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Energy reforms as adaptation and mitigation measures to climate change: A case of Ghana

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Abstract

Climate change tends to negatively affect the energy sector globally. Fossil fuel energy production has been accepted globally by scientist and the public as a major contributor to climate change. However, the impact of precipitation variations and increasing temperatures on major energy (electricity) production in developing countries are underestimated. The annual growth in the demand for biomass, electricity, and petroleum products estimated at 3%, 6 – 7% and 5% per annum respectively calls for an assessment of its CO_2 emissions and contribution to global warming and the place of energy sector strategy and development plan in reducing these emissions as well as meeting energy demand for economic development. The nations total energy consumption of 8162.6 KTOE in 2012 emitted 30.71 Million tonnes of CO_2. Ghana's Energy Sector vision of achieving access to modern energy forms by 2020 will cut down CO_2 emissions from Biomass by 20% which is approximately 6.14 Million tonnes with 16% (≈0.8 Million tonnes of CO_2) and 7.5% (≈0.8 Million tonnes of CO_2) increase in electricity and petroleum products respectively. These strategies and development plans are however vulnerable to climate change due to the high dependence on hydropower energy generation and high cost of renewable energy in Ghana.

Keywords: Climate Change, CO_2 emissions, Hydropower, Energy Reforms, Vulnerability

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1. Introduction

Climate since the beginning of time has been changing from one equilibrium state to another. This has been observed by climate scientists by monitoring the shift of climatic condition or variables to a new equilibrium position with values of climatic elements changing significantly. The most significant variable that one needs no instrument to recognize is the current changes in atmospheric temperature popularly known as global warming. Global warming refers to increase in the average temperature of the atmosphere, oceans and land masses of the earth. A key finding of the Inter Governmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) is that temperature rose by 0.6 ± 0.2 °C over the 20th century. This warming occurred during two periods: 1910 to 1945 and 1975 to 2000 (IPCC, 2001). There is more evidence that this temperature increase is as a result of increasing concentrations of greenhouse gases (GHG) in the atmosphere. The subject of debate is whether “most of the temperature rise over the last 50 years is attributable to human activities”. The assumption that most of the GHG in the atmosphere was produced by human activities is the basis for TAR’s projection of 1.4 to 5.8 °C temperature rise between 1990 and 2100 (IPCC, 2001).

Watson et al. (1997, p. 7) stated that "the African continent is particularly vulnerable to the impacts of climate change because of factors such as widespread poverty, recurrent droughts, inequitable land distribution, and overdependence on rain-fed agriculture. Although adaptation options, including traditional coping strategies, theoretically are available, in practice the human, infrastructural and economic response capacity to effect timely response actions may well be beyond the economic means of some countries" in IPCC special report. The impact of these changes is already manifesting in Ghana. ITU News (2012) reported that, excessive rainfall in 2010 led to the overflow of Ghana’s major water body, the Akosombo Dam Reservoir, which provides electricity to the nation and its neighbouring West African countries. The overflow flooded communities close to the Volta River for the first time in 20 years. An estimated 378,000 people were displaced as a result of the floods as reported (ITU News, 2012).

A review of the energy sector which is the highest contributor of greenhouse gases globally, will greatly influence the current and future greenhouse gas emissions as both adaptation and mitigation measures. The three major types of energy consumed in the country are: biomass (firewood and charcoal), petroleum products and Electricity (hydro and thermal plants) which have varying Carbon dioxide (CO_2) emissions. The National Oceanic and Atmospheric Administration’s Annual Greenhouse Gas Index, quoted in their bulletin, shows that from 1990 to 2011, radiative forcing by long-lived greenhouse gases increased by 30%, with CO_2 accounting for about 80% of this increase (WMO, 2011). Knowing the amount of CO_2 emission by energy type will inform policy makers about the effects of decisions taken in increasing or changing one energy type to another. Biomass emits more CO_2 than fossil fuels, globally known to be a major contributor to these changes in climate by its CO_2 emissions. This higher emission from biomass emphasises the relevance of the energy sector strategy and development plan of the nation to cut down the use of biomass by making Liquefied Petroleum Gas (LPG) accessible to majority of Ghanaians by 2015 (Ministry of Energy of Ghana, 2010).

1.1. Research objective

Energy has become a necessity for development especially in Africa. Studies must be conducted to report and monitor the emissions from this sector on the African continent since it contributes more to the GHG emissions globally (Baumert et al., 2005). The unavailable and easily accessible documented CO_2 emissions reports and projections nationally as done for energy demand and supply in the annual report "Energy Outlook", creates a gap between our energy consumption and GHG emissions, which further affects policies for energy changes. This poses questions which have not been answered, such as, which factors contribute to regional, and national level changes in the amount and average output rate of CO_2?

Therefore, the objective of this study was to determine the CO_2 emissions from energy consumption by type in Ghana from 2001 to 2012 and assess the significance of the 2010 Energy Sector Strategy and Development Plan to CO_2 emissions reduction.

1.2. Demography, geography, and economy of Ghana

Ghana is a West African country with an economy which was traditionally oriented toward agriculture amongst service and industry, contributing immensely to its Gross Domestic Product (GDP) but now the last in the three sectors in order of contribution to GDP. Today, Ghana has a thriving gold and timber industry. As a former British colony, Ghana uses English as the language of commerce and government. It shares a common border with the Republic of Togo on the east, Burkina Faso on the north, La Cote d'Ivoire on the west and the Atlantic Ocean on the south. The 2000 Population and Housing Census puts Ghana's population at 18.9 million, an increase of 53.8% over the 1984 population of 12.3m, and estimated at 25.9 million in 2012 (EC, 2013; GSS, 2008 cited in Arthur et al., 2010). In 2012, Ghana's population was estimated at 25.9 million with increasing average of 0.5 million yearly as shown in Figure 1. The total land area of Ghana is 238,533 km^2. The country is divided into six agro-ecological zones on the basis of the climate, natural vegetation and the soils. These agro-ecological zones from north to south are: Sudan Savannah Zone, Guinea Savannah Zone, Transition Zone, Semi-deciduous Forest zone, Rain Forest Zone and the Coastal Savannah Zone (KITE, 2008). Energy consumption is increasing with increase in population; this suggests more demand for energy in the future (Figure 1).

The Services sector remains the largest, contributing about half (49.3%) to GDP. Five of the activities in this sector recorded growth rates above 10 percent in 2012. These sectors are: Hotels and Restaurants; Transport and Storage; Financial Intermediation; Information and Communication; and Business Services. The industry sector contributed 27.6% and Agriculture 23.1% (GSS, 2012). Meanwhile, the 2000 Population and Housing Census (PHC) showed that about 80% of the economically active population work in the informal sector showing the important role household enterprises play in the economy (GLSS 5, 2008). About 3.4 million households in Ghana own or operate a farm or keep livestock and more than half of households (1.8 million), which cultivate crops, hire labour for their operations. The two most important crops, in terms of sales, are maize and cocoa (GLSS 5, 2008). Provisional estimates for 2012 showed a growth of 7.1 percent in GDP over the 2011 revised estimates (GSS, 2012).

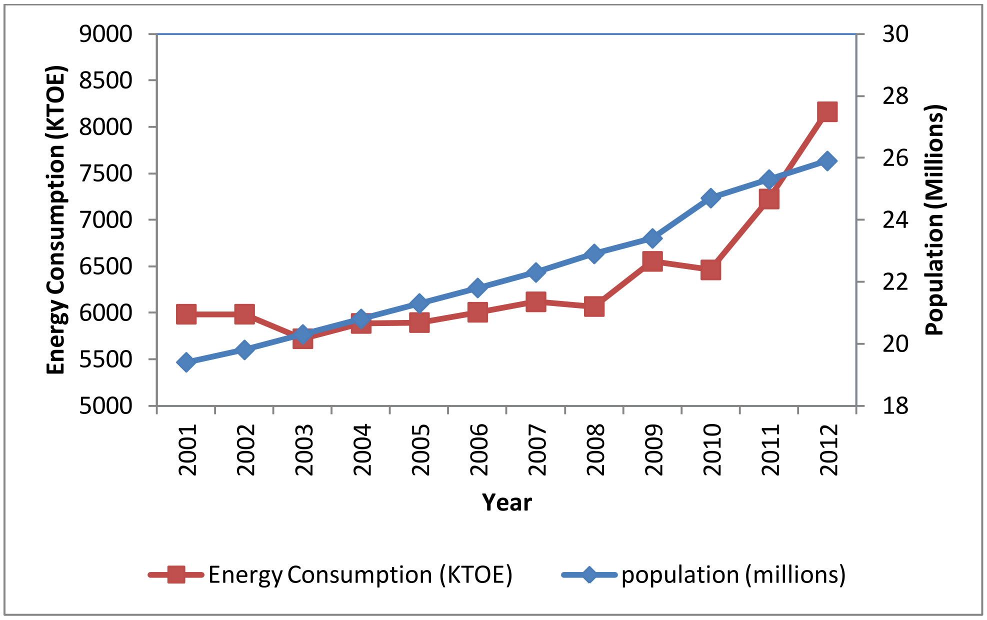

Figure 1. Population and energy consumption from 2001 to 2012

Source: Energy Commission, 2013

2. Review of energy sector strategy and development plan and its vulnerabilities

The Ministry of Energy of the Republic of Ghana developed strategies and development plans in 2010 to meet the energy demands of the nation with climate change in mind. Every strategy discussed in this section is from the strategy and development plan (Ministry of Energy, 2010). The vision for the energy sector is to ensure availability of and universal access to energy services and for export by 2020. To achieve this vision the plans seek to increase access to electricity from improved and modernised electricity distribution infrastructure to reduce system losses from 25% to 18% by 2015. The sector strategies and plans are grouped under the following sub-sectors; power (electricity), petroleum and renewable energy. All review in section 2.1, 2.2, and 2.3 are referenced to the Ministry of Energy (2010).

2.1. The power sub-sector reforms

The Ministry of Energy has strategised to increase electricity generation capacity to 5,000 MW by 2015. In order to achieve this, existing thermal plant power stations in the country will be expanded and more hydropower stations will be built. In progress were the 125MW and 100MW expansions in the Osagyefo Power Barge Project and Aboadze TICO power plant station respectively. There is approximately 60% thermal power generation and expansion and 40% for hydropower from the plan. Only 50 MW from wind power is to be completed by the end of 2013. Thermal power generation is more because the sector proposes to achieve 50% gas-based generation of thermal power plant production. The discovered Jubilee Oil fields in the country and the completion of West African Gas Pipeline (WAGP) Project to Tema in 2011 makes this achievable. The vision to achieve a universal access by extending electricity to all households in the nation by 2020 implies increase in the amount of distribution and transmission power loss and calls for improved and modernised transmission and distribution infrastructure for efficient service delivery which will reduce losses to 18% by 2015. The discovery of at least one hydropower site in every region in Ghana makes her a hydroelectric based nation despite the recent focus to increase thermal power generation.

2.2. Petroleum sub-sector reforms

Biomass as the major energy type consumed in the nation mainly as fuel (firewood and charcoal) can be reduced by the availability and accessibility of petroleum products to replace them, example is LPG. The plan as stated by Ministry of Energy (2010, p.17), "seeks to manage Ghana's oil and gas resource endowment to ensure sustainability in reserves and the environment through judicious exploitation and intensive exploration". The National Petroleum Authority has been setup to be responsible for the regulation of all activities related to upstream, midstream and downstream oil and gas industry in Ghana and to prohibit the flaring or venting of natural gas produced within the nation to maximise the utilization of natural gas reserves of the country. The strategies developed were to construct pipelines from Jubilee Field and WAGP to gas processing plants, develop the Jubilee Field, and explore the Voltaian Basin. The latest completion of these will be in 2015. Tema Oil Refinery (TOR) capacity will be increased from 45,000 BPSD to 145,000 BPSD while the Government has already initiated the process of building new refineries. Petroleum product storage capacity will be expanded nationwide and also facilitate the availability of more petroleum product distribution outlets in deprived areas to increase access density. With regards to LPG, it is intended to increase access from the current level of 6% of households to 50% by 2015. National Gas processing plant will be established on time to produce LPG from associated gas to be produced from the Jubilee Oil and Gas Field with an estimate of 10,000 barrels (1,340 tonnes) per day. To increase accessibility in the Northern part of the country, a petroleum products pipeline will be constructed to Northern Ghana with 90 days strategic stocks establishment for petroleum products throughout the country. The plan will also expand local cylinder manufacturing capacity in support of the National LPG Programme. This Sub-sector development will see to the reduction of the higher percentage of biomass consumption in Ghana.

2.3. Renewable energy sub-sector reforms

Ghana is well endowed with Renewable Energy Resources particularly biomass, solar, wind energy resources, and to a limited extent, and mini-hydro. Solar radiation levels are estimated at about 4-6 kWh/m^2. Average wind speed along the eastern coastal areas is estimated at 5m/s at a height of 12 metres. Wind speeds of 9 m/s have been recorded on the mountains along south eastern corner of the country. The wind speed regime along the coastline suggests that wind can be harnessed for power generation as well as for mechanical applications. The development plan has established Grid-connected 50 MW wind farm project to harness these resources to support energy generation in the country. Solar PV programme for public institutions and estate development and develop the Kpone Mini hydro and Bio-fuel projects are in progress and the development of Renewable Energy law is also on course. The plan proposes to achieve 10% increase of renewable energy supply in national energy mix by 2020. Tax incentives will be provided for the importation of all equipment used in the development of renewable and waste energy projects. Renewable energy has high potential in Ghana but low exploitation and utilisation due to high cost of renewable energy production.

One important reform is the promotion of the establishment of dedicated woodlots for biomass (wood fuel) production. This will reduce the rate at which trees are cut down and promote Reducing Emissions from Deforestation and forest Degradation (REDD+) programme in Ghana. There is significant amount of wastes generated in Ghana which conversion technologies like combustion, gasification, pyrolysis, anaerobic digestion (biogas), fermentation and esterification will produce energy from them. Some waste-to-energy technologies that have been developed in Ghana are anaerobic fermentation of municipal waste and industrial liquid wastes to produce biogas for heating and electricity generation, combustion of solid wastes to produce electricity in Combined Heat and Power (CHP) systems. The focus is to convert municipal, industrial, and agricultural waste into energy as a means of managing the growing sanitation problems and contributing to energy supply security. In view of this, Metropolitan waste-to-power, Institutional (Universities, Polytechnics, and Senior High Schools) biogas projects funded by the Government and private sectors will take place from 2010 to 2015.

2.4. Vulnerability of hydro power to climate change

The changing climate and modification of precipitation and temperature patterns can affect hydropower output in four major ways: surface water evaporation, reduced runoff due to drought, increased runoff due to flooding, and siltation (Mukheibir, 2007). Each of the mentioned factors in its increased or decreased form will alter hydro power generation. "Increased variability in weather (intensity of peak flows, changes in seasonal patterns) could also increase uncertainty in river flows and the capacity of reservoir storage" (Harrison et al., 1998 cited in ADB, 2012, p. 20). Run-of-river hydropower systems, which by definition lack water storage, are significantly affected by daily, dry-season, wet-season, and annual changes in precipitation changes in precipitation (ADB, 2012). Nutsukpo et al. (2011) discussed four models showing varying changes in precipitation across the country. According to them, the CNRM- CM3 and ECHAM 5 GCMs showed that there will be little change in annual precipitation in most regions of the country. CNRM-CM3 showed an increase in the extreme southern part of the country, while ECHAM 5 showed an increase in the southeastern part of the country. According to CSIRO Mark 3, there are possibilities of general reduction in precipitation across the country: –200 to –100 millimeters per year in the middle belt, –100 to –50 millimeters in the northern savanna zone, and –50 to +50 millimeters in the southwestern corner. MIROC 3.2 showed decreased precipitation in the south and increased precipitation in the north. The decrease in precipitation and river runoff for the mid-latitude subtropical areas are places, where hydropower is often a primary source of electricity (Water News 2010). Neumann and Price (2009) discovered that, 1% change in precipitation is likely to result in at least a 1% change in power generation although changes in power generation are harder to predict for run-of-river systems.

Ghana's energy sector strategy and development plans show signs of susceptibility to climate change, particularly on hydropower production. These produced energy crises in 1984, 1998, 2002 and 2007 with a sure possibility of recurrence due to the cyclical nature of climate forcing (World Bank, 2010).

2.5. Vulnerability of solar photovoltaic systems to climate change

ADB (2012, p.27) states that " Solar photovoltaic panels have an operating lifetime of 20 or more years and photovoltaic systems are vulnerable to hail, wind, and extreme temperatures. Solar cell output is usually rated at 25ºC with output typically decreasing by about 0.25% (amorphous cells) to 0.5% (most crystalline cells) for each temperature rise of 1ºC. Cell temperatures for roof-mounted arrays in warm climates can easily reach 50°C–75ºC. At 50ºC, output can be 12% below rated output".

Solar photovoltaic panel output can decrease by 40%–80% within a few seconds when cloud covers the atmosphere, and builds up gradually as the sky clears (Kleissl, 2010). For large arrays, this rapid fluctuation can cause localized voltage and power quality concerns because shading of one panel affects the entire array connected to a single inverter (Mills et al., 2009 in ADB, 2012, p. 28). The four models according to Nutsukpo et al. (2011) predicted temperature increase for Ghana coupled with cloud changes due to rainfall patterns will affect the performances of solar panels.

2.6. Vulnerability of thermal power generation to climate change

The efficiency, output, and production of electricity can be affected by climate change. An increase in ambient temperature as reported in ADB (2012), will lead to a decrease in the in temperature difference between ambient and combustion which will reduce the efficiency of turbines (Contreras-Lisperguer and de Cuba, 2008; Wilbanks et al., 2007). Reduction in power output is proportional to temperature increase in gas turbines. Neumann and Price (2009), estimated that 5.5°C increase in ambient air temperature may reduce output by approximately 3-4%. The goal of achieving 50% gas-based generation of thermal power plant production in times of temperature increase as predicted will cost more funds due to the reduction in output with temperature increase (Neumann and Price, 2009).

Access to sufficient water for cooling and returning it to the source at a temperature low enough to sustain and maintain aquatic ecosystems will be an issue of concern in the nation (Greis et al., 2010). A considerable amount of water is needed for fuel processing, cooling and power production under thermal power generation. Climate change is projected to reduce water availability especially in the sub-Saharan zone (IPCC, 2007). Therefore thermal plant will be competing with men for water use though the basic need of water supply in the country is not fully met.

3. Methodology

3.1. Data sources and CO_2 emission factors

Energy generation, production, and consumption data were collected as secondary data from the February, 2013 National Energy Statistics report by the Energy Commission of Ghana. Ghana as a developing country is industrializing, implying that CO_2 emission from energy consumption is expected to increase with years. CO_2 emission factors for the calculation of the emissions in Ghana of the study period from 2001 to 2012 are shown in Table 1. The major conversion made from the reported data (EC, 2013) was 1 GWh to 86 TOE (Tonnes of Oil Equivalent) to determine the biomass consumption from the total energy consumed.

Table 1. CO_2 emission factors

Fuel Type	**CO_2 factor (CO_2 lb/mmBtu)**
Biomass (wood)	213
Gasoline	154.91
Residual Fuel Oil	171.98
	(CO_2 kg/mmBtu)
Kerosene	75.20
Aviation Turbine Kerosene	72.22
Premix	70.22
LPG	62.98
	(kgCO_2e per unit)
Grid Electricity (kWh)	0.5246
Gas Oil (tonnes)	3528

Source: (EPA, 2010; Carbon Trust, 2011; PFPI, 2008; DOE/EIA, 1997)

3.2. Determining local emission factor for electricity consumption in Ghana

Emission factor in Table 1 for Grid Electricity is for United Kingdom calculated over five rolling years (Carbon Trust, 2011). This section calculated the average electricity consumption emission factor for Ghana in order to arrive at the CO_2 emissions attributable to electricity consumption. This will be compared with the UK and US emission factors. Generally, national or European emission factor may be used. The following simple rule1 was used:

$$EFE = [(TCE - LPE - GEP) \times NEEFE + CO_2LPE + CO_2GEP] / (TCE) \qquad (1)$$

(Source: SEAP, 2010)

where

EFE = local emission factor for electricity [t/MWh_e]

TCE = Total electricity consumption in the local authority [MWh_e]

LPE = Local electricity production [MWh_e]

GEP = Green electricity purchases by the local authority [MWh_e]

NEEFE = national or European emission factor for electricity (to be chosen) [t/MWh_e]

CO_2LPE = CO_2 emissions due to the local production of electricity [t]

CO_2GEP = CO_2 emissions due to the production of certified green electricity [t]

National or European Emission factor for electricity used was for United Kingdom. Since GEP and CO_2GEP are not applicable to Ghana, equation (1) reduces to;

$$EFE = [(TCE - LPE) \times 1.201] / (TCE) \quad (2)$$

Equation (2) was used to determine the local emission factor for electricity in Ghana.

4. Results

4.1. Energy consumption by type (2001 to 2012)

The bulk of energy supply in Ghana is met from Biomass. Biomass accounted for 49% of the total energy consumption in 2012 (EC, 2013) compared to about 71±1% of total primary energy supply and about 60% of the final energy demand in 2008 (Arthur et al*.,* 2010). Biomass (wood fuel) consumption was followed by petroleum products at 41% and electricity making up the rest as shown in Figure 2. In terms of sector wise utilization of electricity, the industry sector of the economy consumes the highest of average almost 49% of Ghana's Electricity consumption but the residential sector leads in Biomass consumption. The significant residential sector share of the Ghana's energy demand is due to the high usage of Biomass comprising mainly of firewood and charcoal which is 66.3% (EC, 2013). Electricity and Petroleum comprise Hydro and Thermal and Liquefied Petroleum Gas (LPG), Kerosene, Aviation Turbine Kerosene (ATK), Gasoline, Gas Oil, Premix, Residual Fuel Oil (RFO) respectively.

The total energy consumption from 2001 to 2012 has been increasing, obviously due to increase in population and the industry sector. From Figure 3, Biomass reduced from 2001 to 2010 at an average rate of 1.82±3.18% and began to rise at about 7.82% to 2012. Petroleum products consumption was unstable, with increase from 2004 to 2007 and began to drop till a rise at an average rate of 10.8% while Electricity consumed over this period dropped in 2002, started rising from 2003 to 2006 and went down again in 2007 before maintaining an increasing average rate of 7.81±31.92% to 2012 (Figure 3). The high deviation in the increasing rate of power consumption was due to the small increase of 71 GWh from 2011 to 2012. These trends show the increase in petroleum products and electricity generation in the nation which are replacing the local firewood and charcoal usage.

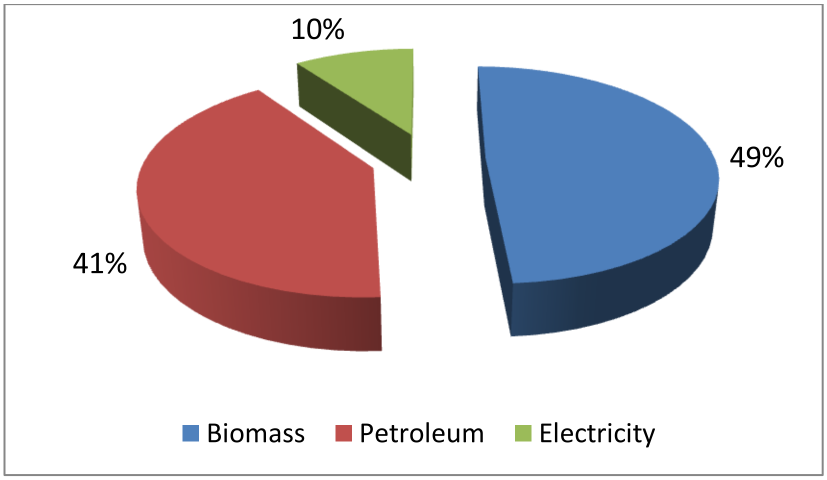

Figure 2. Energy Consumption in 2012

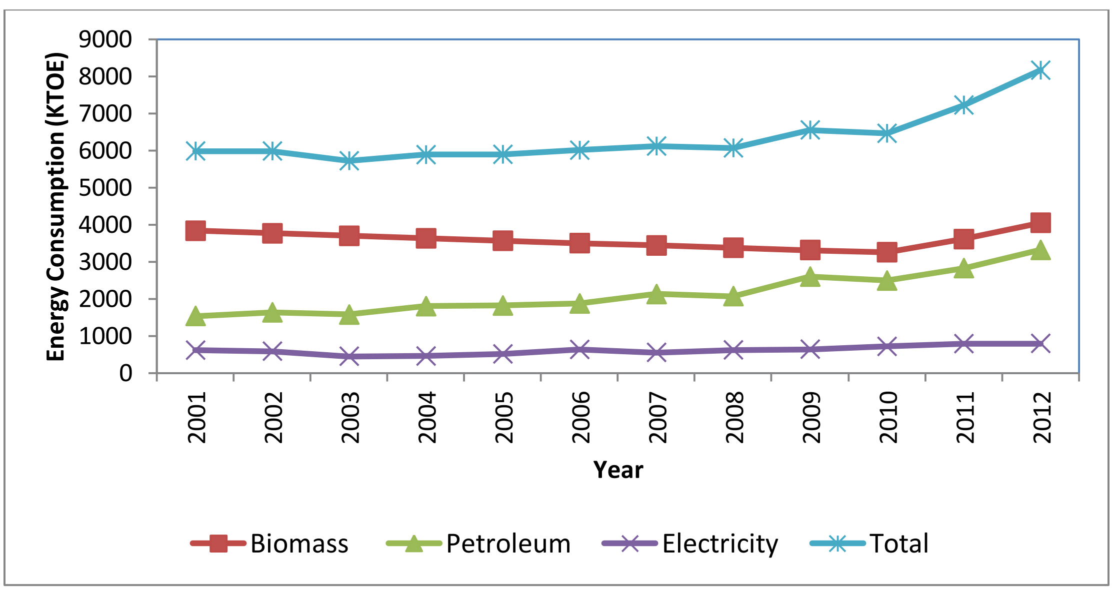

Figure 3. Energy Consumption in Ghana from 2001 to 2012

Source: Energy Commission, 2013

According to the consumption records, there is no consistent increase or decrease in energy use in the country but stochastic.

4.2. CO_2 Emissions from energy consumption by type

The mean local emission factor for electricity in Ghana calculated over 2001 to 2012 is -0.1890±0.08. This implies that the emission factor by local consumption is zero from the adopted formulae from Sustainable Energy Action Plan (SEAP, part 2). Exportation of electricity to neighbouring countries (Burkina Faso, Togo, and Benin) contributes to the negative emission factor per the formulae because power generation is higher than consumption.

Carbon dioxide emissions in Ghana are mostly originating from the consumption of biomass (firewood and charcoal) and petroleum products and electricity followed in that order as shown in Figure 4. Biomass has a higher CO_2 emission rates than the other two sources of energy, implying that the higher the biomass consumption the higher the amount of CO_2 emitted.

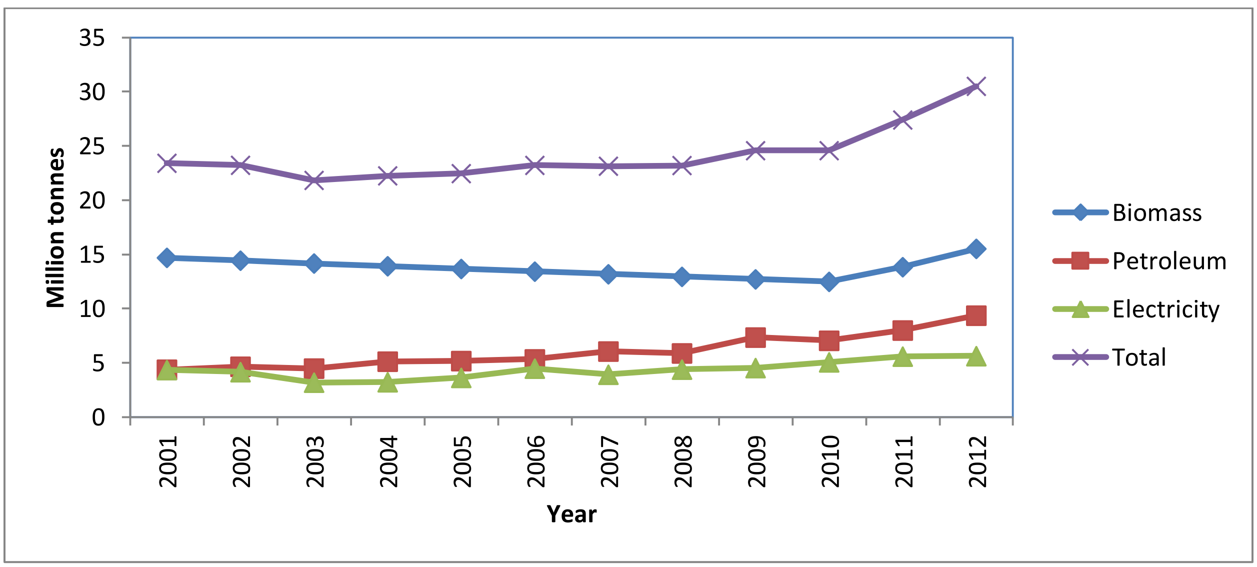

Figure 4. CO_2 Emissions from 2001 to 2012

The total CO_2 emission in 2012 was 30.51 Million tonnes, higher than previous years. This may be attributed to the higher consumption of biomass in that year though electricity and petroleum products accessibility increased. Figure 5 shows the percentage emissions of carbon dioxide by energy type in Ghana in 2012. Biomass had 1% increase of CO_2 emission to consumption. The growth in Industry represented by GDP (from 20.4% in 2008 to 27.6% in 2012) (GSS, 2012) means energy demand and consumption will increase in the country. Meeting this demand will boost the economy and make life more comfortable to citizens but it might also be a significant contributor to global warming if energy strategies planned to change energy sources in the country are not met.

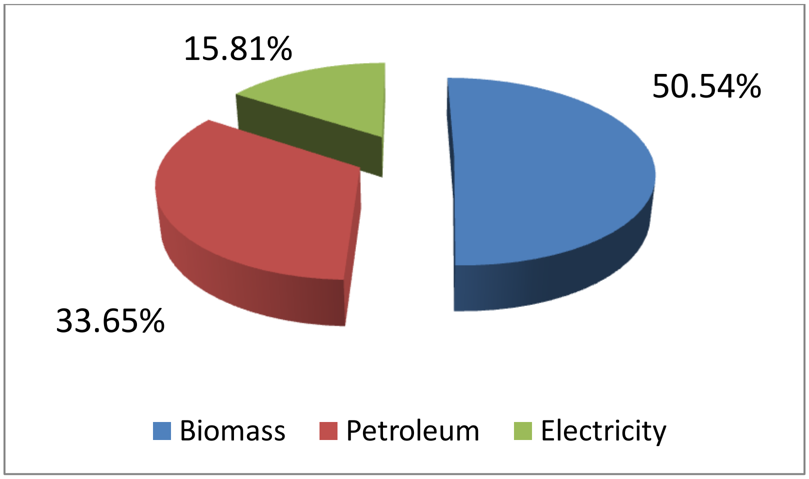

Figure 5. CO_2 Emissions from 2012 Energy Consumption

4.3. Significance of strategies and development plans to CO_2 emissions reduction

The Energy Sector vision of achieving access to modern energy forms by 2020 (Mahu & Essandoh, 2011) proposed energy consumption of Biomass, electricity, LPG and other petroleum products to be 30%, 20%, 25% and 25% respectively and the annual growth in the demand for fuel wood and charcoal is estimated at 3% per annum. Electricity demand, on the other hand, is growing between 6% and 7% annually while consumption of petroleum products is estimated to increase at about 5% per annum. Achieving this goal means that Ghana will cut down CO_2 emissions from Biomass by 20% which is approximately 6.14 Million tonnes with 16% (≈0.8 Million tonnes of CO_2) and 7.5% (≈0.8 Million tonnes of CO_2) increase in electricity and petroleum products respectively.

5. Discussion and conclusion

Women in Ghana bear the brunt in the use of the wood fuel based energy economy in the country, constituting the highest percentage of energy consumption till now. The health impacts of indoor air pollution from traditional biomass fuels and their negative impacts on women, girls and babies remain a critical issue. Reducing biomass usage by reaching 50% household with LPG by 2015 will reduce the negative health implications it has on women. Biomass also emit more CO_2 than fossil fuel (Bituminous coal = 205.3 lb CO_2/mmBtu, Natural gas = 117.8 lb CO_2/mmBtu) at 213 lb CO_2/mmBtu. Reducing biomass usage and establishing dedicated woodlots for fuel wood will preserve forest and biodiversity to sequester carbon as an adaptation measure in the country.

Large amounts of investments is going into government policies to increase hydropower production in the energy sector of Ghana with sixteen potential sites all over the country, one under construction (Bui Dam) to be completed in 2015. Though, hydropower is seen as a low-emission energy source that can meet the growing energy demands of Ghana it has its own vulnerabilities to climate change. These vulnerabilities on hydropower as well as thermal power have to be carefully considered to know what role hydropower and thermal power should play in the country's energy future. The energy strategy and development policy is climate inclined but there is also the need to know how climate will impact the strategy.

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