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Policy interventions in renewable energy for sustainable development: is Ghana on the right path to achieve SDG 7?

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Policy interventions in renewable energy for sustainable development: is Ghana on the right path to achieve SDG 7?

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Abstract

Goal 7 of the Sustainable Development Goals seeks to ensure universal access to affordable, reliable and modern energy services and increase substantially the share of renewable energy in the global energy mix by 2030. This target provides an opportunity as well as a challenge to African countries including Ghana. Indeed, the Ghana Energy Commission estimates that Ghana has about 34 potential hydro sites and enjoys about 330 days of sunshine annually. For instance, the three Northern regions, Volta and northern parts of Brong Ahafo have radiation levels with monthly average of between 4.0 and 6.5kWh/m2/day. These hydro and solar resources, coupled with abundant waste, wind potential of about 2000 MW and tidal potential can make Ghana a net exporter of power when the needed investment is provided. This paper examines the policy interventions in renewable energy in Ghana over the past 20 years. It also includes a review of the literature on the relationship between renewable energy investment and sustainable development and provides policy recommendations to fast-track renewable energy technology deployment in Ghana.

Key Words: Renewable Energy, Ghana, Sustainable Development Goals, Energy supply and demand

1. Introduction

Renewable energy is the answer to the lack of energy access and unreliable power supply in Ghana and other African countries for three reasons. First, renewable energy sources are indigenous and help to promote self-sufficiency in energy supply. This helps to reduce the impact of price and supply volatility of fossil fuel on the economy. The dependence on renewable energy helps African economies to save the money that would be used to import crude oil. For instance, African economies spent USD 18 billion in 2010 to import crude oil (IRENA, 2012). This amount exceeds the foreign income Africa received in the same period. Adding the cost of oil imports to that of oil subsidies, Ghana and for that matter Africa stands to gain more if there is investment in renewable energy to reduce dependence on oil. Second, renewable energy offers a technologically viable alternative to connect rural areas to electricity in the form of off grid or mini grid systems. This will help businesses in remote areas and improve healthcare and education. Finally, because renewable energy sources are locally based, they help create jobs in terms of construction, operations and maintenance for the indigenes and the economy as a whole. These advantages together with the fact that renewable energy is carbon-neutral and non-depletable make it the ideal source of energy for sustainable growth in Africa. Since agriculture in Africa is mostly rain-fed, curbing the impact of energy on the climate will help boost productivity.

Access to energy is a necessary condition for Africa to achieve the Millennium Development Goals including poverty reduction (Brew-Hammond, 2010) and one of the requirements of the Sustainable Development Goals. Brew-Hammond and Kemausuor (2009) posit, that lack of electricity is a major cause of poverty in Sub-Saharan Africa (SSA). The irony is that, Sub–Saharan Africa (SSA) countries including Ghana have a lot of renewable energy potential which is mostly left unexploited. Unexplored renewable energy resources, monopolised distribution regime, distorted tariff system, thermal plants break down and intermittent rainfall pattern has led to one the worst power outages in Ghana since independence.

Contributing to the literature on renewable energy, Karekezi (2002) identified three main reasons for the growing interest in renewable energy in Africa. The first reason is the petroleum price increases especially between 1998 and 2011, which induced an increase in import expenditure of African countries. The second reason is the quest of many countries to boost electricity supply and reduce power outages. For instance, countries such as Ghana and

Nigeria embarked on power rationing in the past, which had adverse effects on their economic performance. The third reason is the commitment of international bodies to curb global emissions. Though efforts have been made to switch from traditional sources of renewable energy to modern sources, the challenge has been the huge upfront investment required for such energy transition.

As a medium to long term solution, the Government of Ghana (herein referred to as Government) in 2010, introduced a Bill on Renewable Energy to parliament. One of the main goals of the Renewable Energy Law (Act, 832) is to increase the share of modern forms of renewable energy to 10% in terms of power generation. According to estimates by the Ministry of Energy and Petroleum, the government will need $1 billion in investments in renewable energy from 2012 to 2020 to achieve this target.

Renewable energy consumption has been growing faster than non-renewable energy, growing at a rate of 3% per annum (IEA, 2009). According to Apergis and Payne (2012), the increased growth in renewable energy consumption has been due to environmental concerns about fossil energy consumption, volatility of oil prices and energy security concerns. The signing of the Kyoto Protocol and the establishment of carbon certificate traded markets like the European Union Emission Trading Scheme (EU ETS) has helped increase the use of renewable energy. Since these emissions-related Initiatives are confined to the developed world, the few studies on the relationship between renewable energy consumption and economic growth have been restricted to the developed economies.

In this paper, the various policy interventions in renewable energy production and consumption over the past two decades are examined and policy recommendations to fast track the deployment of renewable energy technology.

2. Energy and Sustainable Development

The Energy Information Administration (2011), forecasts that global energy demand will increase by 53% between 2008 and 2035. This has led to increased investments and supply of conventional fuels such as coal and crude oil (Byrne & Wang, 2014). Since coal, natural gas and oil are non-renewable, these investments only satisfy the short to medium term demand. Therefore, the emphasis should be on renewable energy investments. Apart from the fact that renewable energy comes from infinite sources such as the sun, it is also environmentally friendly and promotes job creation. For instance, each million US dollars invested in

renewable energy creates four permanent jobs. These jobs are created directly through direct-employment and indirectly through economic growth enhancing effects such as using solar panels to power a fridge to sell water. The same amount invested in renewable energy creates more than sixteen permanent jobs (Singh et al, 2001).

Indeed Sims, Mabee, Saddler and Taylor (2010) indicate that fossil fuels provided 85% of global primary energy in 2007. In the same year, the consumption of fossil fuels accounted for 56.6% of all greenhouse gas emissions (Rogner et al., 2007). Due to this, Kankam and Boon (2009) suggest that there is the need to shift from fossil fuel consumption to renewable energy if both developed and developing economies wish to pursue the Sustainable Development Goals. Renewable energy consumption is a major component in any effort to combat climate change (Heal, 2009). In his inaugural address, President Obama asked America to harness the energy of the sun, wind and soil to power the cars and fuel the factories. This is due to the fact that renewable energy is carbon neutral and comes from a source that replenishes itself (Reiche, 2010). Several countries have set renewable energy target. In America, the Department of Energy has a target of 25% of electricity generation from renewable energy by 2025 (Heal, 2009). The European parliament on the other hand has agreed to 20% target from renewable energy in total energy consumption by 2020 (Aune, Dalen, & Hagem, 2012). Several African countries have similar targets. According to Mohammed, Mustafa and Bashir (2013), Africa seeks to generate 15% of total energy consumption from renewable energy by 2020. Ghana seeks to have 10% of its energy mix from renewable resources by 2020. These production and consumption targets coupled with high oil prices have led to increased investment in renewable energy. The United Nations Environment Programme (UNEP) in their 2011 report, indicated that investment in renewable energy increased from $33 Billion in 2004 to $211 Billion in 2010. Factors that have accounted for this rise in investment in renewables include global effort to combat climate change, energy security concerns, the desire to achieve the millennium development goals (MDGs) and declining cost and competiveness of recent renewable technologies (Giovannetti & Ticci, 2011).

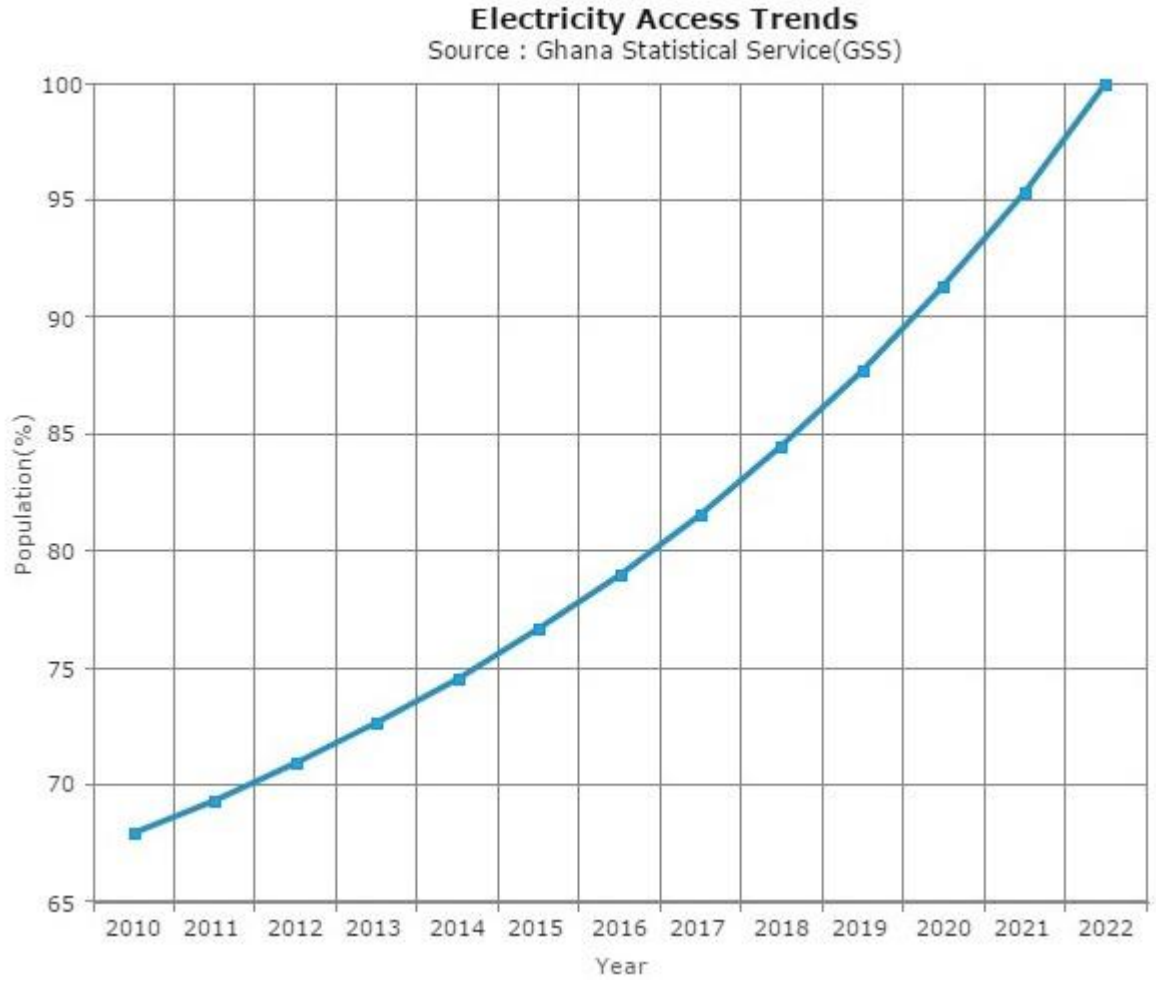
Despite having almost 10% of the world's oil reserves, Sub-Saharan Africa is one of the poorest regions in the World (UNECA, 2011). This has been as a result of years of corruption, natural resource revenue mismanagement, weak institution and conflicts ((Asongu and Nwachukwu, 2016ab). Giovannetti and Ticci (2011) however acknowledged Sub-Saharan's wealth in its untapped sources of renewable energy. According REN21

(2009), Africa has 8% of global hydro potential and together with Middle East, account for 57% of global solar potential. This notwithstanding, about 50% of the population lack access to electricity (Giovannetti & Ticci 2011). The African Development Bank suggests that the energy problem of Africa goes beyond access, to include low generation capacity, large financing gap, high distribution losses, unreliable power supply and underdeveloped energy infrastructure (AfDB, 2010). Briceno-Garmendia et al. (2008) estimates that these energy challenges cost 0.8% of Africa's GDP. Renewable energy types include solar, hydro, geothermal, wind, biofuels, tidal and waste to energy. According to Johnstone, Haščič and Popp (2010), the major factors militating against increased renewable energy consumption is its intermittency nature and high initial cost of renewable energy technology. The IEA (2006) distinguished between three types of renewable energy technologies. These are (i) first generation technologies which have already matured such as biomass, hydropower and geothermal, (ii) second generation technologies which are at the growth stage such as solar, wind and modern forms of bioenergy and (iii) Third generation technologies which are at the introductory stage such as improved geothermal, concentrated solar and ocean energy.

3. Renewable Energy Potential in Ghana

Ghana has set a target to achieve universal access to electricity by 2020. According to figures at the Ghana Statistical Service, Ghana would achieve an access rate of about 80% by 2016. This requires investment in generation, transmission and distribution infrastructure especially due to high population growth and Ghana's quest to industrialise.

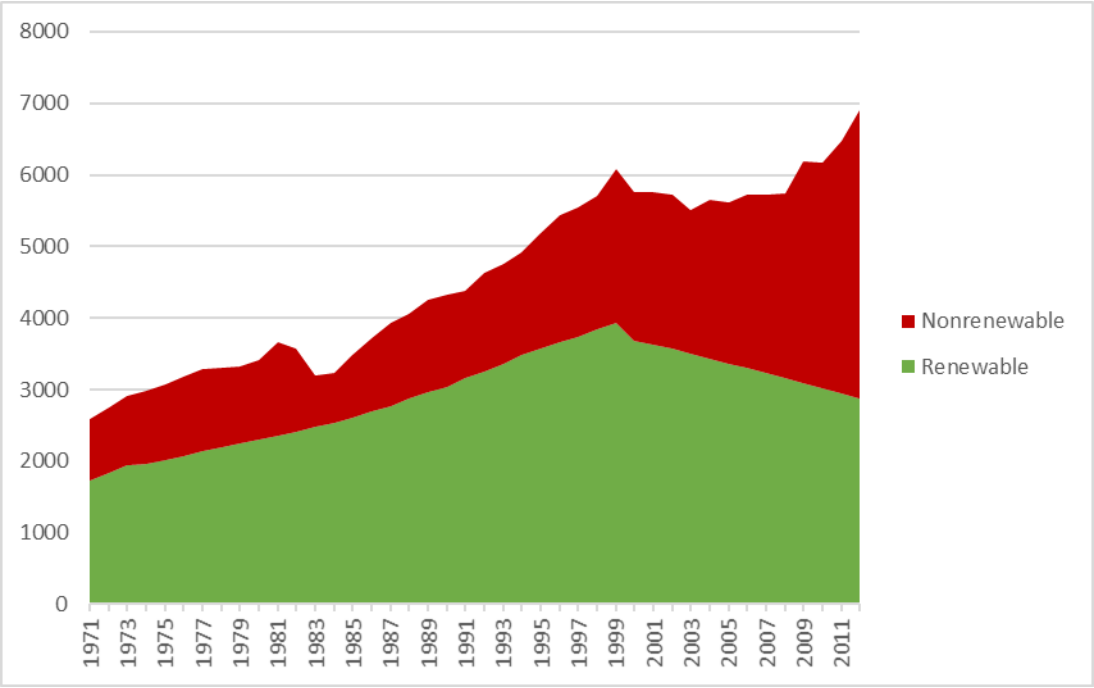
Figure 1. Electricity Access in Ghana



Source: Ghana Statistical Service, 2015

Whilst the access rate is encouraging, much of the demand has been satisfied with non-renewable energy in the form of oil and gas thermal plants and LPG. For instance, the total renewable energy demand (waste, biomass, solar, etc) of Ghana in 1971 was 1978.9 Ktoe whilst in 2012, total renewable energy demand was 2868.5 Ktoe. This represents an increase of 66%. With regards to non-renewable energy (petroleum products including natural gas), 855.9 Ktoe was consumed in 1971 and 4028.8 in 2012 representing an increase of about 470%. The increased appetite for non-renewable energy has negative consequences on Ghana's import bill and the environment. Figure 2 shows renewable and non-renewable energy consumption trends in Ghana from 1971 to 2012.

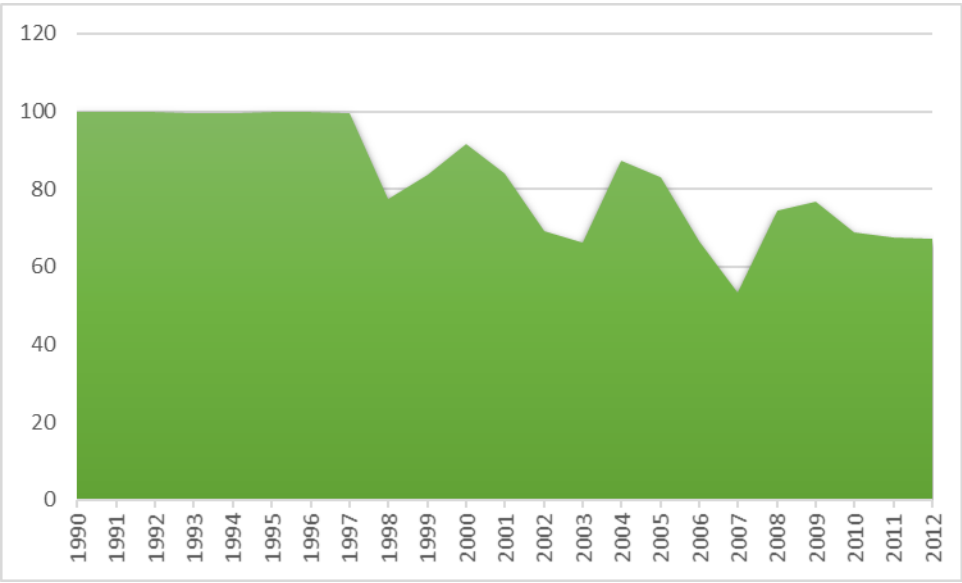
Figure 2. Renewable and Non-Renewable Energy Consumption Trends



Source: Author's estimation with data from IEA, 2015

Ghana depends mostly on hydropower which accounts for about 60%-70% of total electricity generation capacity. As at 1990, Ghana depended solely on hydro for electricity generation. This reduced to 67% in 2012 and keeps reducing. Whilst 67% may be encouraging, all these were supplied by hydro with zero output from solar, wind and other renewable energy sources.

Figure 3. Electricity Generation from renewables



Source: IEA, 2015

According to the Renewable Energy Law (ACT 832), plants below 100MW are considered modern renewable energy and there are 17 potential sites in the country. The Ghana Energy Commission estimates that there are also about 22 exploitable mini-hydro sites ranging from 15kW to 450kW with total potential between 2.6MW to 3.5MW. Table 1 shows renewable energy licences that has been issued as at 2015.

Table 1. Renewable Energy Licences Issued

Category	**Provisional Licences**	**Siting Permits**	**Construction Permits**	**Total Proposed Capacity (MW)**
Solar	55	20	2	2,748.5
Wind	9	2	1	951
Hydro	5	-	-	208.62
Biomass	2	-	-	68
Waste-to Energy	10	2	1	570.81
Wave	1	1	1	1,000
Total	**82**	**25**	**5**	**5,546.93**

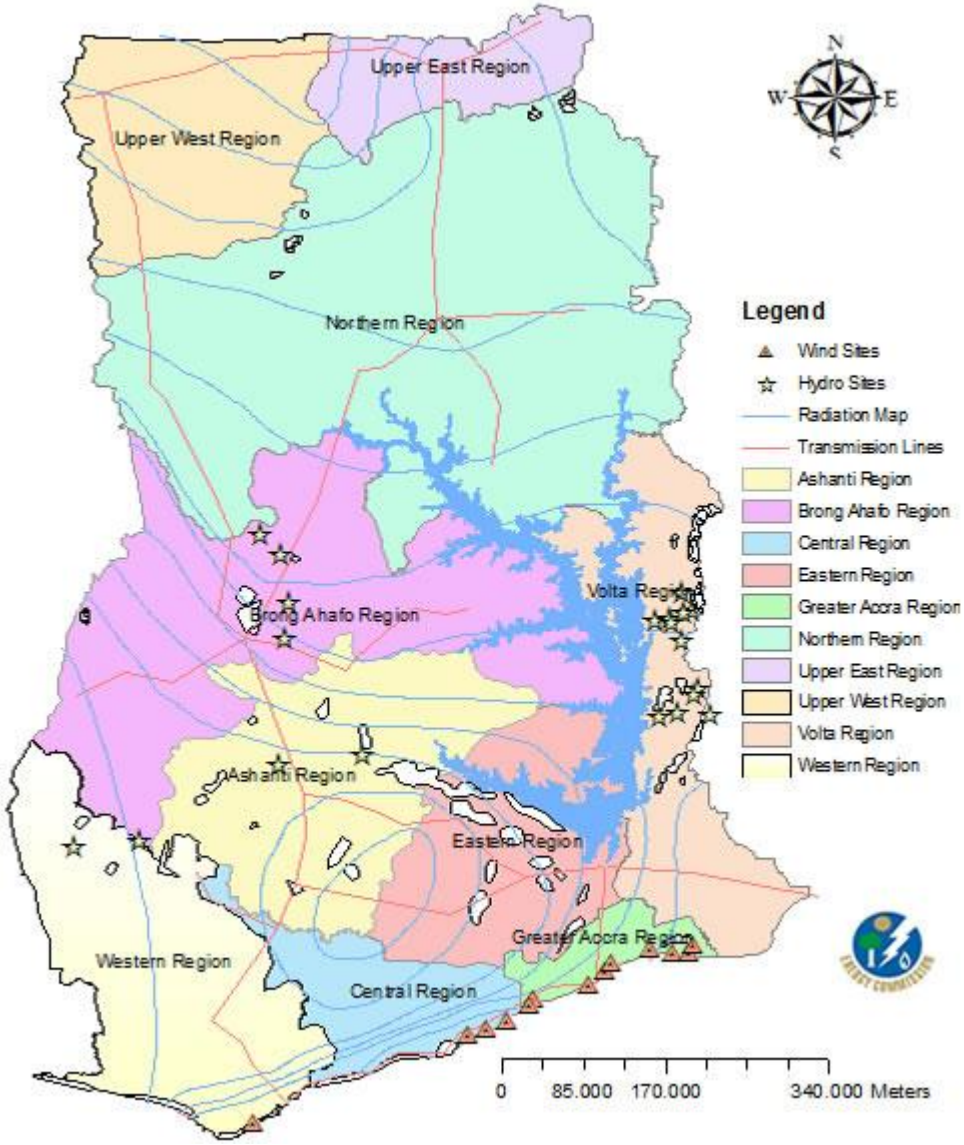
Source: Ghana Energy Commission, 2015

Ghana enjoys about 330 days of sunshine annually. The Solar irradiation levels range from 4.5-6.0kWh/m2/day with the highest irradiation levels occurring in the northern half of the country. Between 2000 and 2014, over 38,000 solar home systems and lanterns have been deployed in more than 120 communities throughout the country for off-grid applications and 25 grid-tied installations with total installed capacity of 7 MW according to the Ghana Energy Commission. In addition, the Government of Ghana procured about 50,000 solar lanterns to be distributed in 2015/2016. The weakness of this intervention is that, it is not coordinated and seem to be driven by political patronage instead of need-based assessment. Further, the Ghana Energy Commission which is mandated to undertake such distribution is often undermined by politicians who undertake the distribution. Finally, there is little education and information on how the solar lanterns or home systems can be assessed.

The Ghana Energy Commission has issued more than 55 provisional licences for utility scale solar projects as at 2015. However, only 2 construction permits have been issued. The large

gap between provisional licences and construction can be attributed to the nature of licence acquisition. Whilst an attempt has been made to undertake a competitive bidding for solar licence in 2016, all the 55 licences were issued through direct negotiations. Again, an investor needs to go through District Assemblies, the Environmental Protection Agency, Ministry of Land, and Attorney General's Department and other agencies in order to secure a construction permit after receiving provisional licence from Energy Commission. This process becomes frustrating, cumbersome and lengthy in most cases and may account for less than 5% of the 55 provisional licence holders obtaining construction permits. This implies that, although licences have been issued for more than 2700 MW of solar energy, these are just 'dream MW' and adds zero to the grid.

Figure 4. Renewable energy potential in Ghana



Source: Ghana Energy Commission, 2016

The average annual wind speeds along the coast and some islands range from 4-6m/s at 50m hub height. This potential can support utility scale wind power and hybrid micro/mini-grid development. Since 1998, investors have been exploring different sites to develop at least 250 MW of wind power. According to a World Bank study in 2014, Ghana produces about 10,000 ton/year of agro and wood processing wastes alone. This presents an opportunity for biomass and waste to energy investments.

4. Renewable Energy Policy Interventions in Ghana

Environmental challenges such as global warming, acid rain and depletion of the ozone layer have often been associated with energy consumption (Sardianou, 2007; Asongu et al., 2016). Due to the global nature of these environmental challenges, the United Nations Convention on Climate Change (UNFCCC) sets out emissions target for developed countries through Kyoto Protocol from 2008 to 2012. The main gases that the Kyoto Protocol covers include carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and Sulphur Hexafluoride (SF_6). Wuebbles and Jain (2001) found that the rising greenhouse gases can be attributed to the increased consumption of fossil fuels. According to Knopf et al. (2010), the amount of fossil fuel reserves not yet used have the potential to add CO_2 beyond any scenario currently estimated.

Explicit interventions in renewable energy in Ghana started in 1998. In 1998, import duty and Value Added Tax (VAT) on solar and wind systems and their components were reduced. This was followed by; the Renewable Energy Service Project (RESPRO), which was a 3-year project funded by the United Nations Development Program (UNDP) to create a non-profit Trust to manage and extend solar energy to needy communities in 1999. RESPRO designed, installed and provided instructions to users, and supervised the installations of 2,000 solar panels that were distributed to schools and households.

In 2006, the Strategic Natural Energy Policy increased the use of renewable energy to 10% in the energy mix. It has been anticipated that the renewable technology would be increased by 30% in the rural areas in 2020.

Also in 2007, The Ghana Energy Development and Access Project (GEDAP) initiated some sector institutional performance to improve electricity and increase the share of renewable

energy in electricity generation. The World Bank, Swiss Economic Compact and The African Development Bank (AFDB) donated 7,500 photovoltaic (PV) systems to schools, hospitals and offices. People at the receiving end of these systems were granted 50% of the appliance purchase force and the remaining 50% were supported by APEX Bank and other Small Medium and Enterprise (SME) related banks. The total duty inputs were exempted.

In 2010, the Ghana National Energy Policy came up with the renewable energy development program where they advocated for the use of waste to produce energy and also have energy managed efficiently. In the same year, 21 micro and medium hydro sites were identified with capacities (4kw-325kw). In order to put these measures into proper perspective and give legal backing to renewable energy interventions in Ghana, the Renewable Energy Law was passed in 2011. In 2013, Feed-in Tariffs (FIT) for the various renewable sources; solar, wind and mini-hydro accounted for 40.2100Ghp/kwh, 32.1085Ghp/kwh and 26.5574Ghp/kwh respectively.

Finally under the net metering code, renewable energy generated and supplied by the facility is credited to the customer. This is set off by electricity purchased from the distribution Utility (ECG and NEDco). A customer installs a renewable energy generation facility that generates more than needed in a period and the meter runs in reverse to produce credit against electricity consumed during that period .Only renewable energy generation to 200kw or above will benefit from net metering support. There is an opportunity for small scale solar investments considering the feed-in tariff of 18.24 US cents per kWh equivalent for systems without back-up storage and 20.14 US cents per kWh equivalent for systems with back-up storage. The feed in tariff is targeted at homes, offices, hospitality industry and small businesses. Under the programme, a capital subsidy is given to beneficiaries in the form of rebate which would pay for part of the total cost of the solar system, specifically, the solar PV modules while the beneficiaries pay for the balance of system (BOS) components. Beneficiaries would also be given the option to take a special bank loan to offset the payment commitments. As at early March, 2016, 82 Provisional Wholesale Electricity Supply Licences had been issued to potential Independent Power Producers (IPPs) proposing to develop a total of about 5,547 MW of electricity from various renewable energy sources. Fifty five (55) of the licences issued are for solar photovoltaic (PV) generation with a total capacity of about 2,749 MW. As at end of 2015, 44 licences were issued a total capacity of 2,472 MW compared with 29 with total capacity of 2,155 MW in 2014. Twenty five (25) licensees have moved to the Siting Permit stage of the licensing process of which 20 are for

solar PV. However, only two companies have been issued with Construction Permit to develop a solar PV project. A Construction Permit has also been issued for a 225MW wind project.

Also, the Energy Commission in collaboration with the Electricity Company of Ghana (ECG) is piloting 33 net-meters equipped with automatic reading mechanism at various residential and commercial facilities. Monitoring of the net-metered solar PV systems by ECG is currently on-going. Implementation of the net-metering Scheme is planned to begin by June 2016.

The Government of Ghana in November 2015 published an invitation for pre-qualification for the procurement of 20 MWp solar PV power. During the first stage of the tender process, 18 bids were shortlisted to subsequently submit proposals. The proposals would be evaluated and ranked for award primarily based on least cost quotation. The award of contract is expected to be issued by August 2016.

5. Conclusion and Recommendations

With the current rate of investment and uncoordinated effort, 10% renewable energy (outside the big hydro dams) by 2020 seems impossible. As at 2016, renewable energy contributes less than 1% of electricity generation in Ghana. However, renewable energy sources such as solar, wind and hydro provide three main advantages over fossil fuels. First, renewable energy sources are cleaner since they emit relatively less or no carbon compared to coal, oil or natural gas. Second, the fuel for renewable energy generation such as the sun, wind, or flowing water are free gifts of nature. This makes the operational cost of renewables relatively cheaper. Finally, renewable energy sources are available and Ghana does not need to depend on other countries or sign commercial contracts to use the sun or the wind. These advantages notwithstanding, renewable energy usage in Ghana is relatively low. This calls for targeted investments, reduced bureaucracy, cost and risk sharing and education to improve renewable energy investments in Ghana. Although universal access to electricity can be achieved between 2019 and 2022, generating a high amount of electricity from renewables by 2030 requires serious institutional, market and technological reform and support.

5. Recommendations

1. Solar Purchase Options: One of the major barriers to renewable energy especially solar is finance. That is, people generally perceive solar and other renewable sources to be expensive.

With regards to solar, one of these 5 models below can help introduce some flexibility and share cost and risks to enhance consumers' interest to purchase solar panels.

Option 1: Cash Sales: A PV system is sold directly to the customer or end-user. This option bestows immediate ownership on the customer.

Option 2: Dealer Credit (The Ameri model without Intermediary model): The PV supplier/dealer sells the PV system to the customer, who enters into a credit arrangement with the PV dealer. Depending on the arrangements, the end-user immediately becomes the owner of the system, or becomes the owner when all payments are made.

Option 3: End-user Credit (The Ameri model with intermediary): The PV supplier/dealer sells the PV system to the end-user, who obtains consumer credit from a third party credit institution. Usually the end-user becomes the owner of the system immediately, but this can be delayed until all payments are made. The PV system can be used as collateral against the loan.

Option 4: Lease / Hire purchase (The Karpower Model): The PV supplier/dealer or a financial intermediary leases the PV system to the end-user: At the end of the lease period, ownership may or may not be transferred to the end-user, depending on the arrangements. During the lease period, the leaser remains owner of the system and is responsible for its maintenance.

Option 5: Fee for service (The ECG Model): An energy service company (ESCO) owns the system, and provides an energy service to the end-user, who pays a periodic fee (e.g., monthly) to the ESCO. The end-user is not responsible for the maintenance of the system and never becomes the owner

2. Competitive bidding to issue renewable energy licence is encouraged to get best offers for the country and to reduce cost.

3. Policy Framework for Solar Panel Distribution: There have been reports of conflicting interventions by the Government of Ghana (Presidency/Ministry of Power) and the Ghana Energy Commission. This calls for a policy framework that brings Energy Commission, the Ministry of Power, the Public Utility Regulatory Commission and the Electricity Company together to coordinate and promote investments in renewable energy.

4. Special Deal with Real Estate Developers: A special arrangement can be signed with the Ghana Real Estate Developers and other private developers to fix solar panels on all new homes. There should be efforts to have net metering schemes to allow solar users sell excess power to the electricity company of Ghana.

5. Operationalisation of the Renewable Fund: This will support SMEs and lifeline consumers to acquire solar. Government can use the energy fund to shift all lifeline customers to solar to minimise or remove electricity subsidies. The operationalisation should be accompanied by structured distribution mechanism and training for those who will receive the panels. The inspectorate division of Energy Commission should be strengthened to offer support to customers who obtain subsidised panels.

6. **There should be a national renewable energy policy that covers investments in Research and Development,** Renewable Energy technology, supportive infrastructure, financing mechanisms, and the use of market-based instruments such as renewable portfolio standards, green pricing, feed-in tariffs, net metering, and tradable renewable energy certificates.

7. Investments in Smart Grids: Renewable energy deployment is often limited by the inability of the grid to cope with volatility in renewable energy supply. It will be prudent to consider investments in smart grids.

8. Supporting technical institutions to produce and promote 'made in Ghana' renewable technologies such as solar panels.

9. The Public Utility and Regulatory Commission (PURC) and the Energy Commission should fast-track the development of the Renewable Energy Purchase Obligations (REPO) to Distribution Utilities and Bulk Customers.

10. In order to minimise the period between the allocation of provisional licences and construction permits, the various agencies should have dedicated renewable energy desks under the coordination of the Energy Commission to fast-track land title registrations, relevant municipal permits for construction, Environmental Impact Assessment (EIA) Report and other statutory requirements within an acceptable time frame that would not compromise quality of work.

References

Ackah, I., & Asomani, M. (2015). Empirical Analysis of Renewable Energy Demand in Ghana with Autometrics. *International Journal of Energy Economics and Policy*, *5*(3).

Ackah, I., & Kizys, R. (2015). Green growth in oil producing African countries: A panel data analysis of renewable energy demand. *Renewable and Sustainable Energy Reviews*, *50*, 1157-1166.

Adom, P. K., Bekoe, W., Amuakwa-Mensah, F., Mensah, J. T., & Botchway, E. (2012). Carbon dioxide emissions, economic growth, industrial structure, and technical efficiency: Empirical evidence from Ghana, Senegal, and Morocco on the causal dynamics. *Energy*, *47*(1), 314-325.

Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, *34*(3), 733-738.

Asongu, S. A., El Montasser, G., & Toumi, H., (2016). Testing the Relationships between Energy Consumption, CO2 emissions and Economic Growth in 24 African Countries: a Panel ARDL Approach. *Environmental Science and Pollution Research*, 23(7), 6563-6573.

Asongu, S.A & Nwachukwu, J. C., (2016a). Foreign Aid and Inclusive Development: Updated Evidence from Africa, 2005-2012, *Social Science Quarterly*,
DOI: 10.1111/ssqu.12275

Asongu, S.A & Nwachukwu, J. C., (2016a). The Mobile Phone in the Diffusion of Knowledge for Institutional Quality in Sub-Saharan Africa, *World Development*,
DOI:10.1016/j.worlddev.2016.05.012

Aune, F. R., Dalen, H. M., & Hagem, C. (2012). Implementing the EU renewable target through green certificate markets. *Energy Economics*, *34*(4), 992-1000.

Brew-Hammond, A. (2010). Energy access in Africa: Challenges ahead. *Energy Policy*, *38*(5), 2291-2301.

Brew-Hammond, A., & Kemausuor, F. (2009). Energy for all in Africa—to be or not to be?. *Current Opinion in Environmental Sustainability*, *1*(1), 83-88.

Ghana Energy Commission, Energy Outlook, 2015 http://energycom.gov.gh/files/Energy%20Outlook%20for%20Ghana%20-%202015.pdf (accessed 5th June, 2016)

Giovannetti, G., & Ticci, E. (2011). Sub-Saharan Africa in Global Trends of Investment in Renewable Energy. Drivers and the Challenge of the Water-Energy-Land Nexus.

Heal, G. (2009). The economics of renewable energy (No. w15081). National Bureau of Economic Research.

Howitt, P., & Aghion, P. (1998). Capital accumulation and innovation as complementary factors in long-run growth. *Journal of Economic Growth*, *3*(2), 111-130.

Johnstone, N., Haščič, I., & Popp, D. (2010). Renewable energy policies and technological innovation: evidence based on patent counts. *Environmental and resource economics*, *45*(1), 133-155.

Kankam, S., & Boon, E. K. (2009). Energy delivery and utilization for rural development: Lessons from Northern Ghana. *Energy for sustainable development*, *13*(3), 212-218.

Karekezi, S. (2002). Renewables in Africa—meeting the energy needs of the poor. *Energy Policy*, *30*(11), 1059-1069.

Knopf, B., Edenhofer, O., Flachsland, C., Kok, M. T., Lotze-Campen, H., Luderer, G., ... & Van Vuuren, D. P. (2010). Managing the low-carbon transition–from model results to policies. *The Energy Journal*, 223-245.

Mohammed, Y. S., Mustafa, M. W., & Bashir, N. (2013). Status of renewable energy consumption and developmental challenges in Sub-Sahara Africa. *Renewable and Sustainable Energy Reviews*, *27*, 453-463.

Painuly, J. P. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable energy*, *24*(1), 73-89.

Reiche, D. (2010). Renewable energy policies in the Gulf countries: A case study of the carbon-neutral "Masdar City" in Abu Dhabi. *Energy Policy*, *38*(1), 378-382.

Renewable Energy Law 2011 (Act, 832). *Renewable Energy Law of the Republic of Ghana*.

Sardianou, E. (2007). Estimating energy conservation patterns of Greek households. *Energy Policy*, *35*(7), 3778-3791.

Singh, A., Nigam, P. S., & Murphy, J. D. (2011). Renewable fuels from algae: an answer to debatable land based fuels. Bioresource technology, 102(1), 10-16.

Sims, R. E., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. Bioresource technology, 101(6), 1570-1580.

Voivontas, D., Assimacopoulos, D., Mourelatos, A., & Corominas, J. (1998). Evaluation of renewable energy potential using a GIS decision support system. *Renewable energy*, *13*(3), 333-344.

Wilkins, M., & Finance, I. (2012). Evaluating Investor Risk in Infrastructure Projects. In *Mobilizing Private Investment in Low-Carbon, Climate-Resilient Infrastructure OECD Expert Meeting–Session Iv, Stand & Poor Ratings Services*.

Wuebbles, D. J., & Jain, A. K. (2001). Concerns about climate change and the role of fossil fuel use. *Fuel Processing Technology*, *71*(1), 99-119.