FEASIBILITY STUDY ON POWERING CELL SITES USING RENEWABLE ENERGY IN GHANA

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Abstract

Most of the cell sites in Ghanaare powered by electricity from the national grid. However, electricity from the grid is not constant and also inadequate for the entire nation. This results in load-shedding and unannounced power outages. According to Mobile's Green Manifesto (2012), the total global electricity and diesel consumption by all mobile networks was approximately 120 terawatt hours (TWh) in 2010, resulting in energy costs of $13 billion and responsible for 70 Mt carbon monoxide emissions. This article seeks to research on the feasibility of using renewable energy as an alternative to the electricity being supplied to the cell sites and to demonstrate the technical feasibility and financial viability of renewable energy as an alternative compared to the use of the national grid. The study use a quantitative research approach, using MTN Ghana as case study. The study showed that mobile network operators could make about 37% profit in their energy cost by using renewable energy in sub-Saharan Africa over a 10-year period.

Keywords:- renewable energy, solar energy, generator, cell sites

1.INTRODUCTION

In today's world, many of us enjoy so many services from wireless technology. Telecommunication companies, radio and television stations, air traffic control systems, ministry of defense, private businesses, usually use wireless communication. In all these areas there is the transmission and reception of data signals using communication equipment such as antennas, transmitters, receivers and radios. In simple terms, a cell site depicts a place where antennas and electronic communications equipment are located, usually on tower or on some other high place, to create a cell in a cellular network[1]. In Ghana, most of the cell sites are powered by electricity from the national grid. However, electricity from the grid is not constant and inadequate for the entire nation. This results in load-shedding and unannounced power outages. Since power outages are so frequent, most transmission stations rely on a back-up power source. The voltage fluctuations affects the radios, transmission systems and other equipments. As a country advancing in wireless technology, the power supply to operators in these various companies would expect constant and adequate power supply from the grid but as it stands now, there has been an increase in tariffs on utility and inadequate supply of electricity has now forced institutions and companies to have generators as backup. Telecom companies and organizations have a reduced income at the end of the day due to cost involved in fuelling these generators. However, in new growth markets particularly, where mobile networks are expanding into rural areas, an electricity grid may not be available. Here, base station sites need to run autonomously. Traditionally, the energy used to operate these sites has come from diesel generators. These not only create copious CO_2 emissions, but require regular refueling and skilled maintenance work, which leads to additional travel and maintenance costs[2]. This source of power also adds significantly to operating expenditure, as the cost of diesel is high and expected to rise further in the future. A sustainable alternative is to use renewable energy sources such as wind and solar power[3].Autonomouscell sites can be configured to best suit the environment of the site. In the sunniest parts of the world, photovoltaic cells can be used to convert sunlight to energy and provide all the electricity needed to operate the site[4]. It is often recommended that solar energy be complemented with wind power, to supplement the solar resource, should sunshine hours be inadequate. It is essential to study the conditions of each site to decide on the optimal configuration of solar panels and wind turbines. Investing in renewable energy generation will ease the cost involved in generating energy in the country.Also, the pressure on the country's electricity generating company (Volta River Authority) will be eased when cell sites in Ghana use renewable source of energy. Countries are now advancing to have a pollution-free environment. Renewable energy generation systems require a considerable amount of raw materials, and purchasing these materials from local businesses can increase local manufacturing employment. Demand for construction, installation, and maintenance of renewable energy generation systems can lead to significant job creation and market development for these technologies[5].

2.RELATED WORK

For all practical purposes, energy supplies can be divided into two classes: Renewable energy i.e. Energy obtained from natural resources and occurring in our environment.

An obvious example is solar (sunshine), wind and biomass energy and Non-renewable energy i.e. Energy resources that are not replaceable or replaced very slowly by natural processes. They are obtained from static stores of energy that remain underground unless released by human interaction[2].

2.1Why use renewable energy?

Many countries are already switching to renewable energy. Apart from looking for clean energy sources from the environmental point of view, the search for new energy sources as substitutes for fossil fuels is another reason providing such drive. With a projected world population of ten billion by the year 2050, the increasing global energy demand will propel a more rapid depletion of the world's fossil fuel reserves[6]. Such possible tightening of energy supplies in the future will inevitably result in an upsurge of fuel and electricity prices. Renewable energy can reduce the reliance on exhaustible sources of fossil fuels. Developed countries are now making more and more investments on the development of renewable energy technologies. Recent growth in the area of renewable energy has been equally strong, with total electricity generation from renewable sources growing by 72 per cent from 1998 to 2008 (from 45 to 78 terawatt hours per year). This means that 66 per cent of all new electricity generated in sub-Saharan Africa after 1998 has come from renewable sources[7].

2.3Comparing Renewable and Non Renewable Energy

Non Renewable energy such as fossil fuels like diesel generators is used to power remote sites have several business drawbacks. When a substation fails to deliver power to a locality, buildings, factories and cell sites become affected. Not only does this bring discomfort but also pollutes the environment as well, making it unhealthy for the inhabitants of that locality. Maintenance and refueling a generator and the risk of theft of fuel from remote sites creates extra costs for service providers. Renewable energy is a domestic resource and offers alternatives to uncertain and increasingly pricey imports of fossil fuels that expose countries to foreign and volatile supply chains.[7] Imports of petroleum and coal over the last decade have steeply increased in most countries in the sub-Saharan region. So have price levels for fossil fuels and their volatility on international markets. The situation for petroleum-based products is similar if calculations ignore the six large oil-exporting countries in the region (Angola, Congo Brazzaville, Equatorial Guinea, Nigeria, Gabon and Sudan) and consider the remaining 41 countries only. While aggregate exports of petroleum-based products from this majority of countries in sub-Saharan Africa grew from 223,000 barrels per day in 1998 to 360,000 barrels per day in 2008 (a 61 per cent increase), imports grew at a much higher level, from 528,000 barrels per day in 1998 to 908,000 barrels per day in 2008 (a 72 per cent increase). Combining these trade figures with the fact that the medium- to long-term price trends for all fossil-fuels are clearly heading upward shows the potential attractiveness of exploiting domestic renewable energy sources [8]. A sustainable alternative is to use renewable energy sources such as wind and solar power, which best suits our environment. It is recommended that solar be complemented with wind power[9]. The rainfall pattern could disturb the intensity at which the solar energy should function, thereby having the wind turbine which works on the speed of the wind, will optimize the use of these renewable energy. Wind and solar powered cell sites need minimal maintenance, are environmentally friendly, and are an excellent alternative for emerging markets by providing low total cost to the service providers.

2.4The situation in sub-Saharan Africa

Some Sub-Saharan countries have put in place national targets for the expansion of renewable energy, and have acknowledged its importance in national development and poverty reduction plans. Despite such political support and endorsement, however, many of the same countries have to-date failed to put in place the supportive policies needed to create the level playing field. Without these policies and incentives, investors and independent power producers will continue to place emphasis on conventional energy options. It is interesting to note that those sub-Saharan countries that appear to lead the way in the expansion of renewable energy are those that have put in place concrete measures that go beyond political statements. Notably, these countries include Kenya, Uganda and Mauritius, and a few others. Sub-Saharan Africa has the world's lowest electricity access rate, at only 26 per cent. The rural electricity access rate is only 8 per cent, with 85 per cent of the population relying on biomass for energy [9]. Even in urban situations with in-principle access to electricity, infrastructure and services are unreliable with frequent power outages leading to great cost and difficulties.According to Mobile's Green Manifesto (2012), the total global electricity and diesel consumption by all mobile networks was approximately 120 terawatt hours (TWh) in 2010, resulting in energy costs of $13 billion and responsible for 70 Mt carbon monoxide emissions. They also estimated that out of the 120TWh; 80TWh of the energy consumption was from grid electricity and 40TWh was from calorific value of the diesel used to power generators used in off-grid and unreliable grid locations. Due to these limited generation and unreliable electricity supplied, companies tend to spend more on diesel for the generators, which emits carbon monoxide. In addition, persistent increases in diesel prices and electricity tariffs have led to a higher operational cost. This article seeks to research on using feasible renewable energy as an alternative to the electricity being supplied to the cell sites and to demonstrate the technical feasibility and financial viability of renewable energy as alternatives compared to existing power approach and solutions.

3.METHODOLOGY

This section focuses on the research methodology used for the study. The data is obtained from MTN Ghana, DENG LTD, Ghana and the Meteorological Service Department of Ghana. The information gathered was used for data processing and analysis.

3.1.Study Approach

The research approach used was quantitative. MTN, Ghana, the largest mobile network operator in Ghana was used as the case study. MTN, Ghana has 2285 cell sites scattered across the country. Data from all these sites were used in the research. Table1 shows the various data sources used for this research.

Table 1. Source of data

Source of Data	
Primary	Interview : MTN Ghana – Bernard Avor, Network Field Service Manager
Secondary	Meteorological Dept.: Weather Pattern in Ghana on Sunshine and wind speed Deng Ghana Ltd: Pricing for individual solar components

3.1.1Study Setting

These were the factors considered under the study of deploying renewable energy.

a. Grid Availability
b. Number of Cell Sites per Region
c. Type of Cell Site (Indoor or outdoor site)
d. Power requirements

3.1.1.1Grid Availability

MTN has the largest number of base transceiver stations in Ghana. Currently, there are 2,245 base stations dependent on the grid whilst 40 cell sites are off-grid. Therefore, in total there are 2,285 base stations owned by MTN. Table 2 shows a detailed distribution of the cell sites.

Table 2. Number of base stations On-grid and Off-grid (Source: MTN Ghana)

NUMBER OF BASE STATIONS	
ON-GRID	2,245
OFF-GRID : Diesel Generator	37
OFF-GRID : Renewable energy (solar)	3
TOTAL	2,285

3.1.1.2 Number of Cell Sites per Region

The number of cell sites was taken into consideration since each region has peculiar whether conditions. Table 3 shows the distribution of cell sites per region.

Table 3. MTN cell sites per region

Region	**Number of Base Stations**
Eastern	238
Volta	166
Ashanti	466
Greater Accra	555
Northern	150
Upper East	61
Upper West	52
Brong-Ahafo	195
Central	176
Western	226

3.1.1.3Type of Cell Site (Indoor or outdoor sites)

There are two main categories of cell sites, namely the indoor and outdoor sites. The indoor site is enclosed with an air conditioner unit to cool the cabinets during operations. This type of site is used mainly for backbone or hop sites. Outdoor sites are placed outside with a fan installed within to cool the equipment in the cabinet. Some of the outdoor sites use air conditioners depending on the environment.

3.1.1.4Power requirement

The power consumption of a cell site depends on the load (antenna's cooling system and transceivers). Outdoor sites usually consume lower than indoor sites due to the air conditioners. A typical example of the power requirement of an indoor cell site is 5kWhr and that of the outdoor cell site is 3kWhr. The installation of solar energy is dependent on the load on a cell site and the average solar radiation. There are three grades of solar panel and these are the:

a. Monocrystalline
b. Polycrystalline
c. Amorphous: This type of solar panel works on heat and is less efficient.

There are three types of installation, namely:

a. Back-up – In case there is power failure, it serves the cell site with power.
b. Stand-alone – This is the installation of solar alone.
c. Hybrid – It is a combination of solar and diesel generator.

3.2System specification

Table 4 shows the specifications for installing solar panels

Table 4. PV system specification

DC Rating	1 kW
Derate Factor	0.8
AC rating	0.80 kW
Array Type	Fixed Tilt
Array Tilt	20.0º
Array Azimuth	180.0º

Source: National Renewable Energy Laboratory (NREL), 2012

3.3AC Power output based on the various solar radiations

Table 5 shows the performance of a 1kW PV module.

Table 5. Performance Results for 1 kW PV module on solar irradiation and its AC output

Month	Solar Radiation (kWh/m2/day)	AC Energy Output(kWh)
1	3.54	82
2	4.55	97

3	5.18	122
4	6.40	145
5	6.72	160
6	6.97	158
7	6.75	157
8	6.38	149
9	6.05	135
10	4.87	112
11	3.96	88
12	3.34	77

Source: National Renewable Energy Laboratory (NREL), 2012

3.4Categorization of solar irradiation based on average sunshine

To determine the amount of energy that can be harvested from the sun, the various regions in Ghana was categorized according to the number of sunshine hours as shown in table 6.

Table 6. Demographic categorization of cell site per region

Groups	Regions under the groups	Average hours of Solar Irradiation	Minimum Solar Radiation	Indoor sites	Outdoor sites
REGION 1	Upper East, Upper West and Northern	7.83	4.967	82	181
REGION 2	Greater-Accra, Volta, Central and Eastern	6.59	3.325	242	893
REGION 3	Brong-Ahafo and Ashanti and Western	5.61	1.967	403	484

3.4.1Installation cost

In solar installation, the labor cost is 10% of the total component cost. The conversion of the dollar to cedi's was done with a rate of 2.77 in April 2014.

Region 1: With a minimum of five sunshine hours for 5kW and 3kW load. Table 7 and 8 shows a breakdown of installation cost for 5kW and 3kW load respectively.

Table 7. Breakdown of installation cost of solar equipment for 5kwhr

Components	Number of pieces needed	Original currency	Converted currency	Currency Number of pieces
250 W modules	162 pieces	$0.5	¢1.39	¢225.18
2V cell at 1500Ah	192 pieces	$400	¢1,108	¢212,736
7.5kVA inverter	1 unit	N 350,000	¢6,417.921	¢6,417.921
100A charge controller	9 units	$175.69	¢486.66	¢4,379.9517
Support structure				¢2000
15mm cable		$40.15		¢111.2155
Total Component Cost				¢225,870.2682
Labour Cost				10% of ¢225,870.2682
				¢22,587.02682
Total Initial Cost				¢248,457.295

Source: DENG GHANA Ltd

Table 8. Breakdown of installation cost of solar equipment for 3kwhr

Components	Number of pieces needed	Original currency	Converted currency	Currency Number of pieces
250 W modules	96 pieces	$0.5	¢1.39	¢133.44
2V cell at 1500Ah	120 pieces	$400	¢1,108	¢132,960
4.5kVA inverter	1 unit	N50,000	¢916.846	¢916.846
48V/80A charge controller	6 units	$175.69	¢486.6613	¢2919.9678
Support structure				¢2000
15mm cable		$40.15		¢111.2155
Total Component Cost				**¢139,041.4693**
Labour Cost				**10% of ¢139,041.4693**
				¢13,904.14693
Total Initial Cost				**¢152,945.6162**

Source: DENG GHANA Ltd

Region 2: With a minimum of three sunshine hours for 5kW and 3kW load. Table 9 and 10 shows a breakdown of installation cost for 5kW and 3kW load respectively

Table 9. Breakdown of installation cost of solar equipment for 5kwhr

Components	Number of pieces needed	Original currency	Converted currency	Currency Number of pieces
250 W modules	270 pieces	$0.5	¢1.39	¢375.3
2V cell at 1500Ah	192 pieces	$400	¢1,108	¢212,736
7.5kVA	1 unit	N	¢6,417.9	¢6,417.921

inverter		350,000	21	
100A charge controller	15 units	$175.69	¢486.66	¢7,299.9
Support structure				¢2000
15mm cable		$40.15		¢111.2155
Total Component Cost				**¢228,940.3365**
Labour Cost				**10% of¢228,940.3365**
				¢22,894.03365
Total Initial Cost				**¢251,834.3702**

Source: DENG GHANA Ltd

Table 10. Breakdown of installation cost of solar equipment for 3kwhr

Components	Number of pieces needed	Original currency	Converted currency	Currency Number of pieces
250 W modules	160 pieces	$0.5	¢1.39	¢222.4
2V cell at 1500Ah	120 pieces	$400	¢1,108	¢132,960
4.5kVA inverter	1 unit	N50,000	¢916.846	¢916.846
48V/80A charge controller	10 units	$175.69	¢486.6613	¢4,866.613
Support structure				¢2000
15mm cable		$40.15		¢111.2155
Total Component Cost				**¢141,077.0745**
Labour Cost				**10% of ¢141,077.0745**
				¢14,107.7
Total Initial Cost				**¢155,184.782**

Source: DENG GHANA Ltd

Region 3: With a minimum of 1.9 sunshine hours for 5kW and 3kW load. Table 11 and 12 shows a breakdown of installation cost for 5kW and 3kW load respectively

Table 11. Breakdown of installation cost of solar equipment for 5kwhr

Components	**Number of pieces needed**	**Original currency**	**Converted currency**	**Currency Number of pieces**
250 W modules	579 pieces	$0.5	¢1.39	¢804.81
2V cell at 1500Ah	192 pieces	$400	¢1,108	¢212,736
7.5kVA inverter	1 unit	N 350,000	¢6,417.921	¢6,417.921
100A charge controller	32 units	$175.6 9	¢486.66	¢15,573.12
Support structure				¢2000
15mm cable		$40.15		¢111.2155
Total Component Cost				**¢237,643.07**
Labour Cost				**10% of¢237,643.07**
				¢23,764.307
Total Initial Cost				**¢261,407.377**

Source: DENG GHANA Ltd

Table 12. Breakdown of installation cost of solar equipment for 3kwhr

Components	Number of pieces needed	Original currency	Converted currency	Currency Number of pieces
250 W modules	343 pieces	$0.5	¢1.39	¢476.77
2V cell at 1500Ah	120 pieces	$400	¢1,108	¢132,960
4.5kVA inverter	1 unit	N50,000	¢916.846	¢916.846
48V/80A charge controller	22 units	$175.69	¢486.6613	¢10,706.5
Support structure				¢2000
15mm cable		$40.15		¢111.2155
Total Component Cost				**¢147,171.3315**
Labour Cost				**10% of ¢147,171.3315**
				¢14,717.133
Total Initial Cost				**¢161,888.4645**

Source: DENG GHANA Ltd

3.5 Stand-alone (17.5kVA) and stand-by (13kVA) generators and their expenses.

MTN, Ghana runs stand-alone and stand-by generators at some of its cell sites. Therefore, in estimating the total cost on power by the company the running cost of these generators was taken into account. This is shown in table 13 and 14.

Table 13. Cost of running 17.5kVA generator for the first month

Cost of diesel generator	¢ 33,240
Labour Cost	¢ 2,172
Total Cost of diesel run per month (24hrs*30days)	¢ 4,824 per month at 1800 litres
Price of diesel in the first week of May	¢ 2.68
Total Installation Cost	¢ 40,236

(Source: MTN Ghana)

Table 14. Cost of running 13kVA generator for the first month

Cost of diesel generator	¢ 24,930
Labour Cost	¢ 2,172
Total Cost of diesel run per month (24hrs*30days)	¢ 3,859.2 per month at 1440 litres
Price of diesel in the first week of May	¢ 2.68
Total Installation Cost	¢ 30,961.2

(Source: MTN Ghana)

3.6 Feasibility of Wind Energy on Cell Sites

In Ghana, there is moderate availability of wind power energy. Along the coast, there is good availability of wind power with the speed of 9.0 – 9.9 m/s at 50m mast height. Since this renewable energy has a maximum potential along the coast with few inhabitants, the power required for those cell sites does not really warrant wind plants installation which would be disadvantaged to Telco companies considering the installation of a few base stations. For instance, Keta and Cape Coast have five (5) base transceiver stations, compared to the number of base transceiver stations in the country, the installation of wind energy would not be beneficial. Wind energy would serve as a good source of energy production but the location of the maximum wind speeds to generate this energy for the Telecom operators would be insignificant compared to the number of total base stations in the country.

4.RESULTS

This section analyzes data collected from various sources and determines the feasibility of renewable energy as an alternative source of energy to power cell sites. From the data collected from all the 10 regions, solar radiation or isolation has an average value between 4.99 and 7.728 kWh/m^2/day. Ghana has monthly average solar radiation of 4.99 and 7.728 kWh/m^2/day with an average daily sunshine of 4 to 8 hours. Northern Region, Upper East and Upper West recorded the highest solar radiation average of 7.668 kWh/m^2/day.

4.1Comparison between a photovoltaic cell and a Diesel Generator

Table 15. Comparison between a photovoltaic cell and a Diesel Generator

Factors	Solar (PV)	Diesel Generator
Resource Availability	Sunlight Readily Available	Fuel is expensive and can be scarce
Mode of operation	Simple	Complicated
Merit	i. Relatively Cheap ii. Silent iii. Very long system lifespan	i. Reliable power all month provided fuel is available ii. Generator not restricted to lightning circuits alone.
LCC (Life Cycle Cost)	Relatively higher installation cost but low maintenance	Low installation but high Maintenance and operational cost
Environmental and Social Impact	No pollution	Air pollution
Demerits	Poor system output due to poor sun exposure.	Environmental and Noise Pollution

4.1.1 Estimation of electric load required on a daily basis

Average Watt hr/day = Power * Quantity* Hours used per day.Therefore the amount of electricity consumed equals average Watt-hour per day * the number of days in a year.

4.12 Estimation of photovoltaic power rated per year

Equation 1, shows the calculation of photovoltaic power per year.

$$PV_{rated\ power} = \frac{P * h_{year}}{H_{isolation}} \quad (1)$$

Where:

P - Power needs

h_{year} - Number of hours in a year

$H_{isolation}$ - Number of hours of solar radiation in a year

PV - Photo-voltaic

4.2 Worst case scenario

Sunshine hours might not be adequate in a day or more. Solar systems are planned by considering the following factors:

4.2.1 Battery Capacity

For a cell site, 3 days autonomy of the site is recommended, but depending on the location, 4 or five days may be recommended[11]. Battery manufacturers specify the maximum allowable depth of discharge; this is different for different batteries and capacities, assuming 70% depth of discharge. This can also be calculated using equation 2

$$Battery\ Discharge\ Capacity = \frac{Demand \times Days\ of\ autonomy}{Max.depth\ of\ discharge} \quad (2)$$

4.2.2 Controller Sizing

From standard practice, to obtain the size of the solar charge controller, the short circuit current of the PV module is multiplied by a factor of 1.56 and the number of panels [10]. Therefore, the controller sizing will be:

$$5.1\ A \times 1.56 \times 8 = 63.65\ A.$$

4.2.3 Inverter Sizing

In the sizing of the solar inverters, it should be noted that the inverter should be 25-30% bigger than the total Watts of all appliances that are to be powered by the system. It must also be able to handle the expected surge or in-rush of current that some large loads draw upon[13]. The method for estimating surge requirements is simply to multiply the total AC watts by three at realistic conditions where system loads do not surge. The main criterion was to match the inverter's input voltage with the nominal battery voltage and choosing the desired AC output voltage of 240 V AC. The total AC load is approximately 44 kW, which must be the inverters size and therefore equal to the minimum inverter continuous watt rating.

The minimum surge rating will be:

44 kW × 3 = 132 kW.

4.3 Cost of powering cell sites (MTN Ghana)

Most of the cell sites solely rely on the national grid, as the main source of power. 17.5 kVA and 13kVA generators are being used as a stand-alone and stand-by power source to the cell sites. The renewable source of energy proposed is more economical than the existing condition of using the 17.5 kVA and 13kVA generator and the national grid, which also depend on the fuel. Currently, in the second week of May 2014, a liter of diesel costs GH¢2.68. For instance, MTN Ghana uses 17.5kVA generator, which consumes 2.5 liters per hour, and 13kVA generator, which consumes 1.5 liters per hour. Table 16 and 17 shows a breakdown of the cost of running a 17.5kVA stand-alone generator and a 13kVA stand-by generator respectively.

Table 16. Cost of running 17.5kVA generator as stand-alone for a year

Amount of fuel used/day	24 hours * 2.5 liters/hr = 60 liters/day.
Cost of fuel/day	60 liters * GH¢2.68 = GH¢160.80 per day
Cost of fuel/month	GH¢160.80 * 1 month(30 days) = GH¢4,824
Cost of fuel/yr	GH¢4,824 * 12 months = GH¢57,888 at 21,600 liters
Cost of fuel for 15yrs	GH¢57,888*15years = **GH¢868,320**
Total cost for 37 off-grid sites	37 sites*GH¢8,68320 = GH¢32,127,840

Table 17. Cost of running 13kVA generator as stand-by for a year

Amount of fuel used/day	5 hours * 1.5 litres = 7.5litres/hr.
Cost of fuel/day	7.5 litres * GH¢2.68 = GH¢20.10 per day
Cost of fuel/month	GH¢20.10 * 30 days = GH¢603 per month
Cost of fuel/yr	GH¢603 * 12 months = GH¢7,236
Cost of fuel for 15yrs	GH¢7236*15years= **GH¢108,540**

In addition, MTN Ghana pays 3.2 million Ghana cedis to the utility providers per month. This is 80% of the power taken from the grid and 20% for diesel generator.

3.2 million * 12 months = 38.4 million a year.

4.4Cost of using renewable energy to power all the cell sites

Since most of the cell sites would be converted to outdoor sites, for the purpose of this research, 10% of the sites would be indoor sites whiles 90% would be for outdoor sites. Table 18 and 19 shows a breakdown of the cost of installing the solar panels.

Table 18. Percentage of cell sites per region

Groups under region	Total number of indoor sites (10%)	Total number of outdoor sites (90%)
Region 1	26	237
Region 2	114	1022
Region 3	89	799

Table 19. The total cost of installing solar per region

Groups under region	Cost of indoor sites	Cost of outdoor sites	Total Cost
Region 1	¢6,459,889.67	¢36,248,111.04	¢42,708,000.71
Region 2	¢28,709,118.2	¢158,598,847.2	¢187,307,965.4
Region 3	¢23,265,256.55	¢129,348,883.1	¢152,614,139.7
Total Cost	**¢58,434,264.42**	**¢324,195,841.3**	**¢382,630,105.8**

4.5 Total cost of using grid and diesel generator over a 15 year period

Running a diesel generator includes both maintenance and re-fuelling costs. Servicing a generator every three (3) months costs GH¢500. This analysis does not include the cost of diesel generator, the installation of generator, and the labor cost since these occur once. Table 20 shows this breakdown.

Table 20. Total cost of utility and diesel generator over a period of fifteen years

Utility cost	Cost for 17.5kVA Stand Alone Generator	Cost for 13kVA Stand-by Generator	Total Cost
GH¢576,000,000	GH¢2,141,856	GH¢1,169,627,040	GH¢1,748,068,896

5.CONCLUSION

The initial cost of solar installation is high depending on the sunshine hours at a particular location but has lower maintenance and operational costs. Diesel generators have lower installation cost but higher maintenance and operational cost. Sunlight is readily available while fuel is expensive and scarce. Ghana has an average solar radiation of 4.99 to 7.728, which is a good energy production scale for the country. The total cost of running 17.5kVA and 13kVA and the utility bills per month for a period of ten (10) years will cost GH¢384,739,480 whiles installing solar energy in all the cell sites will cost GH¢ 382,630,105.80 and has an efficiency of 25 to 30 years at its peak operation. From table 20, in a fifteen (15) year period, the money used in installing solar would be recovered in less than 10 years. MTN would make profit of **37.09%** and in a twenty five (25) year period, they would make profit of **62.25%,** this depicts the fact that, solar energy is a cost effective alternative source of energy to the existing power approach being used by MTN,Ghana

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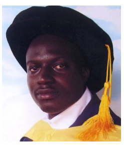

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