UNIVERSITY OF EDUCATION, WINNEBA

COLLAGE OF TECHNOLOGY EDUCATION – KUMASI

THE IMPACT OF USING SOLAR POWERED LED BULBS AS AN ALTERNATIVE SOURCE OF ENERGY FOR STREET LIGHTING IN GHANA

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DECLARATION

CANDIDATE'S DECLARATION

I, **Emmanuel Ogyadu Lartey** declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Signature…………………………

Date…………………..

SUPERVISOR'S DECLARATION

I hereby declare that the preparation of this work was supervised in accordance with the guidelines for supervision of thesis/dissertation/project as laid down by the University of Education, Winneba

Prof. Humphrey Danso

Signature…………………………..

Date……………………….

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I express my deepest gratitude to my supervisor Dr. Humphrey Danso for his guidance and constant support in helping me to conduct and complete this research work.

I also express my profound gratitude to all the lecturers in the Electrical/Electronic Technology Education department for taking us through the program.

DEDICATION

This work is dedicated to the memory of Patience Oforiwa Afari (2002-2020). It is well.

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ABBREVIATIONS

AC	Alternating current
CO_2	Carbon dioxide
CFL	Compact fluorescent lamp
DC	Direct current
GEF	Global environment facility
GW	Gigawatts
HID	High intense discharge
HPS	High pressure sodium
IEA	International energy agency
IR	Irrelevant radiation
KV	Kilovolt
KW	Kilowatt
LED	Light emitting diode
LPS	Low power source
MPPT	Maximum power point tracking
MW	Megawatt
MH	Metal halide
PV	Photovoltaic
RESPRO	Renewable energy service project
UNDP	United nations development program
UV	Ultraviolent

ABSTRACT

The existing street lights in the country uses high pressure sodium (HPS) lamps and mercury vapor lamps which is powered from the national grid. These types of street lights consume a lot of power and put a lot of pressure on the national grid. Considering the number of street lights in the country in terms of the amount of energy it draws from the national grid, it is important that another source of power is used to ease the burden on the national grid and also provide a reliable supply of street light in the country. The main objective of the research is to determine the impact of using solar powered light emitting diodes (LED) lamps in place of the existing grid connected high pressure sodium (HPS) lamps and mercury vapor lamps street lamps. The research looked at the existing conventional/traditional grid connected street light in terms of cost of initial installation, cost of maintenance, power consumption, brightness/luminous intensity, lifespan and other accessories compared to the off-grid/ stand-alone solar powered street light. The findings show that solar powered LED street light has a higher energy savings capacity (40%) than the existing high pressure sodium (HPS) lamps and mercury vapor lamps and also provides reliable supply of light and alleviate some of the burden on the national grid. The conclusion of the research is that using solar powered LED street lighting system will lead to an increased initial installation cost but savings made due to reduced maintenance cost and longevity of the solar powered LED lamps is very significant and cost effective.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The main purpose of this research is to investigate the impact of replacing all grid powered street lights in Ghana with solar powered street lights. The type of light to be used will be stand-alone solar powered LED lamps. A stand-alone solar-powered street or area lighting system is designed and operated completely independent of the power grid.

Typically, there are two types of solar streetlights: off-grid and grid-tied. Off-grid solar streetlights are disconnected from the electric utility company and stand-alone like a small solar lighting system unit. They convert solar energy into battery storage during the day, and then illuminate the road at night.

Street lighting is very important in our cities and towns because it improves safety for drivers, riders, and pedestrians at night. Decreased visibility in the dark increases the vulnerability of road users to accidents and mishaps. Well-lit roads help both pedestrians and drivers navigate easily, alert them to possible obstacles and approaching vehicles.

Crime is also lower in areas with good street lighting, as criminals often use the cover of darkness to harass pedestrians. Street Lighting also provides opportunities as people can carry on their activities in the absence of natural light. This includes street vendors, hawkers, and others. Beautification is another benefit of street lighting, which helps add character to the cityscape at night thus helping people appreciate their city even in the dark.

Solar powered LED lamps are very ideal for street lighting. Some of the important reasons why LED Street lights are considered more when it comes to street lighting is that LED lights are environmentally friendly, they also have a higher output compared to conventional lights, they are also free from hazardous chemicals such as mercury and lead which give out toxins.

LED lamps have a greater lifespan and electrical efficiency that is many times better than the conventional lighting system. Beside this, LED lights are significantly much better than the most fluorescent lamps as well. Solar lights are very simple, effective, and easy to install.

In addition, they're also easy to maintain since they utilize solar energy rather than electricity, which means each light is self-sufficient and can be installed and work for many years with little or no maintenance at all. Many LED manufacturers are constantly focused on developing advanced street lights which will bring low power consumption and superior brightness.

LEDs are on the streets since the early 90s, when cities throughout Europe and USA started replacing incandescent-based traffic lights by LEDS. The market share of LEDs has continued to grow in the field of street lighting, and it is expected that this type of light source will dominate in the future, at the expense of high intensity discharge street lamps.

If properly used, LEDs present lifetimes of 10 to 15 years, which is equivalent to more or less 60,000 working hours (that is at least 3 times higher than current technologies), offer energy savings that can achieve 50%, and have a low environmental impact.

They also reduce light pollution (better light distribution by the ability to precisely control light direction through optical optimization), have better color rendering and color temperature, and lower power consumption (higher efficacy (in lm/W), more lux per Watt) (IEA, 2013).

Moreover, LEDs have a lower operating and maintenance cost mainly because they offer a reduction in energy use as well as a higher lifetime. Thus, the return on investment for new equipment based on this technology will be faster, even with higher initial cost as still happens today. It is important to stress that accomplishing the standard regulations for luminance level and uniformity is easier to achieve using LED street lamps than with conventional lamps.

LEDs have also a dimming option that allows an adjustment of power using intelligent systems, which will reduce, even further, energy consumption and light pollution, as well as a quick turn on/off (because the problem with hot ignition is eliminated).

With respect to nocturnal insects, LEDs have also a big advantage: LEDs emit light in a small peak in a blue range and smaller than conventional light sources in the green range; since insects are attracted to the emission of UV-blue and green light they will be less attracted by a LED light source (IEA, 2013).

In addition, as LED can reduce power consumption in lighting, cooper wire of transmission lines can also be reduced (IEA, 2013).

Globally, renewable energy is going through exciting times with increasing investment in many countries. Solar PV capacity increased from 3.1 GW in 2005 to 227 GW in 2015. Within the same period, wind power capacity increased from 59 GW to 433 GW (Ministry of energy, 2019).

In view of the global trends, the Government of Ghana has identified renewable energy as one of the options that could contribute to the overall energy supply mix and minimize the adverse effects of energy production on the environment. Indeed, renewable energy programs and projects implemented in recent years have demonstrated that renewable energy interventions have enormous potential to reduce poverty and improve the socio-economic development of the country, particularly, in rural communities (Acheampong, 2014).

Annual electricity demand growth is estimated at about 10%. Energy Commission estimates that a capacity addition of about 200 MW per annum is required to catch up with the increasing demand in the medium to long term. It is projected that electricity demand would reach about 23,000 GWh by 2020, rising to about 40,000 GWh by 2030 (Energy commission, 2016).

At the end of 2015, more than 10 MWp of stand-alone solar PV systems have been installed in

Ghana. These are being used for inter alia, lighting, water pumping, powering of computers for the teaching and learning of ICT and vaccine refrigeration across the country. Over 70,000 solar lanterns have been disseminated.

Stand-alone solar PV systems are market driven in Ghana, spurred by government and donor supported community projects in the past. There have been several of these government projects but a few cases stand out for enjoying several years of success. Notable community cases implemented include the Weichau project, Isofoton project – funded by the Spanish government (Acheampong, 2014). Renewable Energy Services Project (RESPRO) – funded by UNDP and GEF, and the ARB Apex Bank project. The objectives of these projects were to provide lighting solutions and other services to these communities, and many of them worked successfully until grid extension reached the community. All these projects were based on the fee-for-service model and community ownership was key to their success (Energy commission, 2016).

With a growing interest in solar PV off-grid systems, there is a growing market for components in the country. Another important lesson, which is currently informing government policy on rural off-grid projects, is to target remote and island communities where it is not economical and accessible to extend the national electricity grid.

Other decentralized lighting systems that have been disseminated in the country include street and community lighting systems and traffic signals. More than 5 MW capacity of solar PV has been installed for street and community lighting. Many of the solar street lights and traffic signals are championed by the Urban Roads Department of the Ministry of Roads and Highways. There is presently no financing model for the replacement of system components once installed (Del Rio & Burguillo, 2008).

There are several solar systems installers in Ghana today, even though many of them are located in Accra, with very little representation in other parts of the country (Del Rio & Burguillo, 2008).

1.2 Problem Statement

The recent case of power crises leading to power outages in most part of the country is a major concern for both stakeholders and consumers of electricity in Ghana. These outages affect industries, schools, hospitals, homes etc.

Since most of the street lights in Ghana are connected to the national grid, power outages result in a total darkness in communities and on highways causing a serious danger to security, people and properties.

Secondly, as resources for generating electricity are seriously running out there is a need for power to be generated from renewable energy sources. There is a need for Ghana to diversify its energy system and supply. It would be appropriate to investigate if other forms of energy efficiency technology and source of energy can be employed to provide reliable street lighting

Furthermore, since most of the existing power plants generate a lot of waste and harmful gases such as carbon diode, methane which are greenhouse gases can lead to global warming and associated impacts (melting of glaciers and polar ice, sea level rise, changes in local rainfall and climates, increases in storm severity, impacts on biosphere and agriculture, changes in ocean circulation, etc.)

Additionally, global demand of electricity is increasing tremendously and the existing electricity producing plants are not able to meet the demands.

Moreover, the existing lamps used in street lighting consumes high amount of energy as compared to LED bulbs thus the quest to save energy is addressed.

1.3 Purpose of research

The purpose of this research is to investigate the impact of using solar powered LED lamps as street lights in Ghana.

1.4 Objective of the thesis

1. Determine the technical feasibility (power and light sources) of using LED lights in replacing the already existing conventional street lights in Ghana.

2. Determine the overall impact on taking all street light off the national grid.

3. Determine the economic/financial feasibility of using solar PV together with LED technologies to replace the existing streetlights in Ghana.

1.5 Research questions

- How feasible is the use of LED lights in place of the conventional grid connected street lights?
- What is the impact of using solar powered LED lamp?
- Is it economically viable to replace the existing street lights with solar powered LED lamps?

1.6 Justifying the research work

Unlike traditional street lights which consumes a lot of power the LEDs consumes very small amount of power which makes if preferable when it comes to electricity conservation.

Another major attraction of LED street lights is energy efficiency when compared to other street lighting technologies such as MH (Metal Halide) and HPS (high pressure sodium). Researchers are constantly looking for ways that they improve efficiency of upcoming models of LED lights. A good example is a product that was created by LSGC (Lighting Science Group Corporation). One of the models the group has produced does not only possess 60% more efficiency than previous models, but it also has a lifespan of a dozen years.

Solar energy systems/power plants do not produce air pollution, water pollution, or greenhouse gases. Using solar energy can have a positive, indirect effect on the environment when solar energy replaces or reduces the use of other energy sources that have larger effects on the environment. Solar photovoltaic (PV) produce a very clean and environmental friendly source of energy which will go a long way to help address the problem of global warming.

1.7 Significance of the research

This research will contribute to knowledge and provide significant benefits to the academics, practitioners, governments of developing countries and the power distribution companies. The outcomes of this study have economic, environmental and social benefits.

1.8 Limitations of the research

This thesis is limited to the Ga south municipal assembly area and no design was carried out.

1.9 Structure of the research

This research comprises five chapters. The first chapter gave a general orientation of the study. This contained the introduction, statement of the problem, objective of the research, specific objectives, justifying the research work and research question. Chapter two focuses on the review of related literature, the review involves theoretical and empirical studies related to the problem under study. Chapter three dealt with the research methods employed in the study. The chapter describes the research design, the population, sample and sampling procedures, and data gathering instrument, data collection and analysis of the study. In chapter four, the main focus is the presentation of results and findings. The outcome of the research is presented and explained in this chapter. In chapter five, significant findings are identified, presented and discussed. The discussion highlights the major findings of the research and the inferences made from them in view of findings from related previous studies. Finally, chapter five focuses on Summary of Findings, Conclusions and Recommendations, it includes suggestions for future research work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This part of the study reviews the main concepts of investigating the impact of solar powered LED bulbs on the national grid. The main concepts include using low power consumption LED bulbs powered by solar energy. The impact of solar powered LED bulbs on the national grid.

2.2 Background

The most abundant fuel source in the realm of renewable energy is the sun. Solar panels produce electricity through individual photovoltaic cells connected in series. This form of energy collection is viable in regions of the world where the sun is plentiful, and can be used in isolated regions or on houses to supplement the rising cost of electricity from a power grid. The possibility of harnessing the solar radiation to power streetlight is very viable since most parts of Ghana receive sunshine throughout the year.

Street Lighting has become one of the key necessities of our daily life activities, especially at night. However, it is one of the vampires in our energy use. Rising energy needs oblige investment in sustainable and clean energy production and use. As a social facility, street light is a key indicator of socio-economic development position of a country. Streetlights also play an important role in improving the general business and living climate of urban and peri-urban areas. Due to the high demand on the national grid, it is important to diversify the country's energy system and supply. Such diversification would require energy efficient technologies and sources of energy that is independent of the national grid such as solar power.

In Ghana, most of the energy production plants uses either hydro, gas and oil which is not too reliable due to weather patterns in case of the hydro or non-renewable and expensive in case of the oil and gas.

A good solar power plant can mitigate some of the current problems in the energy sector and bring great relieve to power production companies, policy makers, industry players and the general public.

Stand-alone solar powered street light will go a long way to reduce the pressure and high power demand on the national grid. These stand-alone solar powered streets light can also provide power to communities which are not on the national grid and also provide uninterruptable power supply to street light and traffic light in our towns and cities.

2.3 History of street lights

Street lighting has been around since humans began living together. As early as 500 BC, the ancient Romans used oil lamps filled with vegetable oil in front of their homes. In 1802, William Murdock used a gas light fueled with coal gas (Teri, 2018).

Not long after that the city of London, England decided that instead of just having the lamps in front of homes, the use of the gas lights lit an entire street in 1807. The United States began to use these gas lights as well but not until 1816. The city of Baltimore, Maryland was the first city to use gas lights. From gas lights, improvements were made, and the gas lights were switched to electric lights which are more energy efficient (Teri, 2018).

Yablochkov Candle, invented by Pavel Yablochkov in 1875, was the first electric street light to use arc lamps in 1878. Three years later in Paris, France, the city began switching out the gas lamps for electric lamps and had already replaced about 4,000 street lights. The United

States followed suit and by 1890, 130,000 arc lamps were installed on many city streets. Once the electric street lights came along, improvements were made little by little. Today, there are many lights to choose from (Teri, 2018).

There are many traditional street lights that are efficient, but some very old street lights still in use are not energy efficient. Solar photovoltaic street lights can be very energy efficient if the systems are set up correctly. Traditional lighting versus solar lighting will be described (Allery, 2018).

2.3.1 History of Solar Powered streetlights

Earlier studies conducted on solar powered streetlights delivered a high level of understanding of how solar energy is utilized around the world, and how this project fits with the application of solar powered street lighting. The awareness of using solar energy to power a street light started in the 1990's as a way out to the high cost of operating street lights throughout the year. The design of the early systems incorporated lamps with loads lower than 50W; this was used primarily for lighting paths or walkways. Many of the systems at that time used lamps ranging from low pressure sodium lamp to fluorescent lamp. Notable areas around the world where case studies have been done on the viability of powering street lights with solar energy were carried out in countries/cities where solar insolation amounts were high. Some of the countries/cities include New Mexico, California, Thailand, and Spain (Harrington et al, 1996).

The Parks and Recreation Department of Albuquerque, New Mexico One of the earliest studies was conducted by (Harrington et al, 1996). The results of the study showed the potential of using solar energy to power street lights. This study built the groundwork for future designs.

Studies conducted in Thailand used a basic photovoltaic system that worked seven hours a day and established how different types of lamps worked 7in the remote villages (Hiranvardom et al, 2003). The lifespan of the bulb, cost, light output in lumens, wattage, and color rendering were the categories that were instrumental in determining the type of light to use. Due to its lower cost and the adequacy of light production, the fluorescent lamp was selected (Acheampong, 2014).

2.4 Street lights

A streetlight is a raised source of light on the edge of roads designed to turn on at a certain time each night. A major task of street lighting is to increase safety for motorists and pedestrians, particularly at intersections where pedestrians may be. Lighting in the night provides psychological comfort for society's more vulnerable members. When designed properly, street lighting can be an effective tool in promoting outdoor safety (Acheampong, 2014).

There is a wide variety of light sources for outdoor use and had been in use as street lights ever since the invention of street lamps. Incandescent, fluorescent, high intensity discharge (Mercury vapor, mercury halides and high pressure sodium), low pressure sodium and most recent LED are popular choices for street lamps (Ahmed et al., 2012).

Street lighting is a public good benefit that enhances safety, comfort, commercial prosperity, and socialization (Hurst, 2011).

Safety and security increase not only because criminal activities are easily detected and prevented but also because traffic accidents decrease. Commercial prosperity occurs as a consequence of higher productivity and extension of marketplace hours.

Socialization will also increase with street lighting because an illuminated village invites people to the streets and contributes to a decrease of rural exodus.

There are 3 main objectives to achieve with street lighting (International Commission on Illumination, 2010):

1. To allow all street users to proceed safely (motorized traffic vehicles, slow moving vehicles, cyclists, pedestrians and animal drawn vehicles)

2. To allow pedestrians to see hazards, orientate themselves, recognize other pedestrians and give them a sense of security

3. To improve day and night time appearance of the environment

Usually, street lighting is supported by a public entity (government, municipality, or other) that should purchase the equipment. Users have the responsibility of using it properly and report operational issues to the contractor (Hurst, 2011).

In some countries, street lighting is a public responsibility while in others all the taxpayers contribute to street lighting, and finally in others just some of them pay for it. For example, in Portugal, municipalities have to pay for street lighting (Basto, 2010), in Ghana urban communities and companies contribute with some extra payments or taxes for street lighting (as well as rural electrification projects) and in Sudan the group of families in the vicinity of each light are supposed to cover their cost (if not, the light is moved). Street lighting systems consumes 43.9 billion kWh of electricity every year all over the world (Liu, 2014).

Regardless of who pays for street light, a bet in energy efficiency is essential because energy efficient technologies and designs can reduce street lighting costs substantially. This may help municipalities to expand their services by providing lighting in low income and other underserved areas (Panguloori, 2010).

Some recommendations related to street light strategies should help to accomplish optimal lighting solutions (Kostic, 2009).

Nowadays, in the whole world, street lights consume enormous electric energy. The number of street lights is not known accurately, but it is said that one hundred million or one billion street lights exist in the whole world (Noriaki et al., 2013).

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There are 3 main objectives to achieve with street lighting (International Commission on Illumination, 2010.).

2.4.1 Types of lamps used for street lights

Street lights can be categorized into the following groups:

(a) Incandescent (b) Compact Fluorescent lamp (c) High- intensity discharge (d) Light-Emitting diode

2.4.1.1 Incandescent

When solids and liquids are heated, they emit visible radiation at temperatures above 1,000 K; this is known as incandescence. Such heating is the basis of light generation in filament lamps: an electrical current passes through a thin tungsten wire, whose temperature rises to around 2,500 to 3,200 K, depending upon the type of lamp and its application (Singh, 2014).

Figure 2.1 Incandescent lamp

It has the lowest efficiency or the highest power consumption among the lights, which the Powers are mostly wasted in the bulb heating. By controlling the intensity of the figure 2.1, it will greatly improve its power efficiency hence achieve power saving. Filament lamps can thus be effective heating devices and are used in lamps designed for print drying, food preparation and animal rearing (Singh, 2014).

2.4.1.2 Compact Fluorescent lamp

The fluorescent tube is not a practical replacement for the incandescent lamp because of its linear shape. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and compact electronic ballast in the base of the lamp. Compared to general-service incandescent lamps giving the same amount of visible light, CFLs use one-fifth to one-third the electric power, and last eight to fifteen times longer. A CFL has a higher purchase price than an incandescent lamp, but can save over five times its purchase price in electricity costs over the lamp's lifetime. Like all fluorescent lamps, figure 2.2 contain mercury, a neurotoxin especially dangerous to children and pregnant women, which Complicates their disposal. In many countries, governments have established recycling schemes for CFLs and glass generally.

Most CFLs have built-in electrical ballast and fit into a standard screw or bayonet base. Some make use of separate ballast so that the ballast and tube can be replaced separately. Typical average lifetime ratings for linear fluorescent tubes are 10,000 and 20,000 hours, compared to 750 hours (110 V) and 1000 hours (240 V) for filament lamps (Satwinder, 2014).

Some types of fluorescent lamp ballast have difficulty starting lamps in very cold conditions, so lights used outdoors in cold climates need designed for outdoor use to work reliably.

Figure 2.2 Compact Fluorescent lamp

2.4.1.3 High- intensity discharge

A high- intensity discharge (HID) are a type of electrical gas-discharge lamp which produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube.

This tube is filled with both gas and metal salts. The gas facilitates the arc's initial strike. Once the arc is started, it heats and evaporates the metal salts forming plasma, which greatly increases then intensity of light produced by the arc and reduces its power consumption. High-intensity discharge lamps are a type of arc lamp. High discharge lamps make more visible light per unit of electric power consumed than fluorescent and incandescent lamps since a greater proportion of their radiation is visible light in contrast to heat (Harrington et al, 1996).

Various types of chemistry are used in the arc tubes of figure 2.3, depending on the desired characteristics of light intensity, correlated color temperature, color rendering index (CRI), efficiency, and lifespan (Singh, 2014).

Figure 2.3 High Intensity Discharge lamp

2.4.1.4 Light-Emitting diode

Solid state LEDs has been popular as indicator lights since the 1970s. In recent years, efficacy and output have risen to the point where LEDs are now being used in niche lighting applications. Indicator LEDs for their extremely long life, up to 100,000 hours, but lighting LEDs are operated much less conservatively (due to high LED cost per watt), and consequently have much shorter lives. Due to the relatively high cost per watt, figure 2.4 is most useful at very low powers; typically for lamp assemblies of fewer than 10 W. LEDs are currently most useful and cost power applications, such as nightlights and flashlights. Colored LEDs can also be used for accent lighting, such as for glass objectives and even in fake ice cubes for drinks at parties (Singh, 2014). They are also being increasingly used as holiday lighting. Solid state LEDs has been popular as indicator lights since the 1970s. In recent years, efficacy and output have risen to the point where LEDs are now being used in niche lighting applications. Indicator LEDs are known for their extremely long life, up to 100,000 hours, but lighting LEDs are operated much less conservatively (due to high LED cost per watt), and consequently have much shorter lives. Due to the relatively high cost per watt, LED lighting is useful at very low powers; typically for lamp assemblies of fewer than 10 W. LEDs are currently most useful and cost-effective in low power applications, such as nightlights and flashlights. Colored LEDs can also be used for accent lighting, such as for glass objects, and even in fake ice cubes for drinks at parties. They are also being increasingly used as holiday lighting (Singh, 2014).

Figure 2.4 Light emitting diode (LED) lamp

2.4.2 Solar-powered LED lighting

A diode is the simplest semiconductor device. Broadly speaking, a semiconductor is a material with a varying ability to conduct electrical current. As a current passes through the LED, the materials that make up the junction react, and white light is emitted.

LEDs are considered to be future low power consumption lighting sources to urban on-grid population as well solar-powered

LEDs clean lighting to rural off-grid communities (Ude, 2006). Furthermore, no GHGs emissions and mercury content are the most imperative features of solar-powered LEDs lighting (UNEP 2006). With the adoption of solar-powered LED Lighting minimizes the use of kerosene fuel-based lighting. Replacing kerosene with the LED lights offers several benefits: reduced air pollution, improved studying conditions for children, saved lives from kerosene risk, reduced spending by poor families on kerosene, reduce health risks (Halliday, 2003).

The LED bulbs offer significant advantages over the traditional kerosene: emitting a brighter light, requiring less maintenance, improved studying conditions for children, saved lives from kerosene risk, and lasting longer. One of the greatest benefits, however, would be the elimination of fumes and smoke which would both improve the health of families and reduce greenhouse gas emissions.

2.4.3 Solar Street lights in Ghana

4.94MW of the solar PV capacity is grid-connected whilst3.00 MW is dedicated to streetlights. (Hagan, 2015).

The Energy Commission in 2009 reported that the Ministry of Energy financed the installation of 46 solar street lights to determine the feasibility of the replacement of the conventional street lights at the following places: (i) the University of Ghana, Legon, (ii) the University of Cape Coast, Cape Coast and (iii) the Army Recruit Training School, Shai Hills (Acheampong 2014).

The street lighting system employed in Ghana is the cobra head type, which employs the use of mercury vapor lamps for its illumination. The operating voltage is 240V and typical lamps used have wattages ranging from 120W to 400W but the 250W mercury lamps are mostly used as is the case in the Western Region Hence, the issue of high power consumption with lumen depreciation associated with mercury vapor lamps poses a challenge in trying to conserve electrical power (Nunoo & Attachie 2010).

A typical solar powered street light is as figure 2.5 below.

Figure 2.5 Solar powered street light in Ghana

2.4.4 Traditional Street Lighting

Figure 2.6 has been around for a very long time. The raised source of light on the edge of a road or path is used to help people see at night. Traditional street lights are connected to the electrical power grid and there will be a monthly bill for the electricity that the street lights use. Recent incorporation of LED light bulbs has improved energy efficiency and many cities have switched to LED street bulbs to save on operational costs (Allery, 2018).

Figure 2.6 Traditional Street light

2.4.5 The role of LEDs in street lighting

Because of their advantages as compared to the other conventional light sources, majority of the off-grid lighting manufacturers are designing and producing their products with LED technology (van Eekhout, Undated). Some notable advantages of the LEDs are their energy efficiencies and their longer lifetime (Khan & Abas, 2011). Most LEDs have efficiencies which range from 50 to 140 lumen/W (Gaur & Thakur, 2010).

Some other good attributes of LED technologies are that they have better lighting at lower costs. LED lights also have an improved quality of life, income and health. They also have reduced greenhouse emissions and reduced fire hazards (Muller & Kamins, 2003).

All these advantages will be of an immense contribution to the reduction of electricity tariffs and the reduction in the health hazards associated with the use of the sources of lights. When this technology is fused into our lighting system, it will reduce the cost involved in the repair and maintenance of our street lights; hence it will make room for improved lighting system in the country. The reduction of greenhouse gases produced by these lights will help against climate change.

2.5 Solar Energy

The solar irradiation level in Ghana ranges from 4.5 to 6.0 kWh/m2/day with the highest irradiation levels occurring in the northern half of the country. The Government is piloting a number of initiatives on the deployment of solar energy systems (Energy commission 2015).

The idea of using solar energy to power a street light began in the '90s as a solution to the cost of operating street lights throughout the year. The design of the early systems incorporated a lamp load of less than 50W, and was used primarily for lighting paths or walkways. The majority of systems studied have used lamps of either the low pressure sodium lamp or the fluorescent lamp variety. The common areas where case studies have been done on the viability of powering street lights with solar energy were done in regions of high amounts of solar insolation. These areas include New Mexico, California, Thailand, and Spain (Bollinger, 2017).

Conventional sources of energy such as gas, coal, oil etc. are finite and the generation of electricity from these sources produces greenhouse gases that are detrimental to the planet.

There are various infinite sources that can be converted into electrical energy and can be used in the generation of electricity, such as solar energy, wind energy, hydropower, and geothermal energy (IEA, 2007).

Solar energy is the most direct, common, and clean energy on our planet we have already found until now. Total solar energy absorbed by the Earth is about 3,850,000 exa joules (EJ) in one year, which is even twice as much as all the non-renewable resources on the earth found and used by human being, including coal, oil, natural gas, and uranium etc. The solar resources can be seemed inexhaustible (Hao, 2013).

Photovoltaic (PV) is the method of generating electrical energy from solar radiation. Photovoltaic energy generation involves a PV module which is constructed from the semiconductor material showing photovoltaic effect. These modules become more and more attractive for obtaining "green" electricity because of their flexibility, ease of installation, constant reduction of production costs, and continuous increase of performance (Pearce *et al.,* 2007).

Solar radiation is the most important and major renewable energy source. During the whole day plenty of solar energy is radiating being unused. If this energy can be stored in a battery in form of electrical energy by using these PV modules and later can be used to run the electrical appliances (such as street light) then no doubt this is the best utilization of the available solar energy (Mohapatra, 2017).

2.6 Types of Light Sources

As mentioned above, different types of light sources are available on the market. For street lighting applications the most commonly used are HID and LED. These two types of light sources will know be briefly presented (Mohapatra, 2017).

High-intensity discharge light sources can be divided in four types: metal halide, high-pressure sodium, low-pressure sodium and mercury vapor. The light production technique is similar to the one used in fluorescent lamps but here visible light is produced, and so there is no need for the phosphor coating. The bulb is made from a quartz or ceramic glass envelope (Hao, 2013).

LEDs are on the streets since the early 90s, when cities throughout Europe and USA started replacing incandescent-based traffic lights by LEDS. The market share of LEDs has continued to grow in the field of street lighting, and it is expected that this type of light source will dominate in the future, at the expense of high intensity discharge street lamps (Lumileds & Phillips, 2014).

With respect to nocturnal insects, LEDs have also a big advantage: LEDs emit light in a small peak in a blue range and smaller than conventional light sources in the green range; since insects are attracted to the emission of UV-blue and green light they will be less attracted by a LED light source. In addition, as LED can reduce power consumption in lighting, cooper wire of transmission lines can also be reduced (Wu, 2009).

2.6.1 Light-emitting diodes (LED)

Light-emitting diodes (LED) are semiconductors. When electrons pass through this type of semiconductor, it turns into light. Compared to incandescent and CFL bulbs, LED lights are more efficient at turning energy into light. Therefore, less of the energy radiates from the bulb as heat (Hao, 2013).

Figure 2.7 stands for light emitting diode which is also known as a semi-conductor device which converts electrical energy into light energy. Semi-conductor is extrinsic type semiconductor where impurities are added to form a p-n junction. The diode emits electrons, photons in the form of light energy when it is forward biased (Lohiya & Kalyani, 2015).

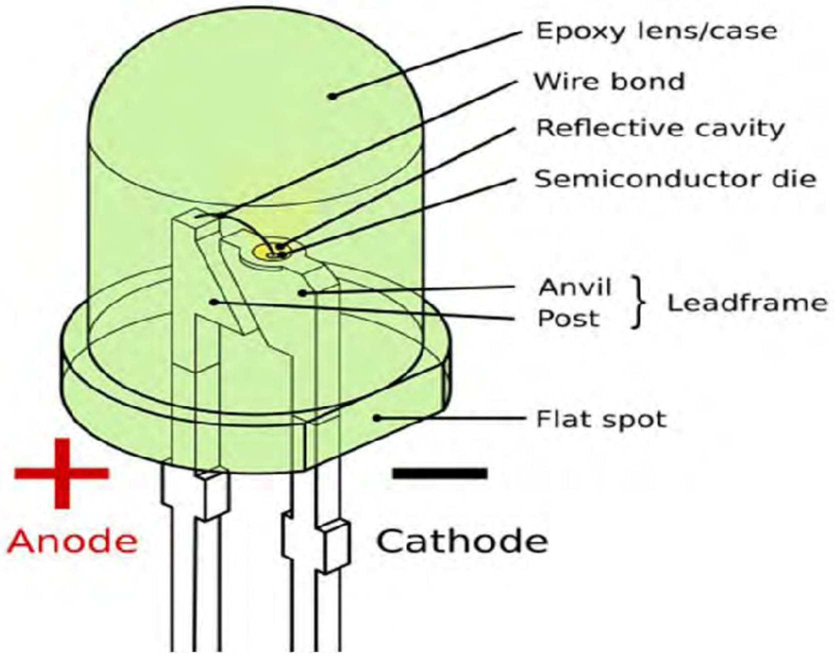

Figure 2.7 Light emitting diode (LED)

2.6.2 Solar powered street lights

Studies that have been conducted on solar powered street light highlighted a great level of understanding of how solar energy is utilized around the world, and this project fits with the application of solar powered street lighting.

Solar Street lighting applications is determined by the improvements in equipment effectiveness and the advancement of new technologies (Acheampong, 2014).

The use of Solar Powered LED Street Lights has become an interesting topic of research as well as application in the commercial world. In today's application, most of the common High Intensity Discharge (HID) lamps, often High Pressure Sodium (HPS) lamps are being replaced by more low powered Light Emitting Diode (LED) lamps (Wong, 2014).

According to (Hao, 2013) the solar street light does not need to set up the transmission line or route the cable, and no any special management and control are required. It can be installed in the entire public place such as the square, the parking lot, the campus, the street or the highway etc.

Authors like (Wu et. al, 2008) have recommended the use of solar PV systems with light emitting diode. They argue that the higher optical efficacies of LED and its energy saving potentials make it economically viable to combine the solar PVs and LED lambs. The Climate Group, 2012) outlined the benefits of LED lights as applied to outdoor use. They concluded that LED saves between 50%-70% energy when compared to conventional lights. The group also concluded that that the efficiency of LED lights has increased by a factor of 10 since 2000. The Climate Group also cited initial cost and awareness of the LED capabilities as the barriers to the use of LEDs (Wu et. al, 2008).

In figure 2.8, solar energy is used to charge a self-contained battery during daylight; at night, the battery powers the street lights. Solar LED street lighting is an especially cost-effective solution for parking lots, parks, residential streets, airports, and other applications where providing electricity is expensive or problematic. Two additional benefits of these types of LEDs is ease of installation - since the lamps rely on solar power, there is no need to dig trenches to lay underground cables - and immunity to power outages (Silverman et al., 2009).

Street lighting is defined as a public lighting system designed to give luminance to streets. By definition therefore, the positioning of the luminaire should be such that the area of peak intensity of the luminous flux (lamp output) distribution is directed towards the street surface only. A Street is one or more carriageways together with adjacent footways or shoulders. Residential roads, since they include footways, are normally referred to as streets (Ministry of energy, 2011).

The solar street light does not need to set up the transmission line or route the cable, and no any special management and control are required. It can be installed in the entire public place such as the square, the parking lot, the campus, the street or the highway etc.

The street lighting is closely related to people's daily life. Following quick development in process of the global urbanization, the green, efficient, and long-life solar powered street light gradually enters into our lives.

A good solar powered street lighting system is characterized with high efficiency, energy-saving, long-life, high color rendering index and environmental protection, which not only has a great significance on energy-saving of the city lighting, but also has close relationship with people's health and the economic development. So it is a noticeable issue how to design a reasonable solar powered street light system.

A stand-alone solar-powered street or area lighting system is designed and operated completely independent of the power grid. The equipment and maintenance costs associated with a stand-alone solar-powered system are compared with the cost of using electricity to run grid connected street lights (Bollinger, 2007).

Figure 2.8 Solar powered street light

2.7 The Future of street lights

The future of street lighting applications will be determined by improvements in equipment effectiveness and the advancement of new technologies.

The studies that incorporated light emitting diodes (LED) detail the advancements made towards the implementation of solar energy to light highways. The large amounts of power required to operate the high pressure sodium lamp entail the use of large solar arrays and a battery bank to handle overcast days. To decrease the power demand without changing the bulb required incorporating high-efficiency ballast (Libo et al., 2003).

The HPS lamp requires a high frequency electronic ballast to operate with the efficiency of the lamp depending on the ignition and acoustic resonance disturbances (Ben-Yaakov & Gulko 1997). The implementation of high-efficiency HPS lamps into current designs increases the cost of the stand-alone system, but also increases the number of days the light would last. The best way to limit the increased cost comes in the design stage, when the selection of the other equipment is determined. To supplement the rising cost of the improved lamp, the cost of solar panels decreases with the lower wattage ratings. Efficiency of the maximum power point tracking (MPPT) is another option that would increase the performance of any stand-alone system. Improving the duty ratio and the algorithms that control the real power from the solar panel reduces the energy lost to heat (Salas et al., 2002). The newest form of street lighting that shows promise is the LED. The studies conducted in California analyzed the application of LED lamps in comparison with the other forms of street lighting. The study in San Diego looked at the LED as a solution to the high cost of running the HPS lights (Tetra Tech, 2007). The results show the new technology produced too little light to be used on city streets, but would lead to further interest in future applications of the light (Lohiya & Kalyani 2015).

The analysis of the studies presents a strong argument that with the advancements in equipment and design, the likelihood of implementing stand-alone street lighting will improve.

The wide-spread replacement power grid lighting with stand-alone lighting hinges on cost and reliability. When studies prove a system design provides consistent lighting and would pay for itself in five to ten years, the idea moves from being a novelty item to small-scale utilization (Hao 2013).

2.7.1 Future stand-alone street lighting

The future of stand-alone street lighting applications will be determined by improvements in equipment effectiveness and the advancement of new technologies (Hiranvadom, 2003).

The studies that incorporated light emitting diodes (LED) and HPS lamps detail the advancements made towards the implementation of solar energy to light highways. The large amounts of power required to operate the high pressure sodium lamp entail the use of large solar arrays and a battery bank to handle overcast days. To decrease the power demand without changing the bulb required incorporating high-efficiency ballast (Bollinger, 2007).

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2.8 Solar Photovoltaic

Solar panels produce electricity through individual photovoltaic cells connected in series. This form of energy collection is viable in regions of the world where the sun is plentiful, and can be used in isolated regions or on houses to supplement the rising cost of electricity from a power grid. To convert the sun's energy, the cells capture photons to create freed electrons that flow across the cells to produce usable current (Penick & Louk, 1998). The efficiency of the panel is determined by the semiconductor material that the cells are made from as well as the process used to construct the cells. Solar panels come in three types: amorphous, mono-crystalline, and polycrystalline (Messenger & Ventre, 2002). The more efficient the material the panel is constructed from, the greater the cost. To maximize results, there are many features that can be used to control the output of the photovoltaic panels. The power needs determine what components are used to produce the desired voltage and current for the project such as converters, solar trackers, and the size of the panel. Converters transform the variable output from solar panels to constant voltages to maximize the continuous supply of usable power for either present needs or stored for future use (Bollinger, 2007). The output power of the panel is affected by many variables that continually changes throughout the day. This produces fluctuations in voltage and current that makes the panel inefficient unless the outputs are constantly adjusted to maximize the power output. The oscillating conditions are determined by environmental factors, chemical composition of the panel, and the angular position of the sun (Penick & Louk, 1998). Since solar energy is only produced during the day, requiring an energy storage application by either a battery or connecting to the power grid to provide power during the night.

PV powered lighting systems have existed for many years but they have a high initial cost and low conversion efficiency which makes them difficult to accept. However, in the past 20 years photovoltaic solar electricity production has grown by 20 to 25% per year. This grow has been driven by an increase in efficiency of solar cells, and mostly by lowering the production cost through improvements in manufacturing technologies and economies of scale (Costa et al., 2010).

2.9 Harnessing the Sun's Energy

A solar panel is made up of a collection of individual solar cells connected in series or parallel to maximize voltage or current output. The average voltage output for the individual cell is around half a Volt with a current of 400 milliamps. This is dependent on the efficiency of the silicon compound, temperature, and light conditions (Bollinger, 2007).

A standard 12V panel is laid out with 36 individual cells that are wired into nine cells in series and the four rows in parallel to generate a maximum voltage of 17V to 30V at optimal conditions (Walker et al., 2004). The disadvantage of connecting the individual cell stems from varying differences between the cells. Shading and an underperforming cell causes localized power dissipation that is transformed into heat (Xu & Yuvarajan, 2003).

2.10 Past stand-alone research studies

Past studies provided an increased level of understanding of how solar energy is utilized around the world, and how this project fits with the application of stand-alone street lighting. The idea of using solar energy to power a street light began in the '90s as a solution to the cost of operating street lights throughout the year. The design of the early systems incorporated a lamp load of less than 50W, and was used primarily for lighting paths or walkways. The majority of systems studied have used lamps of either the low pressure sodium lamp or the fluorescent lamp variety. The common areas where case studies have been done on the viability of powering street lights with solar energy were done in regions of high amounts of solar insolation. These areas include New Mexico, California, Thailand, and Spain (Bollinger, 2007).

One of the earliest studies was conducted by the Parks and Recreation Department of Albuquerque, New Mexico. The design of the system used two 50W photovoltaic panels with a 35W low pressure sodium lamp (Harrington & Hund, 1996). The stand-alone systems were designed to last for six hours a night and used a boost converter due to the design of a working maximum power point tracker was still in the development stage. The results of the study showed the potential of using solar energy to power street lights, and built the groundwork for future designs (Harrington & Hund, 1996).

Isolated parts of the world are ideal places to study the abilities of stand-alone lighting systems due to the lack of electricity to those regions. The test done in Thailand used a basic photovoltaic system that worked seven hours a day and established how different types of lamps worked 7in the remote villages (Hiranvardom, 2003). The categories that were instrumental in determining between the low pressure sodium (LPS), the high pressure sodium (HPS), and the fluorescent light were the lifespan of the bulb, cost, light output in lumens, wattage, and color rendering. The fluorescent lamp was selected due to its lower cost and the adequate production of light (Hiranvardom, 2003). This study conveyed the problems that affect the design of the system, due to the availability and cost of replacement parts. The HPS lamp worked more effectively than the other two lamps in the test, but cost seven times more than the fluorescent lamp (Hiranvardom, 2003).

2.11 Solar Panels

The sun is a living fireball whose rays reach one side of the spherical earth during day time. Scientists have employed modern tactics to develop the solar cells that can directly convert the energy from sunlight to electrical power. Solar cell is an electronic device that converts energy. The Greek term 'Photovoltaic' refers to the process of electricity generation from light. When a series of Photovoltaic or Solar Cells is put together, they form a Solar Panel. The panels absorb energy from the sun which is converted to electricity by the solar cells.

The main feature of photovoltaic cells is that we can get direct electricity when light is incident on them. Efficiency of this conversion mostly depends on the type of the solar panel (Allery, 2018).

Solar street lighting, unlike traditional street lighting, has not been around for many years. These street lights are not connected to the electrical power grid: the solar light will produce its own energy from the sun (photovoltaic panel) and store the energy in a battery until the light turns on once it is dark enough. There are a few different ways that solar lighting can be used off grid.

One way the solar can be connected through a micro grid which essentially a mini power grid used specifically for the lights; another way is that each street light can be a stand-alone system (Bollinger, 2007).

2.12 Electrical Grid Systems

An electrical system delivers electricity from producers and consumers; it is an interconnected network. Generating stations are part of the grid and produce kinetic energy which is turned into electrical power. The produced kinetic energy or electricity is sent to a generating transformer where it is stepped up and converted to kilovolt amperes (kV). To carry this electricity, the grid uses high voltage transmission lines. The transmissions lines connect to a step-down transformer where the electricity flows from high voltage to lower voltages. The lower voltages vary depending on the customer and where the electricity is being sent (Allery, 2018).

A micro grid system is a basically a mini version of the electrical power grid system. A micro grid system can run with the traditional electrical grid system or stand-alone if batteries /energy storage is used. Figure 2.9 is a local grid with control capabilities. Generally, if the micro grid is connected to the main grid, the whole system will go down during an outage. If the micro grid is a stand-alone system with batteries as back up storage, it generates its own local energy when the grid is down during emergencies where there is power outages and bad weather outages.

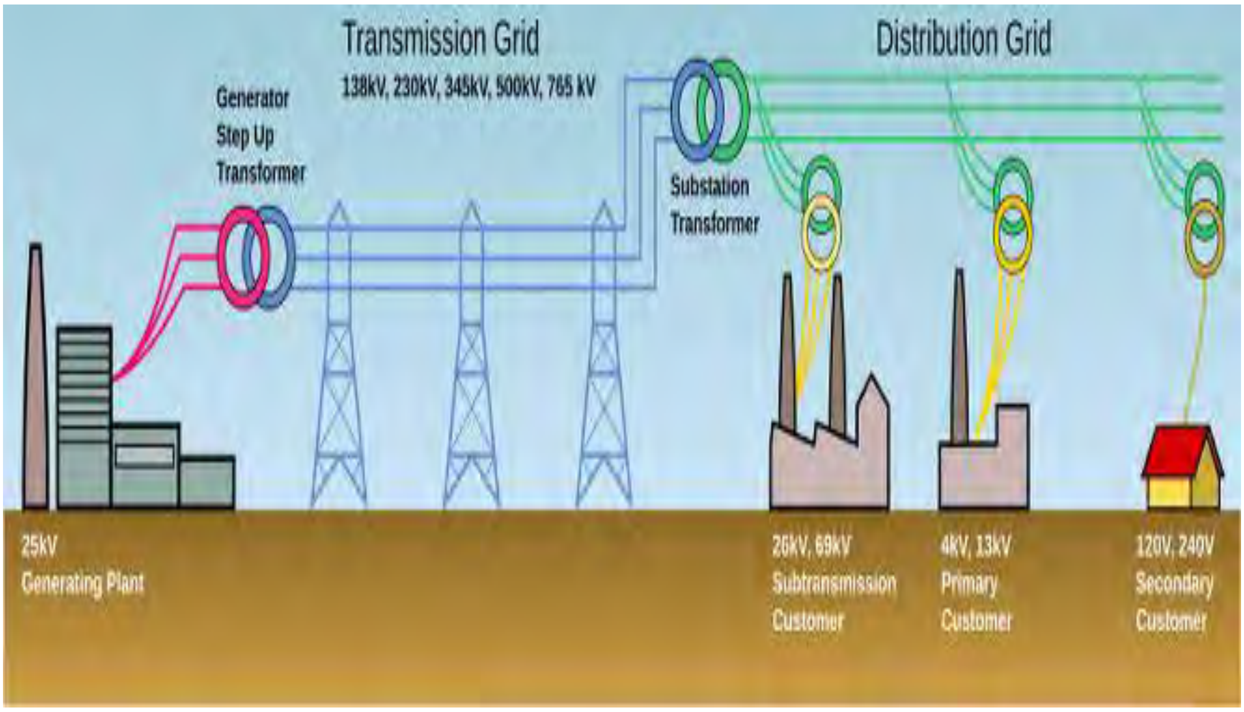

Figure 2.9 Electrical Grid Transmission and Distribution

2.13 Cost–benefit analysis of Photo Voltaic (PV) systems

The three major components of the life-cycle cost of Photovoltaic systems are capital investment cost, maintenance cost and decommissioning cost. The cost of decommissioning comprises of the net sum of dismantling and disposing the systems, and the potential worth of the recyclable aluminum frames. This is estimated to be 2% of the capital investment and can be safely neglected (Kannan et al., 2006). The cost of maintenance involves that of cleaning and other minor costs, which comprises 2% of the total life-cycle cost and can also be neglected according to (Ha Pham et al., 2008). The capital investment cost, which is the main cost of PV systems installation, is usually calculated as the sum of the cost of the PV modules and the Balance-of-System (BoS) cost that includes all other upfront costs such as the cost of the mounting structure, wiring, inverter and the cost of installation (Acheampong, 2014).

(Lee et al. 2013) stated that, “in estimating the cost of PV systems, the annualized life-cycle cost which is the cost per year of owning and operating an asset over its entire lifespan provides a finer estimate of the actual cost than the simple payback calculation”.

Lee et al. (2013) stated that, “the annual PV-related cost C is the sum of the annualized investment of PV systems and the net energy cost ∑CE, which is the annual sum of the hourly cost of electricity minus any possible earnings from the feed-in tariff and any incentives.

Based on their observations, (Lee et al. 2013) concluded that “an hour-by-hour energy performance simulation is necessary to provide the information to conduct the cost–benefit analysis for decision-makers to assess the economic viability of the deployment of PV systems.

2.14 Performance of some solar street lighting projects

A survey was conducted by (Ismail et al. 2012) to embark on performance assessments of in-stalled Solar PV system in Oke-Agunla, Akure local government of Ondo State in Nigeria.

There were visits to the village and the equipment on ground was examined while the people were interviewed. Both functional and non-functional facilities were traced to their manufacturers using the identification data on them and rated to ensure their efficiencies (Acheampong, 2014).

Energy demands were also prorated, and observed the need to improve on the present energy supplied. Results of the assessments showed that PV facilities used were inadequate, trained technicians were not available giving room for quacks working on the facilities occasionally resulted in further complications and poor facilities maintenance. The assessment result showed that just 14.52% of the 4.5 kW installed solar PV was utilized due to significant malfunctioning and deterioration in performance. It was later concluded from this study that the installed solar PV systems were inefficient as a result of poor maintenance, lack of technical know-how and inability of the project contractors or managers to take these factors into consideration while embarking on the solar PV installations (Acheampong, 2014).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter looked at the methods, techniques and materials used in other to help achieve the objective of this research. The research looked at the existing conventional/traditional grid connected street light in terms of cost of initial installation, cost of maintenance, power consumption, brightness/luminous intensity, lifespan and other accessories compared to the off-grid/ stand-alone solar powered street light.

The research was used to establish the technical feasibility replacing all street lights in Ghana with solar powered LED bulbs, its impact on the national grid. This research employed the use of energy efficient lighting technology and renewable energies for street lighting services in Ghana. It involved economic comparison of street lighting design of LED Solar Powered Street Lights and conventional sodium lamps.

3.2 Study Area

The site for the study is Weija which is the capital of the Ga south municipal assembly in the greater Accra region of Ghana. This municipality was selected because of convenience and also for the availability of data for the research. Weija has become a hotspot for economic activity because of the ultra-modern shopping centre, the West Hills Mall, which has been built there. The Ga South Municipality is located in the South Western part of Greater Accra. It lies within Latitudes 5°47'30"N and 5°27'30"N and Longitudes 0°31'30"W and 0°16'30"W. The Municipality shares boundaries with Upper West Akim to the North, Weija-Gbawe Municipal Assembly to the East.

The temperature in Weija is generally high with an average mean of about 32.26ºC. Average maximum temperature is 33.26 ºC and the average minimum of 31.2 ºC (Agyei, 2006).

February, March and April are the hottest months. Studies conducted by the Energy Commission (2003) revealed that, Weija has an average solar irradiance of about 5.217 kWh/m^2- day. The electricity coverage is over 87.53% for municipality (Ministry of Energy, 2010) thus; there are still some communities without electricity. Street lights in the Municipality are not at its optimum and the Municipality seeks to rehabilitate non-functioning street lights in the major towns and rural communities.

The Ga south Municipal Assembly currently has about 780 streetlights made up of two different lamp types (Ga south Municipal Assembly, 2017). The power consumptions of streetlights vary from 250W to 400W. The 400W lamps are used for the main (ceremonial streets) and the 250W for residential streets.

It costs the Municipal about GHS65, 000 quarterly for the maintenance (replacement of lamps, damaged poles and stolen cables) of streetlights (Ga south Municipal Assembly, 2017).

The study area, Ga south Municipal Assembly currently has about seven hundred and eighty (780) installed and functioning double lamp street lights using 858,480kWh/yr. of electricity (Municipal Engineer, Ga south). There are more neighbourhoods in the municipality without streetlights than there are with streetlights and the number of potential solar street lighting opportunities is in the hundreds. Majority of these streetlights have been installed on the mallam junction to kasoa highway, most of the lamps are double lamp streetlights on that stretch. All the streetlights use High Pressure Sodium (HPS) lamps with wattages ranging between 250W- 400W. Since the ceremonial road contains the highest number of streetlights located on a straight stretch, the analysis will be carried out using this stretch of road. The analysis would be carried out to consist of the cost involved in installing, operating and maintaining a new conventional streetlight using High Pressure Sodium (HPS) lamp and cost involved in the installation of solar powered streetlight.

Two roads that qualify for street lights are the Ceremonial and Residential Road. The ceremonial roads are the main roads that lead to and from the Municipality and residential roads are roads that lead to the various neighbours of the Municipality. Ceremonial roads require 400 Watts illumination whiles a Residential road requires a 200 Watts illumination.

3.3 Methodology

3.3.1 Technical Details and Components

The solar powered street lighting system consists of independent installations where the energy is produced on the spot. They are energy self-generating stations that ensure a reliable supply of electricity that is not reliant on the power grid. The major components used are as follows;

- Solar panel
- Light source: LED lamp.
- Battery/charge Controller:
- Pole: 8 to 15 meters high and 4 millimetre in diameter, composed of a galvanized steel frame with powder anti-corrosion coating.
- Accessories: all necessary cables, (cable joined) and screw bolts.

3.3.2. Photovoltaic selection and battery

- To size the solar PV panel and battery, the following is assumed
- Hours of operations per day: 12 hours from 6pm – 6am hours daily
- Assumed days of autonomy: 3 days
- Battery voltage level: 12 V
- Array inclination: 15 degrees

Using a 250watt LED lamp powered by a solar PV will require an average daily energy 0.680 kWh.

3.4 Factors taken into account when determining the viability of street lighting systems

A comparison of traditional grid-connected streetlights with solar-powered streetlights is conducted in order to determine the economic, social, and environmental benefits.

The focus of the examination is on the essential components of the two systems for a period of twenty (20) years. The main components of expenditure for the street lighting are:

- The cost of purchasing products
- The cost of installing components such as transformers and cables
- The cost of energy consumption
- The cost of operating and maintaining the equipment.

3.4.1 The cost of purchasing conventional street lights

The cost of 400W Solar Street Lights which includes the solar panel with all mounting accessories (25 years life span), mounting brackets, anchor bolts and inbuilt battery (9-12 years life span) which can works for 15-25 years with one year warranty.

Table 3.1: Conventional Streetlight Investment Cost: source Bui Power Authority streetlight construction, 2013

Component	Quantity	Cost $	Total Cost $
400 Watts (W) High Pressure Sodium Lamps	240	200	48,000
Light Pole	120	200	24,000
Transformer	1	5000	5,000
Cable	3	3000	9,000
Labour cost	120	200	24,000
Installation Cost	120	200	24,000
Miscellaneous Cost	120	500	60,000
Initial Investment Cost			**194,000**

3.4.2 The cost of installing components such as charge controller and cables

Table 3.2: Solar Powered LED streetlight Investment cost

Component	Quantity	Cost $	Total Cost $
200Wp Solar PV panel	120	300	36,000
LED Lamp 80w	240	120	28,800
300Ah, 12volts	120	300	36,000
Charge Controller	120	120	14,400
Pole	120	200	24,000
Lamp bracket	120	50	6,000
Battery Box	120	20	2,400
Labour Cost	120	100	12,000
Installation Cost	120	250	30,000
Miscellaneous Cost	120	500	60,000
Initial Investment Cost			**249,600**

Battery Cost:

The cost related to battery replacement for the solar powered LED is assumed to be the cost of electricity consumption for the solar system with five year life span of the battery. The cost associated with battery replacement will be USD 36,000 for every five years and USD 900,000 for the life span of the system.

Maintenance Cost:

For estimating the maintenance cost of the solar powered LED streetlights the under listed is assumed:

- The lifespan of the solar panel is 25years;
- The Lifespan of LED lamps 50,000 hours, which means they can be used for more than

10 years without any replacement;

- The life span of controller is 10 years and
- The Life span of light pole 30 years

Therefore the cost of maintenance for the 25yr period will be USD 42,800 made up of the cost of LED lamp replacement and charge controller. From the above analysis the total cost of the solar powered LED streetlight including equipment purchasing, battery cost and maintenance will be USD 1,149,600 for 25 years.

Table 3.3: Capital Expenditure/ Operational Expenditure of current and proposed methods of street lighting

Type of Structure	Capital Expenditure	Operational Expenditure
Grid Powered Street lights	194,000	1,311,440
Solar Powered LED Streetlights	249,600	942,800

The operational expenditure of the grid powered street light as indicated in the table above includes the maintenance cost and the cost of electricity consumed. The capital expenditure for the solar powered LED Street light includes the cost of battery replacement, replacement of LED.

3.4.3 The cost of installation of transformers and cables

The use of transformers and installation cables are totally eliminated when it comes to the installation of solar powered street lighting. This makes the initial installation of solar powered street lighting projects cheaper, easier and faster to install than the conventional grid dependent street lighting.

The amount of energy consumption

A high-pressure sodium street light can draw up to 1000 watts, and an incandescent light used in the 1900s needed 320 watts. Some LED street lights require only 73 watts and produce a higher quality of light. Therefore, for the same area of coverage of street lighting the cost and the amount of energy consumed is less for the solar powered LED light than the conventional on-grid street lighting. In addition. the solar powered LED produce an improved quality of light.

Maintenance and operating costs

Life expectancy of solar panels is thirty years, the LED lamps have a lifespan of at least 50,000 hours, which means they can be used for more than 10 years without requiring any replacement. The lifespan of the charge controller is 10 years and 30 years life span for the pole.

Charges related to electricity consumption for the solar system is condensed to battery replacement within five years of use considering their five years lifespan.

Maintenance on the solar powered street light is less frequent as compared to the conventional grid connected street light. Apart from the batteries which needs some periodic replacements, the other parts of the installation do not really need regular maintenance /replacement.

3.5 Solar powered LED street light estimation

For the initial installation of solar powered LED Street light consisting of 100 solar panels and 200 LED lamps, the estimate below is made.

Table 3.4 Solar powered LED street light estimation

Component	Quantity	Cost $	Total Cost $
300W Solar PV panel	100	300	30,000
LED Lamp 80w	200	120	24,000
300Ah, 12volts	100	300	30,000
Charge Controller	100	120	12,000
Pole	100	200	20,000
Lamp bracket	100	50	5,000
Battery Box	100	20	2,000
Labour Cost	100	100	10,000
Installation Cost	100	250	25,000
Miscellaneous Cost	100	500	50,000
Initial Investment Cost			**208,600**

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter involves the discussion of findings and results from the research work. The discussion brings out the real meaning and significance of the findings. The result and findings as discovered by the research determines the viability or not for the use of solar powered LED lamps to replace the conventional on-grid street lighting system in Ghana.

4.2 Energy savings capacity

It was discovered that the solar powered LED light has a higher energy saving capacity (between 25% – 40%) than the High Pressure Sodium (HPS) Lamp and Mercury Vapor Lamp which is used in the conventional grid connected street lights. This is because the LED bulbs require small amount of energy to produce its light. Lamp performance is measured by a variety of metrics, but the most significant metric is lamp efficacy (lumens generated per watt of energy consumed). The performance of LED lamp is high as against high-pressure sodium and mercury vapor lamp.

Table 4.1Energy savings of LED over High pressure sodium lamps

High Pressure Sodium (HPS) Lamps	Light emitted diode lamps	Energy saving over HPS lamps (wattage)
100 watts	60 watts	40
150 watts	90 watts	60
200 watts	110 watts	90
250 watts	125 watts	125
300 watts	150 watts	150
350 watts	170 watts	180
400 watts	190 watts	210

Figure 4.1 is a chart representing the energy saving capacity of the LED lamps over the high pressure sodium lamps.

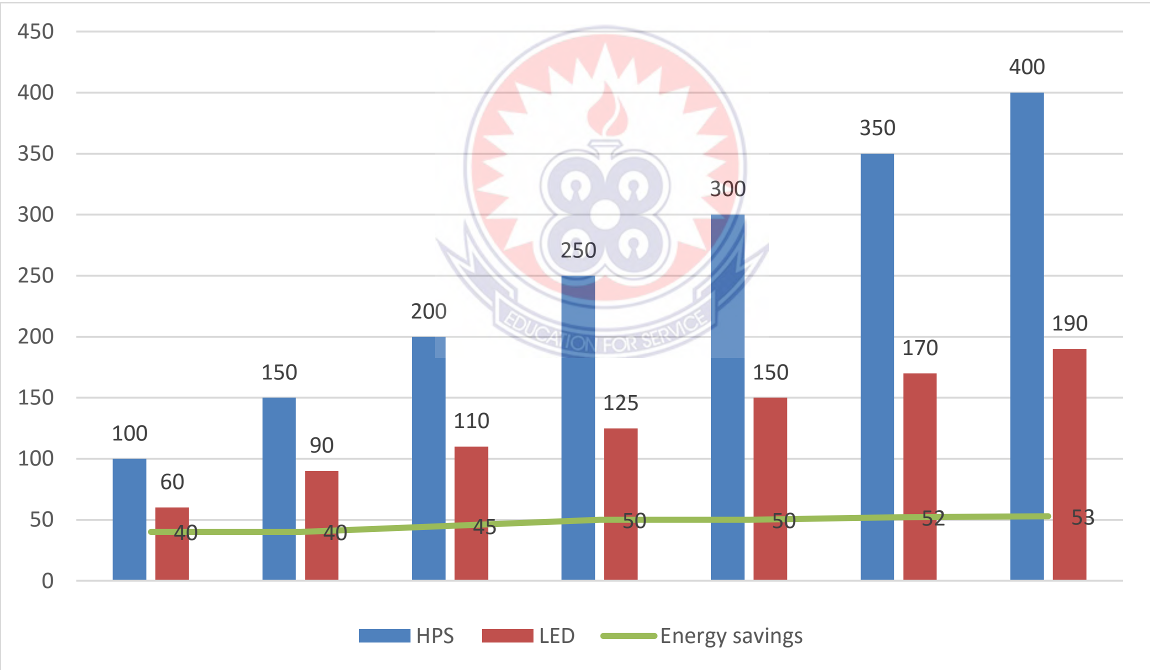

Figure 4.1 LED energy saving capacity

4.3 Financial analysis

The cost of initial installation of solar powered LED street light is higher (between 35 to 55%) than that of the conventional grid connected high-pressure sodium and mercury vapor lamps. This is as a result of the usage of solar photovoltaic (solar panels), inverters and switch/controller unit for each pole. It was also discovered the running/operational and maintenance cost of the solar powered LED street light is about 15% higher than that of the conventional grid connected high-pressure sodium and mercury vapor lamps since the batteries and other parts of the solar powered system will have to be replaced periodically. Figure 4.1 is a pictorial representation the financial analysis between the high pressure sodium lamps and the LED lamps.

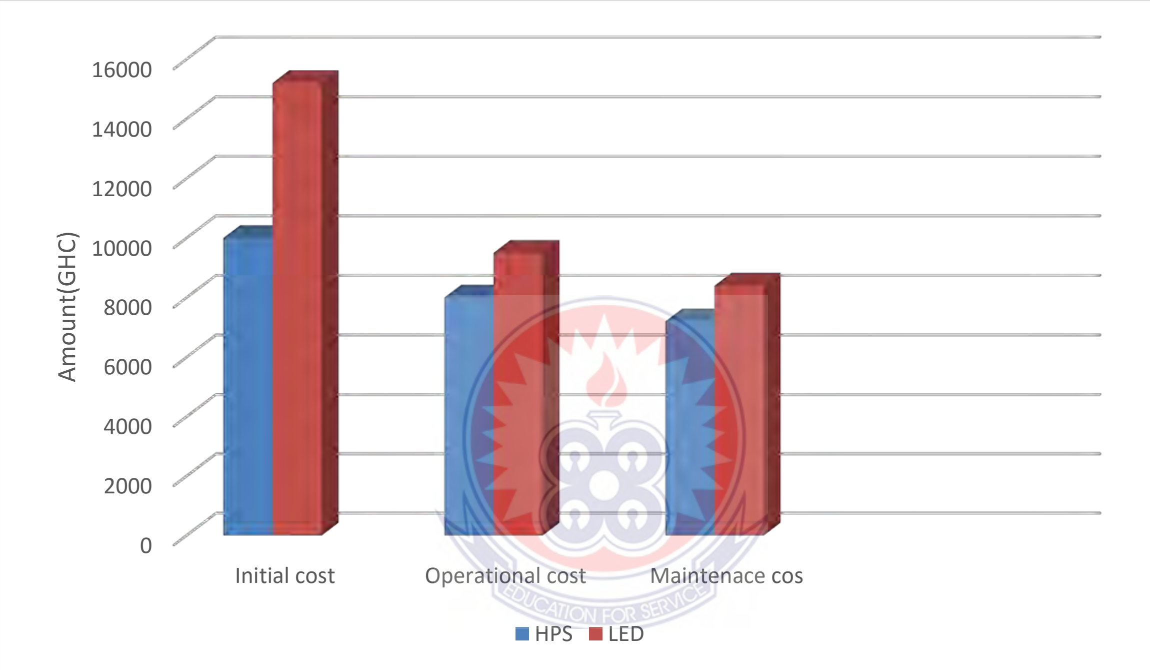

Figure 4.2 financial analysis of HPS and LED lamps

4.4 Duration

For the duration, the solar powered LED street light last about 20% longer than the conventional grid connected street lights. Because the LED bulbs are made up of many tinny bulbs coming together to produce the light, failure in some of the little LED does not automatically cause a total failure of the lamp. With the grid connected high-pressure sodium and mercury vapor lamps, any little defect will cause the bulb to stop working. Figure 4.2 represent the duration of some types of lamps used for street lighting.

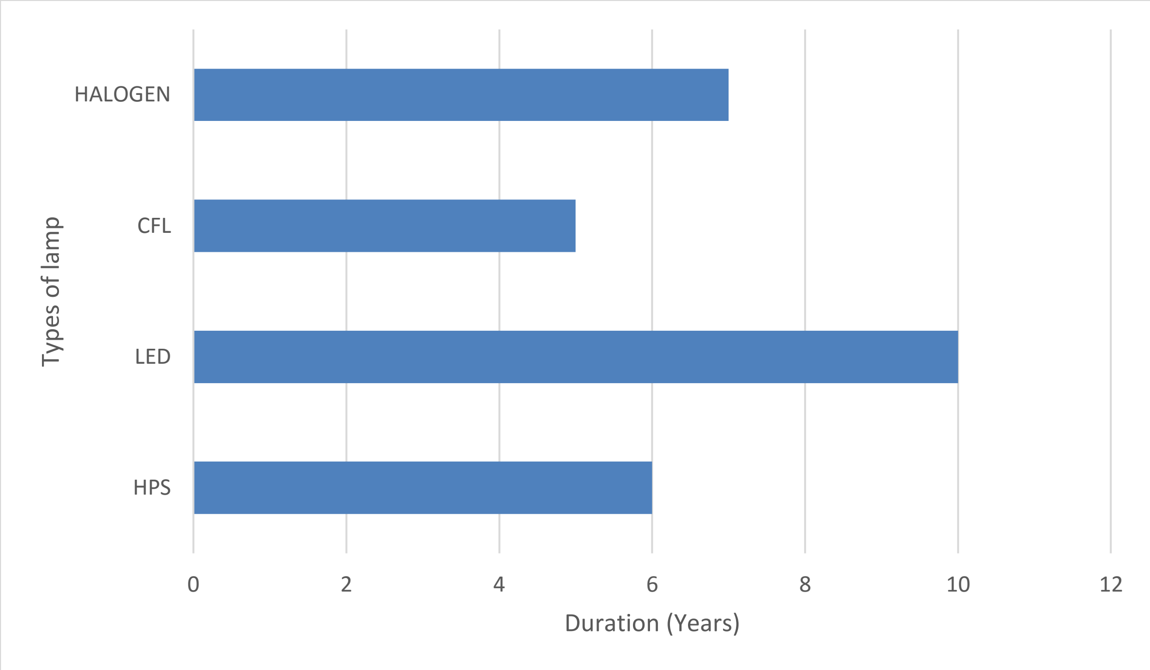

Figure 4.3 duration of some types of lamps used for street lighting.

4.5 Quality of light produced

The solar powered LED street lights produce a very bright and quality of light which is about 18% brighter compared to the high-pressure sodium and mercury vapor lamps. This means that fewer number of lights / poles are required to provide lighting for a particular area with the use of the LED lamps compared to the high-pressure sodium and mercury vapor lamps. The quality of light produced by the HPS and that of the LED lamps are represented in figure 4.3

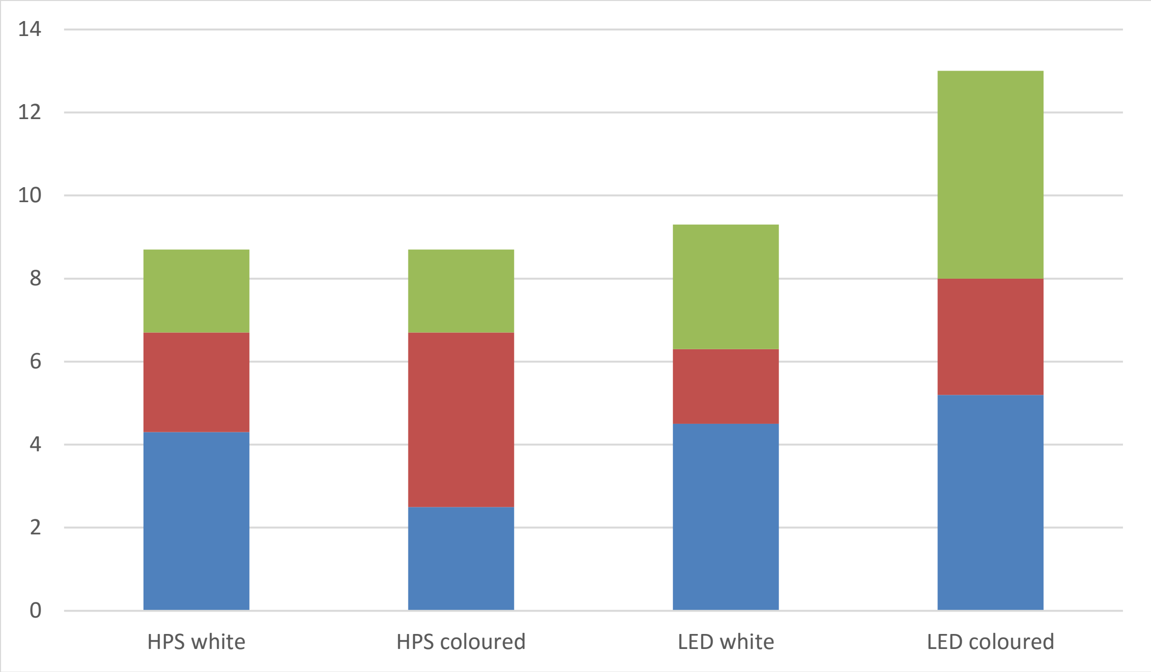

Figure 4.4 quality of light produce by HPS and LED lamps

4.6 Viable Light Emissions

LEDs produce a very narrow spectrum of visible light without the losses to irrelevant radiation types (IR, UV) or heat associated with conventional lighting, meaning that most of the energy consumed by the light source is converted directly to visible light.

Low and High Pressure sodium lights produce a very narrow spectrum of light (particularly low power source lights (LPS)). For this reason, LPS lights are actually desirable as indicated in figure 4.4 they minimize electromagnetic interference near facilities conducting astronomical observation.

4.7 Emission

This area too looks at the amount of greenhouse gasses that will be spared in case the conventional grid connected lights are supplanted by the solar powered LED street lights.

As the conventional street lights are replaced with solar power based LEDs, the CO_2 emissions are almost negligible for the replaced LED lights which are favorable from environmental hazards point of view. As for as environmental effects are concerned, it is fruitful to encounter the effect of CO_2 emissions for the conventional grid connected street lights. Figure 4.5 is a graphical presentation of CO_2 emitted by LED and HPS lamps

Figure 4.5 CO_2 Emissions between HPS and LED lamps

4.8 Discussion

From the literature review, solar powered LED lamps provide a reliable and standalone source of street lighting. The LED provides brighter lights as against the yellow lights provided by the HPS thus saving energy and emitting less amount of carbon dioxide which goes a long way to make the environment clean and safe.

4.8.1 Energy savings capacity of solar powered LED street lamps

Solar powered LED street lights provide much higher lumens with lower energy consumption. LED lights give energy consumption up to 40 percent lower than high pressure sodium lamp (HPS) and mercury vapour lamps which is widely used as lightning source in the traditional grid connected street lights. According to (Nan & Zaw, 2014) Solar powered LED street lights provide up to 45% of energy saving over the traditional HPS lamps. The solar powered LED street lights lack of warm up time also allows for additional gain of efficiency, the traditional grid connected high pressure sodium lamp (HPS) and mercury vapour lamps require an extra warm up time which use a lot of energy and cause a considerable amount of delay in the lightning process.

The amount of power that can be saved by using solar powered LED street lights over the years of usage on an annual basis (energy saved) increases over the years. This clearly indicates how much amount of energy can be saved over the years of usage by switching to solar powered LED rather than grid connected pressure sodium lamp (HPS) and mercury vapour lamps.

4.8.2 Financial analysis

The initial cost of installation of the solar powered LED street light is higher compared to the initial installation of the conventional grid connected pressure sodium lamp (HPS) and mercury vapour lamps because of the need to procure solar photovoltaic modules (solar panels), battery systems, switching systems, charge controllers, converters / inverters. The materials involved in the installation of a new solar powered LED system is very numerous compared to the initial installation of the conventional grid connected systems. Mahmoud (2015) concluded that one disadvantage of LED light is the high initial cost.

(Nunoo et al., 2010) also concluded that the use of LED technology can help relieve the government's ever-present budgetary and environmental challenges as well as improve streetlight quality through features like reduced glare and better colour rendering.

Operational and maintenance cost involve in the solar powered LED systems is also very high compared to the traditional grid connected systems because of the need to replace solar panels, batteries, charge controllers, switching units, converters/ inverters etc.

Cost of labour involved in the installation and maintenance of the solar powered LED street light is very high compared to the conventional grid connected pressure sodium lamp (HPS) and mercury vapour lamps as it requires specially trained and qualified technician to install, operate and maintain.

4.8.3 Duration of operation and durability

The duration for the installation and operation of a solar powered LED street light is longer compared to the grid connected pressure sodium lamp (HPS) and mercury vapour lamps. Mahmoud (2015) in his comparison of solar powered LED and HPS said the LED last longer than the HPS.

Solar powered LED street light are the latest development as a light source. Their unique characteristics including compact size, long life and ease of maintenance, resistance to breakage and vibration, good performance in cold temperatures and lack of infrared or ultra violet emissions are beneficial in many lighting applications.

Light Emitting Diodes is a current operated device and hence constant current driver circuits should be designed for its use.

For durability, the solar powered LED lamps last longer and can stand harsh weather conditions than the conventional grid connected pressure sodium lamp (HPS) and mercury vapour lamps.

4.8.4 Quality of Light

For the luminous intensity (quality of light produced), the solar powered LED street lights are better and brighter than the grid connected pressure sodium lamp (HPS) and mercury vapour lamps. According (Nunoo et al., 2010) solar powered LED lamps can effectively radiate 85% of light output from the LED lamps to hit the road surface. This means that fewer number of lights / poles are required to provide lighting for a particular area with the use of the LED lamps compared to the high-pressure sodium and mercury vapour lamps.

4.8.5 Environmental Impart

The use of the stand-alone solar powered LED street light is friendlier on the environment as compared to the grid connected pressure sodium lamp (HPS) and mercury vapour lamps. This is because the solar powered LED lamps emit very little carbon dioxide into the environment.

(Nunoo et al., 2010) concluded that the use of LED technology can help relieve the government's ever-present budgetary and environmental challenges as well as improve streetlight quality through features like reduced glare and better colour rendering.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter present the summary of findings, conclusions and recommendations of the research work.

5.2 Summary of findings

At the end of the research a lot of interesting findings were made and those findings are as follows;

- The stand-alone nature of the solar powered street lights makes it possible to connect area which are not connected on the national grid and places which are isolated and remote. Moreover, since the stand-alone solar powered street lights does not depend on the national grid, frequent power outage is not a problem, making it possible to provide uninterruptible power supply.
- The use of solar powered LED light consumes 40% less energy compared with the grid connected High Pressure Sodium (HPS) Lamps and Mercury Vapour Lamps which is used in the conventional grid connected street lights. Therefore, using solar powered LED lamps save a lot of energy.
- Using the stand-alone solar powered LED street lights is more environmental friendly (emit 56-60% lower CO_2) as compared with the grid connected High Pressure Sodium (HPS) Lamps and Mercury Vapour Lamps as it emit very little CO_2 into the environment.
- In terms of maintenance and operational cost of running, the stand-alone solar powered LED lights is better (upto 30% savings) than the conventional grid connected street

lights. There is the need of a very little maintenance and operational cost associated with the stand-alone solar powered LED street lights.

- With respect to duration, the solar powered LED Street light last longer (23 to 35% duration) than the conventional grid connected street lights. Because the LED bulbs are made up of many tinny bulbs coming together to produce the light, failure in some of the little LED does not automatically cause a total failure of the lamp. With the grid connected high-pressure sodium and mercury vapor lamps, any little defect will cause the bulb to stop working.
- The solar powered LED street lights produce a very bright and quality of light (80-100 Lumen/watts) compared to the high-pressure sodium and mercury vapor lamps. This means that fewer number of lights / poles are required to provide lighting for a particular area with the use of the LED lamps compared to the high-pressure sodium and mercury vapor lamps.

5.3 Conclusions

In conclusion, the use of stand-alone solar powered LED street light as alternative to the grid connected high-pressure sodium and mercury vapour lamps is viable and feasible. The stand-alone nature of it makes it possible to be installed on highways which are far away from residential areas. Stand-alone solar powered LED street lights are not affected by frequent power outages therefore a reliable source of light is guaranteed when needed especially at night. The use of light emitted diode (LED) lamps provide brighter source of light and can also last longer than the high-pressure sodium and mercury vapour lamps that are used in the grid connected street lighting system. Moreover, the use of the stand-alone solar powered LED lamps goes a long way to protect the environment since it emit very little carbon dioxide (CO_2) into the atmosphere. LED diodes lamps are very electrically efficient, which could save a lot money over time. Additionally, where an HPS bulb needs to be replaced every few grows to maintain its brightness, individual LED diodes lamps keep their brightness practically forever. With an LED grow light, it's almost certain something else will break on the lamp before any diodes start losing their brightness. Although the cost of initial installation of the stand-alone solar powered LED is higher than that of the grid connected street lighting system the long term usage and the other benefits associated with the stand-alone solar powered LED lights makes it very feasible. From the research, it can be concluded that the use of stand-alone solar powered LED street lights is technically and financially feasible in the long term.

5.4 Recommendations

Considering the remote nature of some street lights, the vital nature of street lights in our communities and on highways, the heavy demand of electricity on the national grid etc., stand-alone solar powered LED lights should be adopted for use on all the street lights in the country. The adoption should be started by piloting it on places such as security zones, police barriers and other checkpoints, tollbooths and on highways of remote areas.

There is also the need to train and have personnel for installation and maintenance work to ensure the effectiveness and longevity of the system.

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