

## Climate Change and the Viability of Renewable Energy in Ghana

Caleb Mensah<sup>1,2,4,5\*</sup> and Mary Magdalene Mensah<sup>3</sup>

<sup>1</sup>Department of Matter and Energy Fluxes, Global Change Research Institute CAS, Brno, Czech Republic

<sup>2</sup>Earth Observation Research and Innovation Centre, University of Energy and Natural Resources, Sunyani, Ghana

<sup>3</sup>School of Natural Resources, University of Energy and Natural Resources, Sunyani, Ghana

<sup>4</sup>School of Geosciences, University of Energy and Natural Resources, Sunyani, Ghana

<sup>5</sup>Mendel University, Brno, Czech Republic

### Abstract

The observed changes in climate is expected to have adverse effects on the demand and supply of energy as projected by most global climate models, due to growth in towns, cities and other socio-economic indicators globally. As such, there is the need for countries to start considering clean but sustainable energy technologies to support other existing sources of energy and possibly reduce or stop the usage of those energy sources that tend to emit more greenhouse gases into the atmosphere and the pollute the environment. The application of renewable energy technologies that support measures to mitigate climate change but yet meet the future energy demands is highly recommended. However, there are certain global and national challenges that also inhibit the opportunities to be realized from the successful application of these renewable energy technologies. Inadequate information on these modern energy sources to create the awareness, easy access or availability to the raw materials and technology, and market failures for the application of these renewable energy resources are the identified challenges that contribute to these hindrances.

This study sought to assess the viability of alternative but clean renewable energy resources, with much emphasis on the need to harness the tremendous energy from Wave energy, as a way of augmenting the existing sources of electrical energy in Ghana, with the threat of global climate change looming. The study further suggested that there was the need for proper regulatory and legal frameworks to ensure sustainability of any future renewable energy technology facilities, and the need to further partner with other countries that have been successful with these technologies, whiles encouraging private-public partnership as a means of financing the construction and operation of any future renewable energy technology plants.

**Keywords:** Climate change in Ghana; Renewable energy technology; Wave energy; Sustainability; Carbon footprint; Carbon market

### Introduction

Increase in the concentration of atmospheric greenhouse gases and aerosols coupled with observed variations in solar activity changes the earth's heat/radiation budget and further increases surface temperatures globally. Carbon dioxide (CO<sub>2</sub>) has risen by about 30% and is still increasing at a rate of 0.4% per year. This increase is anthropogenic, because the changing isotope composition of the atmospheric CO<sub>2</sub> betrays the fossil origin of the increase. These observed changes in the concentration of greenhouse gases are projected to lead to regional and global changes in climate related parameters (such as temperature and precipitation trend). A rise in the earth's surface mean temperature of about 1-3.5°C by 2100 and an associated increase in sea level rise of about 15-95 cm have been forecasted by most global and regional climate models. It is projected in Africa, that about 75 to 250 million people will be exposed to increased water stress [1]. The use of coal, gas and light crude oil, LCO, in power production has been a major source of greenhouse gases which is increasing the rate of global warming and climate change. It has therefore been suggested that the world turns to cleaner sources of power production such as wind, solar, geothermal and nuclear energy.

There is a growing need for clean energy technologies throughout the world due to a global decline in fossil fuel reserves from greenhouse gas emissions [2-4]. Sub-Saharan Africa accounts for 13% of the world's population, but only 4% of its population have access to energy. Thus, with a rapid growth of economy and energy by 45% since 2000, other renewable sources of energy will provide the cleanest alternative sources, regardless of its initial capital and land use [5]. One easy option for most African countries is Wind energy, which has the

potential of producing a higher amount of energy (about 1,300 GW) than the current electricity consumption level of the whole of Africa [6]. Renewable Energy technologies can also offer benefits with respect to air pollution and health. Ghana like other many African countries have experienced a rise of about 7% per annum in electricity demand over the last decade. At present 75% of the Ghanaian population is connected to the national grid. The national goal is to achieve 100% universal electrification by 2020 [7]. The peak electricity demand of the country is even expected to exceed the already generating capacity of 3,000 MW of 2015 with a higher demand in future energy estimated at 26,600 GWh and about 5,000 MW by 2020 [8]. This is due to the relatively high population growth, economic aspiration of the country and the extension of electricity to rural areas. Thus, energy derived from vast the vast renewable resources of the country could be assessed and put to good use to generate much to meet the current access deficit to electricity experienced in most parts of Ghana, whiles still meeting international targets on climate change mitigation measures or policies. The Ghanaian government's consideration for crude oil and gas powered thermal power generation plants, as a solution to the current national energy deficit, come with serious environmental

**\*Corresponding author:** Caleb Mensah, Department of Matter and Energy Fluxes, Global Change Research Institute CAS, Brno, Czech Republic, Tel: +420 511 192 221; E-mail: [caleb.mensah@uenr.edu.gh](mailto:caleb.mensah@uenr.edu.gh)

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effects that will pollute the atmosphere with hydrocarbons and other harmful pollutants that can increase the greenhouse effect and contribute to climate change on a large scale. It is imperative that the country generates enough energy to meet the demands of the growing population while at the same time making sure that adverse impacts on the environment are minimized.

Recent papers by Deichmann et al. and Gyamfi et al. [9,10] sought to suggest and explain new ways through which these renewable sources of energy aside the hydro-electric power generation could be used to support electricity generation in Ghana and sub-Saharan Africa. These papers failed to discuss the viability of Tidal/wave energy as another non-polluting and a cleaner renewable source of energy as compared to the others for electricity power generation. Studies have also shown that the increase in population and urbanization will lead to high demand for energy and as such alternative sources of energy should be considered to make up for the possible future deficits. Renewable sources of energy which are environmentally friendly need to be considered than for government of Ghana to consider energy from crude oil or coal which involves the burning of fossil fuels to pollute the environment [10].

As such, this paper seeks to assess the viability of other forms of renewable energy sources in Ghana, whilst throwing much light on a cleaner and more predictable form renewable energy resource, Tidal or Wave energy in Ghana, to augment the existing sources of electric energy with the threat of global climate change. Ghana's dependency on hydroelectric power supply dates back to the 1960s but is currently supported by thermal power. In 2012, the total grid electricity generated in Ghana was 12,164 GWh (8,071 GWh (66%) of hydropower and 4,093 GWh (34%) of thermal power) as against 11,200 GWh in 2011. A study by Gboney, 2009 reveals the regulatory framework and energy efficiency policies for Ghana's renewable energy resources. Through the Renewable energy development programme, technical feasibility and cost analysis of new and possible future renewable energy sources are being investigated or looked into for consideration and development. This will ensure the sustainability of such renewable energy technologies and better inform government on the establishment of national policies that will see to its proper management and efficient utilization for national development [11]. This will in turn ease the burden on Ghanaians and have a positive effect on most businesses that rely on the national grid for survival.

In 2002, "Solar and Wind Resource Assessment" (SWERA) Ghana project made an assessment on the viability of the wind energy production in Ghana. The results from the feasibility study was quite encouraging and showed how Ghana could benefit immensely from this modern technology to augment the current energy supply [12,13]. However, detailed scientific research has not been adequately conducted into the sustainability of establishing several wind farms at potential areas in Ghana. Another feasibility study was conducted by Adaramola et al. 2014 [14] to evaluate the wind power generation along six coastal towns in Ghana. Much scientific works need to be carried out to identify other possible cities or towns across the country where large-scale wind farms and solar energy generation systems could be established.

## Renewable Energy Sources and Sustainability

One of the key challenges of this century is the management of anthropogenic factors that contribute to climate change. The IPCC through its reports have pointed out to the evidence of an enhanced greenhouse effect from the frequent burning of fossil fuels for energy

generation, thereby leading to a rise in emission rates of greenhouse gases such as carbon dioxide (CO<sub>2</sub>), methane, and other harmful gases into the atmosphere. Climate modelers through their scientific projections anticipate more emissions of these greenhouse gases since the global demand in energy supply keeps rising. Consequently, this will have more negative impact on the climate and lead to enhanced global warming and increased variability in precipitation pattern around the globe, affecting various sectors of national economies [1]. Implementation of anticipated climate change policies is expected to require significant action by the electricity industry, which was responsible for 40% of global CO<sub>2</sub> emissions in 2003. Of this, 70% was from coal-fired plants, 20% from natural gas fired plants, and 10% from oil-fuelled generation. Releasing greenhouse gases such as carbon dioxide (CO<sub>2</sub>) into the atmosphere causes climate change across the globe. Over 86% of the UK's CO<sub>2</sub> emissions originate from the production and use of energy [15]. About 19.64 pounds of carbon dioxide (CO<sub>2</sub>) are produced from burning a gallon of gasoline that does not contain ethanol. About 22.38 pounds of CO<sub>2</sub> are produced by burning a gallon of diesel fuel [5].

Thermal energy sources and also hydroelectricity to some extent have huge negative environmental impacts. Yet, the Ghanaian government continually sees these as key solutions to the energy crises in Ghana. These forms of energy production involve deforestation, pollution to the air and destruction to water bodies, ozone depletion, acid rain, and radioactive emissions. These emissions of CO<sub>2</sub>, SO<sub>2</sub> and other harmful gases released through the thermal energy production further contributes to global warming and climate change. As such, it will be an excellent approach to turn to renewable energy resources, that will ensure a sustainable environment while meeting the required energy demands of the future generations. Despite these opportunities, there are challenges that hinder the sustainability of renewable energy sources towards climate change mitigation. These challenges include market failures, lack of information, access to raw materials for future renewable resource deployment, and our daily carbon footprint. Research into alternate sources of energy dates back in the late 90s when the world started receiving shock from oil produces in terms of price hiking [16]. It is now evident in literature that replacing fossil fuel-based energy sources with renewable energy sources, like geothermal energy, bioenergy, direct solar energy, hydropower, wind and ocean energy (tide and wave), will gradually help the world achieve the idea of sustainability. Asumadu-Sarkodie and Owusu, 2016, suggested some measures and policy recommendations which could be considered to help achieve the goal of renewable energy, and thus, help reduce emissions, mitigate climate change and provide a clean environment as well as clean energy for all and future generations.

Another advantage of renewable energy sources is that they have the tendency to replenish naturally without being destroyed. Examples of such renewable energy sources which Ghana and other African countries could resort to, include; geothermal energy, bioenergy, hydropower, solar energy, wind energy and ocean energy. It's worth noting that utilization of the full potential from renewable energy sources will help reduce emission of greenhouse gases from fossil fuel combustions for energy generation. A study by the U.S. Energy Information Administration in 2012 [17] also revealed that a fraction of about 22% of the total world energy generation was supplied from renewable energy resources alone. Their naturally occurring sources make them sustainable as they are produced from a progressive flow of energy in our environment. Renewable energy sources do not produce any harmful substances into the environment and as such considered as environmentally friendly. A sustainable biofuel will neither change

the net CO<sub>2</sub> emissions, nor would it negatively affect food security, nor threaten biodiversity [18]. It also expected that renewable energy technologies would provide exceptional opportunities for climate change mitigation through substituting conventional based energy sources [19].

### Some other renewable sources of energy

**Mini-hydropower dams:** Hydropower dams are huge structures constructed on top of riverbeds to contain or reserve water and control the flow of a river, as a means of checking flood activities. These reservoirs are created purposely for irrigational purposes or for energy generation. Hydropower dams are the main sources of hydroelectric power, and this is harnessed from energy stored as a result of water moving from one higher level to another lower level. The generated energy is used to spin turbines that produce electricity for commercial purposes. These large turbines are usually constructed for an optional flow of water [20]. A higher percentage of Ghana's electricity generation is from hydropower generation. The oldest and largest in Ghana, the Akosombo Dam, was constructed in 1965 on the Volta River. Other minor sites as compared to Akosombo Dam have since been constructed to produce energy like the Kpong and Bui hydropower projects. Energy derived from these hydropower dams does not pollute the environment and these dams could store so much amount of energy for several hours [21]. No greenhouse gases are produced from the power generation and are considered as a green source of energy, yet, it has a minimal effect on the vegetation and society through deforestation and displacement of people from their homes (who might not even be well compensated for their loss) during construction. Thus, the exploitation of other sources of renewable energy could be preferred to the creation of other potential hydropower sites in Ghana.

**Bioenergy:** Bioenergy is another source of renewable energy harnessed from strictly biological sources. It is essential and could also be converted to biodiesel to power vehicles for transportation purposes, domestic purposes like for cooking or even in heating systems and more importantly for generation of electricity. Bioenergy has a wide range of sources, from which this energy could be obtained. Some of these sources include wood residues from forest by-products, wastes from sugar cane, cow dung and other agricultural waste products [22]. The energy generation process does not include emission of harmful greenhouse gases to pollute the atmosphere, and thus could prove very useful in future energy generation plans. Studies by Hoogwijk, Faaij, Eickhout, de Vries, and Turkenburg [23] proved that the "theoretical potential of bioenergy at the total terrestrial surface is about 3,500 EJ/year. The yield of biomass and its potential varies from country to country, from medium yields in temperature to high level in sub-tropical and tropical countries". However, further research works are being recommended to investigate its sustainability and contribution to mitigation of climate change.

**Direct solar energy:** Main source of solar energy is from the solar irradiance using photovoltaic (PV). This technology could be used to produce enormous amount of heat energy that could also be used to power systems for energy generation. Photovoltaic panels are used to absorb this thermal energy to produce direct electric currents, which are later converted to alternating currents by an inverter for onward distribution and transmission [24]. Plans are far advanced through a joint public-private solar project partnership with a UK based Blue Energy Group in Ghana to acquire one of the largest solar power plant in Africa and the world. The project is expected to cover a 182 hectares wide area of land, with 630, 000 PV panels mounted to a 37, 000 tonnes

of supporting structure and 2, 000 km connected wires at Nzema, which is 200 km north of Takoradi. This forms part of government's effort to meet targets set in the 2011 Renewable Energy Act of augmenting the current level of energy supply to 5, 000 MW by 2020 [2-4]. According to the World Energy Council [25], "the total energy from solar radiation falling on the earth was more than 7,500 times the World's total annual primary energy consumption of 450 EJ" [26].

**Geothermal energy:** Geothermal energy is harnessed naturally as a source of heat energy from the interior of the earth. Its origin is as a result of the decay of certain radioactive elements stored and other physical processes taking place within the interior of the earth over several geological years. These sites marked for extraction of geothermal energy sources are areas on the earth's surface with active volcanic activities. Thus, the energy can be obtained through drilling and connection of geothermal systems underground for electricity generation [27]. Geothermal energy systems are installed to mine heat from hydrothermal reservoirs below the earth's surface through wells and other means. These reservoirs found within the molten iron liquid outer area of the earth's core (approximately 5100 km from the surface) are naturally adequately hot (temperature ranges between 4300°C to 6000°C) and permeable. These Enhanced Geothermal Systems (ESG) with hydraulic stimulation transfer the heat from the core to the surface, through a hydrothermal medium of a fluid circulation system that converts the hot water into steam and transferred to turn turbines coupled with generators for electricity production [24]. The heat produced from these geothermal systems can sustain about 42 million MW of power and already used in most mid-latitude countries for electricity generation, especially for their warming systems in rooms, swimming pools and other direct applications that involve application of heat [28].

As such for the sustainability of such a massive project in Ghana, there is the need for the assurance of a continuous availability of these geothermal reservoirs which are naturally occurring and in abundant supply. Unfortunately, there are not adequate information or evidences of volcanic activities in Ghana and most West African countries to indicate the logical viability of geothermal energy. However, studies within these countries continue to investigate the viability of this alternative source of energy [29].

### Tidal/Wave energy

The shoreline is affected by tides and waves.

**Tidal energy:** The interaction of the combined effects of the gravity exerted by the sun, rotation of the earth and the moon gives rise to periodic shifts called tides, that move several gallons of sea water around. Tides are predictable and regular as compared to many other renewable energy sources like sunshine and wind. The gravitational forces of the moon and sun causes water levels to rise gradually to certain higher levels and drop to the lowest point, causing "the ebb and flow" at least once or twice daily [30]. Thus, coastlines experience two high and low tides daily. The potential energy generated at tidal estuarine sites from these change in tidal heights of at least 5 m, through the rise and fall of these tides are harvested by tidal technologies and used by tidal barrages to turn turbines for electricity generation [31].

There are mainly two modern tidal technologies used for energy generation. The first uses the energy from the rise and fall of the sea levels at distinct heights to produce energy through a "tidal barrage" system while the second harnesses the currents from ocean tides through the "tidal stream technologies" [32]. The tidal barrage works

like hydroelectricity power generation, where the construction of a fairly low dam wall (barrage) “blocks off an existing tidal estuary to create a tidal reservoir”. The several underwater tunnels of the dam cut into its width to allow sea water flow in through them in a controllable way using sluice gates (movable flood gates on barrage). Fixed within these tunnels are huge water turbine generators that spin as the water rushes past them, generating electricity. As such, sites marked for this kind of tidal technology must be characterized with enough tidal range and the site should be built in a way not to reduce the tidal range [30]. Secondly, “tidal stream technologies are carried out like underwater wind turbines, to generate power from the kinetic energy extracted from fast-flowing deep tidal currents. The generators of this system are sunk to depths within the ocean of about 20-30 meters for operation. These systems can be applied at only sites with strong tidal flow. This is a new technology being applied across the world to mimic the operation of wind turbines on land in sub water region. Tidal barrages require sites with tidal range of at least 7 meters, while tidal turbines require currents moving at speeds of 7–11 km/hr. Good sites are located in areas where incoming water are funneled into narrow channels, bays, river mouths and fjords. Tidal streams are also where underwater valleys force currents to constrict and speed up” [32].

**Wave energy:** Waves are mainly caused by wind and affected by the wind speed, length of time for which the wind blows and the distance or fetch over which the wind blows. These ocean waves can travel over longer distances and carries both kinetic and gravitational potential energy that get transported due to the strong winds that drive them [33,34]. Similarly, the energy obtained from the waves; use a wave energy converter to generate electricity. Earlier studies by the International Panel on Climate Change (IPCC) showed that an estimated 32 PWh of energy per year could be derived from wave energy [35]. This is about twice the global electricity supply of 17 PWh in 2008 [36]. The energy from the waves is harnessed by focusing the waves into a narrow channel to increase their size and power to spin the turbines and produce electricity through the process. Alternatively, waves could also be channeled into a catch basin or reservoir where the water flows to a turbine at a lower depth and powers the turbines to produce electricity. An average height difference of 4 ft 10 seconds wave striking a coast produces close to 35,000 horsepower per mile of a coast [35,37,38].

Commercial wave energy production started only 10-15 years when the demand for clean but cost effective viable energy sources was so high globally. As explained earlier, wave energy is considered more predictable and consistent than other renewable sources of energy that depend on the sun’s exposure and wind or even tidal energy which depends on the mass movement of the water body [35,39]. It also provides much higher return on capital investment than other renewable sources of energy (solar and wind), as it has the potential of generating about 30, 000 Watts of power per square meter [38].

**Wave energy project in Ghana:** Ghana is a West African country, geographically situated along the Gulf of Guinea, and has a coastline of about 539 km. The country boasts of the of the world’s largest artificial lake, Lake Volta, which extends through small portions of the South Eastern part of Ghana. The Volta Lake has many tributaries but the major ones are the Oti and Afram rivers that drain into it. Ada Foah is a coastal town located near the Volta River estuary in between the Volta River, Songor wetlands and the Atlantic Ocean. It is found within the Dangbe East District of the Greater Accra region of Ghana [40]. This city, which is 100 km from Accra has been selected as the site for Ghana’s test production of electricity from Wave energy. The

town’s coastline is characterized by long swells and occurrence of “high waves and undertow” which frequently floods and cause severe coastal erosion, inundating properties, roads and other farmlands [40]. A joint private-government partnership between the TC’s Energy Limited of Ghana and the Ghanaian government will see a Swedish Wave Energy developer, Sea based Wave Energy, install Turnky sea based wave parks at Ada Foah to generate about 1000 MW of electric power. Following an MoU signed on March 20, 2018 in Brussels, after feasibility studies carried out in 2015, works are expected to begin as soon as possible in building Africa’s first Wave energy power plant in Ghana. Studies have shown that the average wave height of about 2.5 meters off the coast of Ada is enough to power this new technological system of electricity power generation. The sea based wave parks comprises of buoys connected to linear generators, joined to flexible hinges, with movements of the waves causing parts of the buoys to move vertically up and down. This causes each of the hinges connected to a pump release oil through a hydraulic motor and spins the connected turbines to produce electricity. The generated power is then expected to be transferred to the national electricity provider, Electricity Company of Ghana (ECG), for onward distribution to the public at cheaper prices. Completion of this project will see the government of Ghana get closer to its target of increasing the country’s already installed electricity generation capacity from 3,167 MW to 5,000 MW in the medium term, while still looking at other environmentally friendly renewable forms of energy (Figure 1).

The UK government after the successfully initiating a major wave energy programme in 1976, halted works in 1982 due to slow progress from cost reductions. Yet other countries like Norway, realized the potentiality of the of the programme and continued to launch the first wave energy power station (350 kW and 500 kW rated power shoreline Oscillating Water Column prototypes) at Bergen. However, in 1991, UK restored its interest in the wave energy programme by installing a first commercial wave plant of 75 kW prototype LIMPET Oscillating Water Column (OWC) on Islay, Scotland. The LIMPET OWC was later upgraded to generate 500 kW commercially in 2001, hence becoming the first world’s commercial grid connected to a wave energy device [41]. Below is a Land Installed Marine Power Energy Transformer (LIMPET) in Isay, Scotland (Figure 2).

Sweden’s Seabased Company has begun constructing the world’s largest commercial wave energy at Sotenas in Sweden. The company recently installed a second project in Ghana comprising 6 Seabased’s wave energy devices providing 400 kW of power [41]. Currently, several pre-commercial demonstration projects are underway in other countries like the UK, Spain, Portugal, USA, Japan, Denmark, China, Korea, India and now Ghana to solve energies challenges [42]. As such



**Figure 1:** Works currently ongoing at Ada Foah (Source: TCs Energy Limited of Ghana).

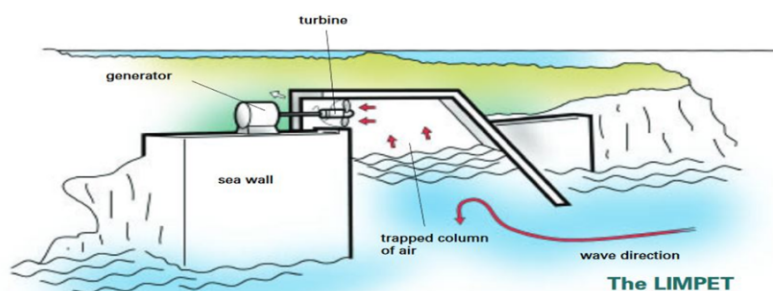


Figure 2: The LIMPET (Source: www.dti.gov.uk/renewables/schools for a wave energy case study).

Ghana is the first African country to ever try this new technology in power generation at its coast (Figure 3).

**Key benefits and challenges of wave energy to Ghana:** Wave energy is a non-polluting and renewable source of energy, which produces no waste or harmful emissions into the environment during its normal operations [43,44]. It has the tendency to naturally replenish itself over shorter periods and this makes it less environmentally destructive than other forms of renewable energy sources like hydro-electric dams that involves destruction to vegetation cover for siting of dam. As such Ghana resolving to this form of energy supply to help meet its energy supply deficit will further reduce our dependence on carbon based fossil fuels, while still enhancing the energy efficiency and reducing greenhouse gas emissions.

Installation of Wave energy converters (WEC) are expensive, but once constructed, the costs of running and maintain the project are quite low [45,46]. The on-going Wave energy production in Ghana is expected to cost about US\$4 billion, with the cost expected to further rise. However, the returns from the project will be worth the cost, as about 1000 MW is expected to be produced and added to the national grid for supply to homes.

On the other side, there are other challenges that this wave energy production project off the coast of Ada pose to inhabitants. These challenges are not considered as critical to that of other sources of energy [44]. The transport and use of the wave energy systems will have an impact on the local fishing activities of the area, as the fishing environment will be affected [47]. Not much is known how the impact will be as this is still a new form of ocean based technology being tested and used in few countries. Also, the potentiality of enhanced coastal erosion from the change in currents and waves flow is high. Site preparation during installation, like on shore heavy construction works, dredging and scouring of the sea bed to install electrical cables and other on shore, will lead to ocean bottom disturbances. The constant noisy nature of the wave energy converter devices will have impact on marine organisms like whales and dolphins which use echo location to hunt, while creating unbearable noise to inhabitants living around the power plant establishment [48]. Recreational activities patronized by most tourists to the estuary will be interrupted as there will be tight restrictions around places close to the power generation plant [49,50].

### Social and economic development from renewable energy sources

The Sustainable Development Goal seven (7), which touches

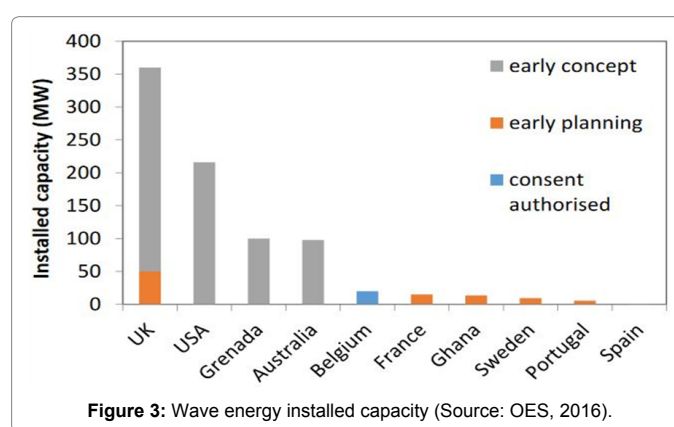


Figure 3: Wave energy installed capacity (Source: OES, 2016).

on provision of an affordable and clean energy, urges governments to utilize the availability to renewable energy sources as ways of tackling current energy issues, since these resources are generally distributed across the globe. Countries need to assess these concerns from a local context, and find ways of properly utilizing and managing these resources for the greater benefit of energy production in both urban and rural areas, especially in sub-Saharan Africa and South Asian regions [51]. Implementation of these modern renewable energy technological systems are quite expensive but reap massive results and protect the environment from pollution during combustion of fossil fuel. Edenhofer et al. [24] found that “renewable energy reduces energy imports and contribute diversification of the portfolio of supply options, which reduce an economy’s vulnerability to price volatility and represent opportunities to enhance energy security across the globe”. The study goes on to state how “the introduction of renewable energy will make contribution to increase the reliability of energy services, to be specific, in areas that often suffer from insufficient grid access. Distributed grids, based on the renewable energy, are generally more competitive in rural areas with significant distances to the national grid, and the low levels of rural electrification offer substantial openings for renewable energy-based mini-grid systems to provide them with electricity access” [24].

The development of every nation’s economy is bound to the sufficient supply and utilization of energy for productivity. Renewable energy study in 2008, showed that approximately 2.3 million jobs worldwide may be created from the application of renewable energy technologies to develop the health, educational, and human development sectors of national growth, whilst still ensuring sustainable environment [24].

## Electricity Generation Capacity of Ghana

With Ghana lower middle income status, the country has a nominal GDP of \$50 billion and GDP per capita of \$1902. Average annual GDP growth has topped 8% for the past 6 years reaching as high as 14% in 2014. With such impressive economic figures, it is to be expected that demand for energy to power this growth will be high. Inefficient supply of electricity to all towns and cities in Ghana (only 80% nationwide coverage) raises concerns and calls for maximum efforts to meet the energy deficits. The hydropower electricity generation accounts for about 68% of the national total installed energy capacity. The government of Ghana in 1997, as a way of complementing the supply of energy for commercial purposes, has gone on to install thermal plants which uses light crude oil. This was explained to be on short term basis, whilst other renewable and environmentally sustainable sources were looked into. However, the recent hikes in prices of high crude oil on the international market, have caused the operation of these thermal plants to be very expensive, with attempts made to install combined cycle power generating plants that use liquefied petroleum gas, LPG, but this has also been hindered by problems with the supply of gas from Nigeria.

In 2006, the Energy Commission of Ghana came out with a comprehensive report on the supply and demand of energy between the periods 2006 to 2020. This report is known as the Strategic National Energy Plan (SNEP). SNEP is a comprehensive way of looking at the available energy sources and resources of the country and how to tap them economically and timeously to ensure a secured and adequate energy supply for sustainable economic growth now and into the future. Energy efficiency measures were also emphasized in the SNEP and major sectors for energy conservation have been examined in this respect. The aim is to establish an effective national infrastructure for energy planning and create a consensus reference framework for the development of the energy sector (Figure 4).

Currently, Ghana has a total electricity generating capacity of 3,200 MW made up of hydro, thermal power plants, and other renewable energy resources such as solar PV and modern biomass that can be exploited for electricity production. As in 2015, the country's electricity demand was between 14,000 GWh to 16,400 GWh, while its available supply was approximately 15,000 GWh. Total hydro now is 1,580 MW thus 49.9%; Total thermal 1,579 MW signifying 49.8%; Total Renewable 8.2 MW-0.3%. Hence total installed capacity in Ghana is approximately 3,167 MW as clearly shown in Table 1 below [52].

## Cost-Benefit Analysis

Renewable Energy (RE) is mostly hailed as a “win-win solution” for sub-Saharan Africa. Concerns for electricity generation from renewable sources of energy are a sure way to tackle both the deficit in electricity supply to the rural areas whilst adhering to strict climate change mitigation measures or policies that enhance environmental protection. Sub-Saharan African countries are already showing good response through the introduction of several initiatives that would provide sustainable energy. An example of such an initiative is the United Nations Sustainable Energy for All (SE4ALL), which is a US-led Power Africa initiative. There is also the New Energy Deal for Africa or the Africa Renewable Energy Initiative being embarked on by Africa leaders after 21<sup>st</sup> Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC COP21) [53] held in December, 2015 at Paris, France. This project is being fully supported by the African Development Bank's (AfDB). Even though there is a caveat to financially support the use of renewable sources

of energy for power generation in Africa, different viability studies are being carried across the continent in many countries, to investigate the sustainability of such future projects on the continent's abundant resources for renewable energy technology.

Most sub-Saharan African countries rely on electricity generation from hydropower due to its least-cost source. Further studies to convince several African governments invest and undertake in projects that harness renewable energy sources are limited and countries are unsure about the sustainability of such projects. Thus, the low patronage by several countries as the cost of implementation of such renewable energy technologies is very expensive. Notwithstanding, some available literature have shown that “renewables are increasingly the least-cost alternative in many developing countries. Onshore wind and solar photovoltaics (PV) are becoming sources of low-cost electricity where large-scale deployment has driven down installed costs [54-59].

Recently published long-term remuneration contract prices for renewable energy technologies to be commissioned between 2015 and 2019 have shown prices to be as low as US \$5.1 cents per kilowatt-hour (kWh) for onshore wind and US\$6.5 cents per kWh for solar PV in South Africa. This is quite expensive as compared with the cost of energy generation from combustion of fossil fuel-based plants. As such, new policies being formulated need to take into consideration, the cost assumptions from similar areas within the continent like in South Africa, and encourage many African countries to also follow suit. The cost of renewables is highly contextual and time specific, as it mostly depends on the availability of the natural renewable resources and the ability to tap into its huge opportunities by proper management and development. These are highly dependent on the available finances, technological progress, experience in management, local capabilities and existing infrastructure of the specific country. Collaborations or partnership with other countries and private companies, which are far advanced in such renewable energy technologies, could be considered to enable the host African countries tap into and benefit from the rich experience and successful implementation of similar projects. However, there is the need to successfully carry out viability studies to ascertain the feasibility of such projects in host countries, as some of these results could be misleading.

## Conclusion

The Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) of the IPCC Working Group III provides an assessment and thorough analysis of renewable energy technologies and their current and potential role in the mitigation of greenhouse gas emissions. This seeks to demonstrate the economic, social and environmental viability of low carbon development pathways in the energy sector by creating new economic opportunities and increasing energy access through the use of renewable energy. Due to already existing viability studies for renewable energy technologies being already carried out, Ghana is one of few fourteen new pilot countries, which has been selected to benefit from the Scaling-Up Renewable Energy Program (SREP) in Low Income Countries under the Climate Investment Funds (CIF). There is also the World Bank Carbon Financing Unit (CFU), which are available for any of the 34-member Organization for Economic Co-operation and Development (OECD) countries to implement project-based greenhouse gas emission reductions programmes in developing countries. These emission reductions projects are financed through one of the CFU funds, on behalf of a contributor and the project monitored and regulated within the framework of the Kyoto Protocol's Clean Development Mechanism (CDM).

### NATIONAL INTERCONNECTED TRANSMISSION SYSTEM OF GHANA

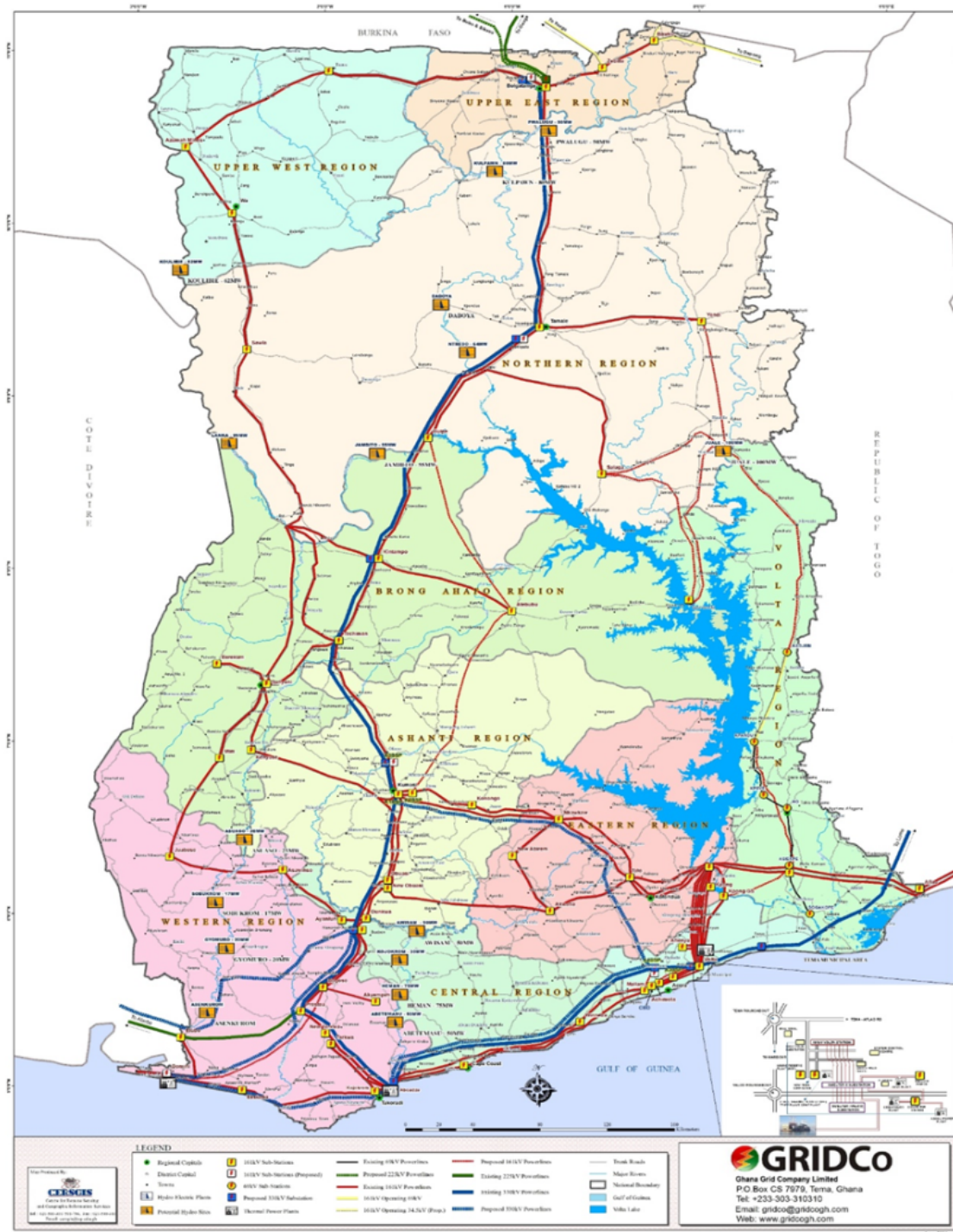


Figure 4: Map of Ghana indicating the locations of major power plants and the interconnected lines for power distribution (Source: Ghana Grid Company, GridCo).

Moreover, private businesses are also encouraged to switch to renewable energy sources, in assuming responsibility and accounting for how we treat the environment, and inform citizens on how their consumption patterns will affect the living and working conditions of people in developing countries. European governments and

companies, through international lobbies, seek to compensate for remaining emissions by purchasing carbon credits from pro-poor carbon projects. There is already good response from majority of the industrialized countries that ratified the Kyoto Protocol. Some of these countries have put in place strict domestic policies and regulations to

Plants installed	Capacity (MW)	Type	Fuel type
AKOSOMBO	1,020	HYDRO	WATER
KPONG	160	HYDRO	WATER
BUI HEP	400	HYDRO	WATER
TAPCO (T1)	330	THERMAL	LCO/GAS
TICO (T2)	220	THERMAL	LCO/GAS
OSAGYEFO POWER BARGE	125	THERMAL	GAS
T3	132	THERMAL	LCO/GAS
TT1PP	126	THERMAL	LCO/GAS
TT2 PP	50	THERMAL	DFO/GAS
CENIT Energy Ltd	126	THERMAL	LCO/GAS
MRP	40	THERMAL	DFO
SUNON ASOGLI	200	THERMAL	GAS
KARPOWER BARGE	225	THERMAL	GAS
GENSER POWER	5	THERMAL	GAS
VRA SOLAR PLANT	2.5	RENEWABLE	SOLAR
NOGUCHI SOLAR	0.72	RENEWABLE	SOLAR
OTHER SOLAR (OFF GRID AND NET METERED)	3.8	RENEWABLE	SOLAR
JUABENG OIL MILL BIOMASS	1.2	RENEWABLE	BIOENERGY
TOTAL INSTALLED CAPACITY	3,167		

**Table 1:** Ghana's total installed electricity capacity as at 2015 (Source: Volta River Authority, 2015).

cut off the production and emission of greenhouse gases and other pollutants into the atmosphere. The cost of reducing one ton of carbon dioxide will cost between \$15 to \$100 in industrialized countries. As such, efforts being made by the World Bank's carbon finance products will help grow the market by expanding the frontiers of carbon finance to new sectors, so that many other countries would also benefit from these opportunities.

A declaration from the Bonn International Conference for Renewable Energies 2004 that was adopted by the ministers and government representatives from 154 countries acknowledged that "in the context of Renewables 2004, renewable energy sources and technologies include: solar energy, wind energy, hydropower, tidal/wave energy, biomass energy including biofuels and geothermal energy, with no distinction with respect to scale". This was in line with all the debate that ensued in 2002 at the World Summit on Sustainable Development. These international agreements have gone a long way to protect the environment and ensure that the right thing is done by improving upon technologies that harness the full potential of renewable energy resources. The World Bank and other international financial bodies are assisting to fund the implementation of several renewable energy technologies across the globe, especially those involves carbon trade and are environmentally sustainable.

With the provision of such climate finance for green electrification in Africa, it is imperative for many African Countries to take advantage of such opportunities and invest in other forms of renewable energy technologies that are viable in the respective countries. Supporting policies and regulations need to be made to ensure the sustainability of such future projects to meet the energy deficit of the growing African economy.

As the earth's climate continues to change, it is important to cut down on greenhouse emissions. One of the ways to do this is to change the move away from present means of power production such as coal and crude oil powered thermal plants and embrace ecofriendly means of power production such as solar, wind and nuclear. Adherence to

renewable energy technologies as seen in commitment by government, to support on-going projects in solar energy, wave energy, bio-fuel and mini hydro-power dams, are expected to play an expanded role in meeting the growing demand for electricity in a safer manner that will not contribute more to global warming. It can serve as a means by which Ghana can reduce her carbon footprint. Ghana has to accelerate its infrastructure development if the 2020 target set for the inclusion of renewable energy technologies in its energy mix is to be met. It is much likely that this 2020 timeline in the power mix will not be attained. However, it is never too late to start.

## Recommendations

In order to realize the dream of using alternative renewable energy technologies to power the development of Ghana, it is recommended that a comprehensive feasibility study is carried out with regards to site selection, supply of fuel and the impacts on the environment. Additionally, we recommend that Ghana puts in place the necessary regulatory and legal frameworks to ensure safety and protection of any future renewable energy technology facilities. Furthermore, we recommend that Ghana partners with countries that have been successful with these technologies.

Finally, it's recommended that Ghana uses the opportunities from private-public partnership as a means of financing the construction and operation of any future renewable energy technology plants.

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