers, businesses and consumers.

First and foremost, government should amend the policies on renewable energies so that, the importation cost which are mostly high as a result of higher taxes on PV systems at the ports could be reduced so that the end consumer can afford to buy. Secondly, government should provide the framework which will help PV business to grow. And also should negotiate on behalf of PV business and consumers with the financial institutions in Ghana to provide soft loans for PV business and consumers.

Thirdly, both the government and PV business should provide mass education on PV systems through the various forms of media such as TV, radio, newspaper, schools, internet, house to house campaign etc., to raise the awareness about PV's. Business should improve their supply chain by putting the needs of the consumer in to the design process. Business should try to improve their distribution channel types and their presence in most of the other parts of Ghana by opening offices and agents. There should be a lot of distribution centres and retailers in Ghana for PV's, and business can use those business who are already operating in general electrical goods as their retailers, this is because there are a lot of retailers for electrical appliances and as such using them will increase the awareness and the penetration of PV's in the Ghanaian society.

Fourthly, businesses and companies should offer PV systems training and workshop to retailers, agents and consumers who would like to do their own installations. Businesses should create PV maintenance specialist centres across the country.

Finally, consumers should make conscious effort to learn more about PV's and also to try it.

6.3 Limitations of the Research

This research has some limitations. These are in the areas of sample size, data gathering methodology, government official's interview and consumer's coverage. These limitations are discussed below.

The first limitation was the inability to take samples from each region in Ghana. The survey was conducted in four regions out of ten regions in Ghana, which can actually affect the results of the research if the whole regions were covered. Secondly, the sample size was smaller in relation to the overall population of Ghana, therefore the results cannot be *over generalized* to include the entire country but it could only be used to some level. The reasons for the inability to cover all the regions in Ghana were as result of finance and the limited amount of time.

The second limitation of this research was the method used to gather the data. After the analysis of the results, it was realized that, the needs of the different categories of the consumers cannot be separated in the supply chain development but have to be combined. And this was as a result of the way the questionnaires were structured. The lesson learn't is that next time it will be better to have different set of questions for the different category of consumers of PV systems, because their needs are not the same, therefore the same questionnaire for all of them may not actually bring the correct results

Furthermore, it would have been better to interview some government officials in the energy ministry to know the challenges that they are facing and the mechanisms that

they have putting in place to ensure that the renewable energy policies in the country are working. This is because from the interview with the PV businesses, higher taxes are killing their business and consumers also complain that PV systems are expensive. Even though it is written in the policies that free importation taxes on PV systems, it seems that policy is not working at the Ports, because businesses have to pay higher taxes before they can get their goods. So it would have been better to know from the ministry if they are aware that higher taxes are charged on PV systems even though it is written that it should be free. And how are these higher taxes on PV systems going to help the government achieve its goal of 10% renewable energy mix in the country and also how is it going to help business and consumers?. But because of limited amount of time these couldn't be factored earlier in the research. But hope to include in future researches.

Finally, this research was limited to consumers who are using standalone PV systems and also those who intend to use standalone in the future. The research didn't include those who are connected to solar farms. So it will be better to include consumers who are making use of solar farms in future research.

6.4 Future research suggestions

This research suggests some future research questions for scientific studies.

1. *What are the needs of the various categories of consumers for photovoltaic supply chain development in Ghana?* This will help categorize the needs of the various consumer groups so that it can help businesses and policy makers to make the right decisions.
2. *Solar farms versus single panels which ones are the best in terms of business model in Ghana?* This research will help both policy makers and businesses to know which areas of PV's, to invest more. And it will also help consumers as well to know which of the methods can serve their needs
3. *Project development of PV's for real estate developers in Ghana*. This research will create awareness for real estate developers to include solar PV systems as a backup energy system to their housing projects in the future.
4. *PV businesses opportunity investment awareness for banks and financial institutions in Ghana.* The aim of this research is to create some special awareness for banks and financial institutions to offer loans and financial assistance to solar PV business in Ghana. This research will help them to see the future prospects of PV businesses and their profitability with the constant rising energy problems in Ghana.
5. *What mechanisms can the energy ministry put in place to ensure that energy policies are working well?* The aim of this research will be to provide practical key performance indicators for the ministry to be able to monitor the functionality of their policies.

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APPENDICES

APPENDIX 1. Invitation Letter For Businesses

Vaasan yliopisto
UNIVERSITY OF VAASA

Dear Sir/Madam,

Please I would appreciate if you could spend about 10-15 minutes of your valuable time in answering this question. This questionnaire is part of a Master's thesis at University of Vaasa, Finland. The aim is to find out "*the existing supply chain network for photovoltaic systems in Ghana"*. Furthermore, the questionnaire will help address the major challenges facing the distribution network of photovoltaic systems and to understand the impact of government policies on photovoltaic systems. The results of this survey could be used by policy makers, investors, energy companies and marketing firms in making important decisions concerning the current energy crisis in Ghana. Your contributions and ideas are warmly welcomed. All answers given will be handled confidentially.

Thank you very much in advance for your co-operation.

Yours Sincerely,

Benjamin Tham-Mbiah (MSc Candidate)
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Supervised by:

Prof. Josu Takala

Dr. Emmanuel Ndzibah

APPENDIX 2. Solar Companies Research Questionnaire Sample

COMPANY PROFILE

Name of Company Click here to enter text.

Address Click here to enter text.

Tel Click here to enter text.

Website Click here to enter text. **Email** Click here to enter text.

Contact Person Click here to enter text.

Position In Company Click here to enter text.

Sector type: ☐Distributor /Wholesale ☐Assembly / Production ☐Agent ☐ Retailer

SOURCES OF SUPPLY

1. Where do you get your supplies for PV systems from?
   ☐Europe ☐Americas ☐Asia ☐Africa ☐Other
2. Where specifically do you buy from?
   ☐Factory ☐Distributor / Wholesaler ☐Retailer ☐Other
3. Do you buy all the components of the PV systems from one supplier?
   ☐YES ☐NO
   If you answered NO to question 3, please answer question 4-7, otherwise proceed to question 8

4. Where do you get your supplies for battery?
   ☐Europe ☐Americas ☐Asia ☐Africa ☐Other
5. Where do you get your supplies for PV panel?
   ☐Europe ☐Americas ☐Asia ☐Africa ☐Other
6. Where do you get your supplies for inverters?
   ☐Europe ☐Americas ☐Asia ☐Africa ☐Other
7. Where do you get your supplies for charge controllers?
   ☐Europe ☐Americas ☐Asia ☐Africa ☐Other
8. Would it be if cheaper if you get all your PV components from one supplier?
   ☐YES ☐NO

TRANSPORT

1. How do you transport your PV systems to Ghana?
   ☐Sea ☐Air ☐Land
2. Is the means of transport cost effective?

☐Extremely cost effective ☐Very cost effective ☐Moderately cost effective ☐Quite expensive ☐Very expensive

3. How fast do you get your PV supplies from where you selected above?
   ☐1-2 weeks ☐ 3-4 weeks ☐5-6 weeks ☐7-8 weeks ☐9-10 weeks ☐More
4. What do you think about the Port duties and taxes on PV systems?
   ☐Very expensive ☐Expensive ☐Moderate ☐OK ☐Good

DISTRIBUTION CHANNEL

1. What kind of distribution channel type do you use?
   ☐Assembly / Consumer ☐Assembly/ Retailers/Consumers
   ☐Wholesaler/Retailer/Consumers ☐Assembly/Wholesaler/Agent/Consumer

CONSUMERS

1. Who are your main customers?
   ☐Companies/Institutions ☐Artisans ☐ Tenants ☐Homeowners

2. Do consumers purchase all the components of PV systems from you
   ☐Always ☐Almost always ☐Quite sometimes ☐Not always ☐Not at all
3. How do you get feedback from your customers/consumers after purchase?
   ☐Telephone ☐Fax ☐E-mail ☐Postal Service ☐Social Media
4. How satisfied are your customers?
   ☐Not at all ☐Somewhat ☐Satisfied ☐Quite Satisfied ☐Very Satisfied

MANAGEMENT / IT SYSTEMS

1. How do you manage your supply chain?
   ☐Close partnership with suppliers
   ☐Close partnership with customers
   ☐JIT Supply
   ☐E-procurement
   ☐Few suppliers
   ☐Many suppliers
   ☐Holding safety stock
   ☐Use of external consultants
   ☐Others, specify
   Click here to enter text.

2. What type of supply chain management systems do you use in support of your process?
   - ☐ Materials Requirement Planning (MRP)
   - ☐ Manufacturing Resources Planning
   - ☐ Enterprise Resource Planning (ERP)
   - ☐ Warehouse Management System (WMS)
   - ☐ CustomerRelationship Management (CRM)
   - ☐ Just In Time (JIT)
   - ☐ Bar coding
   - ☐ RFID technology
   - ☐ Other, specify

CHALLENGES

1. What are the challenges facing your supply chain?
   ☐Finance ☐Delivery time ☐Quality of goods
   ☐Higher Taxes ☐Others specify Click here to enter text.

2. At which level of the supply chain do you face most challenges?
   ☐Supplier level ☐Logistics/Transportation level ☐Distribution level
   ☐Retailer level ☐Consumer level
3. How satisfied are you with the current government policies on photovoltaic business/supply chain?
   ☐Not at all ☐Some what satisfied
   ☐Quite satisfied ☐Very satisfied

APPENDIX 3. Focused Group Discussion Questionnaire

1. How important is accessibility to you when choosing a place to purchase PV systems or solar panels?
    - *Would you prefer to buy from the nearest place or you will prefer to buy from a distant place? And why?*
    - *In issues of accessibility*
2. Would you prefer to buy solar PV systems and its components from one dealer? YES OR NO, and why?
3. How important is price to you when choosing PV systems?
4. What factors will you consider when buying a PV system?
    - *Does the output capacity of the PV matters to you?*
    - *Does the portability also matters to you?*
5. Where will you prefer to go for PV systems maintenance and services?
    a. *Are you willing to be trained to do it yourself or you will prefer a specialist?*
6. Is education and information awareness about PV systems very important?
    - *Where will you prefer to have education and information awareness on PV systems?*
7. What medium would you prefer to use to give feedback to your dealer?
8. What are the key challenges in buying PV systems?
9. Is there any idea or contribution that can be added further to improve the supply chain?

Thank you all for your participation.

APPENDIX 4. Invitation Letter For Consumer's

Dear Sir/Madam

Please I would appreciate if you could spend about 5-10 minutes of your valuable time in answering this question. This questionnaire is part of a Master's thesis at University of Vaasa, Finland. The aim is to find out "*the role of the consumer in the development of the supply chain for photovoltaic systems in Ghana"*. Furthermore, the questionnaire will help address the major challenges facing the consumer in the supply chain of photovoltaic systems in Ghana. The questionnaires are designed to capture the consumer's preferences in the supply chain. The results of this survey could be used by policy makers, investors, energy companies and marketing firms in making important decisions concerning the current energy crisis in Ghana. Your contributions and ideas are warmly welcomed. You are required to answer the questions anonymously. All answers given will be handled strictly confidential.

Thank you very much in advance for your co-operation.

Yours Sincerely,

Benjamin Tham-Mbiah (MSc Candidate)
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Faculty of Technology
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bmbiah@yahoo.co.uk

Supervised by:
Prof. Josu Takala
Dr. Emmanuel Ndzibah

APPENDIX 5. Consumer Survey Questionnaire

Category type:

☐ Business/Artisan ☐ Homeowner ☐ Tennant

1. How important is convenience to you when choosing a place to buy PV systems or solar panels?
   ☐ Extremely important ☐ Slightly important
   ☐ Very important ☐ Not at all important
   ☐ Moderately important
2. Which place will you choose to buy solar PV systems and its components?
   ☐ Nearest Retailer ☐ Assembly/Production ☐ Distributor/Wholesaler
   ☐ Agent
3. Would you prefer to buy solar PV systems and its components from one dealer?
   ☐ Extremely preferable ☐ Slightly preferable
   ☐ Very preferable ☐ Not at all preferred
   ☐ Moderately preferable
4. How important is price to you when choosing PV systems?
   ☐ Extremely important ☐ Slightly important
   ☐ Very important ☐ Not at all important
   ☐ Moderately important
5. Which of these electrical output capacities will you choose when selecting a PV system?
   ☐ Very high output ☐ High output ☐ Moderate ☐ Low output
   ☐ Not important
6. Where will you go for PV systems maintenance and services?
   ☐ PV maintenance specialist centre ☐ Road side Electrician
   ☐ PV Agent ☐ Assembly/Production ☐ Distributor

7. Where would you like to have education and information awareness on PV systems?

☐ TV	☐ Business's website	☐ Schools
☐ Radio	☐ News paper	☐ Community centre
☐ Internet	☐ Social Media	

8. Which medium will you prefer to use to give feedback to your dealer?

☐ Telephone ☐ Postal Services ☐ Email ☐ Personal visit

☐ Social media page

9. What are the major challenges for you when it comes to purchasing PV systems?

☐ Finance ☐ Information ☐ Education ☐ Availability ☐ Usability

APPENDIX 6. Consumer Survey Responses Tables

Question 3

Would you prefer to buy solar PV systems and its components from one dealer?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely preferable	27	46,6	46,6	46,6
	Very preferable	17	29,3	29,3	75,9
	Moderately preferable	2	3,4	3,4	79,3
	Slightly preferable	4	6,9	6,9	86,2
	Not at all prefered	8	13,8	13,8	100,0
	Total	58	100,0	100,0	

Question 5

Which of these electrical output capacities will you choose when selecting a PV system?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very high output	19	32,8	32,8	32,8
	High output	19	32,8	32,8	65,5
	Moderate	17	29,3	29,3	94,8
	Low	3	5,2	5,2	100,0
	Total	58	100,0	100,0	

Question 7

$Infoawareness Frequencies

		Responses		
		N	Percent	Percent of Cases
Infoawareness PV[a]	TVq7	16	18,8%	27,6%
	Radioq7	10	11,8%	17,2%
	Internetq7	15	17,6%	25,9%
	Businesswebq7	4	4,7%	6,9%
	Newspaperq7	5	5,9%	8,6%
	SocialMediaq7	8	9,4%	13,8%
	Schoolsq7	10	11,8%	17,2%
	Communitycenterq7	3	3,5%	5,2%
	Housetohouseq7	14	16,5%	24,1%
Total		85	100,0%	146,6%

Question 8

$Feedback Frequencies

		Responses		
		N	Percent	Percent of Cases
Feedback sales[a]	Telephoneq8	35	55,6%	60,3%
	Postalservicesq8	2	3,2%	3,4%
	Emailq8	9	14,3%	15,5%
	Personalvisitq8	9	14,3%	15,5%
	Socialmediaq8	8	12,7%	13,8%
Total		63	100,0%	108,6%

APPENDIX 7. Businesses Survey Responses Tables

Which sector do you operate?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Assembly/Production	3	100,0	100,0	100,0

Where do you get your supplies for PV systems from?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Europe	2	66,7	66,7	66,7
	Asia	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

Where specifically do you buy from?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Factory	3	100,0	100,0	100,0

Do you buy all the componenets of PV systems from one supplier?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	3	100,0	100,0	100,0

Where do you get your supplies for battery?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Europe	1	33,3	33,3	33,3
	Asia	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

Where do you get your supplies for PV panel?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Europe	2	66,7	66,7	66,7
	Asia	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

Where do you get your supplies for inverters?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Europe	2	66,7	66,7	66,7
	Asia	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

Where do you get your supplies for charge controllers?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Europe	2	66,7	66,7	66,7
	Asia	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

Would it be cheaper if you got all your PV components from one supplier?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	2	66,7	66,7	66,7
	NO	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

How do you transport your PV systems to Ghana?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Sea	3	100,0	100,0	100,0

Is the means of transport cost effective?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Quite expensive	1	33,3	33,3	33,3
	Very expensive	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

How fast do you get your PV supplies from where you selected above?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	7-8 weeks	1	33,3	33,3	33,3
	9-10 weeks	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

What do you think about Port duties and Taxes on PV systems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very expensive	3	100,0	100,0	100,0

What kind of distribution channel type do you use?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Assembly/Consumer	1	33,3	33,3	33,3
	Wholesaler/Retailer/Consumer	1	33,3	33,3	66,7
	Assembly/Retailers/Consumers	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

Who are your main customers?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Companies/Institutions	1	33,3	33,3	33,3
	Homeowners	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

Do consumers purchase all the components of PV systems from you?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Always	1	33,3	33,3	33,3
	Not always	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

How do you get feedback from your customers/Consumers after purchase?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Telephone	3	100,0	100,0	100,0

How satisfied are your customers?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Quite satisfied	1	33,3	33,3	33,3
	Very satisfied	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

How do you manage your supply chain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Close partnership with suppliers	1	33,3	33,3	33,3
	Few suppliers	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

What type of supply chain management systems do you use in support of your process?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Materials Requirement Planning (MRP)	1	33,3	33,3	33,3
	Warehouse Manageemnt System (WMS)	1	33,3	33,3	66,7
	Customer Relationship Management (CRM)	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

What are the challenges facing your supply chain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Finance	1	33,3	33,3	33,3
	Higher Taxes	2	66,7	66,7	100,0
	Total	3	100,0	100,0	

At which level of the supply chain do you face most challenges?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Consumer level	2	66,7	66,7	66,7
	Logistics/Transportation level	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

How satisfied are you with the current government policies on photovoltaic business/supply chain

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	2	66,7	66,7	66,7
	some what satisfied	1	33,3	33,3	100,0
	Total	3	100,0	100,0	