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ENERGY EFFICIENCY MANAGEMENT IN AN ENERGY INTENSIVE INDUSTRY: A Case Study of Volta Aluminum Company (VALCO) and Aluminum Works Company (Aluworks)-Ghana.

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ABBREVIATIONS

Aluworks	Aluminium Works Company
EC	Energy Commission of Ghana
ECG	Electricity Company of Ghana
EF	Energy Foundation
GDP	Gross Domestic Product
GEDAP	Ghana Energy Development and Access Project
GES	Ghana Energy Commission
GPC	Ghana Population Council
GRIDCO	Ghana Grid Company
HEP	Hydro Electric Project
IEA	International Energy Association
ISSER	Institute of Statistical and Economic Research
MOE	Ministry of Energy
MoP	Ministry of Petroleum
NED	Northern Electrical Department
OECD	Organization for Economic Co-operation and Development
PURC	Public Utility Regulatory Commission
SNEP	Strategic National Energy Plan
TICO	Takoradi International Company
UNDP	United Nation Development Programme
UNMDG	United Nation Millenium Development Goals
VALCO	Volta Aluminium Company
VRA	Volta River Authority

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ABSTRACT:

The increasing energy crisis in Ghana and the environmental externalities associated with the use of conventional energy sources has called for this thesis to be conducted. In Ghana, there have been an ongoing crisis in the energy sector; more specifically supply security and quality of electricity delivery. Over the years, there has been a mismatch between demand and supply due to insufficient fuel supply constraints and uncertainties regarding rainfalls and water inflows into the Akosombo hydroelectric dam. The aforementioned issues have rendered the aluminum industry, particularly VALCO and Aluworks unable to meet their production targets. This research proposes a concrete solution by observing in a holistic point of view the actual situation facing the aluminum industry and the country at large, hence the topic*: Energy efficiency in an energy-intensive industry- Case study VALCO and Aluworks, Ghana*. The approach used for this research is a case study. Two companies are studied to ascertain their main issues and the challenges. Secondly, a questionnaire was prepared for these two companies followed by an extensive interview with the production managers.

The outcome of the research shows that the main obstacles facing these companies were energy security. This means that there was an unreliable and inadequate supply of electricity from the Akosombo hydroelectric power plant. As a result, VALCO is currently using light crude and natural gas-fired power plant to augment its energy supply.

In conclusion, implementation of energy efficiency technologies such as found in renewable energy can be used for these two companies and the whole country at large. Ghana has enormous renewable energy sources that are economically viable that are untapped thus establishing the use of a hybrid solution such as a combination of solar photovoltaic and hydroelectricity will help solve the electricity issues faced by VALCO and Aluworks

KEYWORDS: Energy efficiency management, energy intensive, Ghana

1 INTRODUCTION

1.1 Background

Energy efficiency management in production and manufacturing industries became a prime concern in the world today. However, this became paramount to the adoption of energy efficiency practices due to scarcity and inadequate supply of energy, unstable energy price, environmental issues such as climate change, emission of greenhouse gases to the atmosphere and finally the need to manufacture competitive products. These phenomena have prompted the usage of more and energy efficient technology to cater for production practices and better management.

According to the author (Kristaps Locmelis, 2017), moving to zero carbon environment will hinder competitiveness for manufacturing industries most especially high energy intense organizations, indeed, effective energy measures could assist the transition period by decreasing the costs of energy and improve the efficiency of energy usage (Locmelis, 2017).

The Ghanaian economy relies on energy (electricity) for its production activities and also household use. In 2015, the growth rate of Ghana's Gross Domestic Products (GDP) has been estimated to be 4.1 percent when the country was experiencing heavy power crisis. In 2014, it has further decreased from 4.2 percent and from 7.1 percent in 2013 respectively (Ghana Energy commission 2014).

However, according to Institute of Statistical, Social, and Economic Research (ISSER 2014), Ghana is losing an average amount worth about US dollar 2.1 million a day on industrial production activities due to power crisis alone (Ghana's Energy Commission).

Nevertheless, there is increasing demand for electricity till date. In addition, Ghana's yearly electricity consumption per capita from 2010 fell below 400 kWh compare to the global minimum average of 500 kWh for lower middle-income developing countries.

Ghana's source of energy since its independence in 1957 was hydroelectricity generated from Akosombo hydroelectric dam; this dam is located at the south-eastern part of the country in a valley that is operated by state's own enterprise Volta River Authority. This hydroelectric project henceforth (HEP) was first designed and initiated in the 1920s to assist the British metropolis with electricity, the term 'metropolis' in this thesis is the centre of a country or region where economic, political and cultural activities take place, nevertheless, in the 1950s the HEP was redesigned by the first president of Ghana to cater for the growing industries and household use (Hilton, 1996).

The Volta River Project comprises hydroelectric dam, an aluminum smelter for processing bauxite, new cities, a deep sea harbor and other related infrastructural investments (Hilton, 1996). However, between the year 1961 and 1965, the hydroelectric dam at Akosombo was built and commissioned in January 1966 with an installed generating capacity of 588MW and later upgraded to 912MW in 1972 to supply electricity mainly to the aluminum smelter companies namely, VALCO and Aluworks and hence the population of 600 million (CEPA, 2007). The dam was producing power beyond the demand. Nevertheless, it could not meet the demand of the increased population and the economy due to drought-related hydropower crisis between 1997/98 of the Volta Lake caused by an annual fall in the water level (Hilton, 1996).

On the other hand, a few additions of power plants, for example, Bui hydropower 400MW, Kpong Hydroelectric power 160 MW have been put in place to rescue the power crisis but have not yield any good results. This has compelled Volta River Authority to

implement power rationalization to the entire country, this has affected businesses and production companies to operate at half capacity hence employees laid off, end users inability to pay on due date, renders the operator (Electricity Company of Ghana) to lose yearly revenue of 12.40 percent, and government inability to meet its revenue target (McCully, 2001).

The use of diesel-powered power plants and other electricity generating equipment are been adopted as an alternative to salvage the electricity crisis due to its efficiency, versatility, reliability, and durability, and hence make it gained popularity for its use (Bugarski, 2012). However, between 2000 to 2017 a number of thermal plants have been installed to bridge the energy gap namely, Takoradi thermal plant light crude fired, Tema Thermal plant diesel fuel fired and Kpong Thermal plant diesel fired respectively (CRO, 2015).

Meanwhile, operating diesel-fired power plants poses threats to human health and the environment as well. Diesel contained gaseous substances such as, carbon monoxide (CO), carbon dioxide (CO2), nitric oxide (NO), nitrogen dioxide (NO2), sulfur dioxide (SO_2), as well as other hydrocarbons (HCs) which are the main contributor to climate change (Bugarski, 2012). Again, a natural gas-fired thermal plant was built with a maximum installed capacity of 200MW which is Asongli Thermal power plant. There was an irregular supply of natural gas from the source West Africa Gas Pipeline from Nigeria to feed the plant due to inability to pay (Energy Commission 2016).

Due to the above energy situation, it must be the need to seek for an optional energy source to assists the escalating energy crisis in Ghana and hence practicing of energy efficiency. In that case, Renewable energy source, for example, wind, solar or hybrid stands the adequate option for Ghana. Part of the population begins patronizing solar

system (PV), but most of the citizen is yet to take advantage of the alternative source of these energy. Indeed, there are numerous hurdles faced by the diffusion of renewable energy sources in Ghana and there as follows: inadequate awareness, government inability to institute strong policy framework and regulation and absence of incentive to attract investors in the sector (Aglanu, 2016).

Ghana is geographically situated in the hot climatic region of Africa with an enormous solar irradiation. Greater Accra, and coastal areas of Central, as well as Volta regions, record solar radiation between 4.0-6.0KWh/m2/day making up to 0.1 percent share of the electricity as well as wind speed of 5m/s and 9m/s along the coastal and mountainous areas (Ndzibah, 2013). Currently, the total share of renewable energy sources (excluding hydro) in the electricity generation in Ghana is estimated to be 0.3 percent which not encouraging (Aglanu, 2016). In view of this, it requires for this research and hence 'Energy efficiency management in an energy-intensive industry' with VALCO and Aluworks as case company Ghana.

Production and manufacturing activities contribute directly and indirectly (via electricity consumption) to about 37 percent of the world greenhouse gas emission of which above 80 percent is emanated from the use of energy (Worrell, 2009). Therefore the main aim is to take a look into the potential distribution and implementation of industrial energy efficiency technologies as well as framework to decrease energy use and greenhouse gas emissions, hence energy efficiency is potentially the most significant and cost-effective means of reducing emissions from industry.

1.2 Research gap, objectives and questions.

There have been several types of research conducted on the energy efficiency management in many industries and also in the renewable energy organizations in the

world. Meanwhile, studies on renewable energy specifically on energy efficiency management were not connected in Africa continents. There are also other researchers on renewable energy in Africa, but these researchers are inadequate to assists the production and manufacturing companies and many others. On the other hand, well-recognized entities that have undertaken a study on energy efficiency in African are African Progress Panel. This institution normally provides information and reports about energy development in Africa and another part of the world. They exhibit the current situation of energy in Africa hence seeking to develop on the political momentum that was created during the previous years to increase energy access in Africa. Another reputable institution has to do with Joint Research Centre JRC- European Commission; they research into the current state of renewable energies in Africa countries. And according to Joint Research Centre-European Commission, renewable energy in Africa is very much that it must allow for a better standard of living for a large part of present and future population in Africa.

In addition, ESI-Africa is another entity that has been delivering news and programs on energy development in Africa. They figure out what the policy makers on the continents are doing with respect to the energy crisis. The study conducted by the above-mentioned researchers were broad and could not have many effects on the continents in a way of transforming the life of the people and the way forward. Indeed there were other individual researchers whom in their own effort conducted an academic research on renewable energy on the Africa continents, for instance, (Ndzibah 2013). These individuals have thrown further light on the energy issues in Africa and specifically on Ghana. For instance, (Ndzibah 2013) has conducted a study on marketing mechanisms for photovoltaic technology in developing countries with Ghana as a case study, the main aim of that study was to enquire into a more and adequate marketing mechanism for photovoltaic in Ghana, he therefore suggested a very new idea known to be ‘’Robin

Hood and Donkey'' which if adopted by governments will be profitable for Ghana. Robin Hood and Donkey principle in this thesis is the policies and framework put in place to address the challenging energy crisis the Ghana and is adopted from (Nzibah, 2013).

Another area of research by (Mbiah, 2013) has to do with supply chain development of photovoltaic energy system a critical analysis of the customer's role. His research has proposed that policy makers and business organizations in renewable energy sector should unite to bring education and to promote consumer awareness. However, this study aims to add together to what the previous researchers have already done on management of renewable energy systems. By the way, this study centered on energy consumed, quarterly and annually by VALCO and Aluworks and the implementation of energy efficiency in these companies in Ghana. The main objectives of this thesis are;

- ✓ To conduct an investigation into the present energy situation in VALCO and Aluworks and hence their energy consumption rate (electricity) both quarterly and annually and;

- ✓ To propose tentative solution to help reach their production quota and the motivational factors required to establish the usage of energy efficiency.

To get this study done, a research question is going to be addressed;

How energy efficiency is managed in an energy intensive industry-VALCO and Aluworks?

The basis for selecting these questions is to get an in-depth understanding of the prevailing energy strategy manufacturing and production companies specifically

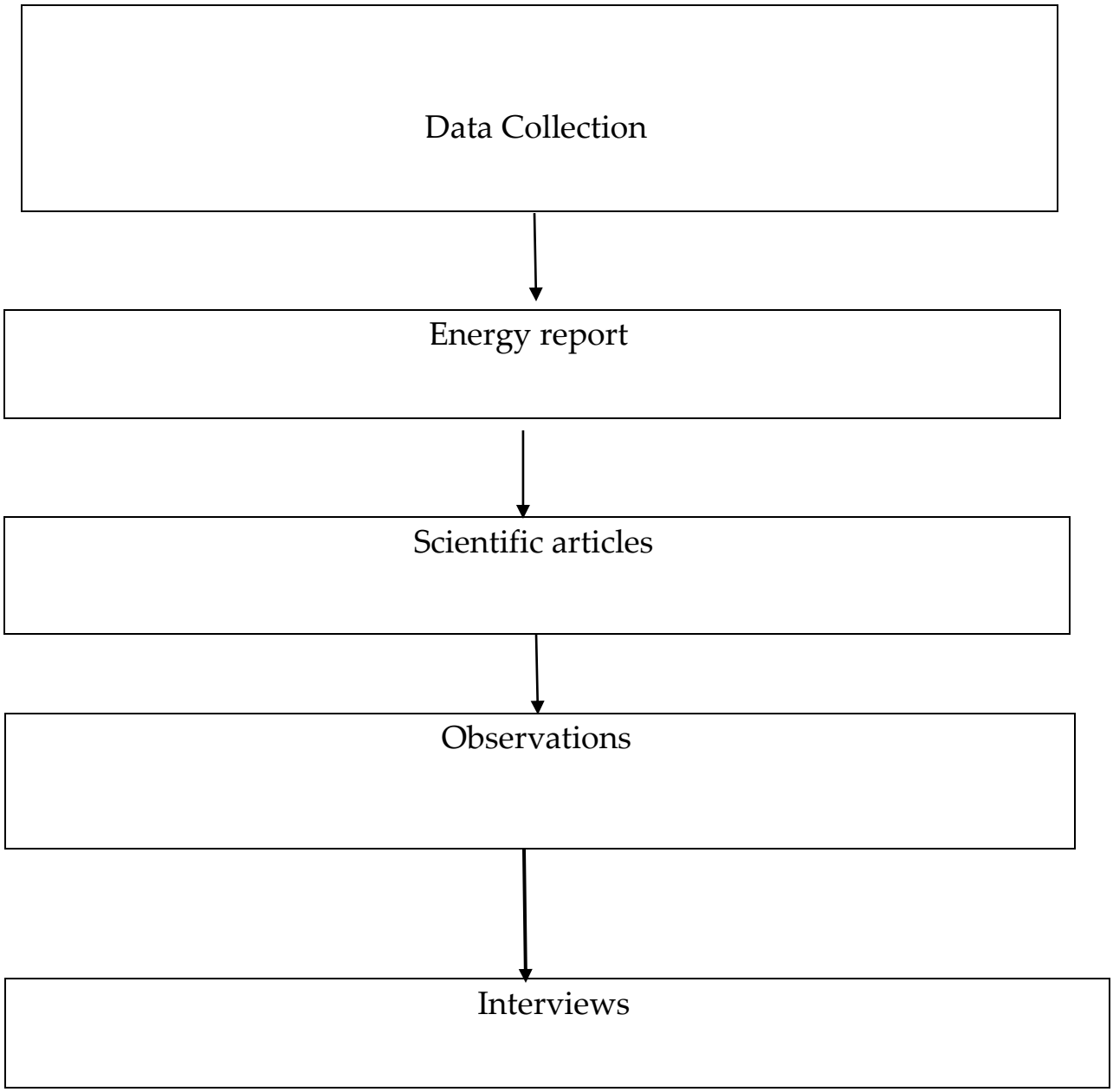
VALCO and Aluworks, to analyze the inadequacy of that strategy and to suggest an idea on the efficient use of energy by these production and manufacturing companies. Furthermore, the questionnaire will assist the researcher to know the exact problems encountering the case companies and propose the use of efficient technology.

1.3 Research Design

The main focus of this research is to investigate the implementation and practices of energy efficiency in VALCO and Aluworks in Ghana. This study justifies scientific, academic and policy frameworks and addresses the stakeholders in the renewable energy sector. The study was inductive research approach; thus enhances the researcher ability to change the presumed way due to new findings. The inductive method creates a connection between the research objectives and the summary findings develop from the raw data (Thomas, 2006). Having in-depth knowledge and clear understanding of the usage of energy efficiency in an industry requires firm theories in an energy efficient management as well as energy-intensive because these are the main theoretical pillars of this study.

This is a qualitative method accompanied by a questionnaire and in-depth interview with the production managers of the case companies in the production and manufacturing industry. More than one approach will be used because data will be collected from different sources to enhance validity and reliability of the study. Data collection for this study will entail survey, interview, scientific articles, and observations and finally energy reports, figure 1below shows the data collection process.

Table 1 Techniques of Data Collection.



The first part of the research, energy reports outlook by the Energy Commission of the government of Ghana will be assessed by the researcher to see the strategy for renewable energy specifically on photovoltaic PV in Ghana and further assess the present framework if it is viable to facilitate the implementation of energy efficiency practices. This is going to be secondary data collection simply because energy outlooks reports are mostly accessible on the energy commission of Ghana's website through the internet. The second part of the research will entail interview in Ghana and VALCO Aluminum Company Ltd and Aluminum Works Company Ltd. The interview will be characterized by a questionnaire which will be used to ascertain the real issues on the ground related to energy efficiency management in those two companies, followed by conducting of an interview, this will be directed to the production managers of the case companies in Ghana. The purpose of this interview is to dig out the actual problem hence understands the present energy consumption rate and further examine the hurdles encountered by the practices of energy efficiency in VALCO and Aluworks in Ghana.

The next part of the research will be scientific articles related to the use of energy efficiency; this will specifically be a secondary data collection together with literature reviews. The final part of the study is the visual inspection of the researcher as he toured the production line will be included in the analysis of the study process.

1.4 Definitions and Limitations.

Certain keywords in this research will constantly be mentioned again and again and will be defined in detail at each step of the research, this will enable the reader to acquire broad knowledge as well as the meaning of those keywords within the scope of this study. There are as follows;

Energy efficiency management-production activities

There are a lot of definitions for energy efficiency management. For example, it is defined as attaining the same services with little energy hence ensuring a safe, reliable, affordable and sustainable energy system for the future (IEA 2016). Furthermore, energy efficiency management is considered as part of environmental solutions to global warming and the best and cost-effective response to be considered to the threat of climate change. In addition, a lot of profit can be generated by energy efficiency improvement in the industry. For this thesis, energy efficiency management is limited to energy saving by management, energy savings by technologies, energy savings by policies and regulations which are all connected to production activities (Hepbasil, 2003).

Energy savings by management, which is mainly the framework or strategy for attaining energy demand when and where it is required. This system can be obtained by tuning and boosting the energy using systems and guidelines to reduce the energy demand per unit of output hence decreasing the overall costs of producing the output from this system (Abdelaziz, 2010). The next to follow is:

Energy saving by technologies, this simply implies that technological application has the capability to decrease industrial energy use to a barest minimum, another way to reduce industrial energy use is by application of high efficiency motors, efficient nozzles in the compressed air system and variable speed drive in motor operated systems (Mekhilef, 2010).

Energy savings by policies and regulations, energy policies are most applicable in the manufacturing and production industry to attain the desired energy efficiency, this policy includes legislation, international treaties, and incentives to investment, agreements, and guidelines for energy conservation, taxation, energy efficiency

standards and finally energy label. (Perroni 2016; also defines energy efficiency as the energy input per output irrespective of the type of energy source related to energy supply source is a separate issue, the researcher has itemized several benefits of energy efficiency management in a production and manufacturing companies are; increase in productivity, reduction of pollution, reduction in noise emissions, less maintenance cost, saving of water, waste reduction, and many more. This study is basically going to be focused on the definition (Perroni 2016; which has to do with the increase in production, reduction of pollution etc.

Energy Intensity this basically refers to the total energy efficiency of a nation's economy measured as a usage of energy per unit of Gross Domestic Product (GDP), normally in tonnes of oil equivalent, (Fawkes 2013). On another hand, Bongseok Choi 2017; also defined energy intensity as the amount of energy consumed per unit of economic output. For instance, dry process and wet process of cement manufacturing have entirely dissimilar energy needs and thus a shift from dry process to wet process will enhance a change in the energy intensity of the industry, also a change in a fuel mix can results in a change in energy intensity because of dissimilar level of efficiency involved in the conversion process. Meanwhile, early days of industrialization ended up in the huge amount of energy use in their production activities, as the economy has shifted into post-industrial stage of the economic development, the service part of the economy has moved faster than the manufacturing sector which resulted in a decrease in demand for energy use for an equivalent grows in the GDP (Choi 2017). In addition, the shift has also increased with household energy consumption. Putting in place more energy efficient technologies causes the energy requirement at all levels of the sector to decrease thus enhancing manufacturing and production activities to expand without a high energy use hence a decrease in energy intensity. Below is the mathematical expression of energy intensity.

$$Energy\ Intensity\ (\text{EI}) = \frac{units\ of\ energy}{units\ of\ the\ Value\ Added\ (or\ GDP)}$$

Energy efficiency technologies reduce energy intensity in the industries such application of renewable energy technologies which are environmentally friendly and a boost to the nation's economy. The decline in energy intensity improve variations in structural changes which includes economic and energy consumption structures, unstable energy price, technological progress and many more (Huang 2017). In addition, energy intensity reduction allows more energy dependent industries to use their resources judiciously and efficiently thereby saving more energy input cost. For instance, the level of energy intensity in an office, accounting, and computing industry are acceptable, because it shows an amount of energy efficiency which is 50 times less than that of production industries (Choi 2017)

1.5 Limitations

Most of the academic research encounters various degrees of limitations in their process. Specific to this research, the limitations are as follows; scope of the sample, financial constraints as well as geographical issues, which these are linked together. The scope of the research is limited only to two industries Volta Aluminum Company Ltd and Aluminum works company Ltd. This will enable the researcher to have an ample time to carry out in-depth study of the case companies. A questionnaire was set for these two companies including an interview with the production managers and a tour of the production line.

1.6 Structure of the thesis

Chapter one discusses the general overview of energy issues in Ghana and the reasons for this research. It explains the research gap, followed by the research questions and objectives. The chapter has also defined the key elements and limitation of the topic under research.

Chapter two begins with the background of the country of the case companies; it also assesses the historical background of the country, explained the political and managerial aspect of the energy situation in the case country under investigation. This chapter further assesses the management of electricity in VALCO and Aluworks, the type of energy use, amount of energy consumed quarterly and annually and the total energy forecast for the future. And finally the adoption of renewable energy as means for energy efficiency improvement.

Chapter three presents the literature review of the study; it provides detail explanation of the production activities and stages of energy intensity in Volta aluminum company and Aluminum works company, for example, the quantity of energy required to covert a material from a solid state to liquid state and carry out analysis of those stages and process. In addition, the chapter will explain the importance of energy efficient technologies to production industries and further high light obstacles underpinning the implementation of energy efficiency.

Chapter four discusses more information about the research methodology, the process of the data collection, analysis of the research outcome, the validity and reliability of the research process.

Chapter five summarizes the final results of the research question and suggest the best way to improve or implementation of energy efficiency in VALCO and Aluworks, it further put forward the recommendations and suggestions required according to the outcome of the study.

2 CASE COUNTRY BACKGROUND

This section of the chapter presents the historical, political as well as technical administrative background of the energy-related systems in Ghana after achieving independence from the British. The section then continues with the overview of diverse types of energy systems available in Ghana, the generated installed capacity, and projected capacities yet to be installed and functional, and however ends by discussing the layout of the current renewable energy policies in Ghana.

2.1 Historical, political and technical administration of the energy systems in Ghana.

Ghana is situated on the West African coast and is the eighth-largest country within the region of 16 nations. Ghana has an area of 238,540 square kilometers, or approximately 92,000square miles, makes it somewhat larger than the United Kingdom and slightly smaller than the U.S state of Oregon. The country's main city, as well as the seat of the government, is located at the coastal city of Accra, with a population approximately to be 4 million in 2017, whiles the country's total population estimated to be 27,752,983 million (Ghana Population Council 2017).

Ghana shared borders 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 to be precise the Atlantic Ocean. Ghana's gross domestic product (GDP) per capita (purchasing power parity) was recorded at $3980.20 (2016) estimated with English as official language mainly used in governments and business affairs in the country (Ndzibah, 2013).

In 6th March 1957, Ghana achieved independence from the British colony; the former name was changed from Gold Coast to Ghana. After January 9, 1993, Ghana officially is known as the Fourth Republic of Ghana through a constitutional democracy in which the head of state is also the head of the government. However, after Ghana's political

independence in 1957, restructuring of the administrative state inherited from colonial masters has become the country's major mission for development. Similarly, a lot of governments, military or civilians made reforms the main priority for their developmental agenda and therefore, used significant resources both human and financial for these efforts (Dartey-Buah, 2014).

Since Ghana's independence, the first energy resource was the Akosombo hydroelectric dam. The project was started in 1961 completed and commission in 1965, it was one of the largest artificial basins in the world, and it covers a total area of approximately 8500 km2 and length of 400 km with a coastline of 5500 km. The Akosombo hydroelectric dam was constructed by Government of Ghana through the assistance of Kaiser Aluminium, it worth $260 million (VRA 2010). The project has undergone three phase; the first phase was the installation of 588MW unit of electricity; the second phase was an additional capacity of 304MW electricity which made up to the total of 912MW. However, the population at the time was only 6.7million people and the industries were also few to require for higher electricity demand. The final phase was a construction of a small dam at Kpong with an installed capacity of 152MW added to the existing which added up to the total of 1,072MW. All those projects were carried out under the management of Volta River Authority which was set up in 1961 by the government of Ghana under the Volta River Development Act 46 to manage, maintain and sustain the Volta River and hydroelectric production.

Another responsibility of Volta River authority is to generate and transmit electricity and also protect the well-being of the settler's community along the lake. The main purpose of the hydroelectric project is to supply VALCO with enough electricity in order to carry out its aluminum smelting production without interruption. Another purpose is to provide electricity for the factories and industries and domestic use and also export

it to the nearby countries, for example, Benin, Togo, Mali and Cote d'Ivoire respectively. The dam also enables large-scale irrigation, modernization of agriculture and development of tourism (Government of Ghana, 2014).

Nevertheless, due to an increase in population and the expansion of the economy the demand for energy (electricity) outweighed the supply. In 2016, the total current population of Ghana was estimated at 28.2 million people as compared to 6.7 million in 1960. The figures below represent the latest census figures of the Ghana population which clearly shows that the total population is over 28 million people far more above the population since Ghana independence in 1957. The figures nevertheless do not require for a tripling of the energy supply but sent a signal of how the electricity demand will outweigh the supply if efficient as well as effective measures are not put in place to arrest the electricity supply crisis (Trading economics, 2017).

Figure 1 Trends of Ghana population

Source: Trading economics .com.

According to Dubey, 2016; the energy (electricity) crisis in Ghana is due to inadequate and unreliable supply of fuel to the thermal power plant to function properly. Furthermore, transmission and distribution losses are considered as an attributes to the insufficient supply of electricity and there must the need to widen the parameter of power generation capacity to meet the increasing electricity demand (Dubey, 2016).

2.2 Types of energy systems, capacity, and future forecast.

Ghana produces approximately 64 percent of its energy (electricity) from hydro sources. In addition, electricity is the main system of energy used in Ghana, as well as the industrial sector, and service sector uses approximately 65 percent of the electricity produced and 36 percent is used by residential. Every year, demand for electricity increases by 10 to 15 percent with supply not able to meet these targets. The increasing expansion of the industrial sector, service sector, particularly in banking, communication, as well as hospitality services, increased in urbanization, the growth of the middle class as well as increasing incomes and total population growth approximately (2.3 percent per annum) seemed the main drivers of increasing electricity demand (Amoako-Tuffuor 2016).

According to Karekezi, 2002; rapid increase in demand of electricity in Ghana can be due to successful setting up of macroeconomic reforms that has triggered an increase in demand for electricity from households, commercial concerns, and industry. This, however, implies that low incomes urban groups have not gain equally from macroeconomic reforms and therefore they are unable to benefit the increase in the provision of modern energy services (Karekezi 2002). Since 2000 to 2010, annual electricity demand from non-residential is approximately 9 percent, residential was 6.2 percent and later increased to 9.7 percent between 2010 and 2013; it again declined to 1.7percent in 2013. In addition, in the same period from 2000 to 2010 industrial electricity

demand declined from 25 percent to 19 percent. The table presents the average annual growth in power demand.

Table 2 Electricity consumption by sector

	2000-2010	2010-2013	2013
INDUSTRY	2.2	9.7	1.7
NON-RESIDENTIAL	8.9	16.5	33
RESIDENTIAL	6.2	7.8	15.4

Data source: Energy Commission, Ghana

According to Ghana's energy commission (2014), the main potential consumers of electricity are: industrial growth, petroleum up-stream and mid-stream activities, mining, ongoing electrification scheme, and energy conservation as well as efficiency measures, also includes rapid development of the four main cities namely: Accra, Tema, Takoradi, and Kumasi has also identified as key drivers of residential demand for energy (electricity). It's therefore projected that Ghana's population to rise to approximately 40million by 2030 and therefore it must the need to expand and diversify the country's production capacity to match the projected future energy demand (Djordjevic 2014).

The periodic power outages and loads shedding shows supply and demand mismatch. World Economic Forum's Global Competitiveness Report 2013-2014 has ranked Ghana 114 in quality of electricity delivery hence scored 3.0 (below the world mean average of 4.5) (Amoako-Tuffuor 2016). Since the inception of the electricity crisis in 1984, reduced

water level and droughts were identified as the prime cause of the shortfalls in the production capacity and energy supply. On the other hand, increases in the price of crude oil, mismanagement, the monopoly of the energy sector, a patchwork of government policies, neglect as well as obsolete energy infrastructure were also known as responsible to the energy supply pitfalls. During 2013, approximately 64 percent of the electricity supply is produced from hydro source and 35 percent was from thermal plants. The table below present the electricity generation from 2014 to 2015.

Table 3 Existing main power plants in Ghana

Generating station and Plant	Installed capacity, MW		Dependable capacity, MW	
	2014	2015	2014	2015
Hydro				
Akosombo	1030	1020	960	900
Kpong	160	160	140	140

Bui	400	400	380	380
Thermal				
TAPCO	330	330	300	300
TICO	220	330	200	300
TT1PP	125	136	110	110
TT2PP	49.5	49.5	45	45
MRP	80	80	40	75
T3	132	0	120	0
Sunon-Asogli	200	380	110	110
CENIT	126	126	110	110
Renewables				
Solar	2.3	2	22.5	21
Total	2946.0	3003.2	2807.5	2722

Source: Energy Commission 2014-15.

The table above shows an overview of present electricity generating systems in Ghana, the types of plants, year of installation, and the state of operation of this system. It can

be seen from the table that Akosombo produces 1030 MW of electricity, due to droughts caused by climate change it has dropped to 900 MW and same applies to Kpong and Bui respectively. The thermal plants have the same phenomenon because they cannot operate at full capacity due to the high cost of fuel. From the table, it is obvious that despite the promotion of renewable energy, the installed capacity is currently very low. According to Energy Commission, the total capacity generates by these energy sources are woefully inadequate to cater for growing population and industrial operation of the country. To curtail from this sporadic electricity delivery, manufacturing and production companies, businesses and households has employed the use of genset for their activities. Nonetheless, there have been more than 4500 solar systems supplied to 89 communities across the country, yet not enough to provide electricity for production companies. Furthermore, during the end of 2014, additional 25 grid-tied solar PV was installed via private sector participation bringing the overall total national capacity to 8MW (Djordjevic 2014; Hagan 2015).

The Energy commission's 2015 report forecast an increase in capacity of electricity. This forecast also indicated that most of the electricity generating sources will maintain their generating capacity in 2015. The most challenging aspect was the thermal plants, which in 2015, was relatively contributing little to the generating capacity, and thus operating under capacity.

Typically, the policy objectives of Ghana's energy sector towards achieving Millennium Development Goals is to provide reliable, adequate and cost-effective delivery of high-quality energy services for households, industries, agriculture, and transport. Nevertheless, the policies and plans have not yielded any effective results to enable the population to attain optimum benefit of increasing access to energy services. It has also been recognized that energy sector must address these challenges such as; insufficient

energy supply infrastructure that needs a large investment, insufficient access to electricity, transmission and distribution losses, ineffective regulatory capacity and enforcement, management and operational difficulties, and vulnerable to climate change to enable sector to achieve its maximum operation. Research has indicated that the power sector might encounter future challenges as results of increasing living standards and rising needs for clean energy if all the numerous challenges have not been taking care of (Dubey, 2011).

Although Ghana is geographically located in the tropics, it has more than enough solar radiation available throughout the year that can be useful for electricity generation capacity to the country. Even though the required technologies to convert solar irradiation to electricity are now available, Ghana is yet to experience the deployment of these viable technologies for power generation. In 2002, United Nation Development Programme UNDP project has carried out an assessment on Ghana's solar energy sources, this high-resolution solar assessment was pivoted on data from the geostationary satellite Meteosat (Modjinou, 2014). The table below presents the solar PV systems, installed capacities and generations.

Table 4 Small-scale Solar PV Systems in Ghana

Solar PV systems	**Installed capacity (KW)**	**Generation (MWh)**
Rural home system	450	700-900
Urban home system	20	50-60
School system	15	10-20

System for lighting health centers	6	10-100
Vaccine refrigeration	42	80-90
Water pumping	120	240-250
Telecommunications	100	100-200
Battery charging system	10	10-120
Solar street lights	10	40-60
Total	**793**	**1340-1820**

Source: Energy Commission, 2011

It is estimated that the country receives an average solar radiation of approximately 4.0-6.5Kwh/m2 with an equivalent sunshine duration of 1800-3000 hours every year which is viable for on grid and off grid connections (Kemausour, 2011). Even though, with the assistance of Photovoltaic Geographical Information Systems PVGIS, technicians are able to construct devices and offer actual information and advice customers on the potential of the installed capacity, or yet still offers effective arrangement of data for technicians on radiation of photovoltaic systems as well as optimal inclination of the PV modules and the calculation of the perceived electricity generation from PV systems of different power ratings. PVGIS is basically an online tool used to calculate solar electricity production of a photovoltaic system. Nevertheless, Eastern, Western, Ashanti, Brong-Ahafo, and part of Central and Volta regions receive monthly average level

between 3.1-5.8 KWh/m2. The three northern regions also receive a very high monthly average solar irradiation of between 4.0-6.6KWh/m2. Along the coastal line, Greater Accra, Central, and Volta regions have monthly average solar radiation that varies between 4.0-6.0 KWh/m2. Also, there is the high intensity of solar irradiation in Northern Ghana than that of Southern Ghana (Energy Commission, 2009). The figure below presents the solar radiation intensity across the entire country.

The imbalance in supply and demand of electricity generation in Ghana is very high and corrective policies are needed to increase the present generating capacity by considering renewable energy systems such as photovoltaic, wind and biomass so as to achieve reliable, accessible and affordable electricity in the country. Energy Commission report shows that there is a possibility that the net final electricity consumption will rise from 6,900 Gigawatt-hour in 2000 to approximately 18,000 Gigawatt-hour by 2015. Nonetheless, if this projection will materialize then Ghana will pay more for refined oil importation due to unavailability of dependable refinery centers in the country. In order to secure consistent flow of electricity supply, the government planned to double the present production capacity (electricity) by the installation of diesel and gas systems by 2020, not bearing in mind that those energy sources are a threat to the environment due to their carbon emissions leading to climate change. Indeed, the National Energy Policy aimed of adding 10% of renewable energy to the total energy production by 2020 which was translated into the generation master plan as 10% of electricity mix and it will be based exclusively on the grid-connected application (IRENA 2015).

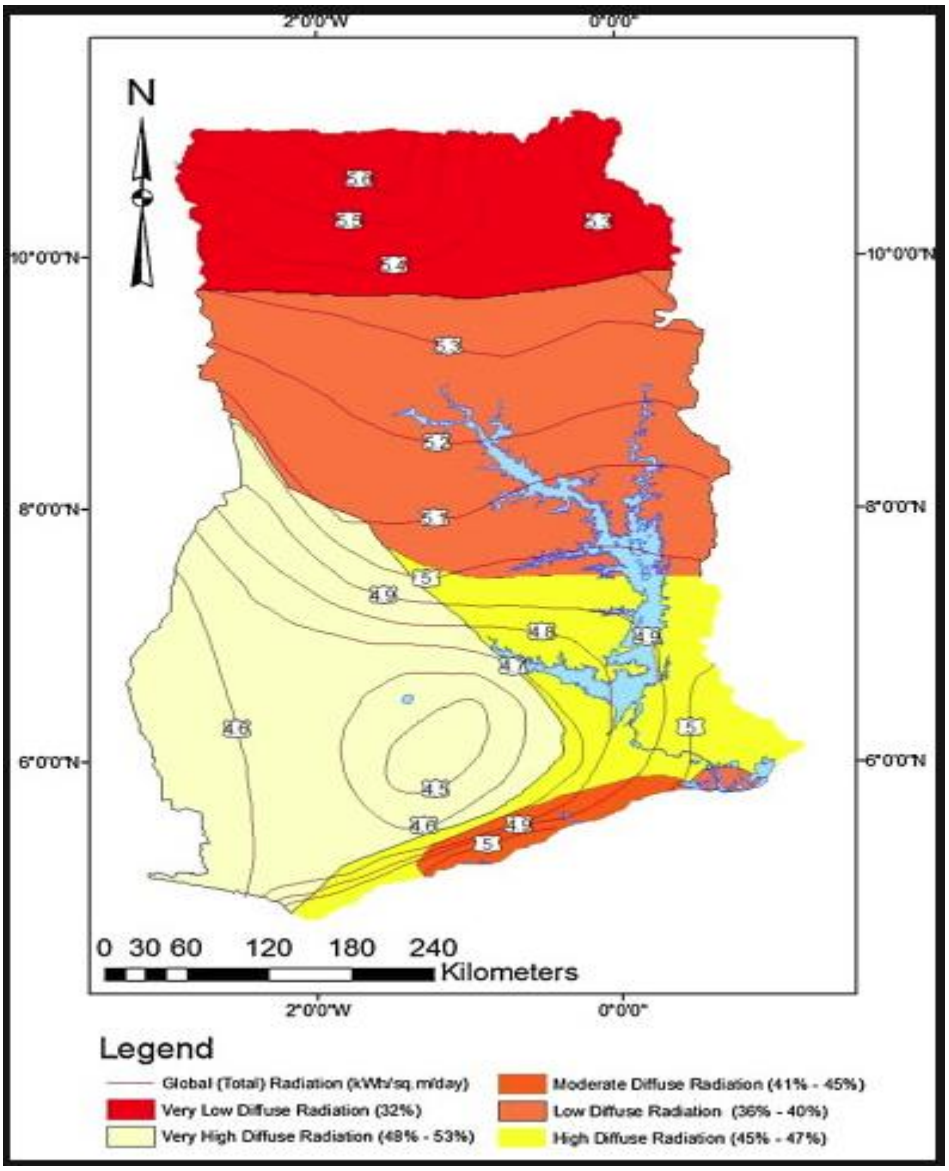


Figure 2 Solar resource potential of Ghana. Source: Ministry of Energy, 2011

As a recommendation, it will rather be laudable for government to offer capital subsidies in a form of incentives for Independent Power Producers (IPP) and thus promoting technological research for clean energy, generating incentives and thus feed-in-tariffs

system. There is a need to consider the adoption and usage of renewables and energy efficiency technologies. This approach will enhance future energy security using diverse resources of energy supply.

2.3 Renewable energy policy and regulation in Ghana.

Over the past years, a number of policies mechanisms have has been put in place by successive governments of Ghana to improve access to energy services for the inhabitants. There have been efforts made to restructure the power sector in order to provide adequate and reliable electricity and promote renewable energy services based on energy efficiency and clean technology. Nonetheless, Ghana's Energy Commission's reports show that primary energy constitutes about 90-95 percent of wood fuel (precisely biomass), 5-10 percent hydro energy, and photovoltaic energy contribute less than 1 percent. Indeed, patronizing of renewable energy by manufacturing companies, households and government is very less and thus also lack proper documentation. This has developed a restructure in the energy policy framework of the country. Considering the mismatch between supply and demand, the government has developed a strategic national energy plan of (SNEP) 2006 to 2020.

SNEP energy policy constitutes a current social-economic and environmental policy, links between the energy sector and other parts of the economy, international connections of the sectors and indeed considering the policy of importation and adoption of clean energy products in the country. Another energy policy implemented since 2000 was Ghana Energy Development and Access Project (henceforth GEDAP). This is multi-donor funded project which comprises, the World Bank, International Development Agency, Global Environment Faculty, African Development Bank, Global

Partnership on Output-based Aid, Africa Catalytic Growth Fund and Swiss Agency for Development and Corporation. It is development aimed to step up the operational efficiency of the power distribution system, intensify access to electricity to the population and assists transform Ghana to decrease carbon economy via a reduction of greenhouse gas emissions (Brew- Hammond).

Furthermore, United Nation's Millennium Development Goals in collaboration with the energy sector present the country with achievable milestone; for example, Ghana needs to raise the standard of living of the populates through a significant reduction of poverty without having compromise the environment. The United Nation's Millennium Goals (*henceforth* UNMDG) and other similar institutions emphasis on wiping out poverty and hunger by creating awareness on sustainable energy and environmental policies with the prime aim of job sustainability. In addition, the UNMDG intend to assists in protecting the interests of a generation yet to come and help to raise the living standard of inhabitant dwelling on less than a dollar per day. Furthermore, some of the goals of UNMDG's also involve Clean Development mechanism under the Kyoto Protocol, which paves the way for a country to attain assistance in developing its energy resources. Some of the 10 aims of The Strategic National Energy Plan include encouragement of economic development with presenting energy as a catalyst, are most significantly essential in supporting the market needs and to put in place effective policy framework. Another vital objective includes raising the future energy security by engaging in patronization of diversification of energy supply, by allowing private sector's participation in developing energy infrastructure and service delivery and finally facilitating the development and usage of renewable energy as well as energy efficiency technologies (EC 2006; EC 2009).

To attain the above objectives the government in collaboration with the ministry of energy intends to install policies to encourage public-private sector partnership. The policy includes security of the private sector investment in conjunction with the public sector to make the most out the energy delivery system by widening electricity generating capacities, strengthening and widening the scope of electricity transmission networks and many more. In addition, the government has also pledged to ensure energy efficiency management of the present infrastructure by rearranging the public utilities to attract private involvement. Furthermore, they also plan to distinguish the monopoly of the energy sector on electricity delivery by improving regulatory transparency and separating the existing electricity supply systems. Nonetheless, the government pledge to attain 10 percent of diffusion of the country's renewable energy electricity demand by 2020 and further facilitate the usage and development of renewable energy as well as renewable technology.

This intended plan by the government shows essentially the importance and advantage in the usage of renewable energy systems by adding 10% to the already existed conventional energy mix in the country. Electricity will be produced from renewable energy systems particularly from photovoltaic, small and medium-sized hydropower plants, municipal solid and industrial wastes, biomass and also from wind energy. Lastly, the government will alert users as well as energy suppliers on the environmental impacts associated with the use of energy, thus collaborating with international in efforts to ensure maintenance of energy delivery and reduce climate change. Meanwhile, the government objects to build up the current regulatory agencies particularly, the Public Utility Regulatory Commission (PURC) and the Energy Commission (EC) to exercise their ability and capabilities. The strategy also involves building a capacity for supporting and training the Ghanaian people in all aspects of energy development as well as managing of the power sector reforms.

However, the proposed policy framework for commercial and service sector involves governmental supports for energy efficiency and conservation measures in the service sector thus promote installation and usage of pre-paid metres in all public sector buildings and offices and also establish electricity consumption ceiling for agencies, government departments, ministries and entire security service as a form of energy efficient measures. Again, the setting up of these measures will also involve strengthening the activities of the Energy Foundation (EF). In addition, the policy measures will therefore include a mandatory usage of electricity pre-paid rather than that of credit metres for all government department and agencies and entire ministries thus establishing a committee which involves the PURC, EF, EC and Ministry of Energy as chair to ensure a ceiling for the ministries, the agencies and government departments.

In view of these plans, any governmental body violating these measures will have to settle with their own funds. And finally, the regulation of the electricity consumption regulated by the public institutions will establish an efficient operation as an example for the other services to follow. Another proposed policy for the supply sector comprises government support in developing alternative energy resources and the resources will comprises of generation of electricity from renewable energy sources and considers other alternatives such as decentralize and mini-grid system for decreasing the delivery cost of electricity to the remote areas. The setting up of the policies may also include supporting the private sector investment with an incentives package particularly access to concessionary loans, financial instruments (such as subsidies, tax incentives, and loan facilities) and grants for infrastructure investment besides renewable energy investment normally needs huge amount of financing for the same capacity due to high upfront costs (Beck 2004).

Furthermore, the government pledge to pave a way for an environment that enhances entry of multi-players into the electricity generation market hence enticing involvement of private and public investors to grasp the opportunity of the opening up of the electricity generation market. And lastly, the government also aim to seek foreign development assistance to facelift the present electricity infrastructure, it does also plan to maintain its commitment to attain the National Electrification Scheme objective of 100% electrification by 2020. Meanwhile, to do away with anxiety on the government budgetary allocation on subsidies, the government policy measures must play a leading role to establish and promote a competitive market environment which is viable from the economic development and technological innovation standpoint thus prompt the need to combine a wide range of non-conventional energy technologies to its generation portfolio so as to step up energy security and to cushion the country from external shocks particularly price hikes of fossil fuel. Nonetheless, sustainable or viable energy systems can offer such an opportunity (Ndzibah 2013; Palper 2011 and Katzenbach 2017).

2.4 Electricity management in Ghana

Electricity utilities, as well as power networks, were initially designed to operate on vertically integrated monopoly model, this enables the entity to carry out all the activities of the sector particularly, generation, transmission, and distribution. End users are tied to the single choice of supplier in this model thus also protect the end users from high prices (Razeghi, 2017). This traditional approach was to made available supply of electricity demands whenever needed and thus also attempt to balance the overall costs and the total revenue of a utility when considers the entire relevant components such as, price of the good, quantity of the good, number of good, rate of return on investment, the rate base, the expenses particularly, operating expenses, costs of inputs, remuneration for labour and other administrative costs, depreciation and taxes on the income and other taxes. Arguably, the shortfall of the traditional approach regulation

was cost-minimizing behavior. In this context, in the competitive environment, competition ensures that regulated firms minimizes its cost but in the regulatory environment, there is absent of incentive for the regulated utilities to reduces costs below the approved by the regulator. Another mishap has to do with lack of recognition of efficiency, this essentially implies that if a regulated firm is able to attract low-cost capital the rate of return allowed to it will eventually be lowered which does not recognize the efficiency of the management in attracting low-cost capital (Bhattacharyya, 2011).

According to a model developed by Averch and Johnson, which demonstrate that, public regulation creates an incentive for the regulated firm to invest in tangible assets thus the allowed profit is based on the rate base. The above mishaps require for restructuring and deregulation of electricity supply sector whiles changing the operation system of the industry. The reform in the management of electricity sector is essentially moving from the vertically integrated monopoly structure of the industry, and drivers behind this reform are; the decline of the natural monopoly rationale, regulatory failure, contestable markets, and failure of public monopolies, national debt problems and finally decline of the public good rationale.

Over the previous years, many successive governments of Ghana have applied a lot of policy frameworks to step up access to energy services for the citizens. Persistent efforts have been used to rearrange the power sector thus provide reliable and adequate electricity and promote clean energy services on the basis of energy efficient as well as energy efficiency technologies. Arguably, on the part of the power sector, increasing demand of energy and restrictions in electricity supply and lack of financing were the key points that prompted reforms (Brew-Hammond 2010). In addition, there have been relevant frameworks put in place to address the obstacle faced by Ghana's energy sector which involves regulation of electricity tariffs, deregulating the price of the petroleum,

setting standards for the industry, education, permitting, distribution of information and stakeholder involvement.

To have adequate, reliable and proper functioning of the all the players in the energy sector and to establish the necessary perfect environment for the protection and enhancement private investment in the sector, a series of regulatory agencies have been set up by Act of Parliament. These institutions are; The Ministry of Energy (MoP) is a state-owned and a mouthpiece of the government that is responsible for formulating and implementing fuels and electricity policies and also ensures improvement in the distribution of electricity across the length and breadth of the country particularly, the communities and towns in rural Ghana. Second is the Energy Commission; this institution serves as a governmental adviser on energy policies and strategy and thus also responsible for the analytic planning of energy as well as electricity system expansion and supply of licensing to regulated firms in the energy sector.

The third entity is the ''PURC'', Public Utilities Regulatory Commission; this body is mandated to regulate and oversee the supply of utility services to end users and also see to other related matters, it is institutionalised to supply guidelines on the rates chargeable for delivery of utility services, to inspect and approve rates chargeable for supply of utility services, to ensure and protect the interest of the consumers as well as suppliers of the utility services, also supervise standard of performance for provision of services, to initiate and carried out investigations into the standard of quality of services render to end users and finally ensure fair competition among public utilities and many more (PURC 1997). The fourth entity has to do with Volta River Authority (VRA); it duty is to generate and supply electricity to large industry and mining companies and to the two electricity distribution companies namely, Electricity Company of Ghana (ECG) and Northern Electrical Department (NED). The Electricity Company of Ghana (*henceforth*

ECG) is mandated to see to a supply of quality, reliable and safe electricity services to Greater Accra, Ashanti, Eastern, Western, Central and Volta Regions and to support socio-economic growth and development of Ghana, it is a limited liability company and state-owned functions under the Ministry of Energy (ME). Next is the Northern Electricity Development (*henceforth* NED) this is a subordinate to Volta River Authority and its responsibility is to purchase electricity and distribute it efficiently, safely and reliably to the northern belt of Ghana particularly, Brong-Ahafo, Northern, Upper East, and Upper West Regions in a commercially viable manner. This two electricity distribution companies operate initially as an individual entity, but due to the on-going Power Sector Reforms ECG and NED were considered to merge or operate as one distribution company (NEDCO, 2012).

Currently, the transmission functions of electricity has been separated from the generation and many responsibilities of VRA, hence this function has been assigned to a new company Ghana Grid Company (GRIDCO), another new agency was set up by the government, the Bui Development River which was established to foresee to the construction of 400MW hydropower plant on the Bui river. Furthermore, an opportunity for Independence Power Producers was established, Takoradi International Company (henceforth TICO) an independence power producer is already in operation and several others at different forms of the project development (Osono, Centpower, and Asogli). An entirely new rural electrification agency has put forward yet to be set up under the present World Bank-funded GEDAP (Kemausuor, 2011). It is apparently essential to note that the present institutional structure of the entire energy regulation is monopolistic thus enable the administration as well as the regulation process bureaucratic in nature.

Indeed, the above-mentioned points provide some clarifications to the type of electricity generation, distribution and transmission management in Ghana. In addition, the

chapter highlights the increasing demand and insufficient supply of electricity in Ghana. Hence the electricity supplied capacity is lower than the demand; the problem at hand shows a significant challenge to the government to find a suitable and lasting solution to the electricity crisis. Attempt to solve the electricity crisis will rely on how much the government, the various institutions as well as the public will be compared to invest in resources to attain the objectives of increasing the electricity generating capacity by means of sustainably and efficiently assists in the promotion of economic development and growth.

2.4.1 Background of the case company 1-(VALCO)

Volta Aluminium Company Limited popularly known as VALCO is located at a heavy industrial area in Tema, it has been established by the first President of Republic of Ghana, Dr Kwame Nkrumah to promote an integrated aluminum industry in the country. The company is the most important long-term investment in Ghana and one of the biggest enterprises in the country and also the second largest smelter within the Sub-Sahara Africa, and a main producer of primary aluminum for the world market; it currently staffed 574 employees mostly Ghanaians holding several technical, professional and managerial positions. Nonetheless, in 1964, the construction of the plant began and commercial production from plant started in March 1967. Furthermore, due to increased costs of production and huge power requirements, there was no integrated aluminum industry and alumina plant to produce alumina from the bauxite ore, therefore VALCO, the biggest local and the most popular smelter in the country imports alumina to smelt into ingots which has its electricity source from the Akosombo hydroelectric dam. The figure below present the stages involved in producing aluminum ingots from alumina.

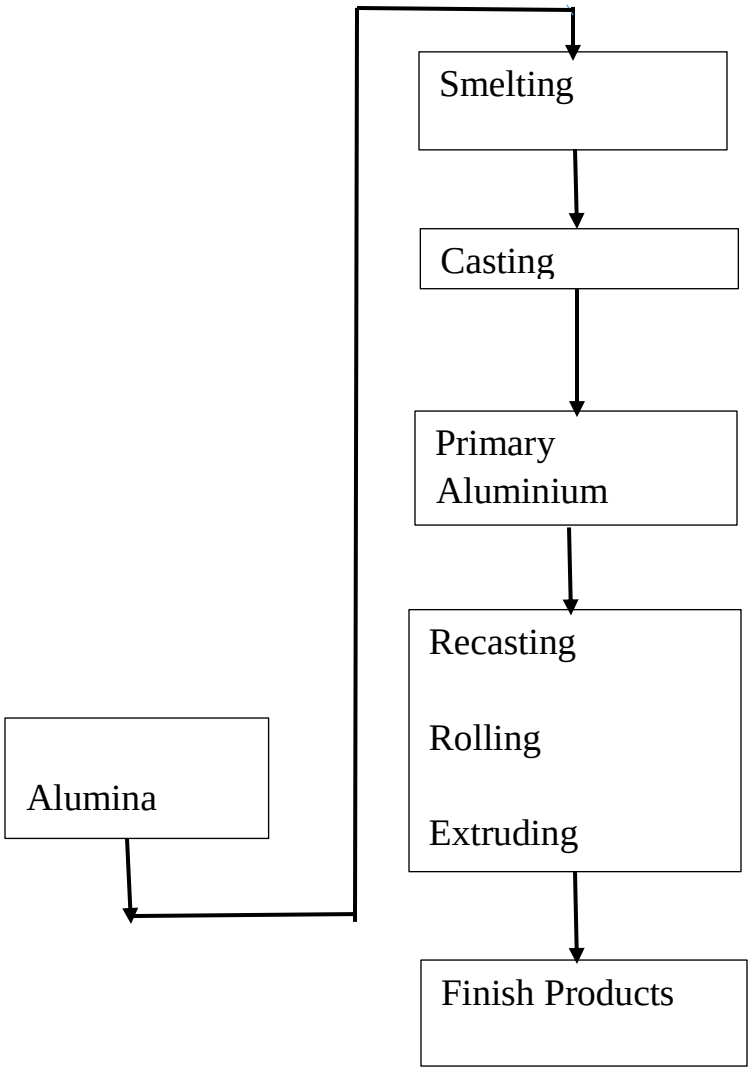


Figure 3 Stages involved in producing ingots from alumina

This smelting process requires huge quantity of energy to produce the ingots because large amount of heat is applied to the ore to melt out a based metal after which the molten aluminium descend by the assistance of gravity to the bottom of the cell where it is

gradually collected, and time to time the metal is siphoned out from the pots and conveyed in crucibles to casting shops where it is then placed into electrically powered or gas/fuel oil fired holding furnace to be transformed into finished products mainly, the ingots. Due to power intensity of the process, it requires cheap continues flow of electricity supplied by Akosombo hydroelectricity and Kpong dams but, the industry is faced with limited supplied of electricity due to the largely low water level in the Volta hydropower dam. In addition, the smelter has an initial operating capacity of 200,000 tonnes per year of ingots with six potlines but has been inoperative between 2007 and 2011. In early 2011 the plant resumed operation, producing 3000 tons per month purposely for local consumption with only 20% capacity, plans are underway to add second potline bringing the production capacity up to 6,000 tons per month. In 2015, the overall electricity generated for gross transmission was 11,692 GWh and that generated in 2014 was 13,071 GWh. Furthermore, in 2013 the total electricity generated was also 12,927 GWh, about 1,377 GWh less than that in 2014 and 1,235 GWh less in 2013; this means that electricity generation dwindles every year thus affecting production activities of both VALCO and Aluworks respectively. In 2016, the overall electricity requirement of the country is expected to be 16,798-16,900 GWh, at which VALCO will be able to operate with one potline, the electricity is again expected to increase from 18,185 to 18,737 GWh with VALCO expected to add the second potline to increase the economic growth to 4.5% (EC,2016).

2.4.2 Background of the second case company- Aluworks.

ALUWORKS Limited is an aluminum continuous casting and cold rolling mill company geographically located at heavy industrial area Tema, Ghana. The company was set up in 1982 and was officially commissioned and started production in commercial quantity in 1985 with an initial operating capacity of 10,000 metric tons of different aluminium products. In 1992, the plant capacity was expanded to 20,000 metric tons per year and in

2002, it was again expanded to 30,000 metric tons with an equivalent labour force of about 440. Today the labour strength is approximately 265. Apart from continues casting and rolling, it also produces aluminium sheets, coils, corrugated roofing, louvre blades and many others and supply aluminium to the Ghanaian local hollowware manufacturers such as Pioneer Kitchen Limited, Domod Company Limited, and Lion Aluminium products which they also produce households cooking utensils, window frames, curtain rails, corrugated roofing sheets, doors handles and many more. The figure below present the process involved in the aluminum cold rolling.

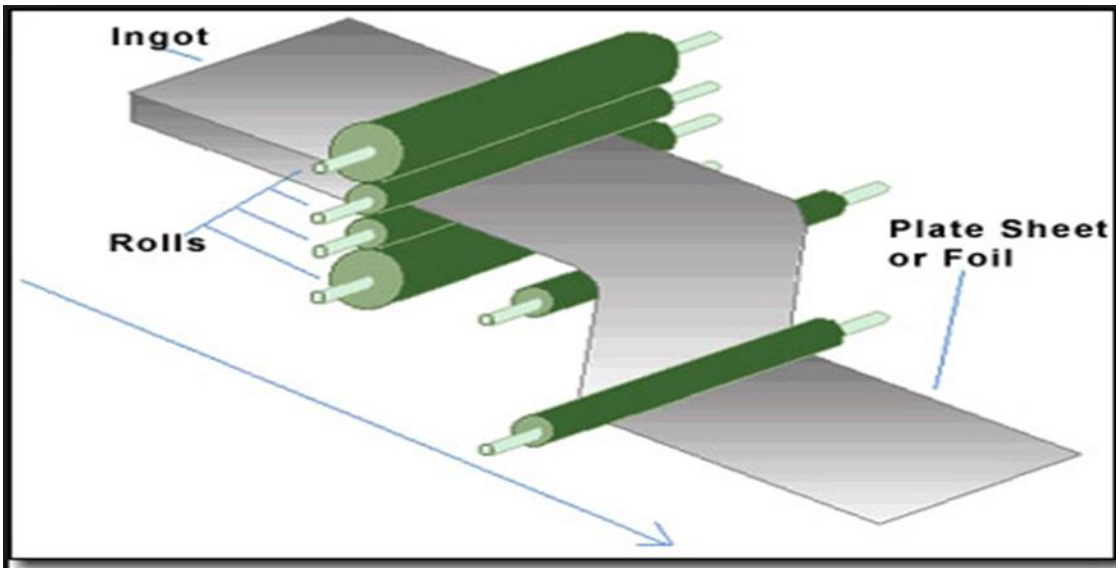


Figure 4 Cold rolling mill for ingots

Source: www.world-aluminium.org

Arguably, the production process continuous on which coils are passed through coil mill to further decrease the thickness upon the customer requirements, it may then goes leveling, heat treatment, slitting, cutting to length, and finally goes coating processes to meet the customer demand. Rolling mills is a machine used in a factory for deforming or shaping metal by passing it through lubricated rotating work rollers at a torque of 3,000 foot-pounds. This portion of the process is energy intensive because the ingots pass

to and from between the rollers, decreases the thickness ranges between 25 to 50 mm (1 to 2 in), with an equivalent increase in length. Ideally, rolling is defined as the way of plastically deforming metal by passing it between rolls. Indeed, rolling is a most highly used deforming process, which provides extensive production as well as close control of the final product, the metal undergoes highly compressive stress due to frictions between the rolls and the metal surface. The table 5 below also demonstrate the specification for the rolling mill.

SPECIFICATION FOR ROLLING MILL:

Table 5 specifications on rolling mills

PROCESS	LUBRICANT	TEMPERATURE OC	GAUGE RANGE (mm)
Hot rolling	Oil-in-water Emulsion	270-560	2-600
Cold Rolling	Oil-based/water-based	Ambient-170	0.15-6
Foil Rolling	Oil-based/Water	Ambient-140	0.005-0.6

Source: IJEAS, 2016.

The hot rolling stages involves aluminium strip being cooled in room temperature and further fed into the cold roll mill line, processed in between rollers to slowly reduce the thickness to the required gauge and then wound into a coil, followed by cold rolling which involves the treatment of the metal below its re-crystalized temperature, this rises the strength of the metal to about 20% to enable accuracy and surface finish to the products. Cold-rolling of metal has played a significant role in the manufacturing industry by providing strip, sheet, and foil with good surface finishes and increased mechanical strength of close control of product dimensions.

3 REVIEW ON ENERGY MANAGEMENT AND CONSUMPTION RATE

3.1 Energy efficiency management –production activity

Energy efficiency management can be defined as the means of using less quantity of energy to achieve the same quantity of output or service due to an investment in new technologies without changing the consumer behavior which can reduce well-being (IEA 2017). Similarly, in production perspective, this implies to the reduction in energy consumption, whiles on the other hand, increasing the usable output of the manufacturing or production process and yet achieving increased productivity and efficiency. Energy efficiency management is essentially important in all aspect of production industry because it practices reduce the amount of energy needed to deliver a given product and can play a leading role in decreasing the negative externalities linked with the present modes of production activities. To increase the use of energy efficiency in the manufacturing industry needs an interdisciplinary approach, this approach requires the involvement of a quite lot of department in the company such as, management, production, quality, IT and many others to effectively improve the energy performance in the industrial sector (Estrada, 2017). There are many existing processes and tools that are related to energy efficiency management which can relatively assists production companies to achieve efficiency in their production activities. These processes have individual different approaches to energy efficiency management from a different standpoint and need the participation of individual department in an organization to makes it function effectively. These processes can be *technological selection*, which means the chosen of the most suitable technology that best-suited for a particular production activities which can rapidly assist achieve the organization's economic and social development goals. These technologies can be machined tool, industrial robot or flexible manufacturing systems which are energy efficient in

operation. And the others are, Process monitoring, Modelling and analysis and finally, manufacturing scheduling (Ortiz, 2017).

3.1.1 Uses and Benefits of energy efficiency technology systems-solar PV systems

Electricity generation; In this instance, electricity generations from energy efficient technologies can be used domestically such as for solar water heating, TV, lighting, and many others; it is also applicable for industrial purposes such as the production of materials and many more. In addition, because it uses the panel, battery, and inverters, the system needs to upgrade when the capacity of the increases.

Agriculture; the Solar photovoltaic system is however applicable for taking care of irrigation of farmland and livestock watering system.

Transportation; It is obvious that currently, motor vehicles use solar power as their source of energy, and also for traffic lighting systems in urban and rural areas, and lighting for highways roads etc.

Security system such as alarm systems and CCTV can use energy efficient technologies.

Residential sector has been identified as the most energy consumed. It has exceeded the major sectors such as industry and transportation. Its main energy consumption occurs in hot water production and space heating, the heat production is mainly based on non-renewable carbon-rich sources which are unstainable. Nonetheless, the solar heat pump is been adopted to replace the latter so to increase the renewable energy share and reduce electric energy demand in residential heating applications (Lundqvist, 2017). Many benefits connected to the usage of energy efficiency technologies are as follows;

Assets values

Current research has established that individuals, as well as businesses, are willing to pay for a rental or sales premium for assets with efficient or better energy performance. The research indicated that the value of this premium for the commercial property shows that every USD 1 saved in energy costs translate on average to acceptance of 3.5% increase in rent and a 4.9% premium in market valuation (IEA, 2014). Communicating the importance of energy efficiency is a prime challenge even among non-energy experts, energy is basically observed as a commodity nor it is seen as a service in a normal sense, energy promotes both goods and services but on the other hand remains largely invisible to the public. For example, consumers purchase light bulbs not because they need light bulbs but because they want light; they purchase industrial machine because they want to increase productivity, energy efficient can enhances these services. In addition, this helps manufacturing organization to make an informed decision before attempting to sell or purchase equipment.

Energy affordable

This ensures reforms of the national energy market to enhance more and efficient spending on electrical energy thus providing energy affordability for low-income earners and production organization. Consumption of energy is an integral part of human life which every household should be able to afford in order to sustain a normal standard of living with respect to heating condition and clean cooking facilities as well as production purposes (Valbonesi, 2014). In this view, with energy affordability, more manufacturing and production companies will be able to produce more goods with less energy use. It has been established that 1.2 billion people, specifically in developing countries are without access to electricity (IEA, 2014). Therefore as energy suppliers expand their own efficiency, they will be able to extend electricity to more households,

thereby assists increased access to energy. In addition, research has shown that in both developing and developed countries, the poorer households are unable to afford the higher up-front cost of energy than the wealthy and similar aspect applies to the industrial sector.

Poverty alleviation

This are set of programs, in both economic and humanitarian, that have been put in place to assist migrate people out of poverty. This specifically means that, as the energy bill is reduced the poor households will be able to have the capability and the ability to acquire more and better energy services, thus they can also spend the freed up income satisfy any other critical needs.

Consumer surplus

This creates the difference between the overall amount that the end users are capable to pay for goods or services and the total amount they normally afford thus energy efficiency ensure savings in expenses from a decrease in energy-related costs, which freed up the consumer to spend the money saved on other goods and services and energy.

Job creation

Energy efficiency will then provide a new opportunities for paid employment, particularly the unemployed due to practices of energy efficiency because production companies will then use less to produce more goods, including expanding the economy.

Energy provider benefits

The energy sector is quickly changing with respect to the trend of deregulation. Over the past decades, government's authorities integrate with individual local utility

companies to supply home and businesses with a single standardized option for electricity. This system helped build the industry and set up important infrastructures to keep the sector in operation. Similarly, it is observed that this regulated system is outdated and non-optimal. Nonetheless, new rules have been established to keep the basic means of transmitting and delivering electrical energy whilst still permit alternative suppliers entry into the market thereby restructuring and unbundling energy.

Resource management

This details the process on which resource of an organization are managed effectively and efficiently, these resources can include equipment, labor resource, schedule and budgets for people, projects, production resources or natural capital stock. In both national and international level, a decrease in energy demand can lower the pressure on the scarcity of natural resources and thus decrease the requirement to explore the increasingly challenging context for extraction, for example, ultra-deep offshore, arctic and shale. This can, however, reduce the related increase investment costs and environmental externalities. Minimizing energy consumption and emissions through adopting of energy efficiency technologies can play a significant role in mitigating waste and related pollutions of land and water thus also assists in combating ocean acidification and reduces the negative effect on the biodiversity. Growth in the energy demand move hand-in-hand with economic transformation as well as social development but there has been a related high cost for the environment. For example, the figure below shows that China and India the two energy giants account for more than half of the world's overall increase in energy consumption over 2012 to 2040 projection period, this implies that by 2040 energy use in the Non-Organization for Economic Co-Operation and Development (OECD) Asia will outweigh that of the whole OECD by 40 quadrillion British thermal units (Btu).

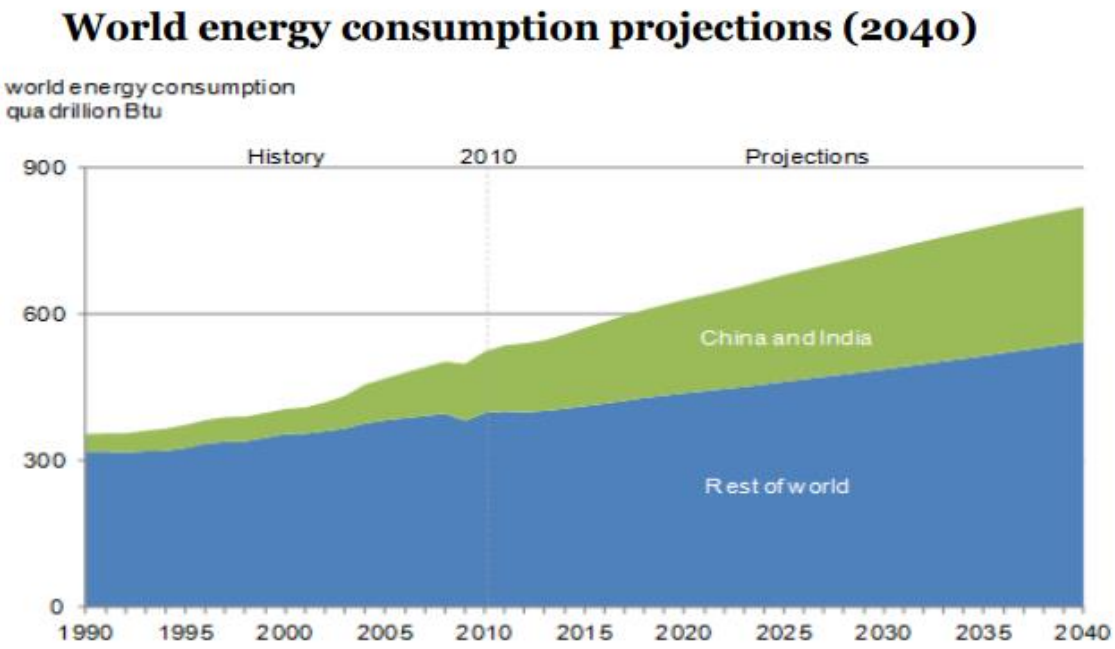


Figure 5 *World energy consumption projections*

Source: IEO, 2016.

Today, resource mismanagement is on the increase due to the replacement of natural capital with man-made capital. Admittedly, energy is needed for heat and mobility, wood for paper products and cleaning water for healthy living, with the assistance of photosynthesis, green plants are able to convert solar radiation, carbon dioxide, and water into chemical energy and thus supports human life, natural capital stock and also absorbed wastes and supports climate stability and protection from ultraviolet radiation (Wackernagel, 1996). Nonetheless, there are much-unlimited energy supplies from the sun that can be harnessed for economic purposes, the sun beams contain approximately 175,00 terawatts to the planet more than compared to only 10 terawatts of that of the commercial energy, specifically fossil fuels. Indeed, switching towards energy efficiency technologies, mainly photovoltaic system, and the economy can be the promising

strategy for decreasing the use of the natural capital stock and thus save the environment.

Energy prices

Arguably, scarcity and erratic price shocks of energy has compared many countries to seek for the alternative. Consequently, achieving efficient energy (electricity) is unsustainable because the cost and price of electricity services are more influenced by several factors such as, supply and demand, import diversification, primary fuel price, severe weather conditions, network infrastructure costs, environmental protection costs and other related charges to carbon emissions. And finally, excise and taxation rates are shown in the prices in order to promote efficient use of electricity (Radovanic, 2015). In addition, the price of energy does not show the actual marginal cost of energy consumption, neither by environmental externalities, average cost pricing or national security. Typically, the environmental costs of energy use with respect to the burning of conventional energy sources, for example, (climate change due to carbon dioxide emissions) are excluded from what end users pay for energy services. The figure below

presents a graphical representation of price of different types of fuel including electricity.

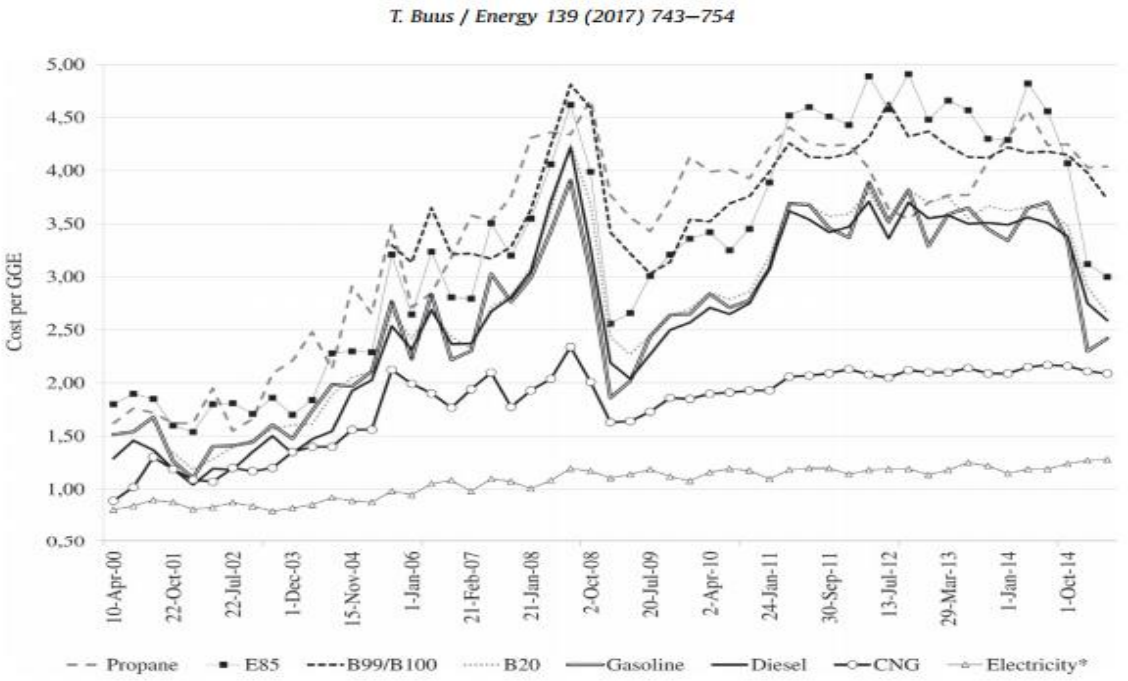


Figure 6 Trends in energy price. Source: Tomas Buus, 2017

Enterprise productivity

This is the total output of individual employees added together. The industrial sector is responsible for approximately 50% of the world energy consumption and a significant impact on global warming. Nonetheless, with respect to industry, small and medium-sized enterprises plays a significant role in the economy worldwide and representing about 99% and providing barely 60% of employment. Increasing energy efficiency in these enterprises will create value for the economy, society, as well as to the enterprises themselves (Catarino, 2016). On the part of costs savings, energy efficiency can provide other benefits that can assist these enterprises to develop and grow, for instance,

productivity improvement, profitability and competitiveness and finally enhanced product quality as well. A reduction in imports dependence on energy and decreasing of environmental impacts not only increase value but also assists businesses and society.

Energy security

Uninterrupted, reliable, adequate supply of energy sources at affordable prices is paramount for society and economic development. Energy security has a lot of dimensions, which first of all has to do with long-term energy security which purposely deals with the time investment to energy supply in tandem with developments and sustainable environmental requirements, and final one has to do with short-term energy security which specifically focuses on the ability of the energy system to react swiftly to sudden changes in the supply-demand balance. Lack of energy security provides negative economy and social impacts of physical unavailability of energy or electricity prices that are not competitive or extremely volatile. Energy security is the main concern for countries that rely entirely on foreign resources (Kitamuri, 2017). Arguably, with respect to the electricity system, high reliance on a single source of fuel is considered a riskier option and it is necessary to practice fuel diversification to avoid supply disruption. Energy efficiency improvements curtail the over-reliance on single imports requirement and supply disruption thus improve productivity and economic growth.

Energy savings

Energy savings is the decrease in the energy bill by changing consumer behavior using the same technology and therefore efficiency is achieved through the mean of energy saving. Progress in the use of technology has traditionally been adopted as the solution to solve the problems of increasing use of resources by the economy (Pius-Ventosa, 2015). Currently, development of more resource-efficient technologies makes it capable and possible to sustain the same level of material welfare using fewer resources, because

this improves productivity factors, resources, and processes. Indeed, rebound effects explained the decrease in the potential or engineering energy savings from technological improvements in the efficiency of supplying energy services. Nonetheless, reducing the quantity of energy used while still achieving the same level of results of end-use sustain the environment, improves productivity and preserves the conventional resource such as coal, gas or oil for future use.

Development goals

Development goals are targets for specific development outcomes, indicators that projects are made to deliver during their lifetime. Furthermore, consistent supply of energy resources is generally accepted but not enough for development within a society. In addition, development or sustainable development requires a sustainable supply of energy (electricity) that for long-term is readily and sustainably available at much reasonable cost and can be used for required activities without affecting society negatively. Use of conventional energy resources such as (coal, oil, natural gas and uranium) are considered to be finite; other sources such as sunlight, wind, hydro and biomass are acknowledged to be renewable and sustainable for long-term use (Dince, 1999). Environmental issues are much of a concern and a significant factor in sustainable development. For several reasons, events that constantly degrade the environment are not sustainable, for instance, cumulative effects on the environment of these events clearly lead to implication such as health, ecological and unproductivity. A huge chunk of environment effects on society is due to the use energy resource. Meanwhile, a society requiring for sustainable development uses sources of energy that do not cause negative impacts to the environment, since all the energy resources have negative effects on the environment, it is reasonable to put across that some of the prime concerns with respect to the limitations imposed on the sustainable development by environmental emissions

and their related negative effects can be overcome through increased use of energy efficiency.

Climate change mitigation

This clearly consists of activities to reduce the magnitude of long-term global warming. Global steel industry with production quantity of 1,129 Mt in 2005 contribute about 2,200 to 2,500 MtCO2 or 6% to 7% of global anthropogenic emission including indirect emission from power consumption (Hanisch, 2009). Similarly, per tonnes of emissions from steel widely depends on the countries; 1.25 tCo2 of Brazil, 1.6tCO2 in Korea and Mexico, 2.0 tCO2 in the USA and 3.1 to 3.8tCO2 in China and India respectively. Furthermore, iron and steel production is a batch process and therefore the efforts to increase energy efficiency involves consistent production process to decrease heat loss, increase waste energy recovery and process gases and properly design of electric arc furnace. Ideally, the intensity of energy use in most of the industrial processes is approximately 50% more than the theoretical minimum, this significantly provide the opportunity to reduce the use of energy and its environmental negative externalities and thus a lot of technology have the ability and capability to reduce industrial carbon emission of which energy efficiency is considered to be the most important, specifically in short-to-mid-term and long-term as well.

Health and social benefits

This refers to activities of programs of an organization meant to promote the welfare of a community or population through assistance policies and guaranteed access to resources to promote health. Improvement of buildings, for example, insulation retrofits and weatherization programmes through energy efficiency established sustainable condition for occupant health and well-being specifically for poor households. Other substantial benefits include improvement in physical health such as a reduced ailment such as respiratory and cardiovascular condition, rheumatism, arthritis and allergies, and many others (IEA, 2014). Improving health and social well-being generates downstream social and economic impact such as a reduction in the public health spending. Improvement of indoor air quality through energy efficiency measures saved European Union's economy as much as USD 259 billion (EUR 109 billion) annually.

Industry productivity

Industrial sector sees energy as an operational cost. Furthermore, energy savings are seen as a minor benefit rather than as a core value- generating proposition. Nonetheless, industrial energy efficiency measures provide potential benefits in addition to energy costs savings such as competitiveness, profitability, production and product quality, improved working environment and decrease operation and maintenance costs. In addition, multi-benefits obtain from energy efficiency measures by industrial firms includes production and capacity utilization, reduced resource use and pollution and improve productivity and value creation for business organizations. Implementations of energy efficiency help business strategic priorities and also strengthening business

investment. The value of production and operational benefits obtained from energy efficiency can be 2.5 times (250%) equivalent to the value of energy savings (IEA, 2014).

Macro impacts

Energy efficiency in entirety has positive macroeconomic effects, specifically by boosting GDP and facilitates employment; this provides benefits across the entire economy with direct and indirect effects on the economic activities measured through gross domestic product, trade balance and energy prices. Furthermore, gross domestic products analysis changes due to large-scale energy efficiency policies, shows viable outcome with economic growth ranging from 0.25% to 1.1% per year. Macroeconomic impacts are driven by two different kinds of effects which are, investment and energy demand reduction (IEA, 2014).

Table 6 *Economics impacts on energy efficiency*

Increase investment in energy efficiency Higher production in energy efficiency sectors Lower production in other sector	Employment Economic output Energy prices Trade balance	Energy cost savings Increase disposable income Higher business profits Improved energy

Source: IEA data and analysis, 2014.

Employment

Job creation is paramount to policy makers, so they usually seek information about expected employment gained from energy efficiency programmes. Typically, net employment undergoes an assessment considering both employment gains and losses. Therefore to establish a clear definition for employment is crucial but direct jobs are however defined normally as those created in either manufacturing or installation of energy efficiency equipment and indirect jobs are those obtained from supply chain effects, so adding these parameters provide the overall gross employment effects. The net employment impact is also determined by subtracting from this total any employment that must be lost anywhere in the economy such as in the energy production sectors or due to insufficient labor market capacity pertaining to high wage rates. The use of energy efficiency programmes in creating employment will rely on the scope and the structure of the investment and the related type of energy demand reduction intervention in support, as compared to similar investment in the conventional energy source (fossil fuels) industry. Energy efficiency service has been identified to create as much as three times the number of jobs per million dollars invested (OECD/IEA, 2014). Arguably, energy efficiency improvement in jobs over maintenance and repairs of equipment can be quantified as a significant source of employment and cannot be excluded, and therefore energy efficiency jobs ranged between low wage jobs to highly skilled technical works and can be seen everywhere.

3.1.2 Factors affecting the underinvestment in energy efficiency technology systems

Adopting energy-efficient technologies could help both private and social rewards, such the economy, environmental, and other social benefits from reduced energy consumption. Ideally, government and firms around the world have developed interests and adopt the policy to increase the use of energy efficiency and grab its benefits. Ideally,

there is wide held view of various obstacles to the adoption of energy-efficient technologies that have stopped the realization of these potential benefits. These obstacles are as follows; market failures, behavioral biases and measurement errors. On the other hand, under the market failure, there are also challenges that explains the underinvestment in energy efficiency, and they are follows;

Imperfect Information for Consumers

Due to imperfection nature of the energy markets, product and services face obstacles from adoption even when their consumer economics appears to be useful. Similarly, lack of information as well as asymmetric information appears to be the reason why end users systematically underinvest in energy efficiency, this is because consumers received insufficient information about the difference in the future operating costs between more-efficient and less-efficient goods required to make an adequate investment decision (Brown, 2001). In addition, asymmetric information is a type of imperfect information where both the seller and the buyer to a transaction have access to different level of information. For instance, a seller may have more information about the quality of a good or product more than the buyer and may be unable to perfectly transfer that information to the market thus leading to a market failure from an asymmetric information point of view. Since imperfect information is known as one of the basic market failure recognized by economists, it is required to provide a rationale for policy intervention. Information problems of different forms are known to be the main source of market failure that attributes for the gap in the energy efficiency investment (Huntington, 1994).

Principal –Agent issues

Principal-agent problems occur when disinterested party are involved in decision to purchase energy-saving technologies, or the persons making the investment decision are

different from the beneficiaries from the energy savings, this emphases on pursuance of private interests by the agent on behalf of organisation, markets and other related collective decisions where the principal depend on the agent to make informed decisions due to imperfect information. A specific example is a landlord-tenant relationship. Because the tenant would eventually benefit from the savings on the energy bill, it is difficult for the owner to invest and moreover incentives for the tenant to invest are less likely since they are more likely than owners to move before they grab the full benefits of their investment (Nelson, 2015)

Credit Constraints

Lack of access to credit deters some consumers from purchasing a more energy efficient product or from making efficiency augmenting improvements to their homes because of high upfront cost. Energy efficient gadgets such as lighting, HVAC or machinery are generally expensive than less efficient options, irrespective of their market sector. Though, if the households decide to decrease their overall costs in their buying decision, the financial aspect needed for the purchase of the quality equipment could be possibly high, this enables the consumer to afford the cheap and inefficient product. Credit constraints are some of the attributes to a market failure which can lead to an energy efficiency gap by underpinning some end users from making privately optimal purchasing decisions for expensive products, and limited access to credit can also be caused by asymmetric information on credit risk, this hinder the difference between the borrowers with good credit risk from those with bad credits risk. Similarly, it is typically difficult for low-income households with much credit risk to borrow funds thus they

face a significant infinite discount rate for investing in energy efficient product (Stadelmann, 2016). From a policy point of view, the credit constraints could be reduced with financial incentives especially with loan facilities or subsidies which seem to be much better than that of rebates. Typically, if the energy savings over the entire life of the machinery outweigh the upfront costs, it is possible that the manufacturing industry would be enticed to invest in energy efficient technology, and having less access to credit facilities will make it impossible to investment into energy efficient products or goods.

Innovation market failures

A rapid transition to a low carbon and sustainable economy includes not technologies alone but also involves policies, user practices, information sharing, markets, and behavioral changes of electricity consumers (Kowalska-Pyzalska, 2017). Research and development spillovers may be attributes leading to underinvestment in energy efficient technology innovation because of public good nature of knowledge, whereby individual business is not able to fully reap the benefits of their innovation efforts but rather accrued partially to other organizations and end users. Learning by doing which simply means that as the cumulative production of technologies inclines, and equivalent cost of production declines, the manufacturing companies learns from experience the way to decrease its costs. Furthermore, learning by doing will be connected to market failure because it produces knowledge for similar firm in the industry and further decreases costs of others without compensation (Palmer, 2009).

Behavioral biases

In this context, end-user fails to behave as foretold by rational choice theory since people are irrational and are unable to do the right thing. Behavior factors are often given as the reasons for unsuccessful adoption of energy efficient products and thus all of the environmental behavior occurs under conditions of bounded rationality. Similarly,

severe rationality is therefore obstructed by information and cognitive constraints. However, the researcher has pointed out that because of numerous factors such as insufficient time to analysis, limited information about issues and adoption, limited processing capacity and lack of interest compare end users to seek for alternatives which might look satisfactorily rather than making an optimal choice of energy efficient product (Kowalska-Pysalska, 2017). Similarly, non-rational behaviour is core to human decision making and therefore any method based on the traditional economic assumption that makes people rational and self-regarding is seriously flawed, this means that if bounded rationality can hinder systematic underinvestment in energy-efficient technology then this could happen if biased decision- making make individuals to consider high rating to initial investment costs rather than to future energy savings. Nonetheless, a bias to initial investment costs can be due to *salience effect.*

This happens when consumers tend to compare information in amount to its intensiveness and give more importance to easily observable factors. On the other hand, end users may tend to recognize the upfront cost simply because it is much larger and directly observable. Analysing the overall value of the energy savings to the life of the investment is more difficult considering the uncertainty surrounding energy savings and rise and fall in energy prices. However, retain the status quo explains when consumers remain to the default setting, for example, people tend to avoid change and pursue with the flow of pre-set alternatives even when the alternatives may produce a good result because they tend to adapt to fewer valuables even if those items affords long-term benefits.

Endowment effects-sunk cost in decision making on energy is another aspect in which households attached to their current appliances are not willing to replace them with more efficient technologies even if it is efficient to do so.

Heuristics

Heuristics are shortcuts to make decisions and therefore consumers use heuristics to analysis the energy consumption, which can lead to systematic underinvestment in the energy efficiency. For instance, households used present energy prices to calculate savings from efficiency investment which they do not consider the increases in price in the future. Measurement error, the next category that explains the energy efficiency gap which consists essentially of several reasons why observed level of diffusion of energy efficiency product may eventually be privately optimal. Typically, there has been possibilities of unobserved adoption of costs, including unaccounted for product characteristics which may be overstated benefits of adoption because of inferior project undertaking relative to assumptions or weak policy design (Gillingham, 2009). In addition, the imperfect discount rate may be used in the analysis when the correct consumers, as well as firm discount rates, should change with opportunity cost and access to capital, income, purchasing versus retrofitting equipment, systematic risk and alternative values. There has been always heterogeneity across consumers with respect to benefits and costs of using energy-efficiency technologies so that what is possible to be privately optimal on average will not be privately optimal for all.

4 EMPIRICAL STUDY

4.1 Research methods

This chapter presents the methodology used in collecting the data, which includes the analysis of the data and also explains extensively on the reliability as well as the validity of the data. The research question for this study is *''energy efficiency management in an energy-intensive industry in VALCO and Aluworks''*.

Gathering data for the purpose of research is one significant and integral part of the research process, and the other part also includes analysis. With regards to the research subject, purpose, as well as data, the research needs a suitable research approach. Research is the developing of new knowledge and the utilization of existing knowledge in a new and creative manner in order to produce new perception, methodologies, and understandings, and thus it involves synthesis and analysis of the earlier research to the extent that it ends up in creative outcomes (O'Donnel, 2012). Having an access to the required materials and the primary data that answers the research questions poses difficulties. There are changes in research methods to choose from when conducting the research itself, and the choice of the methods rely on a specific research project. It is also significant to connect the research to the academic theory. Furthermore, there are variations in getting an appropriate research model for qualitative and quantitative research, especially, when the quantitative research aligned with a precise structure. Qualitative research structure is formed as the research continues from the data gathering towards the analysis of it and its iterative process (Corley, 2012).

4.2 The research approach

Research approach referred to the empirical materials of the research, the way it is gathered and analyzed in well and scientific manner. Research materials are widely grouped as qualitative or quantitative yet these are mutually exclusive. The type of the research approaches can be descriptive or analytical. Arguably, the research question guides the research methods chosen, and therefore the research also concern mainly about the choice to make and the choice required to be precisely established. Research has three main characteristics, the first part is about step by step data gathering, the second part is about step-by-step data interpretation and the final part is the reasons for the research. Therefore research is the ways of searching for answers to your professional and practice questions and it is characterized by the usage of tested procedures as well as methods (Khan, 2018).

4.3 Qualitative and quantitative methods

Qualitative research provides insights of the problem under study and assists to create concept or hypothesis for the potential quantitative research, whiles quantitative research quantifies the problem statement through creating numerical data. In contrast, quantitative research approach is the means of techniques in data collection, particularly, questionnaire or practice of data analysis, for example, graphs as well as statistics which develop numbers. Whiles qualitative research method, data is collected with interviews and observations and analyzed by grouping nun-numerical data. Qualitative research begins with words and ends with words. Empirical data is naturally qualitative and gathered non-standardized information and the research process is natural and

communicative. However, it does not have many observations of certain events and it is difficult to analyze using mathematical techniques to obtain adequate analysis through them. Similarly, qualitative research is subjective in nature than that of quantitative research. The table below present the difference in view point between qualitative and quantitative methods.

Table 7 Different viewpoints in qualitative and quantitative approaches

QUALITITIVE RESAERCH METHOD	QUANTITATIVE RESEARCH METHOD
To understand, interpret, rational approach	Importance in experimentation and verification
Observations and metrics in the natural framework	Factual concentration and reasoning, control of measurement
The subjective approach to data, knowledge, and information, emanating from internal	Observation approach to data, information and as well as knowledge coming from external
Exploratory, process	Hypothesis, deductive and results
Holistic approach	Analytical and precision
Generalization via individual features as well as contents of the phenomenon	Generalization via population

The research approach in this master's thesis is qualitative which uses the interview. The main purpose of this research is to understand the present energy situation in VALCO and Aluworks and propose a tentative solution to help meet their production quota and create the necessary attention of the production and manufacturing industry about the

merit relates to the adoption and the practices of energy efficiency management which is the aim of the this study. Taking into account the design of the research process, three purposes exists in research theory and they are; deductive, inductive and abductive. On the part of deduction process, the theory is verified, and data is gathered to assess the proposition in the already existed theory. This is systematically and methodologically structured, which has operations measured; problems are decreased into its simplest form and more generalized. For the induction process, the entirely new theory is created by generalizing it from micro to macro, and thus data is gathered to deal with the problem and also identify the pattern and themes so that a new theory will be created.

In qualitative research, the methods used for collection of data should be carefully thought to sustain the sensitivity as well as the flexibility with regards to social context to the problem and interpretation. For instance, qualitative interviewees are offered the chance to highlight about their experience, views, and meanings, and therefore this qualitative method are suitable to answer the research questions and also fits adequately for the purpose of this thesis.

4.4 Data collection

The characteristics and purpose of a research design can be that of exploratory, descriptive or explanatory, and this design link to the research questions. Similarly, with the explanatory study, open questions enhance the understanding of the phenomenon under study. Conducting an interview with the experts about specific questions is a better way of unraveling the problem and thus narrowing the study as the research continues. However, descriptive study normally includes surveys that are mainly for identifying the facts and provides a clear concept of the problem, whereas explanatory study develops a relationship among variables. The collection of the data, as well as the analysis, relies on the methodological approach in the study and the progress of the

research also has an impact on the reliability and validity of the research. There are two different types of collecting data and can be grouped as primary and secondary data, and choosing qualitative research approach requires a large amount of data that needs to be collected for a particular topic. Primary data means that the data is gathered for a particular study with methods that are suitable for the purpose, and it is known to be the data that is being analyzed as itself, and is also an information collected for a particular purpose of study either by the author or by someone else (Khan, 2018). Arguably, secondary data is gathered for different purpose and cannot be much suitable for a new research problem because sometimes the information required is available already in many sources, for example, journals, previous reports, censuses, and the researcher can pull that information for a particular purpose of the study and it is significant to assess the quality of data very well (Khan, 2018).

4.4.1 Conducting interview

An interview is written list of questions, which can be open-ended or closed, prepared for use by the interviewer for face-to-face interaction, this can be person-to-person, by telephone or by other electronic media, and this is one of the often used methods of data collection in the social science, this includes asking question of the respondent and recording the answers given. Nonetheless, conducting qualitative research interviews needs diverse skills, careful planning and prepared adequately, and careful listening and note-taking at the same time in the interview arena. On the part of the interviewer, it is significant to collect data as much in the related topic areas as possible in order to ask appropriate questions to gather useful interview data for the purpose of the research (Khan, 2018). However, the researcher uses person-to-person interview targeted to the production managers because is it supposed that the managers interviewed are competent and telling the truth and providing their optimal knowledge and experience to be used in the research. The interview took place at the interviewee work place during

working hours and taken about half an hour, and conducted with the narrative approach at which the interviewees were asked to freely tell and openly of their problem situation in the company.

4.4.2 Research Questionnaires

A questionnaire is a written list of questions, on which the answers are recorded by the respondent. In a questionnaire, respondents go through the questions, interpret what is expected and establish the answers. And thus for certain demographic groups conducting a survey by questionnaire may be effective. According to Brace (2008), questionnaires is the communication medium between the researcher and the subject under study, which is normally ordered on the researcher's behalf by the interviewer, and in this case the researcher articulate the questions at which the researcher demand an answer, and through the questionnaire, the subject's answers are communicated back to the researcher. This approach was chosen because it will help the researcher acquire an understanding of the underlying reasons, opinions, and motivations; it will also provide an in-depth insight into the problem under research and therefore will assists me to establish an idea for the research. The questionnaires developed contains mostly facts concerning the two case companies on their current energy strategy, these questionnaires were channeled to the production managers to testify if they were important to the working environment and thus to find out how the industry is feeling about energy efficiency technology, the obstacles that come along with it as well as it preference. There was also an extensive discussion between the researcher and the production managers specifically about the energy efficiency systems with relation to the case under study, both managers registered their opinion on each question asked after which we took a tour into the production plant to see how it works.

Nonetheless, the questionnaire was developed based on the reality on the ground about electricity issues faced by these production companies, it was further designed with the major parameters that define energy efficiency management and its adoption by the industry. The respondents were contacted personally through e-mails at first. After that the questionnaires were sent to the respondents within two weeks beforehand. The production managers had a good positive behavior towards the research topic and really prepared to answer the questions as well as the interview. Nonetheless, the questionnaires sent to VALCO has initially rejected because there was not an introductory letter attached to the questionnaire, so they requested for the introductory letter from the researcher addressed directly to the company, I communicated back to my supervisor and he did accordingly. The research was conducted on two folds; one was a conducted interview and online research from Ghana's energy commission's website and VALCO and Aluworks website and the other one were carried out based on a questionnaire to the case companies.

The following are the questions and the answers obtained from each question from the production managers of the case companies. The questions were mainly objectives.

What is the kind of energy sources (electricity) do you use for your production and manufacturing activities?

Volta Aluminum Company Ltd uses both renewable energy source (hydroelectricity) and conventional energy source, and

Aluminum Works uses renewable energy source only (hydroelectricity) to undertake their production and manufacturing activities.

Is the current electricity crisis affecting your production activities? Yes or No.

Aluminum works ltd answered (No) to this question, and

VALCO answered (Yes).

Do you have any backup power plant in case of power outage? Yes or No

Both VALCO and Aluworks answered (no) to this question.

What is your daily average electricity consumption rate? i. 1000kwh-2000kwh ii.

2001kwh-3000kwh iii. 3001kwh-4000kwh iv. 4001kwh+

Aluworks consumes 678,783 kWh averagely per month, and VALCO consumes more 4001Kwh per month averagely.

Can your company likely to switch from the conventional energy sources to the renewable source? Yes or No.

Volta Aluminium Company Ltd answered (yes) because it is less payback, produce sustainable electricity and environmentally friendly, and

Aluminum works answered (no) although it produces sustainable electricity.

There is a strong historical data that attest the relationship between the availability of energy and the economic activity.

4.5 Data analysis

Data analysis is the process of bringing order, structure, and meaning to the mass collected data, it further goes on to describe it as messy, ambitious and time-consuming, but yet as a creative and fascinating process (Marshall and Rossman, 1990). There are more approaches to analyze a preliminary data but the ultimate decision of the approach to the data analysis is carried out after the data is collected. The main alternative to a reliable data analysis approaches is data display and analysis approach and dialogue research practice. Furthermore, in it simple terms, the raw data analyzing commerce with grouping the data and condensed the information into findings that are fundamental to the research.

The research involves two major companies under study; Volta Aluminium Company and Aluminium Works.

The first question was mainly about the type of energy source used for their products and manufacturing activities, and the results derived from the questionnaire indicated that the first case company which is VALCO uses renewable energy source (hydroelectricity) because it is cheap and environmentally friendly and renewed by nature but due to variations in the water level as a results of droughts related issues it is difficult to obtain reliable electricity supply from the hydroelectric dam and therefore feel threatened to rely entirely on this source of energy. This compared both companies to use natural gas, light crude and diesel generating power plant to back their production operations. Even though it is established and they are highly aware that the use of conventional energy sources generates negative consequences to the environment. These companies under study cannot afford to be out of operation, so they decided to use this non-renewable energy source to support their continue production operations

and to use this same energy source light crude oil (LCO) to undertake their administrative activities.

The second question has to do with if the present situation of electricity crisis is having a negative effect on their production. Energy and specifical electricity is the backbone of every economy and without constant, adequate and reliable electricity supply economic activates are likely to become halt. According to the respondent, the electricity crisis is highly affecting their production operations and there must the need for the government to restore the electricity in order to bring the full capacity operation of their production work. It is obvious that inadequate electricity supply is adversely affecting every sector of the economy including households but the most hits are the production and manufacturing organizations. Nonetheless, VALCO, the country largest aluminum smelter was highly affected due to over-reliance on the hydroelectricity dam as results it operates with one pot-line instead of six pot-lines; this compared the company to incorporate the use of light crude oil to support its activities. Pot-line in this is a row of electrolytic cells used in producing aluminium. In this instance, to bounce back to full capacity requires constant electricity supply from a consistent and reliable energy source. Moreover, Aluworks is not much affected by the electricity crisis because their production capacity is not as high as that of Volta Aluminium Company, but yet all the production activities takes place in their promises are energy intensive.

The third question was purposely about if both companies have in installation any backup power generating plant in case electricity supply interruption occurs, the results indicated that both case companies under study have not installed any standby plant to even assists in administrative works if electricity supply is cut or an emergency. A standby generator is a back-up electricity generator systems that functions automatically, between a seconds of a electricity outage an automatic transfer switch

senses the power loss, triggers the generator to start and then conveyed the electrical load to the generator and the standby generator starts to provides electricity to the circuits. After the normal power is restored, the generator automatically returned to standby mode. Furthermore, when a dangerous whether occurs or issues relative to the power grid, the generator can supply electricity and this implies that production activities will still continuous even during electricity failure from the main grid. These case companies have not put in place this system due to total reliance on the Akosombo hydroelectric dam. However, this situation requires for a provision of standby plant in case power failure occurs. This is one of the major's challenges faced these companies that need to be addressed.

The fourth question was about average daily electricity consume quarterly and annually of both case study companies. Consequently, Aluworks preferably chose to give monthly average electricity consumption instead of the daily average consumption proposed. On the other hand, VALCO consumes more than 4001Kwh of electricity on daily average more than the range specified by the researcher, this is equivalent to single pot-line capacity. VALCO plant has a rated capacity of 200,000 metric tonnes of primary aluminium annually, but today, it operates at 3,000 metric tonnes annually about 20% of the initial capacity with only 3.5% of electricity consumption. Electricity consumption rate of VALCO is so high that, if the overall electricity demand of the whole country is 16,798-16,900 GWh, VALCO can only operates one pot-line. And if the total energy requirements of the entire country is 18,185-18,373 GWh, VALCO can only be allowed to use two pot-lines. Therefore according to the results, the company consumes 678,783 kWh average monthly. This is tabulated in the table below.

Table 8 Electricity consumption rate of Aluworks

Electricity consumption rate of Aluworks	Kwh
Quarterly	4,0726,98
Annually	24,436,188

Table 9 Electricity consumption rate of VALCO

Electricity consumption rate of VALCO	Kwh
Quarterly	24,006
Annually	144,036

The daily average electricity consumption for VALCO exceeded the range given by the researcher, which means that the company requires for more adequate and reliable electricity to bounce back into the six pot-line operating capacity instead of one pot-line the company operates today. The two tables above demonstrated the difference in electricity consumption between the two companies. It is obviously clear from the table that total electricity consumed quarterly and annually by Aluworks outweighs that of VALCO even though the production processes undertake by VALCO is by far larger than Aluworks. In addition, if VALCO is to operate on full capacity or on peak production, their electricity demand will be much higher than what is it presently thus empirical reality established clearly that Aluworks is by far ahead of VALCO in terms of electricity consumption. Aluworks production plant has an initial rated capacity of 10,000 metric tonnes per year and further expanded to 20,000 and then to a capacity of 30,000 metric tonnes of various aluminium products. So in comparison to their electricity consumption rates, VALCO initially seemed to consume more electricity than Aluworks because of the nature of its production processes. This is because there was a curtailments of electricity to VALCO due to the low level of the lakes that feed the Akosombo dam, this renders under-utilization of the plant and equipment of its production. Aluworks is also affected by the same phenomenon but not as severe as VALCO. Today Aluworks electricity consumption becomes higher than VALCO.

The final question which is number five was mainly about the possibility for the two companies to switch from the use of conventional energy source to renewable energy resource. There is a strong historical data that attest the relationship between the availability of electricity and the economic activities. Over the previous years, the risks and the reality of the environmental degradation have since become more prudent, numerous factors attributed to the impact of the environment includes increased human activities, increased fossil fuel consumption, and industrial activities. Attaining a

solution to this environmental issues faced presently requires long-term potential action for sustainable development. Similarly, Volta Aluminium Company Ltd sees the benefits and the potential in adopting renewable energy technology and would prefer switching from conventional energy source to renewable energy option because it appears to be the most significant, efficient and effective solution to salvage the environment from the harmful emissions. Renewable energy sources are potentially and economically viable for production of electricity and it does not contribute to gases that can cause negative effects on the environment and also renewed by nature.

Ideally, the results emanated from the questionnaire shows that VALCO is using light crude oil in addition to the hydroelectricity to sustain its operational activities, yet they will like to switch to a reliable renewable energy resource because it generates sustainable electricity and does not pollute the atmosphere. On the part of Aluminium Works, they seemed less comfortable with the current electricity supply from the hydroelectric dam, this is because the production process has been divided into two parts; one stage uses diesel power plant for further processing of the aluminium ingots and the other part uses hydroelectricity to reduce the size of the casted ingots to and from the cold rollers and also cutting of the sheet metal into various sizes and shapes according to the customer specification. Generally, most businesses and manufacturing companies in Ghana prefer using alternative energy source in addition to the hydroelectricity they already use in case insufficient electricity supply or electricity failure from the main grid occur.

4.6 Concepts of reliability and validity of the research process

In this study, reliability in scientific research is the degree at which the outcomes and conclusions of a study is repeated over time and are an accurate representation of the overall case under study and therefore if it could be conducted by someone else in the

future under the same methodology the same results will be obtained (Joppe, 2000). The role of the author is linked to the issues pertaining to reliability and validity of the research, therefore the research procedure should be transparently thought through and assess with no logic leaps and false presumptions. The study should be directed and reported in a clear manner that every phase of the study will allow anyone to reproduce the research and evaluate for themselves the reliability of the study with which the outcome should not be random. For instance, if the study involves field work then the information collected from the field should be kept to certify the control over the author's activities, perhaps weak reliability may be hampered by non-systematic errors that emanate from the negligence in establishing the data. On the other hand, where the idea of reliability is connected to the quality of the research, the perception of validity and its different forms confirms the quality of the study by adding reliability, besides both are connected to the research as a source of complete knowledge. In this particular research, a well organised questionnaire was typed and sent to the production managers of the case companies (2) two weeks after I made a followed up and had an oral extensive interview with the production managers to confirm the answers given on the questionnaire thus if another researcher might carry out similar study with the same approach the same results and conclusion will be achieved, therefore reliability as far as this study is concern is much high.

Validity is the ability of an instrument to measure what it is designed to measure. Nevertheless, the perception of validity can be applied to all aspect of the research procedures, and furthermore is refers to the appropriateness of each phase in finding out what you plan to, and it is much more related to measurement procedures (Khan, 2018). The evidence of validity is built every time and continues to the interpretations of the research outcome of the measurement. Furthermore, when a measure contains good test-retest reliability and internal consistency, the author should have an assurance that the

scores shown what they are meant to be. A measure can be adequately reliable but contain no validity. On the other hand, there are three different kinds of validity: face validity, content validity, and criterion validity.

Face validity refers to the extent to which a measurement method looks on its face to measure the construct of interest, therefore a questionnaire that obtain these types of items would have good face validity. Even though, face validity can evaluate quantitatively. For instance, if a test are mend to measure intelligence, the test would be valid if it accurately measured intelligence or measure the intended purpose. Content validity refers to an extent at which a measure covers the construct of interest. Or in other words, it normally concerns on the adequacy at which the test items comprehensively and representatively sample the content area to be measured, whereas criterion-related validity is the degree at which peoples scores on measures linked with other variables (Williams, 2015).

Validity in this research means that the entire research instruments to the study are in a perfect match and therefore determines if the research truly provides what it was made to measure and therefore reflects on the results (Joppe, 2000). On the other hand, only one aspect to confirm the quality of the research is by construct validity and this is mainly about creating the exact operational parameters for the objectives aiming to achieve. This, however, means that fundamental features of elements of the constructs are notable and understood on the same grounds by the researcher and the production managers. This study carries two main constructs*; efficiency management and energy intensity*. These terms were extracted from existing research and their meanings were noted by respondents thus the construct validity of the study is much high. Finally, some of the data for this research were extracted from different prominent institutions in Ghana, for

example, the ministry of energy, energy commission and public utility and regulatory commission (PURC) and many more.

5 Summary and conclusions

This chapter presents the summary of the entire findings of this research. First of all, a brief light will be thrown in the objectives as well as the research questions of the study followed by conclusions and recommendation made out of the outcomes of the questionnaire.

The research objectives were;

- *To conduct an investigation into the present energy situation in VALCO and Aluworks and hence their energy consumption rate (electricity) both quarterly and annually and*

- *To propose a tentative solution to help reach their production quota and the motivation needed to establish the usage of energy efficiency.*

To establish the importance of energy efficiency management practices in the energy-intensive industry specifically in VALCO and Aluworks is one of a difficult task, having to take into consideration the current energy situation faced by entire country and businesses organization. Therefore to get the fact out from this research, a research question was established as a guide into the study;

- *How is energy efficiency managed in an energy-intensive industry-VALCO and Aluworks?*

The research results show that almost all the production and manufacturing companies rely heavily on the hydroelectricity dam for their economic activities until recent loading shedding occur which has rendered most businesses vulnerable to inadequate electricity supply. Therefore with reference to the research question, VALCO is currently using

light crude oil as an alternative to support the hydroelectricity in their activities, whilst Aluworks also uses the same and diesel-fired power plant to processes part of the work.

5.1 Key Findings of the research

The research results reveal that the entire population and most of the companies including VALCO and Aluworks rely heavily on the Akosombo hydroelectricity as the only source of electricity supply. So due to increasing population and expansion of the economic, the demand begins to outweigh supply so the hydroelectric dam could not supply enough electricity to match the demand due to low water level.

The research further reveals that insufficient electricity supply to this production and manufacturing companies was mainly due to unavailability of adequate generation capacity from the existing power plants and also fuel supply challenges and ineffective transmission and distribution systems which causes high distribution losses. Another contributing factor has to do with the loss of revenue emanating from non-payment of bills and lack of tariff structure which makes it impossible for the electricity firm to recover the investments. Nonetheless, the country has smaller hydropower as well as renewable energy resources that when fully tapped, will help bring diversification into the generation mix thus assist curb over-reliance on the hydroelectricity dam and the other thermal generation facilities.

However, there must also be the need for the government to enforce the act of regulations as well as implementing more incentives, granting of soft loans, tax exemptions to attract investment into the renewable energy sector because supporting renewable energy business through private's participation will bring relief on the energy sector and it will help to boost electricity supply.

5.2 Recommendations

There are upfront challenges facing most businesses including aluminum smelting industry in Ghana. Nonetheless, further light has been thrown on the main challenges facing the industry in the research. However, this chapter will propose a tentative solution to help the case study companies to reach their production quota. Ideally, based on the research carried out on the two case study companies and results derived from the study means that both VALCO and Aluminium works ltd requires adequate and reliable energy to undertake their productive activities. Therefore, the researcher recommends that hybrid solution will be the best option to enable Volta Aluminium Company ltd and Aluminium Works ltd to bounce back into peak production and manufacturing operation. Hybrid solution such as combined Photovoltaic system and hydroelectricity or combination of Photovoltaic and bioenergy or combined usage of Photovoltaic and wind solutions will be able to assists these companies recover their optimal operating capacity. This solution will enable these case companies to be electricity self-sufficient and extend the excess to the community in which they operate as their corporate social responsibility.

5.3 Future research suggestions.

This research itemized some research questions that require future research.

1. *What is the actual energy type for the aluminum industry in Ghana?* This will help the policy makers to make an informed decision about the benefits derived from the use of energy efficiency technologies as far as environmental issues are a concern.

2. *What measures is the ministry of energy embarking on to certify that all the renewable energy sources are tapped and used economically?* This will ensure that the numerous energy sources that are going waste over the day are attended to.

3. *What are the influential factors in locating a production plant closer to the power source?* This will draw the attention of energy commission that mounting a production facility far from the electricity source enhances distribution and transmission losses.

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APPENDICES

APPENDIX 1. Invitation Letter for Companies

Vaasan yliopisto
UNIVERSITY OF VAASA

Research Questionnaire

Dear Sir/Madam**,**

Please, I would be grateful if you could permit me to use 5-10 minutes of your valuable time to answer these questions. This questionnaire forms part of my Master Thesis at the University of Vaasa, Finland. The main objective is to find out ‘’*the energy efficiency management in an energy-intensive company such as Volta Aluminium Company Limited’’.* In addition, the questionnaire will assist in addressing the hurdles encountered by Volta Aluminium Company Limited as far as energy usage is a concern. However, the outcome of this survey could be used by Volta Aluminium Company Limited, policy makers, investors, production and manufacturing companies in making firm decisions with regards to use of energy efficiency. Furthermore, all answers will be treated with the utmost confidentiality.

Thanks so much in advance for your cooperation.

Yours Sincerely,
Gabriel Tetteh Tawiah (MSc Candidate)
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Dept. of Industrial Management
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Prof. Jussi Kantola
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APPENDIX 2. Aluminum Companies Research Questionnaire Sample

COMPANY PROFILE

Name of Company…….

Address …….

E-mail ……..

Contact Person……..

Age: ☐ 35-40 ☐ 41-45 ☐ 46-50 ☐ 51+

Position in Company……

ENERGY TYPE

1. Please what kind of energy source (electricity) do you use?

☐ Conventional energy source. ☐ Renewable energy source ☐ Both / Mix (conventional and renewable)

If it is renewable energy source what type?

i. ☐ Solar photovoltaic energy

ii. ☐ Wind energy

iii. ☐ Bio-energy

iv. ☐ Hydro energy

v. Other, please specify:

A) If it is a Conventional energy source, what type?

i. ☐ Nuclear power plant

ii. ☐ Coal power plant

iii. ☐ Natural gas power plant

iv. ☐ Diesel power plant

v. ☐ Others, please specify: ……..

2. Please is the current energy crisis affecting you? ☐ Yes ☐ No

3. Please, do you have a backup power plant? ☐ Yes ☐ No

ENERGY CONSUMPTION

4. Please, what is your daily average electricity consumption?

i. ☐ 1000kwh-2000Kwh

ii. ☐ 2001Kwh-3000Kwh

iii. ☐ 3001Kwh-4000Kwh

iv ☐ 4001kwh+

5. Please would your company likely to switch from conventional energy source to renewable energy source? ☐ Yes ☐ No

Please if YES, tick all that is applicable to the phenomenon.

A) ☐ Less maintenance culture

B) ☐ Less payback time

C) ☐ Produce sustainable electricity

D) ☐ Environmentally friendly

Please if NO, tick all that is applicable to the phenomenon.

A) ☐ High Cost of Installation

B) ☐ High payback time

C) ☐ High taxes

D) ☐ Inadequate knowledge about renewable energy.

There will be no references to individuals or companies and only aggregated response will be reported.