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Renewable Energy Planning and Regulatory Policy: Tools for Sustainable Electricity Generation and Low Carbon Development. The Case of Ghana.

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Declaration

I Mudasiru Mahama, hereby declare that this thesis titled “Renewable Energy Planning and Regulatory Policy: Tools for Sustainable Electricity Generation and Low Carbon Development. The Case of Ghana” is my original work and that no part of it has been presented for award of any degree to the Pan African University Institute of Water and Energy sciences (including climate change) or any other higher institution. I also declare that all other works of people cited in this thesis have been duly recognized as required of academic rules and ethics.

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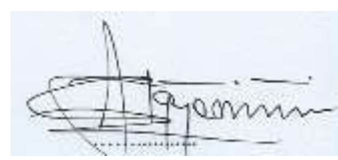

Professor Nana Sarfo Agyemang Derkyi 14/09/2018

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Dedication

I dedicate this write up to my late parents, family and friends who have supported me in diverse ways.

Abstract

Renewable energy is very key to the development of Ghana especially for the replacement of fossil fuels which have become much a talk globally for contributing to climate change. Unfortunately, the country has seen little development and deployment in renewable energy (RE) sector mainly due the numerous challenges/obstacles hindering the growth of the sector. Therefore, there is the need to identify these obstacles and find possible mitigation measures for the development of the sector. The study therefore employed a desktop analysis of the literature, survey approach and collected data from RE developers and stakeholders and using Long Range Energy Alternative Planning (LEAP) for modeling the GHG emission. This study based on the survey collected on identified obstacles, ranked them from most notable to least notable to be addressed if the country needs to develop the RE sector. The average score to obstacles ranged from 4.13 to 2.52 and the overall average score was 3.17 indicating that all the selected barriers are key to the development of RE in Ghana. The study shows that, the most challenging obstacles include cost of financing high interest rate, lack/insufficient incentives (tax rebate, grants etc), lack/inadequate access to finance and long-term capital, grid connection constraints and lack of grid capacity, instability of the local currency (currency fluctuations), insufficient technical know-how for the operation and maintenance of RET. The study also reveals that RE is capable of driving Ghana to a low carbon economy if attention is giving to the development and deployment of renewable energy resources for electricity generation and utilization. Greenhouse Gas emissions from Business as Usual (BAU) of 72,543.8 Mt-CO2eq will decrease by 11.5%, 57.7% and 80.8% by 2030 if fossil fuels are replaced with 10%, 20%, and 40% RE respectively into the current generation mix. Thus, Ghana can achieve its Intended Nationally Determined Contribution (INDC) plan of unconditionally lowering its GHG emissions by 15% relative to BAU by a little over 10% RE replacement in the electricity sector, whiles the conditional 45% can be achieved in the electricity sector with a little less than 20% RE replacement.

Résumé

L’énergie renouvelable est cruciale pour le développement du Ghana, spécifiquement pour le remplacement des énergies fossiles qui sont devenu un sujet de discussion global de par leur contribution au changement climatique. Malheureusement, le pays a connu un faible développement et déploiement dans le secteur des énergies renouvelables, dus principalement à de nombreux défis/obstacles entravant la croissance du secteur. Par conséquent, il faut identifier ces obstacles et en trouver des mesures d’atténuation possibles pour le développement du secteur. Cette étude est basée sur le sondage effectué sur les obstacles identifiés, ils ont été classés, des obstacles plus notables au moins notables à être abordés, si le pays veut développer le secteur des ER. Le score moyen des obstacles varie de 4.13 à 2.52 et la moyenne globale est de 3.17, montrant que toutes les barrières sélectionnées sont importantes dans le développement des ER au Ghana. L’étude montre que les plus grands défis incluent le coût des financements aux taux d’intérêt élevés, le manque ou l’insuffisance des incitations (Rabais des taxes, subvention…), manque ou accès inadéquat aux finances et capital à long terme, des contraintes de réseau de branchement et insuffisance de la capacité du réseau de branchement, instabilité des monnaies locales (fluctuation des devises), insuffisance du savoir-faire technique pour la maintenance et opération des TER. Cette étude révèle aussi que l’ER est capable d’amener le Ghana vers une économie peu émettrice de carbone, si l’on accorde l’attention au développement et au déploiement des ressources d’énergie renouvelable pour la production de l’électricité et son utilisation. L’émission des gaz à effet de serre des activités économiques souvent de 72,543.8 Mt-CO_2eq diminuera de 11.5%, 57.7% et 80.8% à l’horizon 2030 si les combustibles fossiles sont remplacés par 10%, 20%, et 40% d’ER respectivement dans la production mixte du courant. Ainsi le Ghana peut réaliser son plan des contributions prévues déterminées au niveau national (INDC), réduisant inconditionnellement ses émissions de gaz à effet de serre par 15% relatif à l’unité d’analyse comportementale (BAU) avec un remplacement légèrement au-dessus de 10% par l’ER dans le secteur de l’électricité, pendant que conditionnellement, 45% peut être atteint dans le secteur de l’électricité avec un remplacement légèrement en dessous de 20%.

Acknowledgements

"Every history has one quality in common with eternity. Begin where you will, there is always a beginning back of the beginning. And for that matter, there is always a shadowy ending beyond the ending." Edward Eggleston (1837 - 1902) - The Circuit Rider.
I would like to express my heartfelt gratitude to African Union Commission which provided me the scholarship opportunity as well as research grant for this project, my supervisor Prof. Nana Sarfo Agyemang Derkyi for his unsurpassed guidance and advice and the Pan African University Institute of Water and Energy Sciences (including climate change). My sincere thanks also goes to Mr. Ebenezer Nyarko Kumi who supported me in diverse ways for the completion of this thesis. Again, to my family, classmates and friends whose names cannot be mentioned individually but provided me with all the necessary support and advice on this project. I say to all "AYEKOOO".

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List of Acronyms

ECG	Electricity Company of Ghana
BAU	Business as Usual
FIT	Feed-in-tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GRIDCo	Ghana Grid Company
GSS	Ghana Statistical Service
IEA	The International Energy Agency
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent Power Producers
LEAP	Long Range Energy Planning
MW	Megawatts
NED	Northern Electricity Department
NES	National Electrification Scheme
NG	Natural Gas
PURC	Public Utility and Regulatory Commission
REPO	Renewable Energy Purchase Obligations
RE	Renewable Energy
RPS	Renewable Portfolio standard
RES	Renewable Energy Sources
RETs	Renewable Energy Technologies
SNEP	Strategic National Energy Plan

SREP	Scaling-up Renewable Energy Program
SSA	Sub-Sahara Africa
SWERA	Solar and Wind Energy Resource Assessment
UNFCCC	United Nations Framework Convention on Climate Change
VRA	Volta River Authority

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Development of energy is critical to sustainable development in all growth propelling sectors in every economy. Rogner and Popescu, (2001), indicate that energy is a key factor for continues development and economic growth. Worldwide, demand for energy, security of its supply as well as mitigating climate change has become a development challenge for sustainable development (Zahedi, 2010). It is therefore evident that Africa needs to improve electricity supply to enhance energy security and to achieve economic growth (International Renewable Energy Agency, 2013). To ensure sustainable energy supply, two issues must be addressed, first, there should be an increase access to affordable and modern energy services to countries that do not have them, especially those in rural communities and secondly, "to find the mix of energy sources, technologies, policies, and behavioral changes that will reduce the adverse environmental impacts of providing necessary energy services" (Spalding-Fecher et al., 2005). When these issues are addressed, they will ensure sustainable supply of energy and the right mix of energy sources especially for electricity supply mix in developing countries which have low access to electricity taking into consideration climate change mitigation.

It is worthy to note that, globally 15% of the world's population lack access to electricity. This translate into about 1.1 billion people. Urban areas tend to be electrified as a result the increased in electricity access' share is attributed to the faster rate of population growth in urban areas (World Bank, 2017). The world bank indicates that urban population grew from 44% to 53% in 1994 and 2014 respectively. The International Energy Agency [IEA] (2016), indicates that a population of about 634 million in Sub-Sahara Africa (SSA) do not have access to electricity. Although SSA is rich with energy resources, there is lack of energy infrastructure which contributes to the lack of access to affordable, reliable and sustainable energy to its citizens (IEA, 2014). As population growth and economic development are expected to grow, it could lead to increase in energy services demand (Lucas et al., 2015). The world bank puts electricity access of Ghana at 78.3 % as of 2014 down from 23.9% in 1990. In 2014/2015, reported

Ghana's supply deficit of electricity accounted for 25% of peak power. Ghana in recent times faces electricity supply challenges (Climate Investment Fund, 2015). Again, in 2016 "the net grid electricity supplied to the country was almost 12,705 GWh; about 24-33% less than the minimum projected requirement for achieving a marginal economic growth of 4.0-4.5% in 2016. The deficit was equivalent to about 550 MW net and just as in 2015, could contribute to the relatively low economic growth" (Energy Commission, 2017).

When electricity access is improved it will accelerate growth in all sectors such as improving energy technologies for agriculture, water pumping for industrial and human consumption, employment creation and access to modern health services (Lucas, et al, 2017). In attempt to enhance supply of electricity, countries have been relying heavily on conversional sources of energy to power generating plants in other to meet their ever-increasing demand. Rogner and Popescu (2001), argued that energy is a key factor for continues development and economic growth. Although energy production contributes to environmental degradation, such as air pollution and global environmental problems, principally climate change (IEA, 2014). 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". Yadoo and Cruickshank, (2012), argues that there will be sharp global Greenhouse Gas (GHG) emission if those developing countries were to follow the same development paths as today's industrialized countries.

Ghana is no exception to the effects as these phenomena are already manifesting in Ghanaian societies and economy. The World Bank (2010) states that increased climate variability is already affecting the country's economy and households. The impacts place stress on the country's vulnerable sectors: agriculture, coastal zones/marine ecosystems, water resources, and energy production. If nothing is done to help mitigate the effects of such climate changes, by 2050, annual real GDP is projected to be 1.9 to 7.2% lower than it would be otherwise.

Adra (2014) therefore observed that "due to the dangerous and life-threatening factors, many countries are investing therefore in renewable energy, such as solar energy, windmills, hydropower or biomass energy. This shift to a "cleaner energy" should result in the reduction of greenhouse gases and therefore mitigating climate change". Ghana is committed to reducing its GHG emissions as a result intend to develop renewable energy industry with policies, regulations as well as financial injection. Again, Ghana in its commitment to reduce emissions set emissions reduction goal to unconditionally lower its GHG emissions by 15 percent relative to a business-as-usual (BAU) by 2030 (UNFCCC,2015). In other to achieve this goal one of the key areas the country intends to develop is the deployment of renewable energy technologies to support the existing generation mix. Despite the effort to increase the share of renewable energy to the existing supply its share is still a small fraction to national supply. Energy commission (2017) indicates that the percentage share of renewable to national supply is 0.6%. This is as a result of obstacles ranging from renewable sources development, deployment, regulatory policies, financing and implementation of projects in the renewable energy sector. This master's thesis study therefore aims at identifying the obstacles from the perspective of stakeholders (investors, project sponsors and stakeholders) and related opportunities in establishing renewable energy businesses. Finally, it will establish the role RE can play in the reduction of GHG from the existing use of fossil fuel for generation of electricity in Ghana.

1.2 Problem statement

The development of renewable energy sector in Ghana has been a much-attended concern by various governments over the years. However, with concerns and efforts in the sector coupled with the growing environmental concerns on fossil fuels exploration and consumption which leads to climate change as well as their inability to be sustainable forever, there is the need to continue to develop sustainable alternative sources of energy which would be more reliable and have less environmental impact. Policies and regulations have been developed to ensure that the renewable energy sector expands to support the supply of energy/electricity mix to meet the growing demand of electricity in Ghana which is currently growing at 10% per annum yet the sector has seen less development and expansion as planned due to existing obstacles as far as developing and running renewable energy projects are concern. It is also worthy to note that opportunities are available but unknown to attract new investors. The literature within the

Ghanaian context has not highlighted these obstacles much especially from the investors point of view. This master's thesis therefore seeks to identify the various obstacles/challenges ranging from regulations, markets, financing, etc in the sector and the opportunities available for investment in the sector from the perspective of investors within the sector. In doing so, it closes the literature gap and businesses or investors can make good use of the study for informed decisions. In identifying them it will suggest possible recommendations to reduce or mitigate the obstacles that setback the rapid successful development, deployment and expansion of renewable energy technologies. Again, attention in the literature within the Ghanaian context about how RE can contribute to the reduction of GHG emission is missing. According to Bessah and Addo (2013), the annual growth in the demand for electricity is estimated at 6 – 7% per annum which 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 sustainably. This study therefore also seeks to model the role RE development and deployment can help reduce the emission of GHG therefore filling another gap which has been left out within the literature.

1.3 Research questions

1.3.1 Main research question

- ✓ What is the state of renewable energy planning, development and deployment in Ghana?

1.3.2 Specific research questions

1. What are the potentials of renewable energy available in Ghana?
2. What are the obstacles and opportunities available in undertaking RE projects in Ghana from the perspective of investors and other stakeholders?
3. What amount of GHG emissions that can be reduced by substituting RE generation into the current energy mix in the power sector to ensure sustainable energy supply?
4. What will be the scenario when RE resources are supplied at 10%, 20% and 40% to the energy supply mix in the power sector to ensure sustainable supply?

1.4 Objectives of the study

1.4.1 Main research objective

- ✓ To determine the state of renewable energy planning, development and deployment in Ghana

1.4.2 Specific Research Objectives

1. To determine renewable energy potentials available in Ghana.
2. To identify the obstacles and opportunities in undertaking renewable energy projects in Ghana from the perspective of investors and other stakeholders.
3. To model the amount of GHG emission that can be reduced by renewable energy supply into the current energy mix in the power sector to ensure sustainable energy supply.
4. To develop a scenario on available energy resources to supply 10%, 20% and 40% of the renewable energy mix in the power sector

1.5 Scope and delimitation of the study

1.5.1 Contextual scope

First of all, the range of renewable energy technologies assessed in this study focused on solar photovoltaic and Bioenergy technologies (technical potential). This study emphasized on identifying and bringing to bear the obstacles that are faced by investing in renewable energy projects and businesses and also the opportunities that will attract investors to develop and expand renewable energy technologies in Ghana. The study also modelled the role renewable energy technologies could play to reduce emission of GHG in Ghana by estimating the quantity of GHG that can be reduced from investing in renewable energy technologies, using Long-Range Energy Alternatives Planning (LEAP) system model. In the nutshell the study looked at environmental sustainability as far as electricity generation is concern.

1.5.2 Geographical scope

The geographical scope of this study is implementers of renewable energy (solar photovoltaic and Bioenergy technologies) projects and stakeholders in Ghana. Ghana is situated on the west coast of Africa with a total area of 238 540 km^2. The country has a north-south extent of about 670 km and a maximum east-west extent of about 560 km. It shares borders with Côte d'Ivoire to the west, Burkina Faso to the north, and Togo to the east. To the south are the Gulf of Guinea and the Atlantic Ocean. The country is divided into 10 administrative regions. The topography is predominantly undulating and of low relief with slopes of less than 1 percent. Despite the gentle slopes, about 70 percent of the country is subject to moderate to severe sheet and gully erosion. The highest elevation in Ghana, Mount Afadjato in the Akwapim-Togo Ranges, rises 880 metres above sea level.

1.6 Justification of the Study

Planning according to Conyers and Hills (1986), refers to a continuous process which involves decision or choices about alternative ways of using available resources with the aim of achieving a particular goal. From the definition of planning it therefore means planning in the field of energy to include renewable energy technologies in Ghana cannot be ignored if Ghana wants to achieve sustainable energy supply, the right mix of energy and to also mitigate climate change effects which result from over reliance on fossil fuels. Therefore, for sustainable planning in renewable energy, there is the need to carefully understand the barriers and the extent to which they affect the development of RETs in Ghana and to develop appropriate solutions at the local level as well as being able to be implemented elsewhere if possible. This was a critical point in undertaking this study. It highlighted and deliberated the opportunities and advantages renewable energy project investors can access in Ghana. The result in this study therefore can serve as a handbook for investors (especially new investors) and stakeholders and for policy improvement. This made it very important to carry out such an important assignment as it will promote renewable energy technologies and projects as well as ease in doing business in the sector. It will enhance confidence to stakeholders such as insurance companies, financiers, importers of renewable energy materials as it sorts to put across wide range of solutions and recommendations within the sector. This will facilitate easy decision making by all stakeholders and clients.

The study outlined the challenges in doing business in the renewable energy sector which will be used as a yardstick to promote renewable energy technologies and businesses therefore adding to the body of knowledge to the business community to advising clients as well as consumers. This will help in increasing supply of both off-grid and grid connected renewables. This will ensure that Ghana achieves its renewable energy target of 10% to total national mix of supply as well as achieving universal electricity access.

The achievement of the vision of Ghana's climate policy is to " ensure a climate-resilient and climate-compatible economy while achieving sustainable development through equitable low-carbon economic growth for Ghana" (Government of Ghana, 2013). Therefore, this study will address the bottlenecks in the sector which will see massive investment leading to the development of the low carbon economy which Ghana desires to have. With these, climate change effects could be mitigated.

Finally, scenarios developed showed the possible outcomes for GHG emissions reductions in the future if RE resources are replaced with fossil fuels in our current generation mix. This will help sustainable planning and implementation within the energy sector with particular attention to renewable energy development and deployment.

1.7 Organization of Report

This study is structured into five chapters. The first chapter focused on the general introduction; that is the background of the study, the problem statement, objectives of the study etc. Chapter two looked at literature on renewable energy planning, investment, electricity system in Ghana, barriers etc. It delved into the literature to review concepts, trends etc at global, regional and national levels. Chapter three looked at the methodology employed to successfully undertake the study. The fourth chapter looked at data result and associated analysis on the study and the final chapter five looked at the general conclusion to the work and the recommendations on renewable energy development in Ghana.

CHAPTER TWO

LITERATURE REVIEW

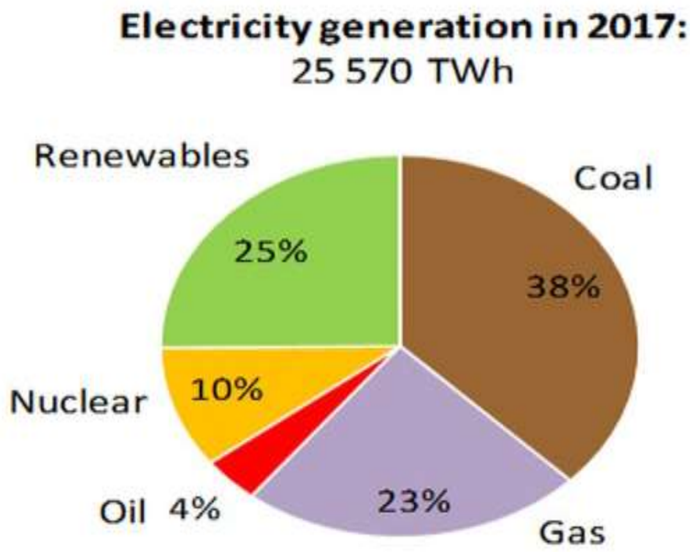
2.1 Renewable Energy Planning and Investment

Planning according to Conyers and Hills (1986), refers to a continuous process which involves decision or choices about alternative ways of using available resources with the aim of achieving a particular goal. Wustenhagen and Menichetti (2012) indicates that policy makers around the world are recognizing the challenge of addressing climate change using renewable energy as alternative sources of energy consumption as more than 80% of global energy supply relies on deplorable fossil fuels, with resources being unevenly distributed across world regions, creating significant energy security challenges. Many countries have integrated renewable energy into their national energy planning and policies for sustainability of energy supply. United Nations World Commission on Environment and Development, in 1987, accepts any development as sustainable if it "meets the need of present without comprising the ability of future generation to meet their own needs." The world Bank (2013), argued that, social equity cannot be achieved if the economic activities of some groups jeopardize the well-being of other people living in other parts of the world. It is therefore very clear that sustainable energy supply cannot be achieved without a recourse to incorporate renewable energy national and regional plans and policies.

In order to overcome the cost-based problems, renewable energy support policies are the main instrument that a regional planner possesses. Long term price guarantees and buying guarantees help investors to convince financial institutions. Besides economical efforts, non-economic factors like removal of legal and administrative barriers are needed for the success of policies. The availability of land resources and public lands are among other support systems for renewable energy related investments (Klessman and Held 2011).
According to the Intergovernmental Panel on Climate Change (IPCC, 2011a), globally, primary energy supply from renewable energy was 12.9%, with biomass accounting for the largest share. Although, renewable energy sources such as wind and solar which accounted for a small fraction

of global energy supply, they have recently experienced significant growth, especially in countries with active renewable energy policies.

The International Energy Agency (IEA) indicated in its 2017 report that global electricity investment dropped by just under 1% to USD 718 billion, with an increase in spending on networks partially offsetting a drop-in power generation. It argued also that renewables have seen substantial investment over the years, for instance, new renewables-based power capacity investment at USD 297 billion, is seen as the biggest area of electricity spending, although renewables investment was 3% lower than five years ago, capacity additions were 50% higher and expected output from this capacity about 35% higher, this due to declines in unit costs and technology improvements in solar PV and wind.



(Source: EIA, 2015)

Figure 2.1 Electricity generation in 2017

The rise in share of renewables was fueled by “unprecedented growth” renewable energy in China and the US, which accounted for around 50% of the increase in power production. Electricity from renewable energy sources in the European Union (EU) rose by 8% and by 6% in Japan and India (IEA, 2017). IEA also indicated that the growth in renewables is not only in the power sector but also the use of renewables to provide heat and mobility also increased worldwide, albeit from low base.

The program "Scaling-up Renewable Energy Program in Ghana Investment Plan (SREP-Ghana IP)" was developed by the Ministry of Power (now Ministry of Energy) of Ghana in 2015 in order to increase investment in the RE subsector to enable the Government's strategy to unlock financing opportunities by fast-tracking the development of the RE sub-sector. The SREP-Ghana focuses on three investment projects (Ministry of Power, Ghana, 2015):

- Renewable energy mini-grids and stand-alone solar PV systems
- Solar PV based net metering with battery storage and
- Utility-scale solar PV/wind power generation.

The Power Ministry sets the following targets on renewable energy projects by 2020, under the Scaling-up Renewable Energy Program in Ghana Investment Plan.

Table 2.1 Renewable Energy Projects Investment target by 2020

Potential Renewable Energy Projects	**Target**	**Required Investment US$ million**
Development of utility type wind farms	50-150 MW	300-550
Development of grid-connected solar parks	N.A	400-700
Solar lantern promotion	2 million units	150-200
Medium – small hydro	150-300 MW	450-900
Modern biomass /waste to energy	20-50 MW	60-150
Development of mini-grid	30-42 units	21 - 38.5
Off-grid renewable energy project	30,000 units	10-25
Sustainable energy for cooking	2.0 million units	10-50
TOTAL Investments		1.4 - 2.6 billion

(Source: Ministry of Power, 2015)

The development of RE projects has seen tremendous improvement in Ghana over the years possible because of the presence of RE legislations and policies. According to Energy

Commission (2016), as at March 2016, 82 Provisional Wholesale Electricity Supply Licenses had been issued to potential Independent Power Producers (IPPs) proposing to develop electricity from various RE sources. Fifty-five (55) of the licenses issued are for solar photovoltaic (PV) generation with a total capacity of about 2,749 MW. By March 2017 the Provisional Wholesale Electricity Supply Licenses issued to IPPs were 90. Sixty (60) of the licenses issued are for solar PV generation with a total capacity of about 3,000 MW. About 30 licensees have moved to the Siting Permit stage of the licensing process of which about 25 are for solar PV. However, only three (3) companies have been issued with Construction Permits to develop a solar PV project. A Construction Permit has also been issued for a 225MW wind project (Energy Commission, 2017). Table 2.2 shows provisional licenses and permit issued by March 2016.

Table 2.2 Provisional Licenses issued for Renewable Energy Electricity by Technology

Category	*Number of Wholesale Electricity Supply Licenses issued*			*Total Proposed Capacity (MW)*
	Provisional Licenses	Sitting permit	Construction permit	
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	2	1	1	1,000
Total	**82**	**25**	**5**	**5,546.93**

(Source: Energy Commission, 2016)

2.2 Electricity System in Ghana

Sub-Saharan Africa of which Ghana is included is a region with rich energy resources, although it has one of the poorest energy supply in the world. The region accounts for the world's 13%

population, but only 4% of its energy demand. Therefore, making reliable and affordable energy widely available will be critical to the development of the region. Since 2000, sub-Saharan Africa has seen rapid economic growth and energy use has risen by 45% (IEA, 2014). Barreto et al., (2003), mentioned that the increasing concern over the potential conflict between increasing demand and security of supply are complicated further by uncertainty over which fuels and energy carriers will supply future needs.

2.2.1 Generation and Demand

Meeting energy needs of people without negatively affecting the economy and environment remains an urgent problem for the development of every nation (Hua et al., 2016). Ghana's electricity generation capacity has been increasing over the years. From the period between 2006 and 2016, capacity increase has more than doubled from 1,730 MW to 3,759 in 2006 and 2016 respectively (Kumi, 2017). Installed generation capacity operational and available for grid power supply as at the end of 2015 was 3,174 MW, about 12% expansion over that of 2014 (Energy Commission, 2016). Kumi (2017) indicates that demand for electricity decreased by 1.88 percent in 2015 before increasing by 7.97 percent in 2016.

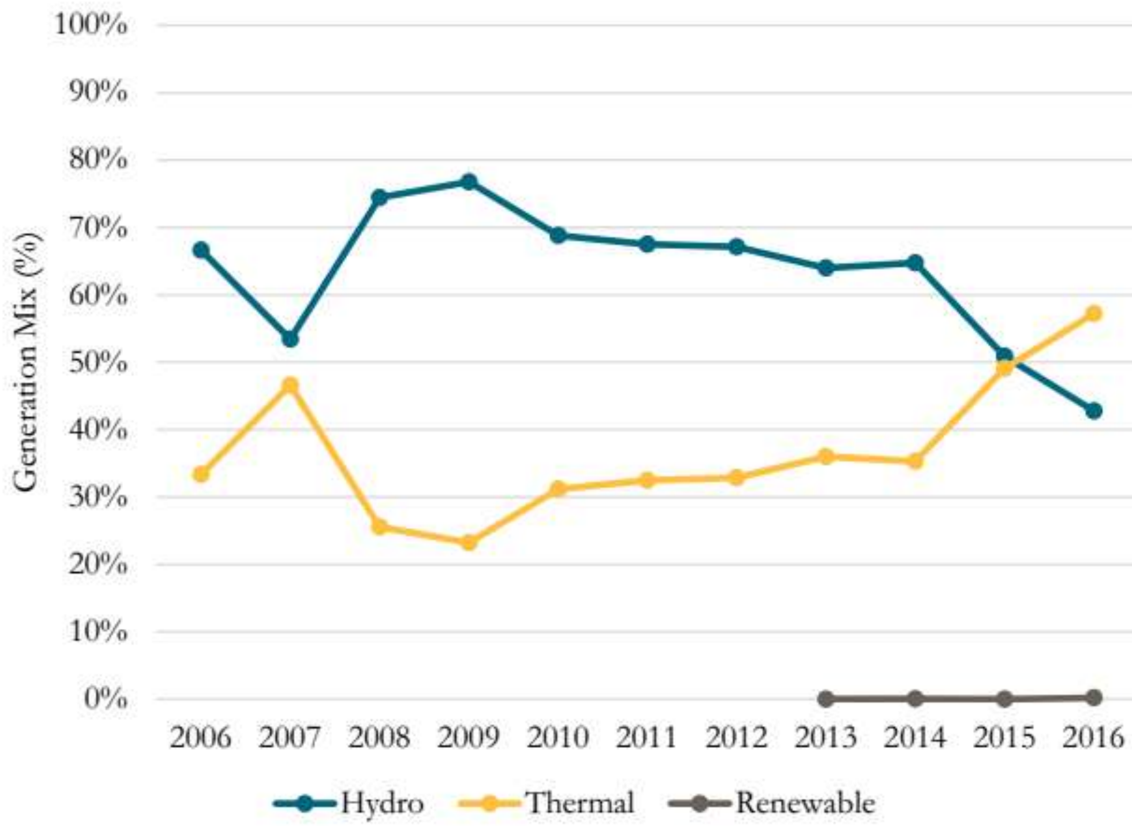
The year 2016 saw an increase of 19% over the year 2015 as compared to 12% for the 2015 and 2014 (Energy Commission, 2017). However, a supply deficit amounting to 25% of peak power was reported for the year 2014/2015 (Climate Investment Fund, 2015). Sakah et al., (2017), stated in their write-up that power plants have not been able to reach their full generation capacity due to; fuel supply constraints, non-perennial rivers together with inadequate and unreliable rainfall from climate variability which leads to significant reduction in the inflow into hydroelectric power plants. Kumi (2017), indicates that despite these challenges the country could achieve its universal electricity access agenda by 2020 with its annual growth rates of 4.38% in the electricity sector. *"Solving Ghana's electricity challenges would require measures including, but not limited to, diversifying the electricity generation mix through the development of other hydro power and renewable energy sources for which the country has huge potential, expanding the prepaid metering system to include all public and private institutions, restructuring the tariff regime to ensure utilities can recover their cost of generation, and* *promoting energy efficiency programs" (*Kumi, 2017). Despite availability of renewable energy resources in Ghana, its generation for electricity is still less contributing only 0.6% to Ghana's generation mix. However, generation capacity is dominated by thermal plants as seen in the Table 2.3.

Table 2.3 Installed Grid Electricity Generation Capacity operational as of December 2016

GENERATION PLANT		**FUEL TYPE**	**CAPACITY (MW)**				**TOTAL GENERATION**	
			Installed (name plate)	***% Share***	**Average Dependable**	**Average Available**	**GWh**	***% Share***
Hydro Power Plants	Akosombo	Hydro	1,020		1,000[11]	460	3,853	
	Bui	Hydro	400		360	345	944	
	Kpong	Hydro	160		148	105	763	
		Sub-Total	***1,580***	***42.9***	***1,508***	***910***	***5,560***	***42.84***
Thermal Power Plants[12]								
	Takoradi Power Company (TAPCO)	Oil/NG	330		300	185	1,192	
	Takoradi Inter. Company (TICO)	Oil/NG	340		320	240	1,903	
	Sunon–Asogli Power (SAPP1)	NG	200		180	180	373	
	Sunon–Asogli Power (SAPP2)	NG	180		170	0	0	
	Kpone Thermal Power Plant (KTPP)	Oil/DFO	220		200	200	199	
	Tema Thermal Plant1 (TT1P)	Oil/NG	126		100	100	178	
	Tema Thermal Plant2 (TT2P)	Oil/NG	50		45	30	26	
	CENIT Energy Ltd (CEL)	Oil/NG	126		100	100	418	
	Mines Reserve Plant (MRP)	Oil/NG	80		70	30	3	
	AMERI	NG	250		240	230	1,204	
	Karpower	HFO	225		220	220	1,855	
	Trojan*	Diesel/NG	25		22	12	39	
	Genser*	Coal/LPG	20		18	0	0	
		Sub – Total	***2,172***	***57.5***	***1,985***	***1,527***	***7,390***	***56.94***
Renewables*	VRA Solar	Solar	2.5		1.5	1	2.5	
	BXC Solar	Solar	20		10	9.5	26.3	
	Safisana Biogas	Biogas	0.1		0.1	0.5		
		Sub – Total	22.6	***0.6***	11.6	11	***28.8***	***0.22***
Total			**3,774.6**		**3,304.6**	**2,448**	**12,978**	

(Source: Energy Commission, 2017)

It should however be noted that the 20 MW BXC Solar is an embedded generation plant, likewise the Trojan and the Genser power plants (Energy Commission, 2017).



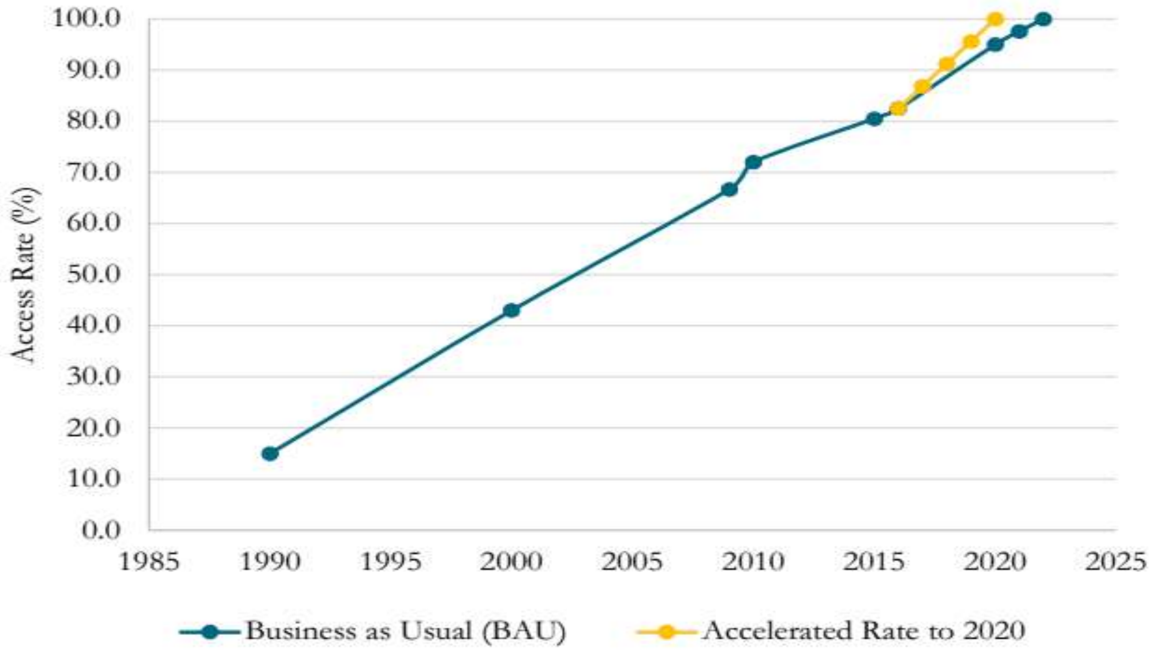
Source: (Energy Commission of Ghana, 2016a; Energy Commission of Ghana, 2017 cited in Kumi, 2017)

Figure 2.2 Electricity generation mix, 2006- 2016 of Ghana.

2.2.2 Electricity Access

According to IEA and World Bank (2017), the pathway out of poverty is narrow and long without access to electricity. In their view the current pace of progress to achieve universal access rate is slow as 1.06 billion people still do not have access to electricity, and 3.04 billion people still rely on solid fuels and kerosene for cooking and heating. Grid and off-grid solutions are therefore very critical for achieving universal electricity access for, although only when they are supported by an enabling environment with the right policies, institutions, strategic planning, regulations, and incentives for countries with low electricity access. With intention of climate change, dropping costs for renewable energy technologies and adequate energy efficiency measures offer a tremendous opportunity for countries to be creative about electricity access expansion with the emphasis on “clean energy (World Bank, 2017).

Ghana, although has seen shortage challenges recently, impeding an otherwise shining access rate to electricity. With the electricity grid covering more than 70% of the country as of 2013 (Kemausuor and Ackom, 2017), 80.51 percent in 2015 and 82.5 percent in 2016 (Ministry of Power, 2016 cited in Kumi, 2017). The high electricity access rate is the result of a roadmap that began in 1989 with the establishment of a National Electrification Scheme (NES). Under the NES, the government laid out its plan to extend electricity access to cover the entire country by 2020 (Kemausuor and Ackom, 2017). In the view of Kumi (2017), the annual increase rate of Ghana is 2.6 % and therefore at this rate the country is likely to miss its universal access rate by the year 2020 with a 5% margin. He indicated that access rate can be attained by 2022 unless measure are put in place to accelerate the progress in which the 2020 target with an annual increase of 4.38 percent in electrification rate. Kemausuor and Ackom (2017) indicated that Ghana’s access rate outshines that of her West African neighbors. Amissah (2004) stated that although the goal of NES was seen to be over ambitious, NES was to provide, within a 30-year time frame, electricity access to all settlements that had an adult population greater than 500. The impressive impacts of the NES were evident in the electrification of 2350 communities within 10 years after the launch. This is more than half of the targeted communities.



(Source: Kumi, 2017)

Figure 2.3 Trends in electricity access rates in Ghana

Table 2.4 Electricity access of Ghana compared to neighboring West African countries

Country	National electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)
Benin	29	57	9
Burkina Faso	17	56	1
Cabo Verde	94	100	84
Cote d'Ivoire	26	42	8
Gambia	36	60	2
Ghana	72	92	50
Guinea	26	53	11
Guinea-Bissau	21	37	6
Liberia	10	17	3
Mali	26	53	9
Niger	15	62	4
Nigeria	45	55	37
Senegal	55	90	28
Sierra Leone	5	11	1
Togo	27	35	21

(Aglina, et al., 2016)

2.2.3 Grid

Ghana's transmission and distribution network has been a major challenge to its electricity expansion since the institution of National Electrification Scheme in 1989 as it as has seen deterioration since then, these has resulted in power supply interruption, transmission challenges and high losses in its system (Ghana Grid Company [GRIDCo], 2010). The transmission lines operate at 330 kV, 161 kV and 69 kV lines. Also attach is 225 kV tie-line which interconnects the Ghana grid with that of Cote d'Ivoire and two 161 kV tie-lines that interconnect Ghana grid with that of Togo. In addition, there is a single circuit 225 kV tie-line of 74.3 km linking the country's network with that of Cote d'Ivoire (Energy Commission, 2017). Losses in the transmission and distribution networks are estimated at 25% (Energy Commission, 2015). Power wastage in the end-use is estimated at 30% (LAUREA, 2010).

Table 2.5 Grid Power Transmission losses since 2008

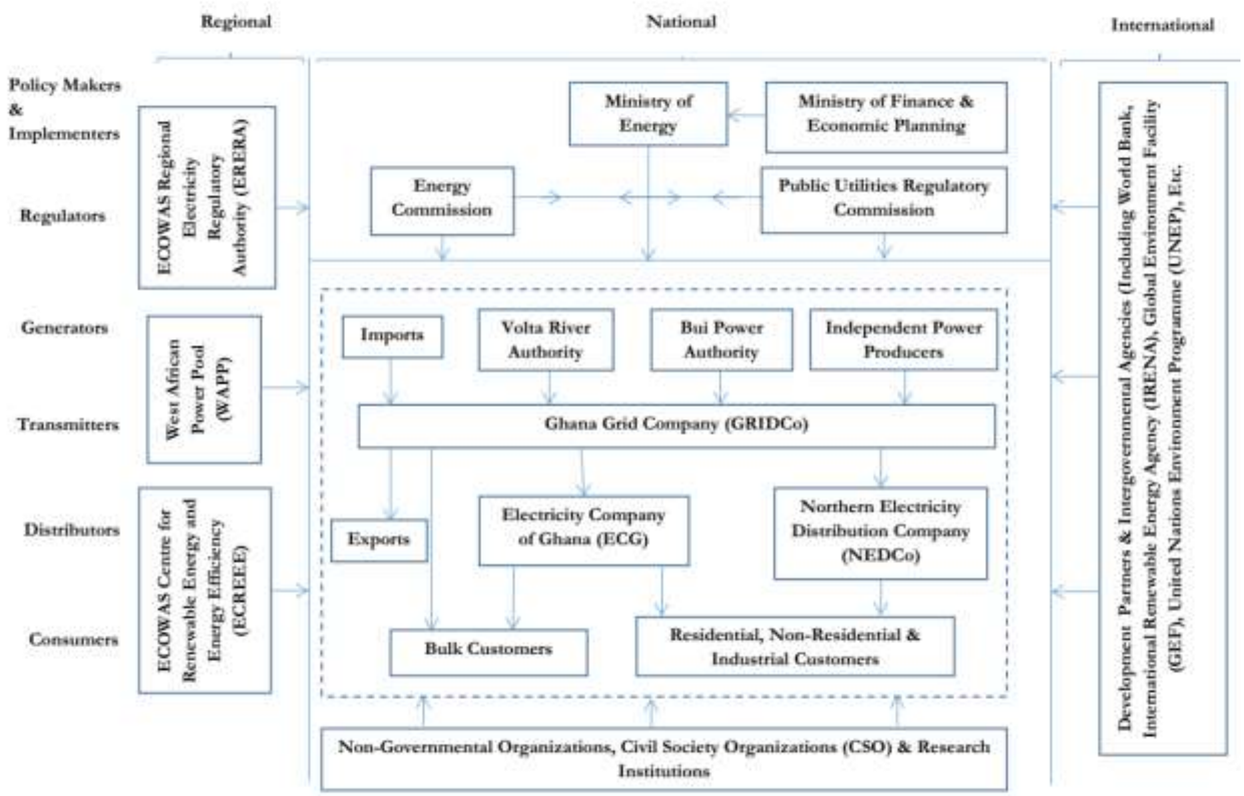
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Transmission losses as % of gross transmission	3.7	3.8	3.7	4.7	4.3	4.4	4.3	3.8	4.4

(Source: Energy Commission, 2017)

Mam and Twaha (2015) noted that poor access to grid is one of the major obstacles to substantial renewable electricity generation or the cost of upgrading the network to connect high quantum of renewable energy. In the view of Bayod-Rújula (2009), priority access to renewable electricity must be given by Grid companies to increase the share of renewable energy in the electricity market. However, the remoteness of resources from key electricity demand sectors and compatibility with existing transmission and distribution networks are major challenges of connecting renewable electricity to the grid (Sakah, Diawuob, Katzenba and Gyamfi, 2017). In other to ensure full development and deployment of renewable electricity there is therefore the need to tackle the bottlenecks that are associated to the grid, that is transmission and distribution challenges need to be critically looked at.

2.3 Market Structure of Electricity in Ghana

Ghana's electricity sector can be classified into three groups; the Ministry, the Regulatory bodies (Energy Commission, Public Utilities Regulatory Commission) and the Industry which comprises utility providers and consumers (Sakah et al., 2017). Ghana's electricity sector was monopolized and manned only by Volta River Authority (VRA), it generated and transmitted electricity throughout the country while also distributing to the Northern Sector through its subsidiary the Northern Electricity Department (NED). The Electricity Company of Ghana was responsible for electricity distribution in the southern sector of the country. Power sector reform in the late 1990s saw the Volta River Authority (VRA), split into a separate generation and transmission system operations which also made it possible for other Independent Power Producers (IPP) to enter the market (Kumi, 2017). According to the World Bank (2007), Ghana's electricity system is dominated by the public-sector management. The Ministry of Energy (MOE) is responsible for formulating and implementing fuels and electricity policies. VRA generates and supply electricity to large industrial and mining units and to two electricity distribution companies- Electricity Company of Ghana (ECG) and NED. The transmission function has been separated from the generation and other responsibilities of the VRA. A new company, Ghana Grid Company (GRIDCo), has been established for this function. The Bui Development Authority is also managing the 400 MW hydro power plant on the Bui River. Kumi (2017) indicates that the Volta River Authority (VRA), Bui Power Authority (BPA) and IPPs are the three major groups that carry out electricity generation in Ghana. The sources of generation include hydro power plants, thermal power plants and solar photovoltaic power plants.



Source: (Kumi, 2017)

Figure 2.4 Power sector regulation and market structure

2.4 Renewable Energy Resources and Potential in Ghana

Ghana’s location within the center of the equator coupled with its climate conditions makes RE sources (solar, wind, hydro, biomass, tidal etc) suitable for the country to take an advantage of, for power generation (Energy Commission, 2014). Essandoh et’ al, (2014) argues that the depletion of hydro sites raises a concern and therefore, there is the need for the development and utilization of other modern sources of RE for power generation to support the existing ones in other to meet the ever-growing energy demand in Ghana. In line with that, Yakubu et al, (2014) also indicates that RE resources such as solar energy, wind energy and potential for small hydro plants are adequately available in many parts of the country although they have not been tapped fully for generation of power. The country over the years has depended heavily on large hydro and has been exposed to the impacts of climate change, affecting the rainfall pattern and distribution, this cause the changes in river flow and runoff that affect hydropower’s supply of energy (Energy Commission & United Nations, 2012). Gyamfi, Modjinou and Djordjevic (2015), indicates that although there are RE resources availability for electricity production in the country, development of solar power has been limited to a few homes, usually in the form of solar home systems and for the fact that there is wind and biomass potential, their harnessing technologies for power generation have not been demonstrated on a commercial scale in Ghana and again, installed capacity of hydropower, for instance, is small compared to the exploitable potential.

According to Lugmayr (2011), RE potential in Ghana is one of the best in the West African sub region, with about 11.5% of medium to large scale RE projects identified in the region located in Ghana, and in relation to identified specific project potential of concentrating solar power (CSP), Ghana has the highest potential (40 MW), and the second highest wind power potential (100 MW).

2.4.1 Solar Photovoltaic (PV)

According to Frankl and Philibert (2009), in recent years, growth in solar PV has been experiencing very dynamic trend. In their view, PV is the fastest growing renewable energy technology, with a fourteen-time capacity increase in the last 10 years and 30% average growth rate annually over the same period. Many parts of Ghana receive 5-8 hours of sunshine per day at 1 kW/m2, therefore the high potential for generating electricity using solar in Ghana. It is worthy to note that extreme large solar radiation resources are available in the northern part of the country although they have the least access to electricity (Energy Commission, 2003). Solar resource is abundant in Ghana. The monthly average solar irradiation is between 4.4 and 5.6 kWh/m2/day (16-20 MJ/m/day), with sunshine duration of between 1,800 and 3,000 hours per annum (Netherlands Enterprise Agency, 2016)

Table 2.6 Solar irradiation in kWh/m^2-day - Solar and Wind Energy Resource Assessment (SWERA) Report

Synoptic Station	Ground(kWh/m^2-day)	Satellite
Kumasi	4.633	5.155
Accra	5.060	5.180
Navrongo	5.505	5.765
Abetifi	5.150	5.192
Akuse	4.814	5.58
Wa	5.520	5.729
Akim Oda	4.567	5.177
Wenchi	5.020	5.093
Ho	5.122	5.223
Kete Krachi	5.280	5.345
Takoradi	5.011	5.200
Yendi	5.370	5.632
Bole	5.323	5.570

SWERA Report, cited in Kwarteng, 2015

According to the SWERA Ghana Project report as cited in Kwarteng (2015), averagely, Wa has the highest level of solar irradiation (5.524 KWh/m^2-day) across the country. With the month of May recording the highest solar irradiation (5.897 KWh/m^2-day), with August recording the lowest measurement (4.937kWh/m^2-day) in Wa. Akim Oda on the other hand records the lowest solar radiation in the country, with solar radiation of (4.567kWh/m^2-day). The highest measurement in Akim Oda was recorded in the month of April (5.176kWh/m^2-day) and the lowest in August (3.802kWh/m^2-day).

In the view of Kwarteng (2015), solar can produce enough electricity for the consumption of Ghanaians. He proves his assertion with the following analysis;

"Let us assume for every square meter (1m^2) exposed to continuous direct sunlight [in an optimal geographical location] for an average of 4.5 hours a day, we will have received 4.5 hours x 1000 watts = 4500 watthours (4.5kwh/m^2) of solar energy during the course of a day. It would be great if 100% of the sunshine became electricity, but solar energy and electricity are not the same. Technology accomplishes the conversion of solar energy to electricity. With an average efficiency of 15 to 40.7 percent, every square meter (1m^2) of solar photovoltaic cells (PV) would produce (4.5 kilowatt-hours of solar energy multiplied by 15% =) between 0.68 kilowatt-hours of electric energy per day. Solar panels (PV) covering an area of 100m^2 (1 Plot of Land) would produce 100 x .68 = 68 kilowatt-hours of electricity per day. It is worthy to note that 68kwh per day is a lot of electricity for a single-family home.

Let's juxtapose this arithmetic nationwide to the unused land surface:

- Size of Unreserved forest land in Ghana = 5 x 10^3km^2 or 5 x $10^9$$m^2$.

- Assuming a Conversion Efficiency (Solar Panels) of 15%.

- Average Solar Irradiation 4.5 kilowatthours (kwh) or 4500wh/day

- Annual average solar radiation = 4.5 x 365 or 1642.5kwh/m^2. y

- Assuming a Performance ratio, coefficient for losses of 0.75

So, 0.15 x 1642.5kwh/m^2.y x 5 x $10^9$$m^2$ x 0.75 or 923.9Gwh/y" (Kwarteng, 2015).

Therefore, in the analysis of Kwarteng (2015), 2% (5,000km^2) of the total land area of Ghana can produce 923.9Gwh/y electricity from solar PV making it a huge potential in the country.

Currently 22.5 MW solar PV potential has been exploited in two grid connected facilities; 20 MW BXC plant at Mankoadze and 2.5 MW VRA plant in Navrongo (Kumi, 2017). Gyamfi, Modjinou and Djordjevic (2015) reported that over 4500 solar systems have been installed in over 89 communities throughout the country. According to Energy Commission (2017), about 571 units totaling 334 kWp had been installed as of December 21, 2016 under the National Rooftop Solar Programme.

The Sector Ministry, through the Energy Commission begun the implementation of a Rooftop Solar Photovoltaic (PV) Programme in the country in February 2016. The programme is aimed at providing 200 MW peak load relief on the national grid through solar PV technology in the medium term. The first phase of the programme is targeted at the installation of 20,000 rooftop solar PV systems in residential facilities (homes) under a Capital Subsidy Scheme, where solar panels up to a maximum of 500 peak Watts (Wp) are given to prospective residential applicants after the prospective beneficiaries have satisfy some pre-conditions (Energy commission, 2017).

2.4.2 Bioenergy

“Bioenergy can not only supplement the shortage of fossil fuels, but also stabilize atmospheric concentrations of greenhouse gases below dangerous levels and help achieve the objectives of the framework convention on climate change” (Long, Li, Wang and Jia, 2013). The Ministry of Food and Agriculture (MoFA) (2012) as cited in Daniel, Pasch and Nayina (2014), stated that Ghana is well endowed with a great variety of organic material that can be used in anaerobic digesters as a feedstock for generating biogas as the country’s economy is strongly oriented toward agriculture, made up of five major subsectors – food crops (59.9 %), livestock (7.1%), fisheries (7.6 %), cocoa (14.3 %) and forestry (11.1%). Gand (2009) indicated that Ghana has about 23,853,900 ha of total land area. Approximately 14,850,000 ha of the are classified as an agricultural land area, of which arable land constitutes 28% and permanent crops 16%. According to Energy Commission (2012), it is estimated that there are about 553,000 t of maize cob and stalk produced with a potential energy of 17.65–18.77 MJ/kg and 19 t of paddy rice husks with a potential energy of 16.14 MJ/kg. As well, 193,000 t of oil palm shells, 136,000 t of sorghum stalks, 150,000 t of millet stalks and 56,000 t of groundnut shells are also produced. In a study conducted by Kemausuor, et al., (2014) titled “Assessment of biomass residue availability and bioenergy yields in Ghana”, they concluded that Ghana can exploit either biogas or ethanol, or a mixture of the two as they have great potential to contribute to energy in Ghana. Their study indicated that total biogas potential from agricultural residues is approximately 2400 Mm3 of methane containing 83 PJ of heat energy. The total ethanol potential from the residues is estimated to approximately 2300 ML or 51 PJ of liquid fuel energy, but caution that the fact that the estimated ethanol and biogas potentials are based on the technical potential of biomass, actual potentials could be much lower in practice. Based on estimations deployed by Ghana's Energy Commission (2010), the total amount of slabs wane, bark and sawdust from wood residues amounted to about 0.35 Mt. Biogas potential from these residues amounts to 19 Mm3 of methane or 0.67 PJ. Ethanol potential is 48 ML corresponding to 1.1 PJ.

If all residues considered are used for biogas generation, then the annual biomass potential is capable of supporting biogas production in about 6.1 million household digesters (1.2 m3/day), in 25,000 institutional digesters (300 m3/day), or in 3,600 large scale plants (2,000 m3/day) (Kemausuor, et al., 2014).

2.5 Regulatory Framework and Policies for Renewable Energy Development and Deployment in Ghana.

Energy promotion and development strategies and policies are well known in Ghana's history (Gyamfi et al, 2015). However, the impacts of these policies and strategies are yet to materialized on large scale energy installation looking at renewable energy installation status currently. The passing of Renewable Energy Act in 2011 to back the generation of 10% of the country's electricity from modern renewable energy sources by the year 2020 is expected to promote renewable energy business in the coming decade. It has created the enabling environment for the exploitation of the renewable energy resources in the country through the introduction of the following (Government of Ghana, 2011):

- Feed-in-tariff (FIT) scheme which is made up of feed-in tariff rates,
- mandatory purchase of electricity generated from renewable sources,
- free access to the distribution and transmission systems, and
- creation of the Renewable Energy Fund dedicated to the promotion development of the renewable energy sub-sector in Ghana.

He et al (2016), posited that, the planning and implementation of RE policies in Ghana appear disintegrated making them ineffective to function as planned. The effectiveness of FIT has been weakened because other supporting regulations are yet to see their implementation. For instance, quota obligations and RE fund are yet to be implemented. Though in force, there is yet to be a beneficiary. Regulation policies, incentives and market mechanisms need to be combined harmoniously. In order to realize the complementary or substitution potential between policy instruments (Cheng and Yi, 2017). The Public Utility and Regulatory Commission (PURC) and the Energy Commission are yet to issue the Renewable Energy Purchase Obligations (REPO) to Distribution Utilities and Bulk Customers (Energy Commission, 2017). It is observed in Energy commission (2017) that the percentage share of renewable to national installed capacity is 0.6% whiles generation to total national generation is 0.22%. This calls for a thorough instigation and understanding of why despites these policies the sector is yet to see massive development and deployment.

In view of IEA (2015), Feed-in tariff for electricity generated from renewable energy sources and Strategic National Energy Plan (SNEP) 2006-2020 constitute key elements of RE policy framework for the development of RE in Ghana.

Table 2.7 Policies and regulations specific to RET in Ghana

Title	Year	Policy status	Policy type	Policy target
Net Metering Code	2015	Planned	Regulatory Instruments>Codes and standards, Economic Instruments>Fiscal/financial incentives>User charges	Multiple RE Sources>Power, Multiple RE Sources
Feed-in tariff for electricity generated from renewable energy sources	2013 (last amended 2014)	In Force	Economic Instruments>Fiscal/financial incentives>Feed-in tariffs/premiums	Multiple RE Sources, Multiple RE Sources>Power, Wind, Solar, Hydropower, Bioenergy
Renewable Energy Act 2011	2011	In Force	Policy Support>Strategic planning, Policy Support	Multiple RE Sources
Ghana National Energy Policy	2010	In Force	Policy Support>Strategic planning, Policy Support	Solar, Hydropower, Geothermal, Multiple RE Sources>Power, Bioenergy>Biofuels for transport
National Electrification Scheme	2007-2020	In Force	Research, Development and Deployment (RD&D)>Research programme >Technology deployment and diffusion, Economic Instruments>Fiscal/financial incentives>Grants and subsidies, Research, Development and Deployment (RD&D)>Research programme	Wind>Onshore, Bioenergy>Biomass for power, Multiple RE Sources>Power, Solar, Wind
Ghana Energy Development and Access Project (GEDAP)	2007	In Force	Economic Instruments>Fiscal/financial incentives>Loans, Economic Instruments>Fiscal/financial incentives>Grants and subsidies, Economic Instruments>Fiscal/financial incentives>Tax relief	Wind, Solar>Solar photovoltaic
Strategic National Energy Plan (SNEP) 2006-2020	2006	In Force	Policy Support>Strategic planning	Multiple RE Sources>Power, Multiple RE Sources>Heating
Renewable Energy Services Programme (RESPRO)	1999	In Force	Economic Instruments>Fiscal/financial incentives>Tax relief, Economic Instruments>Fiscal/financial incentives>Taxes	Wind

Source: (IEA, 2015)

2.5.1 The Renewable Energy Act 2011, Act 832

The Renewable Energy Act 2011, Act 832 was adopted by the parliament of Ghana to provide for the development, management, utilization, sustainability and adequate supply of renewable energy for heat and power generation and related matters (Government of Ghana, 2011). The of the goal Act is to increase RE technologies' share in the total energy mix and achieve 10% contribution in electricity generation by 2020. The law provides the ground for the establishment of two policy instruments; the FIT (a price incentive) and the Renewable Energy Purchase Obligation (REPO). They are available to all electricity distribution utility or bulk customers and aim to boost renewable energy technology deployment in Ghana in a sustainable way. According to Sakah et al., (2017) the passing of the Renewable Energy Act 2011 and the other related support frameworks (i.e. feed-in tariffs, quota obligations, grid access codes, renewable energy fund etc.) have facilitated development of Ghana´s renewable energy industry. This has boosted investors' confidence because there is a legal regime to operate within the RE industry in the country. Kumi (2017) the passage of the Renewable Energy Act, has empowered the Energy Commission of Ghana to develop regulations for the RE industry including the renewable energy grid code and together with the PURC developed feed-in tariffs for investment in the sector. It also provides for the establishment of a RE fund to provide financial resources for the promotion, development, sustainable management and utilization of renewable energy sources. The RE fund provides financial incentives for the development of mini and off grid renewable power systems for remote areas and island communities.

2.5.2 Feed -in Tariff (FIT)

FIT scheme involves an energy supply agreement from electric utilities to purchase the electricity produced by RE producers at a tariff determined by the public authorities and guaranteed for a specified period of time (Menanteau et al., 2003). The agreements for the purchase of electricity are usually ranging from 10-25 years and are extended for every kilowatt-hour of electricity produced (Klein, 2008). The FIT system works as a subsidy allowed to producers of renewable electricity just as a pollution tax does for firms that pollute (Menanteau et al., 2003). In advance countries like Germany and Spain FIT schemes have been very instrumental in deploying varied large scale RE technologies (Poullikkas, Kourtis, Hadjipaschalis 2012). Its benefits to investors is the guarantee for the reduction of investment risk based on long -term financial gain (Poullikkas, 2013). However, Sakah et al., (2017) argues that when FIT rates are too low, production levels relatively remain dormant. Therefore, the market now depends on subsidies rather than market drivers, for renewable energy development which is not sustainable.

FIT rates in Ghana are guaranteed for 10 years and subject to review every 2 years (Parliament of the Republic of Ghana, 2011). In line with the Renewable Energy Act 2011, Act 823, the PURC sets FIT for Renewable Energy in Ghana (Netherlands Enterprise Agency, 2016).

Under Ghana's Renewable Energy Act, only hydro power plants of capacity 100 MW or below are considered renewable and qualifies for RE feed-in-tariffs (Energy Commission, 2017).

Energy Commission (2017) indicated that the prevailing high relatively electricity tariff makes it cost competitive and attractive for some consumers to opt for solar PV electricity having feed-in tariff for commercial applications like lighting in stores, water pumping, or shaving off consumption in the commercial and services sector during peak hours but also as an energy conservation measure. The FIT scheme of Ghana comprises of; the REPO, the FIT rate and the connection to transmission and distribution systems (Essando, Osei and Adam, 2014).

Table 2.8 Feed-in-tariff rates in Ghana (Effective 2014)

RE technology/source	Maximum capacity (MW)	FIT (GHp/kwh)	FIT (USD/ kWh)
Wind (with grid stability systems)	300	55.7369	0.17
Wind without grid stability systems	300	51.4334	0.16
Solar PV (with grid stability/ storage systems)	150	64.4109	0.20
Solar PV (without grid stability/ storage systems)	150	58.3629	0.18
Hydro≤*10*	No limit	53.6223	0.17
Hydro *(10 MW> ≤100 MW)*	No limit	53.884	0.17
Biomass	No limit	56.0075	0.18
Biomass (enhanced technology)	No limit	59.0350	0.18
Biomass (plantation as feed stock)	No limit	63.2891	0.20

Source: PURC (2014). [based on the average interbank selling rates as of 30th September 2014 at a conversion rate of GHS 3.1986 to USD 1.00]

FIT rates in Ghana are quite low against that of industrialized countries but, fairly high compared to other developing countries like China and India
Comparatively, years of FIT guaranteed for investors in Ghana is too short as compared to other countries and RE technologies' project lifespan. Ghana therefore need to improve in other to boast investors' confidence and lower their financial risk. This can be seen in Table 2.9.

Table 2.9 The table below shows the FIT of Ghana compared to other countries

Country	FIT (USD/kWh)		Guaranteed Period (Years)	Priority grid access
	Wind Power	Solar Power		
Canada (Ontario)	0.14 –0.16	0.45 – 0.48	20	Partial
Spain	0.1	0.38	25-30	Yes
Germany	0.06-.13	0.28	15-20	Yes
UK	0.07-0.35	0.11-0.25	20-25	-
Kenya	0.11-0.13	0.12-0.20	20	Yes
Ghana	0.13-0.14	0.15-0.17	10	No
China	0.08-0.1	0.14-0.16	-	-
India	0.09	0.15	20	-

Source: (Sakah et al., 2017)

2.5.3 Net Metering

Net Metering is a mechanism which is a form of billing system designed to inspire consumers of electricity to supplement their purchase of electricity with grid-connected renewable energy self -generation, hence it is designed for applications without system back-up to the main source of supply (Energy Commission, 2015b). The mechanism put in place is a bi-directional meter or a pair of unidirectional meters rotating in opposite directions. In case that the electricity production exceeds the consumption, the electricity-meter spins backwards and the value at the end is smaller than at the beginning of the period (Klein et al., 2008). According to Klein et al. (2008), small scale electricity producers in feed all produced electricity into the grid at a fixed FIT, while at the same time withdrawing electricity for their own use. The net metering system proposed to be used in Ghana provides credits for electricity supplied to the grid. This credit could be used to balance electricity consumed by the generator. The allowed generation capacity is 200 kW per installation with a rolling credit of 1 year (Sakah et al., 2017). In 2017, Energy Commission in collaboration with the Electricity Company of Ghana (ECG) has successfully piloted 33 net-meters equipped with automatic reading mechanism at various residential and commercial facilities (Energy Commission, 2017). The proposed net metering in Ghana has the following compensation and billing (Energy Commission, 2015b);

- ✓ For each billing period, the Distribution Utility shall carry over any excess kWh credits earned by a Customer-generator and apply those credits to subsequent billing periods to offset the Customer-generator's consumption in those billing periods until the end of the Calendar year.
- ✓ Excess kWh credits shall not be used to defray any fixed monthly Customer charges or levies or taxes.
- ✓ Excess kWh credit accrued to the Customer-generator at the end of one calendar year shall lapse.
- ✓ If a Customer-generator terminates service with the Distribution Utility or changes to another Distribution Utilities, the former Distribution Utility shall not be required to provide compensation to the Customer-generator for any outstanding excess kWh credits.
- ✓ The Customer-generator shall be compensated where the decision to change to other Distribution Utilities is from the current Distribution Utility.
- ✓ The price of the electricity injected by a Customer-generator's system into the distribution network shall be end-user tariff charged by the Distribution Utility to the Customer-generator.

2.5.4 Renewable Energy Purchase Obligation

Renewable energy purchase obligation also known as Renewable Portfolio standard (RPS) is a quantity-driven quota system that mandates utilities companies to source a specific fraction of their electricity from renewable energy (Komor, 2004). In the proposed RPS of Ghana, distribution companies and major off-takers of electricity are mandated to source a specific quantity (percentage) of their total electricity from renewables (Government of Ghana, 2011), many but not all such policies include the trading of renewable energy certificates (Wiser et al., 2007). RE based electricity generation and supply irrespective of the producer (company or individual), should be given priority to be dispatch into the national interconnected grid system (Ackom, 2005). Sakah et al. (2017), noted that per the electricity distribution structure of Ghana which is heavily monopolized by state institutions, deployment of RE is likely to result from development of new projects by incumbent companies or their subsidiaries rather than new IPPs. It can therefore be argued that until these limitations are addressed by policy reforms, the REPO for Ghana appears unlikely to make any significant impact on grid connected renewable electricity in Ghana.

2.5.5 Energy Commission Act

Energy Commission Act 541, 1997 was passed by parliament to take up the following responsibilities; a. Recommend national policies for the development and utilisation of indigenous energy resources; b. Advise the Minister on national policies for the efficient, economical and safe supply of electricity, natural gas and petroleum products having due regard to the national economy; c. Prepare, review and update periodically indicative national plans to ensure that all reasonable demands for energy are met; d. Secure comprehensive data base for national decision making.

2.5.6 The Strategic National Energy Plan (SNEP) 2006-2020

The Strategic National Energy Plan (SNEP) completed by the Energy Commission in 2006 comprehensively examines the energy resources available to Ghana. It considers how and when to tap them economically to ensure a secure and adequate energy supply for sustainable economic growth to 2020 (Energy Commission, 2006). The SNEP goal is to enable the development of a sound energy market that would provide sufficient, viable and efficient energy services for Ghana’s economic development. It will be achieved by articulating a comprehensive plan identifying the optimal path for developing, utilizing and efficiently managing the energy resources available to the country. The plan identified renewables (including wind, solar and biomass) as key energy sources for long term development and sustainable electricity supply. For security of electricity supply the SNEP targets 30% penetration of rural electrification via renewable energy technologies by 2020 (Energy Commission, 2006).

2.5.7 The National Energy Policy

The National Energy Policy was completed by the Ministry of Energy in 2010. It envisages the development of an "Energy Economy" that will allow a secure and reliable supply of high quality, environmentally sustainable energy services for all sectors of the Ghanaian economy. At the same time, the country would be transformed into a major exporter of oil and power by 2012 and 2015 respectively (Ministry of Energy, 2010). The specific goal of the policy on renewable energy is to increase its proportion in the national energy mix and ensure its efficient production and use. According to Energy Commission (2006) as cited in Kemausuor et al., (2011), the SNEP took a comprehensive look at the available energy resources of the country and how to tap them economically and in timely fashion to ensure a secured and adequate energy supply for sustainable economic growth up to 2020.

2.5.8 The Energy Sector Strategy and Development plan

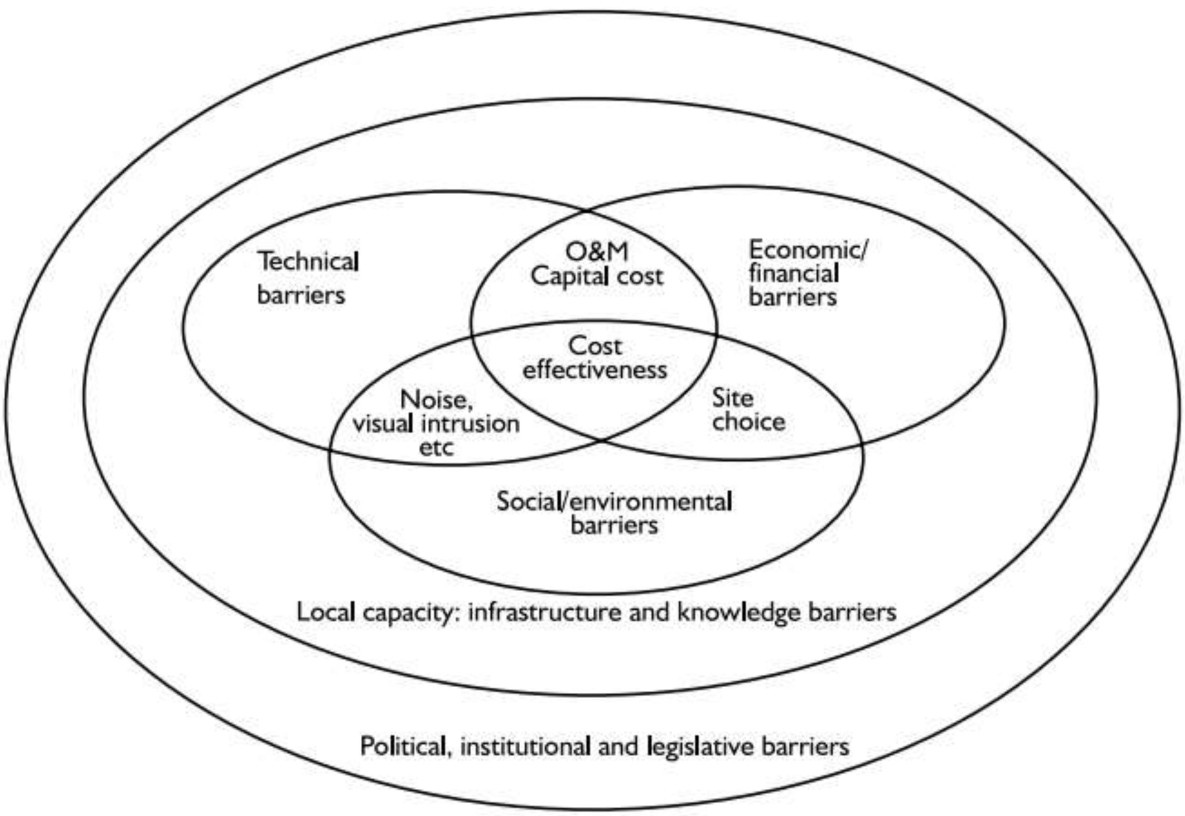
The Energy Sector Strategy and Development plan was also completed by the Ministry of Energy in 2010, building on SNEP. Three main objectives concerning the renewable energy sub-sector are to be implemented under this strategy. The first is to increase the renewable energy supply in the national energy mix to 10% by 2020. The second is to create legislation to encourage renewable energy technology development and utilisation by adopting a renewable energy law. The third is to manage municipal industrial and agricultural waste for energy.

The Energy Sector Strategy and Development Plan indicated that for RE technologies such as wind, solar and mini hydro technologies, the Government will focus on:

- promoting the exploitation and use of mini hydro, solar and wind energy resources;
- supporting indigenous research and development aimed at reducing the cost of renewable energy technologies;
- providing tax incentives for all equipment imported for the development of renewable energy projects; and
- supporting the use of decentralized off-grid alternative technologies (such as solar PV and wind) where they are competitive (Ministry of Energy, 2010).

2.6 Obstacles/Barriers in Undertaking Renewable Energy Projects

Successful transfer of renewable energy and integration of renewable energy systems will benefits developing countries, in respect of social, economic, environmental and sustainable development, and for the world environment (Wilkins, 2002). In the view of Luthra et al., (2015), the literature identifies so many obstacles impending the development of RE. These may include financial barriers, technical barriers, and market barriers such as inconsistent pricing structures; institutional, political and regulatory barriers; and social and environmental barriers. Although some barriers may be specific to a technology, others are specific to a country or a region. Wilkins (2002) also stated that there is a good resource base and potential for the development of renewable energy systems in developing countries. However, the barriers preventing the full potential of RE technology from being reached and slowing down the process of technology transfer are interrelated.



Source: Adapted from Smith and Marsh (1997) as cited in Wilkins (2002).

Figure 2.5 Interrelationship of barriers to renewable energy technology in developing countries

The transition from unstainable sources of energy to RE has become a development challenge in this half of 21st century. Technological innovation, the economy (costs and prices) and policies have to be aligned to achieve full renewable energy potentials, and barriers impeding that growth need to be removed (Verbruggen, et al., 2010).

The development of RE technologies and its transfer will require high initial investment. However, the lack of sufficient government incentives schemes or financing mechanisms to promote the adoption of RE technologies are major setbacks in the development of RE businesses and industries (Reddy and Painuly, 2004). However, Banks in Ghana are becoming more aware about environmental and social sustainability criteria of RE projects now. While there is more awareness now regarding energy businesses due to the number of such businesses operating in the country, the sector is still perceived to be relatively risky, which in turn continues to restrict commercial lending (Haselip et al, 2014). Interest rates charged on financing schemes are usually high and thus prohibitive to developers in most cases (Ahiekpor, 2013). Currently, the base rates of most banks are above 30% making cost of borrowing very expensive in Ghana (UNDP and Energy Commission, 2016). Poor credit availability to the purchase of renewable energy technologies is a major barrier in the adoption of renewable energy technologies (Painuly, 2001).

Many RET projects have failed because of the lack of technical skills to operate and maintain the systems. In the area of solar energy development and utilization for instance, lack of skilled manpower to design and install solar PV systems is still a major technical barrier (UNDP and Energy Commission, Ghana, 2016). According to Luthra et al., (2015), there is a need for technically trained people and people with strong management skills with a practical “hands on” approach. This will reduce the cost of hiring expatriates at high cost making investment in RE high. The inability of technicians and engineers in Ghana to design heavy duty solar dryers was identified as one of the barriers in the promotion of solar water heater technology (UNEP, 2002). The Energy Centre of Kwame Nkrumah University of Science and Technology is the only training centre offering training on biogas technology and bio fuel production in the country.

Mam and Twaha (2015) stated that poor access to grid is one of the major obstacles to substantial renewable electricity generation or the cost of upgrading the network to connect high quantum of renewable energy. According to Energy Commission (2015), electricity transmission and distribution networks across Ghana are inefficient with losses estimated at approximately 25%.

Ghana has grid access policies to limit the impact of RE integration on the weak grid infrastructure (Renschhausen, 2013). If challenges of transmission and distribution losses are not addressed, it will be difficult to be able to generate substantial amount of electricity from renewables as they might not be able to be transmitted with the current available infrastructure. According to UNEP. (2002), the remoteness of resources from key electricity demand sectors and compatibility with existing transmission and distribution networks are major challenges of connecting renewable electricity to the grid. Sakah et al. (2017), indicates that the costs of grid connection and enhancement to the metering point of the grid are borne by the renewable power producer and the actual amount of renewable power fed into the grid is thus tied to conformity to the interests of the grid company. This has serious implications on widespread deployment.

The government of Ghana over the years until 2015, has been subsidizing fuel for transportation in the Ghanaian market and leaving out market forces to determine the price of the commodity even when the price of crude oil increased on the international market. Although no such subsidy incentives have been available for RE products (Bensah et al., 2015). Producers of liquid biofuels do not even have any means of selling their products to potential users since there are no dispensing mechanisms for fuel derived from RE sources. Also, even though standards for biofuels have been developed and adopted, testing and certification procedures are still under development.

In the study of Blechinger and Richter. (2014), other barriers identified are as follows:

- ✓ Lack of regulatory framework and legislation for private investors
- ✓ Gap between policy targets and implementation
- ✓ Lack of legal framework for IPPs and PPAs
- ✓ Diseconomy of scale
- ✓ Utility monopoly of production, transmission and distribution of electricity

In a study of UNDP and Energy Commission (2016) dubbed "China-Ghana South-South Cooperation on Renewable Energy Technology Transfer" they classified barriers into the following categories and identifies some specific barriers under each. This can be seen in Table 2.10;

Table 2.10 Categorization of barriers and their specific barriers

Category	Specific barriers
Market	Market size, Controlled market in favour of conventional systems, failed past experience, Lack of successful reference projects
Economic and Financial	Access to finance and long-term capital, Cost of finance-high interest rate, Lack of consumer financing options, Business climate (currency fluctuations), Insufficient incentives, Operations and maintenance cost,
Technical	Poor operations and maintenance facilities, Lack of infrastructure facilities, Difficulty in getting spare parts and equipment,
Network	Lack of involvement of stakeholders in decision making, Strong network among conventional technology developers and favoured by legislation, Weak network between foreign institutions and local ones.
Legal and regulatory framework	Inadequate standard and codes, Lack of enforcement, Unfavourable policies, political unwillingness, Land acquisition, Challenges with license acquisition, Intellectual Property (IP) rights protection, Administration hurdles in developing contracts,
Information and awareness	Information on cost of acquisition, the benefits to be derived from using the technology and operations and maintenance should be readily available to end users.
Socio- cultural	Lack of understanding of local needs, Consumer preferences and social biases.
Human skills	Technical skills to operate and maintain RET, Inadequate training centres,

Source: (UNDP and Energy Commission, 2016)

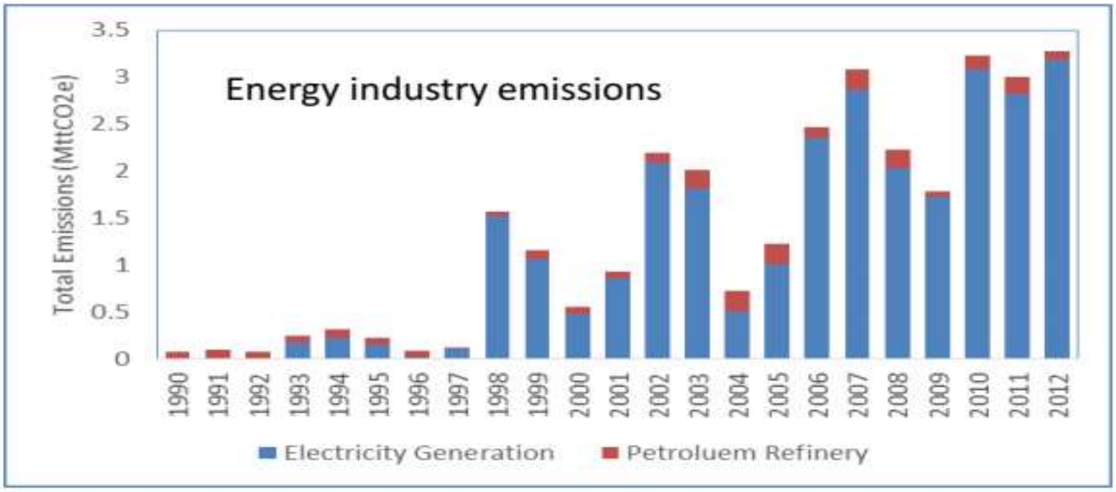
2.7 Energy, Renewable Energy and Climate Change Nexus

Electricity has become a critical form of energy for development throughout every economy. Unfortunately, the key challenge bordering many countries currently is how to produce more cheap electricity in order to satisfy the increasing demands and at the same time, reducing CO_2

emissions to the atmosphere (Budzianowski and Gomes, 2016). According to Bessah and Addo (2013), the energy sector globally has been negatively affected by climate change. It is becoming evident and accepted by scientist and the general public globally that Fossil fuel energy production has been 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. In the view of Watson et al. (1997, p. 7) "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". Although in 2012 the Kyoto Protocol ceases to be a binding protocol on states and the unclear future shape of the post-Kyoto Protocol legislation, developed economies well understand the need for carbon emissions reductions and are developing their own climate protection policies (Budzianowski and Gomes, 2016). Investment in the development of RE source for the generation of electricity is very useful in long-term electricity planning and GHG mitigation (Kusumadewi et al., 2017). The dependence on hydropower for electricity production in Ghana makes the electricity sector vulnerable to weather conditions, particularly rainfall. The country has in recent times experience severe power outages due to prolonged droughts and low water levels coupled with rising fuel prices and this has prevented the existing production facilities to attain full potential (Unite Nations Framework Convention on Climate Change[UNFCCC], 2013). The UNFCCC stated that, the energy sector is one of the sectors with most emissions, 41%, with residential and transport sub-sectors as the main contributors. The increase in emissions in the Energy sector are as a result of increased use of fuels for thermal power generation, poor energy efficiency in road transport, and rising biofuel use in the residential sub-sectors. Yadoo and Cruickshank (2012), noted that RE sources to increase electricity access appear to be the best strategy for climate change mitigation and improve resilience (having access to electricity can improve people’s adaptive capacity to weather related shocks). They stated that the various ways to achieved that are: more RE sources can be integrated into the generation mix of the national grid network and the grid can be extended to rural areas; alternatively, an off-grid RE resource and technology can be decentralised (install at local levels). Fleck and Huot (2009) in their study to compare the life-cycle GHG emissions of an off-grid wind system and a single- home diesel generator found that, the wind generator system offered a 93% reduction of GHG emissions when compared to the diesel system. The two systems were designed to deliver 162.5 kWh of AC power every month over a 20-year period which was a small off–grid.

Ghana in its commitment to reducing the level of emissions developed the Intended Nationally Determined Contribution (INDC) to UNFCCC to reaffirms its resolve to support global efforts against climate change through emission reduction. Ghana's emission reduction goal is to unconditionally lower its GHG emissions by 15 percent relative to a BAU scenario emission of 73.95MtCO_2 eq by 2030. An additional 30 percent emission reduction is attainable on condition that external support is made available to Ghana to cover the full cost of implementing the mitigation action (finance, technology transfer, capacity building) (Government of Ghana, 2015). Ghana's INDC outlined the following mitigation policy actions under the RE sector to Scale up renewable energy penetration by 10% by 2030;

- Increase small-medium hydro installed capacity up to 150-300MW
- Attain utility scale wind power capacity up to 50-150MW
- Attain utility scale solar electricity installed capacity up to 150-250MW
- Establish solar 55 mini-grids with an average capacity of 100kW which translates to 10MW Scale up the 200,000 solar home systems for lighting in urban and selected non-electrified rural households.



(Source: Sampong, n.d)

Figure 2.6 Energy industry emission of Ghana

It can be clearly seen in Figure 2.6 that much of the GHG emission from the energy sector is coming from electricity generation, therefore, calling for greater attention to reduce these emissions. The surest way for GHG emission reduction is investing in RE sources for electricity generation in Ghana.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research Approach /design

The research approach adopted in determining the potential of RE in Ghana was based on desktop study approach. The study delved into the literature to determine the potential of RE from studies conducted by researchers in the sector to estimate and determine the quantities of electricity that can be produced from RE and the very locations suitable for the production of electricity using specific RET. That is, the site and situation of each RET in Ghana.

Again, the approach that was used in the research for identifying the barriers in the RE sector was a survey. Survey is the development of intensive knowledge about a small number of related cases. A case however, is a subject of investigation or scrutiny by a professional person. It helps the researcher to gain a rich and deeper understanding of the case under study. The adoption of this approach was based on the fact that renewable energy projects (solar PV and bioenergy) and stakeholders cut across many cities/communities across Ghana. Moreover, a case study approach of the selected ones provided an in-depth information and understanding of the barriers and opportunities of renewable energy investment and running a business in the sector. The research employed both quantitative and qualitative methods in the analysis of data.

On the other hand, Long-range Energy Alternatives Planning system (LEAP) developed by the Stockholm Environment Institute and Boston University in the USA is an econometric model. It can be used for analysis of energy demand and environment impact analysis. LEAP model can be used in analyzing the influence of energy-consumption, pollutant emission and transportation pattern to energy and environment**.** Also, LEAP system can be used in predicting medium and long-term energy supply and demand in the whole society under the different driving forces/factors and calculate the amount of GHG emissions in the process of energy circulation and consumption (Community for energy environment and developing, N.D). Data requirement for this analysis was obtained from official government agencies' such as the Energy Commission and Ghana Statistical Service (GSS) documents and databases. The scenarios include BAU and emission reduction strategies. The scenarios developed and modelled are presented in Table 3.1;

Table 3.1 Scenario

Scenario		**Description**
BAU		The time span of this study is 2016-2030. In the BAU, Energy system was modelled without any policy interventions. Energy system of the base year 2016 was modelled using the reported data and then existing energy generation/consumption trends projected until 2030
Emission reduction strategy	Scenario 1a	The scenario follows 2010 National Energy Policy target with a target of RE in 2020 by 10% and Ghana INDC plan by 2030.
	Scenario 1b	Scenario with share of RE target in the generation mix to be 20% by 2030.
	Scenario 1c	with share of RE target to be 40% by 2030.

(Source: Author's Construct, 2018**)**

Scenario Assumptions

- ✓ The average growth rates of Residential, Non- Residential, Special load tariff and street lighting of 8.31%, 4.27%, 3.17%, 14.25% respectively from 2006-2016 were used for demand (consumption) projections for the scenario years
- ✓ Fossil fuels are replaced with Renewable energies by 10%, 20% and 40% of total installed plants using the base year (2016) figure in different scenarios.
- ✓ The maximum availability of all generating plants remained throughout all the scenarios.
- ✓ Generated electricity will be dispatched in merit order. The order shall be to dispatch RE electricity generated first before fossil fuels.

3.2 Sampling techniques

Due to the number of renewable energy project developers in Ghana and the stakeholders involved as against time and resources that were used for this research there was the need to carefully sample a section of developers and stakeholders in Ghana to give information of the situation on ground that will represent the views of all. The sampling techniques that were adopted in the study were;

- ❖ Stratified sampling: it is a sampling technique where the researcher divides the entire population into different subgroups or strata. In this case the developers and investors were grouped or classified according to their area of technology (solar photovoltaic and bioenergy).
- ❖ Simple random sampling

Simple random sampling technique was adopted after they have been put into strata. With this, every individual in the target population had an equal chance of being selected. This technique was adopted to sample individuals to share their views on the subject. The technique was adopted because it has unique feature of classifying all the individuals in the population that covers a large geographical area. Random selection means that selected cases are likely to be dispersed throughout the area.

- ❖ Purposive sampling

Purposive sampling which is a non-probability sample was used. It was used to target specifically to choose sampling units who were relevant to renewable energy. It was used to target actual stakeholders in the RE sector.

3.3 Sample Determination

Based on the data from Energy Commission (2016), 55 licenses were issued are for solar photovoltaic (PV) for power generation and four (4) for biomass for generation of power.

Using Yamane (1967) sample determination formula: $\frac{N}{1+N(e)^2}$

Where; n= the sample size

N= the sample frame

e= the margin of error

Based on the figures above, with a margin of error of 5 per cent (confidence level 95 per cent), the sample used for interviewing solar PV developers was;

Sample Frame (N) = 55

Margin of Error (e) = 5% (0.05)

Hence;

$$n = \frac{55}{1+55(0.05)^2}$$

$$N = \frac{55}{1.14}$$

n=48.2

Therefore, to the nearest number; n= 48

Hence 48 solar PV developers were sampled and the four Biomass developers interviewed.

In analyzing the various barriers that were selected, the research adopted a mathematical model employed by Nasirov, Silva and Agostini (2015) to identify the most pressing barrier to the least using their average scores with the scale of 1-5 with 5 as extremely relevant (meaning very key to RE development and if solved will see growth in the sector) and 1 as least relevant (not so important to RE development in Ghana). These weights were multiplied by the total number of respondents for each barrier and this was done using the following;

$$R_j = \frac{\sum_i r_j^i}{n_j}$$

Using the above, the average of each barrier is calculated. r_j^i represent the rate given by respondent *i* to barrier *j* and n_j the total number of responders for barrier j.

The barriers selected were grouped in the various categories as identified in the literature and presented for the survey as in Table 3.2

Table 3.2 Barriers of RE in Ghana

CATEGORY	BARRIER
Market	Market design problems, that obstruct the integration of renewables
	Controlled market in favour of conventional systems
	Lack of successful reference projects/ Failed past experience
Economic and Financial	Lack of Access to finance and long-term capital,
	Cost of financing high interest rate
	Business climate (currency fluctuations)
	Lack of consumer financing options
	Insufficient incentives (tax rebate, etc)
Technical	Grid connection constraints and lack of grid capacity
	Difficulty in getting spare parts and equipment
	Lack of infrastructure facilities
Legal and regulatory framework	Inadequate standard and codes
	Administration hurdles in developing contracts, acquiring licenses/ Longer processing times for large number of permits
Human skills	challenges in Land acquisition
	Lack of implementation and enforcement
	Technical skills to operate and maintain RET
	Inadequate training centres
Socio- cultural	Lack of dissemination and public awareness
	Lack of understanding of local needs, Consumer preferences and social biases

(Author's Construct, 2018)

3.4 Data Required and Sources

There were two main sources of data required for this research- primary and secondary data sources. Primary data basically involved obtaining first-hand information from the field and stakeholders in renewable energy sector in Ghana. Data collected for the research involved; barriers/obstacles in doing business in the field of renewable energy, opportunities in the field etc, Secondary data were obtained from already available literature such as reports, journals, and articles, published and unpublished documents which were the works of people and are of relevance to this study and also state agencies such as Energy Commission and GSS. The purpose of literature review was to examine the extent to which people have written on the subject. It revealed similar studies and their findings.

3.5 Data Collection Methods and instruments/Tools

In the case of data collection methods there were many means through which data was collected from both primary and secondary sources. Utilised once are:

- ✓ Interviews: The researcher used this method to collect data from project developers and stakeholders related to the study using well-structured questionnaires. The questionnaires were both close ended and open-ended questions. Two means were used-through google form and face to face. A limitation was people not willing to disclose information and it took a lot of follow-up calls.
  - ✓ Questionnaires
  - ✓ Checklist: A checklist was used for lay out tasks to be done according to time of day or other factors. It helped to ensure consistency and completeness in carrying out all tasks.
  - ✓ Literature reviews: This was used in already existing documents such as published and unpublished articles, project reports, policy and regulatory documents, books etc.

3.6 Data Analysis and Reporting

A Likert scale was used where respondent rated each barrier on predetermined scale of 1-5. Microsoft Excel and Microsoft Word were utilised in the analysis and used to create charts and tables. The research also used the Long- range Energy Alternative Planning (LEAP) system software in the modelling of the GHG emissions produced from the power sector and the role RE could play in the emission reduction coming from the electricity sector. Pie charts, line graphs and tables were used to present results and accompanied by written analysis as well.

CHAPTER FOUR

DATA FINDINGS AND DISCUSIONS

4.1 Introduction

Basically, this chapter presents the analysis of the data collected on the potential of RE in Ghana, obstacles/barriers that impedes the development and deployment of RETs in Ghana as well as the analysis on the amount of GHG emission that can be reduced by renewable energy supply into the current energy mix in the power sector to ensure sustainable energy supply using LEAP. The analysis of data is done in the discussion phase where meaning is read into the data collected. The analysis in this chapter creates effective grounds for deriving recommending solutions to ensure the successful development and deployment of RETs in Ghana.

4.2 Renewable Energy Potential in Ghana (Solar Energy and Bioenergy)

4.2.1 Solar Energy

Ghana has a great potential of RES and capable of replacing the fossil fuels for the generation and supply of electricity to the economy. It is interesting to know that the country experience sunlight throughout the year with a very excellent potential to produce enough electricity for the needs of the country. Energy Commission (2003) indicated that many parts of the country receive 5-8 hours per day sunshine especially the northern part of the country. In Ghana, monthly average solar irradiation is between 4.4 and 5.6 kWh/m2/day (16-20 MJ/m/day), with sunshine duration of between 1,800 and 3,000 hours per annum (Netherlands Enterprise Agency, 2016). Table 4.1 indicates the solar irradiation of some selected towns in Ghana conducted by SWERA. It is indicated that Wa has average 5.524 KWh/m^2-day solar irradiation, highest in the across the country with a minimum of 4.937kWh/m^2-day solar irradiation recording 4.937kWh/m^2-day in the month of May. Akim Oda on the other hand records the lowest solar radiation in the country, with solar radiation of (4.567kWh/m^2-day). The highest measurement in Akim Oda was recorded in the month of April (5.176kWh/m^2-day) and the lowest in August (3.802kWh/m^2-day).

Table 4.1 Solar irradiation in kWh/m^2-day - Solar and Wind Energy Resource Assessment (SWERA) Report

Synoptic Station	Ground (kWh/m^2-day)	Satellite
Kumasi	4.633	5.155
Accra	5.060	5.180
Navrongo	5.505	5.765
Abetifi	5.150	5.192
Akuse	4.814	5.58
Wa	5.520	5.729
Akim Oda	4.567	5.177
Wenchi	5.020	5.093
Ho	5.122	5.223
Kete Krachi	5.280	5.345
Takoradi	5.011	5.200
Yendi	5.370	5.632
Bole	5.323	5.570

(Source: SWERA Report, cited in Kwarteng, 2015)

Kwarteng (2015), in his analysis indicates that Ghana's 2% (5,000km^2) of the total land area of can produce 923.9GWh/y electricity from solar PV making it a huge potential in the country. Therefore, with 10% of the total land area, the country could generate 4,619.5 GWh/y

4.2.2 Bioenergy

Ghana's land is an arable land capable of producing many varieties of crops and plants. MoFA (2012) as cited in Daniel, Pasch and Nayina (2014), stated that the country is gifted with a great variety of organic material that can be used in anaerobic digesters as a feedstock for generating biogas as the country's economy is strongly oriented toward agriculture, made up of five major subsectors – food crops (59.9 %), livestock (7.1%), fisheries (7.6 %), cocoa (14.3 %) and forestry (11.1%). Gand (2009) indicated that Ghana has about 23,853,900 ha of total land area.

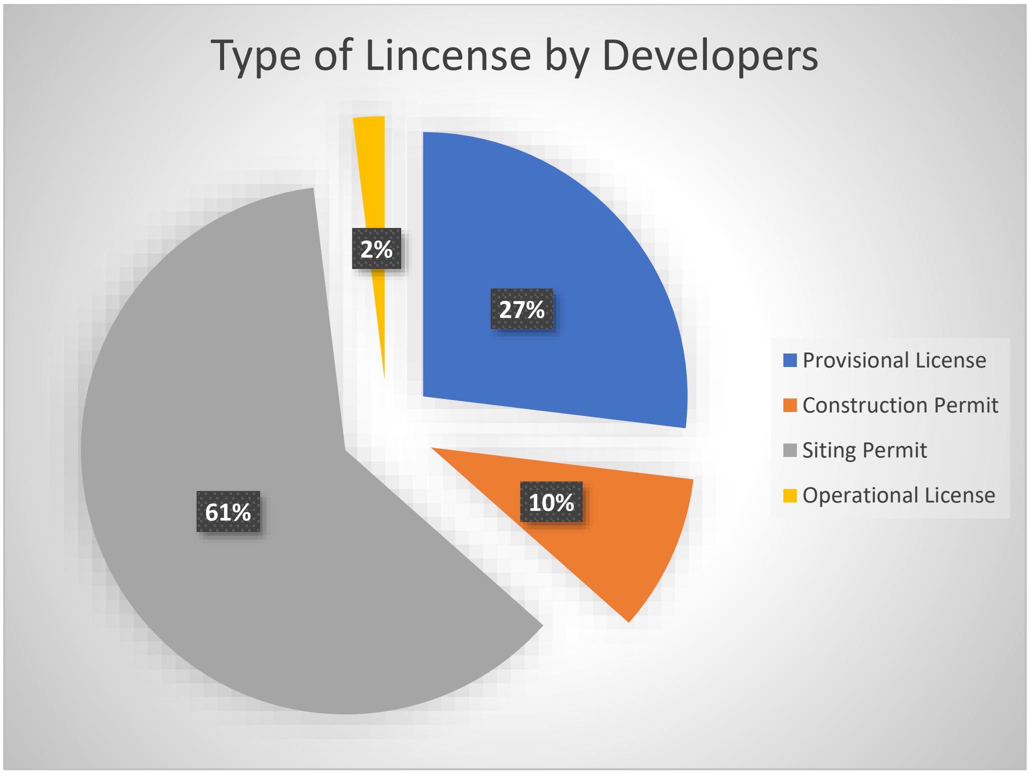
Approximately 14,850,000 ha of the are classified as an agricultural land area, of which arable land constitutes 28% and permanent crops 16%. With this the country has a great potential to produce biofuels for its use and exportation. In the study of Kemausuor, et al., (2014), they indicated that the annual biomass potential is capable of supporting biogas production in about 6.1 million household digesters (1.2 m3/day), in 25,000 institutional digesters (300 m3/day), or in 3,600 large scale plants (2,000 m3/day). They indicated that total ethanol potential from the residues is estimated to approximately 2300 ML or 51 PJ of liquid fuel energy. It can be concluded that biofuel has the potential to replace fossil fuel in the electricity and transport sector which will be a great way to reduce carbon dioxide in these sectors of Ghana.

4.3 Challenges/Obstacles of RE development and deployment in Ghana

4.3.1 Background of Respondents

A total of 56 respondents were sampled for data collection on the challenges of RET development in Ghana. Out of the total 52 were RE developers/investors and the remaining 4 were institutions. The sampling of the developers was to gain an in-depth situation on the challenges of RETs in Ghana which is in connection with the objectives of the study. The institutions that were interviewed were the Energy Commission, Electricity Company of Ghana, the Energy Ministry and GRIDCO.

Of the 52 developing companies (developers/investors), 61% of the developers are holding siting permit, 27% have just been awarded provision license of the development of Solar PV, with 10% holding construction permit as well as 2% having operational license. The Figure 4.1 shows the type of license held by developers/investors who were respondents.



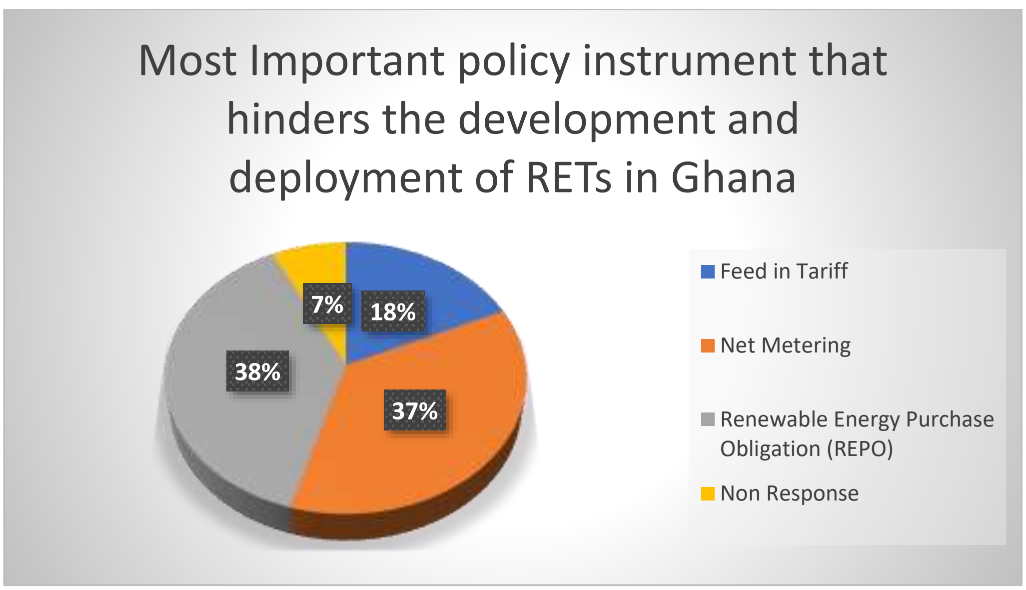
(Source: Author's Construct, 2018**)**

Figure 4.1 Types of License by developers

4.3.2 Policy Instrument for Rapid RETs Development and Deployment in Ghana

The survey conducted also seeks to know from respondents' point of view the most the critical policy instrument that is critical to the development and deployment of RETs in Ghana. The result from the survey as shown in figure 4.2 below indicated that, overwhelming 38% of the respondents selected Renewable Energy Purchase Obligation (REPO) as a critical instrument that can help increase the supply of electricity from RETs. The Energy commission indicated that it has prepared the REPO document and presented to the PURC for implementation and gazzetting. Winkler (2011) as cited in Sakah et al. (2015), indicated that REPO is capable of alleviating deployment barriers related to infrastructure, funding and technology availability. A full 37% indicated that Net Metering is also very crucial to the development of RETs especially at the household and small-scale businesses levels. Respondents indicated that with the implementation of the National Rooftop program, the net metering will be a critical aspect that will achieve its objective of providing a relief of 200 MW peak load on the grid.

The Energy Commission and the Electricity Company of Ghana (ECG) successfully piloted 33 net meters with automatic reading mechanisms (Energy Commission, 2017). During the survey, the Energy Commission indicated that full implementation of the net metering has been put on hold following concerns raised by ECG which is the distribution company after it kicked start the net metering scheme. Again, 18% of the respondents FIT as an instrument crucial to the development of RETs in Ghana. FIT is critical in deploying large scale RE technologies. Poullikkas (2013), indicated that FIT is very beneficial to investors as it guarantees for the reduction of investment risk based on long -term financial gain. In the view of Sakah et al., (2017) when FIT rates are too low, production levels relatively remain dormant. In this case for investors to gain confidence in investing in RETs, there is the need to ensure that FIT is high enough to guarantee investment in the sector. The non-response to this question was 4%.



(Source: Author's Construct, 2018**)**

Figure 4.2 Policy Instrument for rapid development of RETs in Ghana

4.3.3 Obstacles to the development of RETs in Ghana.

Following the survey conducted on RET investors/ developers and institutions on the challenges facing the renewable energy sector, useful information has been gathered on each of the 19 selected barriers although RE barriers are not limited to them alone. This information is useful for policy consideration in the future for the development of the renewable energy sector in Ghana and their replication in other parts of Africa. Based on the data collected from 56 respondents using a scale of 1-5, the average score to barriers ranged from 4.13 to 2.52 and the overall average score was 3.17 indicating that all the selected barriers are key to the development of the renewable energy sector if they are addressed and consideration given in national, regional and local policies as well as planning for the promotion RETs in Ghana.

The average scores and ranks of the barriers are presented in Table 4.2. Included in the table are the variance and standard deviation for statistical purposes. Below the Table is the discussions on the barriers of RETs in Ghana collected from the survey.

Table 4.2 Barriers Affecting the Development of Renewable Energy Technologies in Ghana

OBSTACLES	FREQUENCY OF RESPONSES					TOTAL RESPONSES	AVERAGE SCORE	RANK	VARIANCE	STANDARD DEVIATION
	1	2	3	4	5					
Cost of financing high interest rate	0	2	12	19	23	56	4.13	1	0.75	0.87
Lack/Insufficient incentives (tax rebate, etc)	0	3	14	23	16	56	3.93	2	0.74	0.86
Lack/Inadequate Access to finance and long-term capital	1	6	19	15	15	56	3.66	3	1.08	1.04
Grid connection constraints and lack of grid capacity	1	6	16	23	10	56	3.63	4	0.91	0.96
Instability of the local Currency (currency fluctuations)	1	6	21	19	9	56	3.52	5	0.89	0.96
Insufficient Technical know-how for the operation and maintenance of RET	1	6	21	22	6	56	3.46	6	0.78	0.89
Controlled market in favour of conventional systems	3	10	21	14	8	56	3.25	7	1.15	1.07
Lack of consumer financing options	4	14	15	13	10	56	3.20	8	1.44	1.20
Inadequate training centres	3	9	23	14	6	56	3.20	8	1.01	1.01
Market design problems, that obstruct the integration of renewables	3	10	20	20	3	56	3.18	10	0.93	0.97
Lack of implementation and enforcement	6	10	20	14	6	56	3.07	11	1.28	1.13
Lack of dissemination and public awareness	7	13	17	14	4	56	2.91	12	1.26	1.12
Lack of successful reference projects/ Failed past experience	2	19	21	11	3	56	2.89	13	0.88	0.94
Bureaucratic processes in developing contracts, acquiring licenses/ Longer processing times for large number of permits	4	20	17	8	7	56	2.89	13	1.27	1.13
Lack of understanding of local needs, Consumer preferences and social biases	3	20	21	11	2	56	2.79	15	0.85	0.92
Lack of infrastructure facilities	6	19	18	8	5	56	2.77	16	1.21	1.10
challenges in Land acquisition	7	17	18	10	4	56	2.77	16	1.21	1.10
Inadequate standard and codes	10	19	14	11	12	56	2.57	18	1.21	1.10
Difficulty in getting spare parts and equipment	8	23	17	4	4	56	2.52	19	1.11	1.05

(Source: Author's construct, 2018)

4.3.3.1 Cost of Financing High Interest Rates in Ghana

Following data collected from 56 respondents on the obstacles impending the development and deployment of RETs in Ghana, cost of financing high interest rates emerged as the first major barrier to the development and deployment of RETs in Ghana with an average score of 4.13. It was emerged from RE developers that high interest rates in Ghana is a major setback to the development of the sector as banks willing to give long term loans to developers will charge high rates on borrowing. This has led to some RE projects which were issued with construction permit as far as 2014/2015 unable to construct and generate electricity in Ghana as these projects have not been able to raise the necessary capital as a result of interest rates. Developers indicated that interest rates are high that they are unable to borrow to finance their projects. As confirmed by Ahiekpor (2013), the rate of interest charged on financing RE schemes are usually high and thus does not encourage developers in most cases. This research finding also comes in line with UNDP and Energy Commission (2016) which confirmed that base rates of most banks are above 30% making cost of borrowing for the development of RE projects very expensive in Ghana.

4.3.3.2 Lack/Insufficient Incentives for RET Developers in Ghana

The lack/insufficient incentives were also found to be a major barrier in the development and deployment of the RE sector in Ghana. This barrier was ranked second (2rd) during the survey conducted. It had an average of 3.93. It was realized that the absence of financial incentives such as grants, rebates etc in the RE sector is a major cause of the sectors' inability to develop and expand rapidly in the sector as these incentives would have compensated partially for the high capital requirement for the development of Solar PV and bioenergy as well as all RE projects in Ghana. The implementation of the Renewable Energy Fund (RE Fund) which was established under the Renewable Energy Act 2011 will help solve this barrier as the fund makes provisions to support the development and deployment of RETs in Ghana. The fund seeks to support long term financial aid and resources for RE development and deployment in Ghana (Government of Ghana, 2011). Doe (2014) as cited in Sakah et al. (2017) also confirmed the finding of this survey as he indicated that there is currently no any form of reported government grants for RE financing in Ghana either partially or fully and there by the Energy Ministry of Ghana has shown hesitant in guaranteeing government's support for RE projects and has thus RE directed developers to international financing bodies such as the WB and African Development Bank (AfDB) for partial risk guarantees (PRGs) (CIF, 2015). Upon registration with the Ghana Investment Promotion centre (GIPC) investors are exempted from 100% duties and levies on all imported machinery, equipment, plant parts for RE development and tax holidays for 10 years (Ahlijah and Humphries, 2013 as cited in Sakah et al., 2015). Sakah et al. (2015), therefore stipulated that support for RE development in Ghana has been based on only tax-based incentives.

4.3.3.3 Lack/Insufficient Access to Financing High Initial Capital

The lack/insufficient access to financing high initial capital requirement for the development of RE projects globally and locally has been a major drawback to the development of the sector. In the research conducted, it emerged as the third biggest obstacle drawing back the development of RETs. It got an average score of 3.66. It is interesting to note that project investors/developers will go through all the licensing and permit processes successfully only to be stalled at a point by the inability to raise the enough required capital for the construction and operation of RE projects in Ghana. This was confirmed in the work of Sen and Ganguly (2017) which indicated that a vast majority of RE capital investment is required or made during the construction phase of projects, mainly in the form of debt financing. Unfortunately, this debt financing has become a burden to RE developers/investors due to high interest rates on debt from financial institutions in Ghana. The implementation and operation of the RE fund in Ghana can lessen this challenge by granting loans and capital subsidies to developers at lower rates compared to that of the open market such as the financial institutions.

4.3.3.4 Grid Connection Constraints and Inadequate of Grid Capacity

According to the World Bank (2013), although grid coverage is high in Ghana, its dependability (power outage) and stability of the grid are major obstacles to accept RETs for transmission and distribution. The survey conducted confirmed this as Grid connection constraints and inadequate of grid capacity ranked 4th in the survey with an average 3.63. Ultimately for the development of RETs for large power generation there is the need to have adequate grid capacity to accept and be able to carry large quantum of generated electricity from RETs taking into consideration measures to mitigate and reduce transmission and distribution losses in the electricity sector. The inefficiency of the current grid system has resulted in approximately 25% losses in transmission and distribution (Energy Commission, 2015). In the view of Renschhausen (2013), if the challenges of transmission and distribution losses in the current grid system are not addressed, it will be difficult to be able to generate substantial amount of electricity from renewables as they might not be able to be transmitted with the current available infrastructure.

4.3.3.5 Instability of the local Currency (currency fluctuation)

Stability of the local currency is key to the development of RETs. As it was noted that most, if not all required parts of RETs are imported from other either from Europe or Asia. Unfortunately, the currency fluctuation against the major currencies such as the Euro and Dollar is a setback to RETs' development. In the survey conducted "currency fluctuations" ranked 5th as one of the major obstacles impeding the development of RETs. Citi Business News (2018) reported that although the cedi has witnessed marginal stability against the US dollar, it depreciated by an average of 3.4 percent to the US dollar in 2017. RE developers have identified the fluctuation and more especially the continues depreciation of the currency (cedi) as a major challenge to the development of the RET sector. According to the UNDP and Energy Commission, Ghana (2016), the Ghana cedi (local currency), has depreciated more than 500% to major trading currencies like the Dollar in the last ten years and in 2014 as well as the first quarter of 2015 the local currency depreciated by 14.5% and 12.1 respectively. This trend is a worry to RETs developers and investors as it affects the cost of importing these technologies.

4.3.3.6 Lack/Insufficient Technical Know-How and Inadequate Training Centres

According to the survey conducted, it also emerged that a substantial number of respondents rated the insufficient Technical know-how for the operation and maintenance of RET as a critical barrier for the development of RETs in the country. This obstacle was rated with an average of 3.46 and ranked 6th among the challenges of RETs' development and deployment. Respondents indicated that sometimes there is unavailability of skilled labor to take up some jobs ranging from technical feasibility, installation, maintenance and operation. This is mostly due to the inadequate training centers for RETs which was also ranked 8th on the list of challenges with an average score of 3.20. These findings of insufficient Technical know-how for the operation and maintenance of RET and inadequate training centers were confirmed and in line with studies conducted by Nasirov, Silva and Agostini (2015) in Chile and the study of Reddy and Painuly (2004) in India respectively. Also, in the work of UNDP and Energy Commission, Ghana (2016) it concluded that the lack of skilled manpower to design and install solar PV systems is still a major technical barrier in the sector. This therefore calls for higher educational institutions in RE training to give students hands on practical training of design, installation, operation of RETs. This survey also confirms the study of UNEP (2002) which indicated that the inability of technicians and engineers in Ghana to design heavy duty solar dryers was identified as one of the barriers in the promotion of solar water heater technology (UNEP, 2002). The only institutional training center offering training on Biogas technology in the country is The Hammond-Brew Energy Centre of Kwame Nkrumah University of Science and Technology.

4.3.3.7 *Controlled Market in Favour of Conventional Systems*

Controlled market in favour of conventional systems also emerged as a challenge in the RE development and expansion process. This obstacle was ranked 7th during the survey with an average score of 3.25. Conventional fuels have always been subsidized in the country but little or no such measure(subsidies) are available for RETs. Bensah et al., (2015), indicated that the government of Ghana over the years until 2015, has been subsidizing fuel for transportation in the Ghanaian market and leaving out market forces to determine the price of the commodity even when the price of crude oil increased on the international market. Although no such subsidy incentives have been available for RE products, this makes RETs development and deployment's expansion very slow in penetrating into the market. Again, a key barrier that has emerged in the literature and was confirmed by the study was the fact that there are market design problems, that obstruct the integration of renewables to the already developed conventional fuels. This challenge was ranked 10^{th} on the list of barriers with an average score of 3.18. A study conducted by Nasirov et al. (2015) in Chile also revealed that Market design problems in the integration of renewables is a major obstacle to the development of RETs in the country. Reddy and Painuly (2004) therefore concluded that Market for RETs is subject to imperfect competition with conventional technologies making them unattractive due to the initial investment cost.

4.3.3.8 Lack/Inadequate Consumer Financing Options

The survey conducted also indicated that lack/inadequate consumer financing options is a key barrier to development and deployment of RETs in Ghana especially for off-grid or household-based installations. This obstacle had an average score of 3.20 which is same rank with inadequate training centers on 8^{th} position. Consumers are unable to bear the full cost of initial invest cost of RETs for their household use or small to medium scale businesses and this makes the deployment difficult in the country. Much has not been done as incentives for consumers to acquire Solar PV for their household use. Currently the government of Ghana from 2016 through the Energy commission under the National Rooftop Program is implementing a national rooftop solar PV program with a capital subsidy where solar panels up to a maximum of 500 peak Watts (Wp) are given to prospective residential applicants under some conditions. The government under this program is to distribute 200,000 rooftop solar PV systems for residential facilities. The main focus of the program is to provide 200 MW peak load relief on the national grid through solar PV technology in the medium term (Energy Commission, 2017). With this program being operational with the capital subsidy in place, consumers can afford to install PVs for their home use because their initial cost will be reduced under the subsidy program and consumer financing will not more be a major barrier to RETs deployment.

4.3.3.9 Market Design problems that obstruct the integration of renewable

There is complexity in the integrating of policies especially when it comes to integration of opposing resources. This makes policies prone to poor design and implementing as well as enforcement. Market designs should take into consideration from the individual perspective to a larger perspective in order to ensure proper integration of RE into the market which is already in favour of fossil fuels. Therefore, there is the need to develop a strong customer base such as encouraging public procurement of RE for consumption. If this is not addressed, there is pre determine failure in the integration of RE for communal and social acceptability.

4.3.3.10 Lack of *Implementation and Enforcement*

Ranked 11th on the list of obstacles impeding the development and expansion of RETs is the implementation and enforcement challenge. It is interesting to note that Ghana has policies and regulatory frameworks as well as instruments such as the Renewable Energy Act, Net metering, RE fund, REPO, FIT etc that are key to the development of the RE sector but their implementation and enforcement has been a major challenge to the sector. He et al (2016), posited that, the planning and implementation of RE policies appear disintegrated and therefore the efficiency/effectiveness of FIT has been weakened because other supporting regulations are yet to see their implementation. The implementation and enforcement of the recently developed standards and codes by the energy commission will boast the confidence of investors/developers of RETs. This will lead to quality service provision as well.

4.3.3.11 Lack of Dissemination and Public Awareness

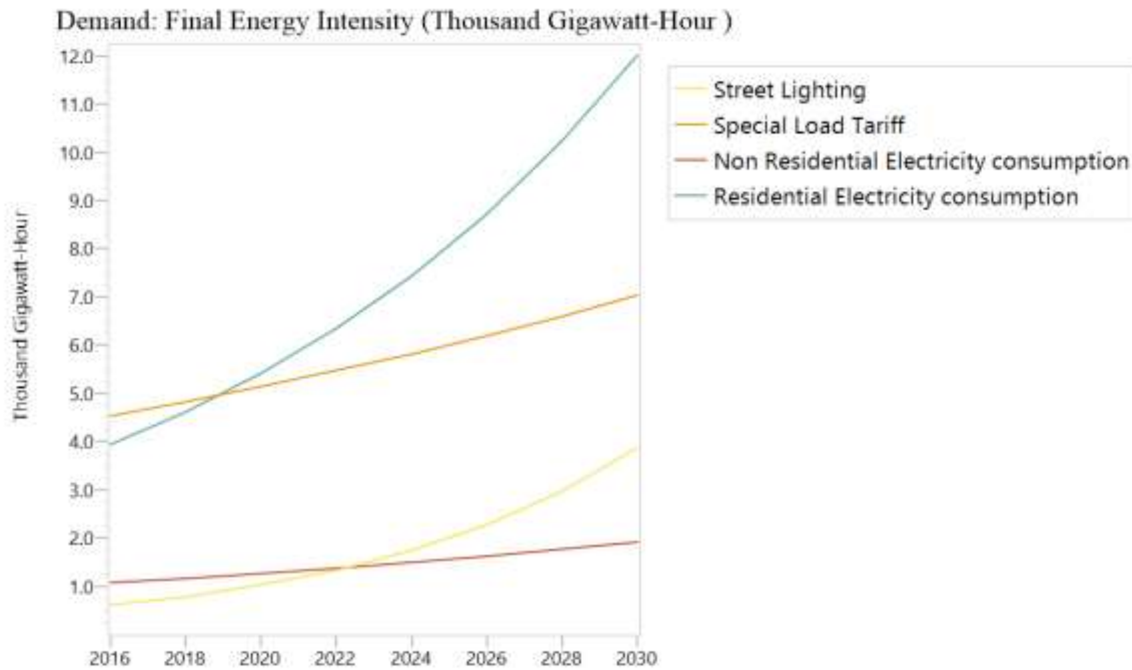
Public awareness on the benefits of RETs to the populace has not been encouraging for the development and deployment of RETs in Ghana. Hence, Lack of dissemination and public awareness ranked 12th with an average score of 2.91. It was revealed in the survey that the public still preserved the RETs to be too expensive to bear despite the long term benefits it has the public in terms reduction in the cost of paying higher utility bills. The public therefore need to be educated on the not just the benefits of RETs to the reduction in cost of utility but also the massive benefits they have in protecting the climate from GHG emissions which are the typical characteristics of the conventional resources. Reddy and Painuly (2004) in their research indicated that consumers while making a decision on purchasing a technology, take the advice of their friends rather than obtaining information from the experts and take decisions which may not be environmentally and economically sustainable in the long run.

4.3.3.12 *Bureaucratic Processes in Developing Contracts and Acquiring Licenses*

Bureaucratic processes in developing contracts and acquiring licenses/ Longer processing times for large number of permits ranked 13th on the list of obstacles in the RE sector scoring an average of 2.89. Developers indicated that longer processes to acquire different licenses and permits is a huge obstacle to the development of the sector. In order to go into large RE investment, developers will have to acquire a host of licenses and certifications ranges from business operation certificates, land title deeds, environmental permits, provision wholesale license, sitting permit, construction permit etc. These certifications and licenses are issued by different institutions and bodies which have their separate requirements before a certification and licenses are issued. This has become a critical challenge as developers have to go through these processes in several months and in most cases years before all certificates, licenses and permits are issued.

4.4 Total Electricity Demand

The level of total electricity demand is expected to rise from 10,129 GWh in 2016 to 24,835.3 GWh in 2030. The analysis shows that demand for street lighting will overtake the demand for non-residential electricity consumption by 2023 all things being equal. This could be due to the ever-increasing demand for street lighting for security purpose in communities and on the streets. It is worthy to note that the outlier for street lighting of 76.4% growth rate between 2009 and 2010 was eliminated from the calculation of average growth rate in the sector. Expected increase in demand from 2016-2030 is presented in Figure 4.3.



(Source: Author's Construct, 2018)

Figure 4.3 Final Energy Intensity (Demand)

It is worthy to note that electricity demand in 2030 is about 2.5 times more than that of the base year (2016). By 2019, demand for residential electricity will surpass that of the special load tariff. This growth can be attributed to the massive rural electrification programs carried out over recent years by various successive governments as well as the governments' commitment to the objective of universal electricity access by 2020 in Ghana.

In a study conducted by Adom et al (2012), titled "modelling aggregate domestic electricity demand in Ghana: An autoregressive distributed lag bounds cointegration approach" indicated that the coefficient for industry efficiency is negative, inelastic and therefore estimated industry efficiency coefficient shows that 1% improvement in industry efficiency achieved, a 0.386% of aggregate domestic electricity consumption is saved per annum and a 1% increase in real per capita GDP leads to a 1.6% increase in aggregate domestic electricity demand, hence, the aggregate domestic electricity demand is expected to see a rise with economic development in Ghana. It therefore confirms why residential electricity demand surpassed that of the special load tariff at a point over the years.

4.5 Total Emissions from electricity Generation under 100-Year GWP: Direct (At Point of Emissions)

From 2016 to 2030 under the BAU total emissions from the electricity will increase from 4,838.8 Mt-CO2eq to 72,543.8 Mt-CO2eq respectively. With an introduction of 10% renewable to replace fossil-based fuels under scenario one termed "Renewable 10 percent" total emissions decreased from 72,543.8 Mt-CO2eq to 64,233.5 Mt-CO2eq indicating an 11.5% decrease in emissions. Based on the 20% replacement of renewable with fossil in the current generation mix, emissions further decreased by 57.7% from the BAU in 2030. And then a decrease of 80.8 using the scenario "renewable 40 percent". The result is presented in Table 4.3.

Table 4.3 Electricity Sector Total GHG Emissions in Ghana

100-YEAR GWP: DIRECT (AT POINT OF EMISSIONS)

ALL FUELS, ALL GHGS

BRANCH: TRANSFORMATION\ELECTRICITY GENERATION\PROCESSES

UNITS: CUMULATIVE THOUSAND METRIC TONNES CO2 EQUIVALENT

SCENARIOS	2016	2018	2020	2022	2024	2026	2028	2030
BUSINESS AS USUAL	4,838.5	14,510.7	24,182.9	33,855.1	43,527.2	53,199.4	62,871.6	72,543.8
RENEWABLE 10 PERCENT	4,838.5	13,323.5	21,808.5	30,293.5	38,778.5	47,263.5	55,748.5	64,233.5
RENEWABLE 20 PERCENT	4,838.5	8,531.1	12,223.7	15,916.2	19,608.8	23,301.4	26,993.9	30,686.5
RENEWABLE 40 PERCENT	4,838.5	6,117.1	7,395.6	8,674.1	9,952.6	11,231.1	12,509.6	13,921.9

(Source: Author's Construct, 2018)

The above result shows that RE has the potential to reduce or eliminate totally GHG emissions if they are replaced with fossil-based fuels for electricity generation in Ghana. The result of this research confirms the study of Kusumadewi et al. (2017), who concluded that "Development of renewable energy source for power generation is very useful in long-term electricity planning and GHG mitigation" after they did a similar study in Thailand.

4.6 Political, Economic, Socio-cultural, Technological, Environmental and Legal (PESTEL) Analysis of Renewable Energy Development in Ghana

Renewable energy take place in space and time and there is the critical need to assess the total "system boundary" of the country that renewable energy projects operate. The stability and positive conditions of these factors are critical to the development of renewable energy projects. Table 4.5 below shows the PESTEL analysis of RE development in Ghana.

Table 4.4 PESTEL Analysis of Renewable Energy Development in Ghana

FACTORS	INDICATORS
Political	✓ Politically and democratically stable (Credible elections every 4 years) ✓ RE target in the national Energy Policy ✓ Government commitment to climate change by being a signatory to COP 21.
Economic	✓ Positive economic indicators • Inflation rate (average inflation rate 11.8 for 2017, 10.4%, 9.6% and 10% for March, April, June 2018 respectively) • 20% Policy interest rate • GDP of 37,053.00 million US dollars as 2015 ✓ Access to wider market within the ECOWAS zone and beyond ✓ RE investment target of 1.4-2.6 billion US dollars by 2020 ✓ Guaranteed FIT tariff for 10 years and subject to renewal after every two years ✓ Tax incentives (10 years tax holidays)
Socio-cultural	✓ Unemployment (percentage of total labour force) rate 5.2% ✓ Youthful population of with a total population growth rate of 2.5 as at 2015
Technological	✓ Availability of wide grid and electricity infrastructure transmission and distribution lines across the and beyond for generated power ✓ Existence of the University of Energy and Natural Resources and the Hammond-Brew Energy Centre of KNUST to train experts in RETs and undertake Research and Development ✓ Acceptability of technological change ✓ Easy accessibility of technical expert and new innovation at the regional and international market due to good international relation.
Environmental	✓ Poorly managed biofuel crop cultivation may also result in deforestation ✓ Existence of climate change policy showing government's commitment to green economy ✓ GHG emission reduction strategy under INDC submitted to UNFCC ✓ Existence of the Environmental Protection Agency (EPA) for environmental assessment of RE projects ✓ Resource availability for RES
Legal	✓ Existence of Renewable Energy Act 2011 ✓ Existence of regulation on standards and grid codes for transmission and distribution of renewable energy electricity. ✓ Independent judicial (court) system

(Source: Author's Construct, 2018**)**

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This part of the study focuses on conclusion and recommendations based on the findings of the research. The recommendations should be taken as suggested strategies to redress the major challenges facing the RE sector.

5.2 Conclusion

Ghana has RE potentials such as solar and bioenergy to help in the improvement in the energy sector and as well increase electricity access across the country. The sector is only crippled with some challenges such as cost of financing high interest rates, high initial investment, grid constraints, currency fluctuations, insufficient incentives, lack of technical skills, inadequate training centres etc. these challenges can be eliminated with pragmatic measures an implementation of already designed policies and regulations in the sector. Government's intervention on the needs to set down appropriate policies to help boost the RE energy market are needed, since there is currently little competition between the renewables and the conventional energies. The country must therefore take advantage of the global market of renewable energy penetration to learn and transfer some appropriate policies and regulations for the development of RETs. In other to keep pace with the high growth rate of the population and the increased economic activities in the country, it is inevitable that there will be exploitation of RE to compensate for increase in electricity demand especially in the rapid development of the country. Renewable energy is not just beneficial for electricity generation but also the ability to mitigate GHG emissions to ensure sustainable development and reduce the impacts of climate changing resulting from the electricity sector.

5.3 Recommendations

Government should create special subsidies and financial incentives regime that are clear and targeted directly at renewable energy. This is because the current general subsidies for business operational in the free zone market (Ghana Investment Promotion Center) does not benefit RE developers and importers of RE components. This could include incentives such as production incentives, insurance, rebates, loans etc. These incentives and financial packages will reduce investment risks as well as absorb investment parts in order to reduce high investment capital requirement. It will also reduce the rate and amount at which investors will have to borrow from financial institutions.

Build Local capacity of technical experts to handle operation and maintenance of RE projects from feasibility to decommissioning. Training cemters should be establishing purposely for RETs. These training centers will focus from technical training to policy makers to influence and advocate for RETs in the country.

For greater relief and electricity generation support on the grid, the current planned net metering system which has already been piloted should be implemented to ensure households, private and public institutions support the grid with their surpluses.

The energy ministry through the energy commission should create avenues and platforms for individual and institutional capacity building about the need to invest in RE projects. In this case financial institutions and insurance companies can be educated on the viability of RE projects so that they can have confidence in financing and insuring RE projects to reduce the high risks. Banks should be motivated to loan out cash to investors through special guarantees from the government and off-takers. This could lead to banks lowering their interest rates once they have higher assurance the project viability and commitment from off-takers.

The PURC should implement and enforce strictly policy on the Renewable energy portfolio obligation to ensure that the market base of renewable energy is broaden and there is legal binding on utility companies to purchase renewable for distribution. That, is a quota of PPAs to dedicated to renewables. This quota should be publishing and must be transparent as well as ensuring strict compliance.

Finally, there should be policy integration of all existing policies and regulations to ensure wholesome implementation and enforcement. The implementation of the RE fund is key to financing this integration and their operations as well as ensuring greater coordination of RE projects, incentives packages etc. Ghana could create a "Green Center" for greater coordination beyond RE to all other sectors working towards greening the environment and making it safe.

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APPENDIX

1. Survey Questionnaire

This questionnaire aims to collect data on barriers/obstacles facing the development, deployment and expansion of renewable energy in Ghana. It is to collect data towards masters thesis of the researcher on the topic "Renewable Energy Planning and Regulatory Framework: Tools for Sustainable Electricity Generation and Low Carbon Development. The case of Ghana". It contains two sections; the first section is the basic information of the company with the second section making up of main data for the study. Section B contains Likert scale items that requires developers to give their views on the barriers/obstacle of renewable energy in Ghana. The scale ranges from 1 to 5 with 5 as extremely relevant and 1 as least relevant.

Kindly complete this survey by picking the most appropriate answer to each question.

This data collection is purely for academic purpose and your confidentiality is highly guaranteed.

SECTION A: BASIC COMPANY INFORMATION

1. Company name ……………………………………………………..
2. What market segment/technology do you operate? a. Solar PV [ ] b. Bioenergy [ ]
3. What is the stage of operation is your company? a. Licensing [ ] b. Full operation [ ]
4. If Licensing, what type of licensing stage is your company? a. Provisional Wholesale electricity supply license b. Siting Permit [ ] c. Construction Permit [ ]
5. ***What is the size of your company (MW)? ………..***
6. ***How many people are employed in your company? …………….***
7. How many of your employees are expatriates?

RENEWABLE ENERGY BARRIERS/OBSTACLES IN GHANA

8. Using the table below please rate the barriers/obstacles of renewable energy in Ghana that impedes the development of the sector on the scale of 1-5 with 5 as extremely

relevant (meaning very key to RE development and if solved will see growth in the sector) and 1 as least relevant (not so important to RE development in Ghana). leave space blank if that barrier is not an obstacle to renewable energy development.

CATEGORY	BARRIER	SCALE				
		1	2	3	4	5
Market	Market design problems, that obstruct the integration of renewables					
	Controlled market in favour of conventional systems					
	Lack of successful reference projects/ Failed past experience					
Economic and Financial	Lack of Access to finance and long-term capital,					
	Cost of financing high interest rate					
	Business climate (currency fluctuations)					
	Lack of consumer financing options					
	Insufficient incentives (tax rebate, etc)					
Technical	Grid connection constraints and lack of grid capacity					
	Difficulty in getting spare parts and equipment					
	Lack of infrastructure facilities					
Legal and regulatory framework	Inadequate standard and codes					
	Administration hurdles in developing contracts, acquiring licenses/ Longer processing times for large number of permits					
Human skills	challenges in Land acquisition					
	Lack of implementation and enforcement					
	Technical skills to operate and maintain RET					
	Inadequate training centres					
	Lack of dissemination and public awareness					

Socio-cultural	Lack of understanding of local needs, Consumer preferences and social biases					

9. In your view what is the single most important policy instruments that is still hindering the development and expansion of renewable energy in Ghana? a. Feed-in Tariff [ ] b. Net Metering [ ] c. Renewable energy purchase obligation/Renewable Portfolio standard (RPS) d. Other [ ] please specify ………………………………….
10. Do your company enjoy any form of subsidies? a. Yes [ ] b. No [ ]
11. If yes, in what form? a. Tax rebate [ ] b. Grants [ ] c. credit [ ] d. export financing [ ] e. others Specify [ ]
12. What recommendation do you have for the development of renewable energy in Ghana…………………………………………………………………………………
…………………………………………………………………………………………

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Research expenditure

ITEM DESCRIPTION	QUANTITY	UNIT PRICE(DZD AND GHS)	TOTAL PRICE (DZD AND GHS)	DOLLAR ($)EQUIVALENT
Flight ticket (Algiers- Accra) return	Return ticket	145700.18**	145700.18	1,374.53
Local transport (Algiers-Tlemcen) return	1	4000**	4000	37.7
Printing of questionnaires and Stationeries	180 pages	1	180	45
Fieldwork hotel Accommodation for data collection	10 nights	165	1650	412.5
Internal travels for data collection	1 person	-	1010	252.5
Long-Range Energy Alternative Software analysis (professional fees)		844	784	196
Hardware storage device	1	260	260	65
Router	1	580	580	145
Airtime for data bundles and communication	6	247	1482	370.5
Report printings for defence Panel	96*5 pages	96	480	120
Comb binding of the reports	5	3	15	3.75
Final printing and Binding				0
TOTAL				3,022.52
Amount given				**3000.00**