

Unraveling the Underlying Mechanisms

A Coevolutionary Narrative of Ghana's Electricity System and the Barriers to Solar Energy contributing to the National Grid

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Abstract

Academic literatures state that the inadequacy of political will, lack of financial incentives, high costs of renewables, low awareness, and prominence of thermal sources is creating barriers to the adoption of renewable energy, despite the favorable environmental conditions for them in Ghana, especially solar. Within the context of sustainability, understanding the mechanisms that have produced these barriers can improve the possibility of identifying pathways to increasing the use of renewable energy in powering development. The importance of identifying pathways is crucial in aiding developing countries, like Ghana, avoid the same high-carbon growth trajectories in the energy sector.

Applying an originally designed coevolutionary framework to the case study of Ghana's modern electricity system, this paper looks to unravel the underlying mechanisms that have produced the barriers to solar energy's uptake on Ghana's national grid. Coevolution is understood as the interdependencies and feedbacks of the electricity system set within and between political, economic, cultural, and biophysical factors. By creating a coevolutionary narrative of Ghana's electricity system the multidimensional integrated factors that have shaped the electricity system were identified. The historic mechanisms responsible for these developments were reinterpreted to understand their relation to the current barriers to solar energy contributing more as a primary energy source. To do this a document analysis of historic archival data and other materials on Ghana's electricity system was conducted and supplemented with interviews with key personal within the electricity sector.

It seems that coevolutions stretching from the construction of the Akosombo Dam, Ghana's first power plant, through the periods of power crisis then power sector liberalization in the 1990s-2000s, to the recent discovery of oil and gas have fostered interdependencies and feedbacks which have greatly contributed to the current conditions prohibiting uptake of solar energy. Particularly, these underlying socio-ecological historical mechanisms have produced the barriers of lack of political will, high costs of solar energy, and prominence of thermal sources.

Keywords: electricity crisis, socio-ecological narrative, socio-economic development, barriers to solar energy, underlying mechanisms

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Abbreviations

Coevolutionary Framework - CF

Economic Recovery Program – ERP

Electricity Company/Corporation of Ghana – ECG

Electricity System – ES

Energy Commission – EC

Government of Ghana – GoG

Gross Domestic Product - GDP

Independent Power Producers – IPP

International Monetary fund – IMF

Megawatt - MW

National Electrification Scheme – NES

National Energy Board – NEB

Power Plants – PP

Public Utilities Regulatory Commission – PURC

Renewable Energy – RE

Selection Environment – Senv

Solar Energy – SE

Volta River Authority – VRA

Volta River Project – VRP

World Bank – WB

1. Introduction

1.1 The Problem

The problem of under-utilization of renewable energy (RE) sources for the electricity sector is a major issue for sustainability in sub-Saharan Africa (SSA) (Kebede, Kagochi & Jolly, 2010). Characterized by an increasing population and income growth, it has been reported that final electricity consumption in SSA is expected to double by 2030 (Sanoh et al., 2013; Welsch et al., 2013). The energy resources being used to meet this growing demand is crucial to sustainability, given the global problems posed by greenhouse gas (GHG) emissions. However, with the importance of alleviating poverty and spurring socio-economic development (SED), SSA governments have prioritized readily available hydrocarbon resources to satisfy electricity consumption (Bradshaw, 2014; Sanoh et al., 2013). This is particularly the case in West Africa, where 70% of the installed generation is run on thermal sources (Mandelli, Barbieri, Mattarolo & Colombo, 2014). Therefore, there is a need to increase RE supply to realize a more sustainable electricity system (ES).

Despite the availability of RE resources in West Africa, their development in supplying electricity generation is relatively low, contributing under 30% to the region's ES (REN21, 2014). Approximately 99% is from hydropower, while non-hydro RE (solar, wind and modern biomass) is just 39MW (2014). Given the controversies surrounding hydropower and modern biomass in relation to their sustainability, solar and wind are perceived as the greener of the RE resources (Hancock, 2015). Of the two, solar energy (SE) has the higher potential in West Africa estimated at 1,265,000,000MWh/year, but its current installed capacity is below 10MW (Mandelli et al., 2014; REN21, 2014).

Understanding the barriers to RE development in West Africa is crucial in identifying pathways for increasing RE supply to the electricity mix. Much scholarly research has been done on the barriers, but what remains understudied are the underlying socio-ecological mechanisms that produced these barriers locally (Hancock, 2015). Therefore, this research aims to fill this research gap. I conduct a case study research of Ghana, which is an important case in West Africa because of its higher levels of development in socio-economy and electricity sector. Specifically, I will look to understand the barriers preventing SE from contributing more to the supply mix, given that SE is the only RE which Ghana has managed to install but on a very small scale (REN21, 2014).

By applying a coevolutionary framework (CF) to narrate the story of Ghana's ES, I plan to determine the socio-ecological historical factors producing the barriers to SE uptake on Ghana's national grid. I

provide a novel approach to answering sustainability questions using holistic and complex systems thinking with an historical narrative (Rotmans & Loorbach, 2009).

1.2 Research Aim, Objective and Questions

The research aim is to contribute to academic literature on barriers to SE uptake onto Ghana's national grid by determining the underlying mechanisms that have produced the current barriers. There is much academic research on barriers to SE in Ghana (Quansah, Adaramola & Mensah, 2014; Asumadu-Sarkodie & Owusu, 2016; Attachie & Amuzuvi, 2013; Gyamfi et al, 2014; Atsu, Agyemang & Tsike, 2016). However, these academic papers fail to explain fully how these barriers to development of solar is impeded by the longer historical developments of Ghana's ES. To fill this research gap, my research applies a CF as first developed by Norgaard (1994) and then furthered by Kallis (2007) to create a socio-ecological narrative of Ghana's ES to unravel these underlying mechanisms. Therefore my overarching research question (RQ) is:

How have the underlying socio-ecological mechanisms hindered SE in contributing to Ghana's on-grid electricity supply mix?

The complexity and multidimensional nature of the problem demands a holistic approach to answering the question. Coevolution allows an integration of socio-ecological contextual environments on different scales for a more comprehensive study (Kallis, 2010). To guide my research I study the integration of power plants (PP) onto the grid, and the socio-ecological conditions in which these decisions were made. Tracking the PP and deciphering the socio-ecological conditions will help me discern patterns and mechanisms which have contributed to the evolution of Ghana's ES. A more complete picture of Ghana's ES narrative is made, allowing us to identify the underlying mechanisms responsible for the barriers to SE. Thus my research objectives are to:

- Identify different PP that have been considered, and integrated, onto Ghana's national grid.
- Define the socio-ecological conditions in which these decisions have been made over the course of the National Grid's lifespan.

To fulfill these objectives I applied the CF (hereafter referred as my CF) to construct three phases of Ghana's ES evolution. The three phases are: Hydro Era, Thermal Complement, Thermal Dominance. For each phase there is a sub-RQ based on my CF, elaborated on in the Methodology, to guide the study of these historical developments:

Sub-RQ 1: Hydro Era (1951-1983): *How has hydroelectricity dominance in the supply mix contributed to barriers to SE in the current Selection Environment?*

Sub-RQ 2: Thermal Complement (1983-2005): *How has thermal complement to the supply mix contributed to barriers to SE in the current Selection Environment?*

Sub-RQ 3: Thermal Dominance (2005-2017): *How has thermal dominance in the supply mix contributed to barriers to SE in the current Selection Environment?*

By answering these sub-RQs, I can identify the mechanisms that have produced the different eras of Ghana's ES and determine how they have related to the barriers to SE.

1.3 Thesis outline

In the following section I elaborate on my ontology and epistemology, and explain my CF. Then I discuss the strategy, materials and methods used to operationalize my CF. The fourth section clarifies what coevolutions I am studying and the following three sections are the coevolutionary reinterpretations of the three respective phases with each phase consisting of a results chapter which ties back to the respective RQ. Finally, I discuss the results and contribution of my research in relation to broader theories on development and energy and end with the conclusion for future research.

2. Methodology

2.1 Ontology & Epistemology

I adopt a critical realist perspective as my ontology, which then informs my epistemology, namely the use of Norgaard's CF.

Bhaskar (2008) posits "it is necessary to assume for the intelligibility of science that the order discovered in nature exists independently of men, i.e. of human activity in general (p. 17)." As Alvesson and Sköldbberg (2009) simplify, critical realism understands that there is a reality independent of human social constructions, and from careful examination of the underlying patterns we can determine some kind of laws.

There are two aspects of this careful examination of underlying patterns I wish to elucidate in regards to my research. The first is the demand of a certain degree of scientific objectivity during this examination, which I plan to achieve with strong objectivity, proposed by Haraway (1988). Strong objectivity, within the context of my research will be achieved by virtue of the rigorousness of my methodology and upfront explanation of methods used in collecting data. Second is to attain a

holistic impression of the underlying patterns in conjunction with critical realism’s search for deeper understanding of the mechanisms that generate empirical phenomena i.e., evolution of Ghana’s ES (Alvesson & Sköldbberg, 2009). It is with my CF that I plan to study the underlying socio-ecological mechanisms that produced barriers to the development of SE as a major primary resource in Ghana’s on-grid electricity supply.

My simplified ontological model as illustrated in figure 1, demonstrates the ES as embedded in larger society and environment systems and is based on my CF. I further expand my ontology and epistemology in the following section.

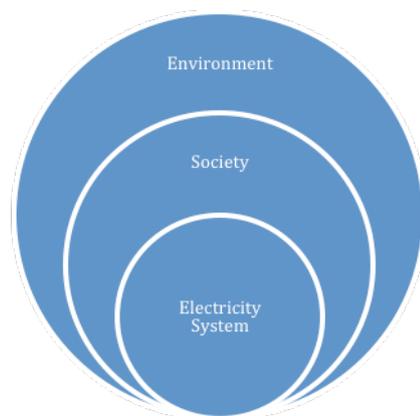


Figure 1 Original Ontological model representing the ES as embedded in larger society and environmental system. Source: own illustration.

2.2 Coevolutionary Framework

2.2.1. Origins

Norgaard (1994) is widely regarded as the founder of the CF and its application on coupled ecological-economic systems; yet the theory of coevolution originated from biological research by Ehrlich and Raven (1964). Advancing the concept Kallis (2007: p 5) explains coevolution as a “general process of generation of new variation and selection,” much in line with Darwinism descriptions of evolution and similar to strains of transition management and complexity thinking (Rotmans & Loorbach, 2009). The main idea of coevolution is that it is a process of coupled change between social and environmental systems through a combination of feedbacks and interdependencies which coevolve to change structures and the systems inter-relationships (Kallis, 2007). Geels (2005) multi-level perspective provides a similar approach to uncovering historical mechanisms, however the CF is better suited for answering my overarching RQ because it allows my research to study the varied

socio-ecological dynamics that produced these mechanisms, which I define in the following sections (Kallis, 2010; De Haan & Rotmans, 2011).

2.2.2. Application to Research

Kallis (2009) asserts that to conduct a coevolutionary analysis the research should specify variations, explain interactions and selection, and combine with other modes of explanation. The application of my CF falls short of a full coevolutionary analysis, but rather provides a comprehensive research method to collecting relevant data in piecing the narrative of Ghana's ES. Within the scope of my research my unit of study was PPs and their source of primary energy determined their variation. I combined the interactions and selection definitions to create a new term called the Selection Environment (SEnv). My CF was an entry point into the history of Ghana's ES and through my analysis of the data, explanations for the processes were derived. In that sense my research was an explorative and descriptive study (Mayring, 2014).

Therefore, the main factors and relationships that have shaped the development of the ES, particularly for electricity supply, could be identified. Toward fulfilling the research aim, the coevolutionary reinterpretation would enable the research to connect the longer historical factors to the current barriers to SE's uptake on the national grid. As a result, the underlying mechanisms that have produced the barriers could be discerned.

Selection Environment and Variations

In constructing a more holistic narrative of Ghana's ES, my CF includes political, technological, cultural, economic and biophysical factors, similar to Foxon's (2011) application. These factors interact with each other creating complex interdependencies and feedbacks, which I call coevolution, which then produce and reproduce a SEnv in Ghana that may be conducive to a particular Variation of PP. The scales of my framework are mostly the international, due to the high level of interconnectivity between international factors and Ghana's electricity system, and national levels, with some reference to regional dynamics specifically for biophysical and technological factors. Therefore, the SEnv is the arena in which the varying factors of political, technological, cultural, economic and biophysical form interdependencies and feedbacks to coevolve and set conditions for a Variation of PP being constructed, depending on its fitness in the SEnv.

Embedded in this SEnv are sub-systems of electricity supply and demand. As figure 2 demonstrates, electricity supply and demand coevolve with each other and are also tied in the coevolutions with

Ghana's political, cultural, economic, and technological systems which are set within the wider ecological systems.

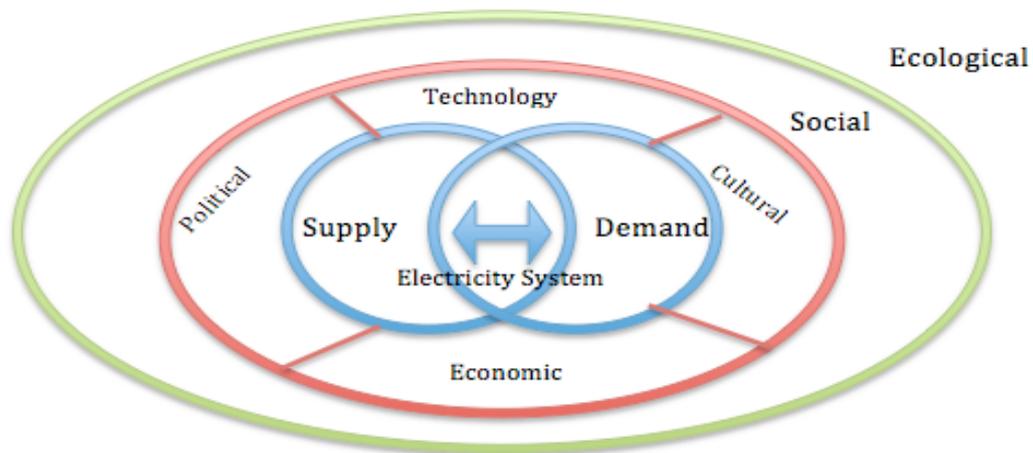


Figure 2 Conceptual model of CF displaying the ES and sub-system of supply and demand, and conditioning factors of political, economic, cultural and technology within the wider social system, which is embedded in the ecological system. Source: own

The Factors

The factors below are original conceptions curated to fit with the specifics of Ghana's SEnv:

Political: relates mainly to institutional arrangements and organizations, policy/acts, and political/development agendas involved in electricity governance stemming from the national (National Electrification Scheme) to international level (liberalization, IMF).

Technology: refers to the PPs that supply electricity to the national grid and other PPs which have been considered as potential providers. After the PP is installed it actively engages in the SEnv, so consideration for its performance is made.

Cultural: refers to practices and perceptions of the domestic electricity consumers. Particularly, how they use electricity and the price they pay for it. To a minor degree consideration for demographic changes are included (rural-to-urban, population growth).

Economic: pertains to economic changes at national (GDP) and international levels directly related to electricity supply or demand, price of electricity, tariffs, market in response to and impacting on electricity supply-demand processes. Economic is also the financial situation in regards to the funding for/ investment in PP.

Biophysical: relates to the main biophysical processes influencing the development of PPs and the conditions in which the technology performs. For example, low rainfall causes low output from hydroelectric dam.

3. Research strategy, material & methods

3.1 Strategy

The research strategy was based on my CF and reference was made to Kallis' (2010) strategy of researching and analyzing archival works and conducting interviews in his paper on water supply in Athens.

The task was to determine the SEnv and define the factors that produced a new variation of PP throughout Ghana's ES history. Three periods were discerned based on the preliminary findings of my CF. That is, the Hydro Era, Thermal Complement and Thermal Dominance. These periods were defined by which variation of PPs dominated the supply system. To answer my sub-RQs, it would be a matter of understanding how the mechanisms that produced these variations have contributed to the barriers to SE in the current SEnv.

As a first step, a timeline of events that shaped Ghana's ES was formulated. The events which were deemed relevant, outside the construction of PPs, were based on the factors of my CF. Therefore, data collected toward creating this timeline fell within the spheres of politics, economy, culture, technology and biophysical. The resultant timelines (see figures 3,4 and 5) consisted of year PP was constructed, historic policy acts, major political events, establishment of organizations and institutions, developmental programs, reports and planning studies, periods of either accelerated economic growth or electricity demand, tariff hikes, climatic events, urban-rural population figures, and crisis all to do with the ES.

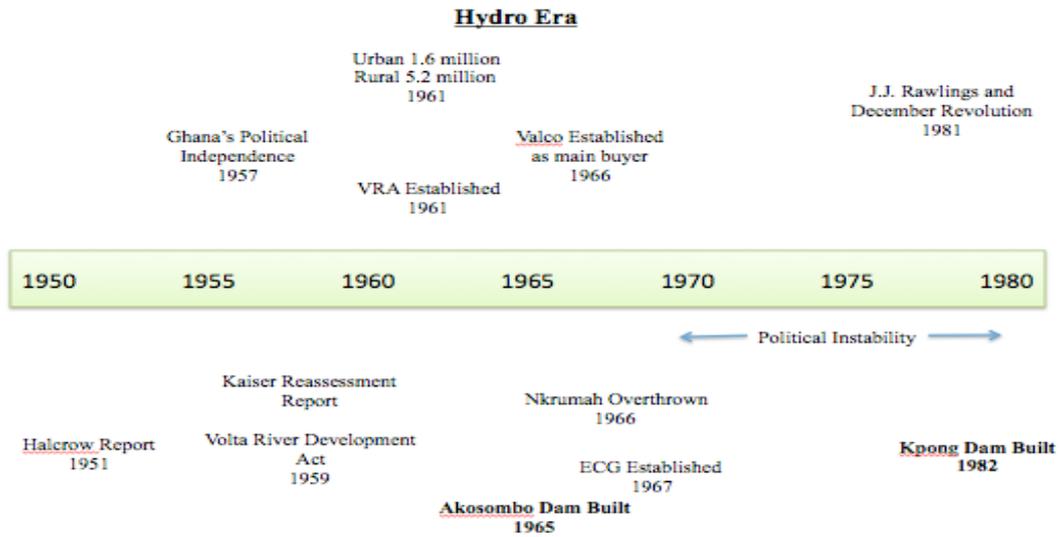


Figure 3, 4 and 5 respectively show CF based chronology of Ghana's ES from 1950-2017. Bold text represent PP constructed and arrows show extended events. Source: Own.

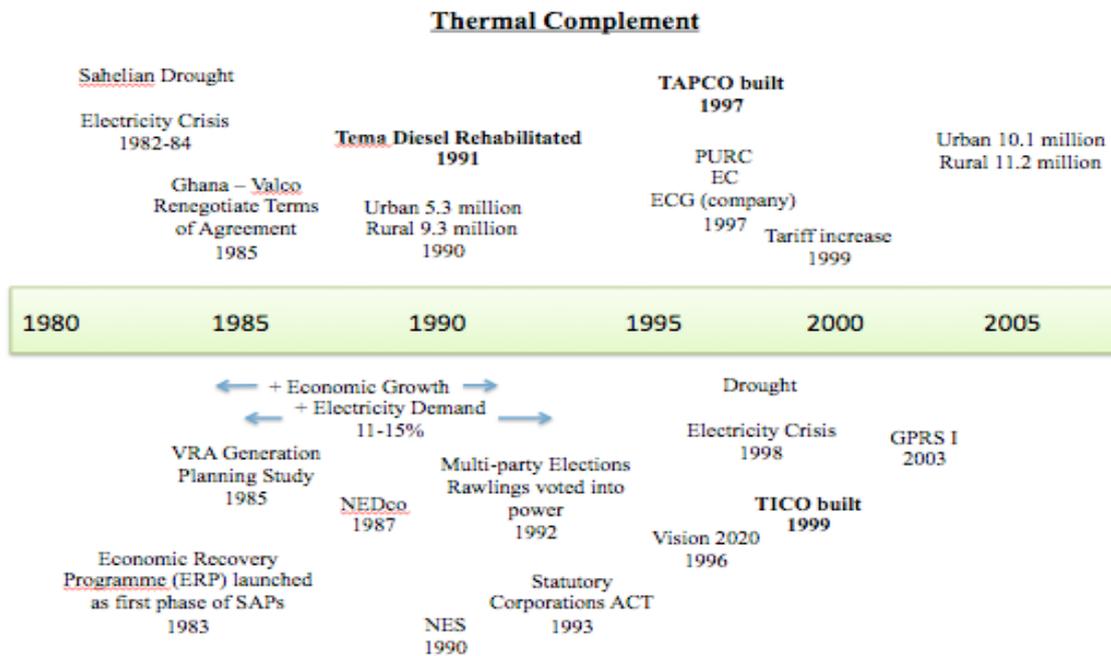


Figure 4

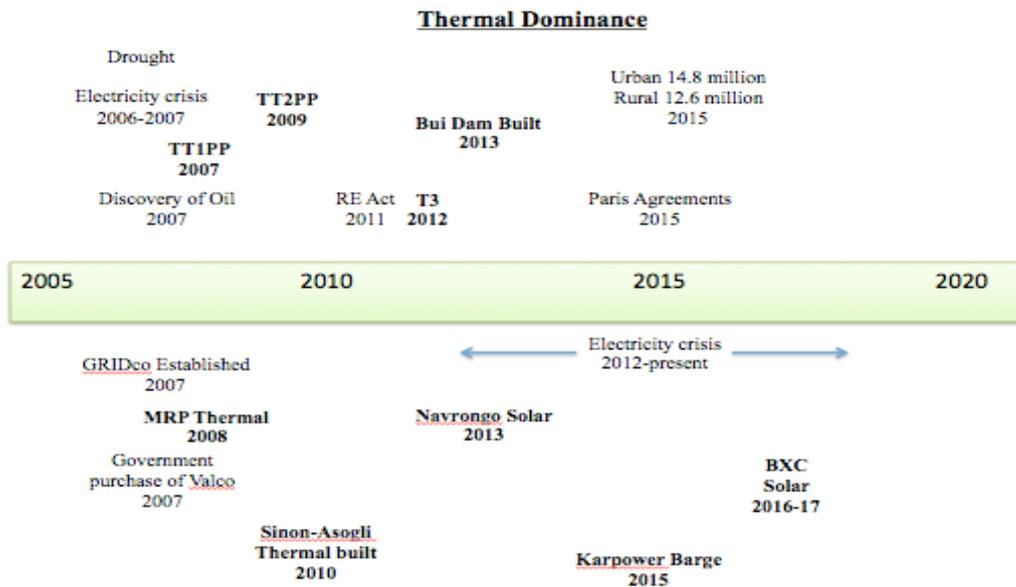


Figure 5

The timelines became a starting point for collecting data. I targeted the databases and archives of libraries of the main state organizations and institutions identified in the timeline for data on Ghana's ES. I then conducted a Google Search for developmental policy documents and filtered for the text which discussed energy policy and electricity (refer to Appendix 1). I referred to political text on Ghana's prominent leaders and historical economic texts on the state and evolution of Ghana's economy, specifically the electricity sub-sector. Lastly, I targeted personal in prominent organizations and institutions involved with Ghana's ES to conduct interviews for the purpose of supplementing the texts and enriching the narrative.

3.2 Materials

Given the interdisciplinary nature of my CF, a broad range of data types and materials (refer to Appendix 1) were pulled.

The Volta River Authority (VRA) Public Library acted as the main source of literature on Ghana's ES over the course of the three periods, but other public libraries and academic and non-academic online databases complemented with relevant data based on my CF, with particular emphasis on the ES.

For the Hydro Era, historical text on the Volta River Project (VRP) and Nkrumah's political and economic ideologies were the main sources of data. The Thermal Complement consisted of a wider range of material from historical and economic text and academic papers to VRA Annual reports,

Master Study documents by VRA and Energy Commission (EC), and essays from conferences and symposiums discussing energy in Ghana. For Thermal Dominance the material gathered was similar to the Complement but with more sources from online databases and EC studies, official government developmental documents as well as online articles for more recent events.

Four interviews were conducted with personnel within Ghana's ES, two from the VRA, one from the EC and another from Ghana Gas Company. Each interview had its own function (refer to appendix 2) in supplementing the other data collected but were specifically meant to gain insights into the broader connections of my CF over the three phases and its relation to barriers to SE. Therefore, the interviews were in-depth since it best fitted with my aims of stimulating conversation on the interviewee's own narratives of the ES (Ritchie & Lewis, 2003).

3.3 Analysis

Though a concrete coevolutionary approach to analyzing data has yet to emerge, the strength of a CF lies in its potential of an historical analysis of interdependent ecological and economic systems (Kallis, 2009). To fulfill this potential for my research, a document analysis was conducted to analyze then synthesize the historical and contemporary data sources toward producing a socio-ecological narrative of Ghana's ES.

A document analysis consists of a process that includes "finding, selecting, appraising (making sense of), and synthesizing data contained in documents (Bowen, 2009: p 28)." Following on Bowen's (2009) description of the process in document analysis and Mayring's (2014) steps in qualitative content analysis, I inductively developed three categories to compress the factors in my CF to find and filter the data in the materials. These categories were the socio-technical, socio-economic and biophysical. Socio-technical referred to the PPs and governance structures controlling generation, socio-economic was how electricity is made productive and consisted of the actors that make up the economy mainly the industry, service and domestic sectors and the biophysical remained similar to its original conception. Once the data from the materials was categorized, references to other sources were made as a way of triangulating the data and corroborating the developments of the ES throughout the phases (Bowen, 2009). Interpretation of the data demanded constant iteration resulting in the emergence of patterns and mechanisms responsible for the developments of Ghana's ES and its contribution to the barriers to SE. The interviews acted as supplements to the appraised data and the final result of the analysis was a coevolutionary reinterpretation/narrative of Ghana's ES.

Because a large portion of the text is historical, to a lesser degree an overarching historical analysis was conducted based on Gardner's (2011) definition as a "method that seeks to make sense of the past through the disciplined and systematic analysis of the 'traces' it leaves behind (p. 135)." The traces referred to in the definition reflect the aim of my overarching RQ, to understand the historical mechanisms that have produced the barriers to SE, thus the indulgence in archival texts to do with the ES.

4. Contextualizing the Study

My CF encompasses a wide variety of potentially relevant information, but the focus of my study is on the evolution of Ghana's sub-system of electricity supply in the post-independence era. Given the interconnections of supply and demand of electricity, my research involves a study of how demand has impacted on supply and vice versa, and these relationships form the ES (Adom, Bekoe, Komla & Akoena, 2012). Worth noting is that Ghana's energy supply mix has and is still dominated by traditional biomass at 64%, while electricity is currently contributing around 9% (Gyamfi et al., 2014). Recent studies show the national electrification rates are at 72%, with urban rates at 78% and rural around 30% (Atsu, Agyemang & Tsike, 2016; Gyamfi et al., 2014). Over the course of the Hydro Era through to the Thermal Complement and Dominance the general trend in supply-demand balance goes from, higher supply relative to demand, then to constantly rising demand relative to fluctuating supply (Eshun & Tuffour, 2016).

4.1 Electricity system

4.1.1 Supply

From its conception Volta River Authority (VRA), state-owned power utility, was mandated to keep supply of electricity ahead of demand, and also insure that all Ghanaians had access to electricity. Currently, the VRA owns 88% of generation assets, while the rest are owned by independent power producers (IPP) (Gyamfi et al., 2014). In the context of my study, the main factors that have determined whether it fulfills its mandate are political, ecological and technological.

4.1.2 Demand

Electricity demand is influenced by the amount of customers the Electricity Company of Ghana (ECG), distributing utility, distributes to and how the electricity is made productive. There are four main types of customers and that is residential, commercial, industry and export. Ghana has been working under many developmental agendas, but in the context of electricity, the National Electrification

Scheme (NES) has played a direct role in expanding ECG and Northern Electricity Distribution Company (NEDCo) customer base.

It is worth noting that these are not all the entities and factors involved in the development of Ghana's ES, but they represent the major ones. It is also worth noting that some of the feedbacks between the systems have longer delays than others, for instance change of government and their developmental agenda takes a shorter time to impact on macroeconomic performance in comparison to the availability of cheap electricity to behavior of electricity users.

5. Analysis & Results

5.1 The Hydro Era (1951-1982)

Sub-RQ 1: How has hydroelectricity dominance in the supply mix contributed to barriers to SE in the current Selection Environment?

Volta River Project (1951-1957)

As momentum was building towards the political independence of Ghana, led by Kwame Nkrumah's socialist Conventions People's Party, the idea of the Volta River basin harnessing hydroelectricity was to be merged with the ambitions of the new Republic (Moxon, 1984).

Before Nkrumah, however, the colonial administration had recognized the potential of the Volta River as a potential source of electricity and its commercial use in powering an aluminum smelter to harness bauxite deposits for export (Moxon, 1984). By 1951 the UK based Halcrow submitted a report, with a number of recommendations including how the VRP should be handled by the soon to be self-governed Ghana, given the size of the project (1984). Specifically, the new government should own and operate the hydroelectric dam and a private company should handle the more specialized operations of aluminum smelting (1984).

Kwame Nkrumah the leading political advocate for self-governance was committed to the idea of the VRP supplying electricity to Ghana from the start (Biney, 2011). Before the realization of the hydroelectric potential of the Volta River, private decentralized diesel generators mainly for mining operations characterized Ghana's electricity supply (ISSER, 2005). For Nkrumah, the prospect of transforming this small-scale electricity operation to one with huge amounts of hydroelectricity was in line with his socialist leanings of centralized rapid industrialization in fulfilling his electoral

mandate of “seeking first the fruits of the political kingdom from which material benefits would flow” (Biney, 2011: p 58). Nkrumah had been convincing the public that with political independence there would be many benefits for Ghana, and he based his campaign for independence on the promise of an “economic paradise” which he would establish (2011: p 58). At the heart of this “economic paradise” was the cheap hydroelectricity supplied from the VRP, which would enable Ghana to actualize SED as was experienced in the industrialized nations (Nkrumah & Obeng, 1997).

Britain’s economic position after the end of World War II combined with a crisis in global aluminum industry derailed the VRP seeing that a large sum of the funding was not forthcoming (Moxon, 1984).

“Economic Paradise” at what Price? (1957-1961)

On March 6th 1957 Ghana gained independence with Nkrumah as president. However, the euphoria of the moment gave way to harsh realities of Ghana’s economic position, as Ghana’s over-dependence on the export of cocoa would be revealed (Biney, 2011). A year or two after independence, the price of cocoa on the world market had been falling, consequently straining Ghana’s reserves and impacting on the prospects of developmental projects, including VRP (Moxon, 1984). But a series of fortunate events led to US President Eisenhower inviting Nkrumah to the White House to discuss matters of the VRP (Moxon, 1984). Nkrumah explained the significance of the VRP to Ghana’s aspirations of diversifying its economy, reducing dependence on cocoa and attaining some level of industrial development, all of which could only be achieved with cheap electric power (Biney, 2011). Important to note that before Eisenhower, Truman’s 1949 inaugural address lay down the markers for the US foreign policy in supporting modernization schemes in Asia and Africa, as a response to the growing Communist threat (Miescher & Tsikata, 2010).

Kaiser Engineers were soon after commissioned to re-appraise the project beginning with a reassessment report, in 1958 (VRA, 2011). The Kaiser Reassessment report relocated the dam at Akosombo with an electricity supply reaching 1,100MW with additional phases completed and the addition of two more dams at Kpong and Bui (Moxon, 1984). Finally in 1961, with Kaiser Engineers establishing an aluminum company (Valco) as the main buyer of electricity at a very cheap rate the international loans to fund the project were approved (1984).

Also in 1961, the VRA was established as a state-owned enterprise under the Volta River development act, with the responsibility for the generation, transmission and distribution of electricity, and supplying cheap electricity to Valco under a 30-year contract (Nkrumah & Obeng, 1997; Moxon, 1984). The added task of transmission was a consequence of the Kaiser report, which

made provision for transmission lines to feed electricity to a new restructured and expanded national grid situated mostly in the southern part of Ghana (Moxon, 1984). In his speech to the National Assembly, Nkrumah illuminated this benefit seeing that “it would provide a large and reliable source of electric power for many years to come for Ghana’s development” (Nkrumah & Obeng, 1997: p 282).

Man’s Greatest Lake (1961-1966)

The VRP demanded a rock-fill dam, but the key biophysical consideration in building the dam was the variations in flow from the Volta River (Moxon, 1984). The Volta River experiences a certain timetable of rise and falls in level throughout the year (Moxon, 1984). Thus, to ensure that a reserve of power was available at all times, the creation of a lake was necessary since the flows from the river varied so widely between flood and low level (Nkrumah & Obeng, 1997). The lake created would cover a surface area just below 3500 squared miles, making it the largest man made lake in the world (Moxon, 1984). Calculations to determine rates of evaporation from the lake were considered, however a lack information would leave the engineers blind to the possibility of reduced rainfall in the Volta basin catchment causing electricity output shortages (1984).

In 1965 power from the PP at Akosombo was produced for commercial use, then in 1966 was formally inaugurated by Nkrumah (Moxon, 1984). The Electricity Corporation of Ghana (ECG) replaced the old Electricity Department as the state-owned electricity distributor after the inauguration (Nkrumah & Obeng, 1997; Moxon, 1984). Additionally, another reservoir between Akosombo and Kpong had been created in the wake of the dam’s completion, laying the way for the next construction at Kpong (Moxon, 1984).

But at the time of the Akosombo’s dam inauguration Nkrumah’s position as head-of-state was under serious threat from both external forces to do with the Cold War, and internal grievances to do with handling of the economy and creation of an authoritarian regime. Nkrumah had transformed the political environment from a multi-party system, to one-party state, finally to a dictatorship (Moxon 1984; Biney, 2011; Miescher & Tsikata, 2010). Justifying these transformations was the back-bone of Nkrumah’s political ideology and belief that development of the economy could only be achieved through a modern socialist state, which would directly operate and control natural resources for the industrialization of the nation (Biney, 2011). The creation of this modern socialist state was based on electrification, which he had now delivered but at several costs to the country’s financial reserves, and from which, as Arthur Lewis the Special Commissioner for the VRP had cautioned Nkrumah,

would not deliver the “economic paradise” he sought to create for the Ghanaian people (Moxon, 1984; Biney, 2011; Miescher & Tsikata, 2010).

Political and Economic Instability (1966-1982)

When Akosombo began commercial operations, Ghana’s demand for electricity was approximately 20% of the supply, or 75MW (Moxon, 1984). Following the overthrow of Nkrumah the new police-military style government opened negotiations with Ghana’s neighbors Togo and Benin to export electricity, since they had grown suspicious of Nkrumah during his transformation (Moxon, 1984). Facing a massive foreign debt of 300 million pounds sterling and critically low national reserve, the new government was now made to embark on a period of stringent economic measures, which stymied the progress of the VRP’s plan to follow suit with the Bui project on the Black Volta (1984). Overall, the booming sales of electricity to industry and to the public and mining operations from the national grid quickly established interdependencies between Akosombo and Ghana’s economy, which was now seeing new industry develop as a result of the available electricity (1984).

Aggravating the economic situation was the prolonged Sahelian drought of the 1970s (VRA, 1982). During the period VRA’s operations were constrained and electrical output curtailed because of the reduction in Akosombo’s lake levels (Moxon, 1984). However, in spite of the harsh national economic situation, political instability, and uncertain hydrological forecasts, the VRA as the governing institute in charge of supplying Ghana’s demand for electricity, was able to raise the funds from eight international lending agencies for the construction of another power plant (Moxon 1984). In a report completed by Canadian International Development Agency in 1975, Kpong dam was confirmed as most feasible form of electricity generation, as opposed to an oil-fired thermal plant which had also been rejected in Kaiser’s report, on the grounds of being too expensive due to the cost of importing fuel and thus raising the price of electricity (Moxon, 1984; Miescher & Tsikata, 2010). The lending agencies involved in the Kpong project included a mix of Middle-Eastern, European and WB funds, but by far the largest contributor was the VRA who had saved from local power sales and sale of bonds to complete the Kpong PP inaugurated in 1982, at 140MW capacity (Moxon, 1984).

By the end of 1982, Ghana’s on-grid electricity supply mix was 100% hydro powered with total generation at 4,932GWh (Akosombo at 4,095GWh and Kpong at 838GWh) (VRA, 2016).

Results

The hydro era's contribution to the barriers to SE in the current SEnv stem from the (a) creation of a cheap source of electricity (b) embedding the entire supply system on the hydrological system of the Volta Basin, and (c) concentrating grid supply in southern major urban centers.

(A) The existence of a potentially vast source of hydroelectricity from the Volta Basin and Nkrumah's belief in creating an 'economic paradise' in Ghana through a rapid socialist industrialization program setup the foundations of the relationship between Ghana's political and economic systems with hydro dominated supply mix. Given that there was virtually no demand for electricity domestically, the creation of Valco as the main purchaser and beneficiary of electricity was crucial in the establishment of the hydroelectric system. The main attraction of the VRP to the international actors was the availability of cheap electricity to power aluminum manufacturing. These interactions formed the basis of interdependencies of Ghana's socio-economy with cheap electricity. Though the electricity was supplied mainly to Valco, the majority of the leftover was directed to urban domestic users who the ECG supplied with cheap electricity. This mechanism would coevolve with the growing domestic demand of electricity over the course of the thermal complement fostering feedbacks with nation-wide perceptions of electricity being seen as cheap and contributing to the political interest, in the current SEnv, to keep electricity tariffs uneconomic. Resultantly, uneconomic tariffs would contribute to the barriers to SE by rendering any new variation of PP as being too expensive.

(B) The construction of the Akosombo and Kpong Dam within the Volta Basin immediately made Ghana's electricity supply dependent on its hydrological processes for favorable electricity output toward Ghana's socio-economy. The result of this mechanism would significantly contribute to the electricity crisis in the current SEnv which has diverted GoG's attention and therefore reduced interest on using SE on the national grid and rather favored the use of conventional thermal sources to resolve the crisis first to continue economic growth toward development.

(C) The establishing of the national grid in the southern regions of Ghana immediately created imbalances in electricity supply with other regions of the country. Not only was electricity disproportionately concentrated in the south, but there was an urban-rural element to the imbalance and these would lead to nation-wide developmental projects based on increasing access to electricity in the North, and further developments to achieve universal grid access in the country. Consequently, the unexpected failures of electricity supply to grid demanded alternative programs to increasing electricity access in Ghana and these would take the form of rural SE development programs which would contribute to the current low awareness of SE especially among commercial entities, acting as a barrier to its uptake for utility-scale application.

5.2 Thermal Complement (1983-2005)

Sub-RQ 2: *How has the establishment of thermal complement to the supply mix contributed to barriers to SE in the current Selection Environment?*

Introduction

Failure of successive governments after Nkrumah to rescue the economy from its deteriorating situation consequently led to Rawlings' December Revolution in 1981. GDP per capita had reduced alongside substantial increases in inflation, while the exchange rate became increasingly overvalued with over half of Ghana's foreign exchange going into oil imports (Debrah, 2009; Tsikata, 1986). As a result of these harsh conditions many industries collapsed and scarcity of goods led to high prices on the market for basic commodities forcing a mass exodus of Ghanaians to neighboring African countries, primarily Nigeria (2009). Rawlings, who had conceded his first revolution in 1979 to the People's Nationalist Party's civilian rule via democratic elections, resumed power with another military coup and established the Provisional National Defense Council (PNDC) as a military government (Shillington, 1992). The PNDC, catalyzed by leftist revolutionary ferment, aimed at recapturing Ghana's economy from neo-colonial forces and these ambitions would have far reaching implications for the coevolutions of ES in Ghana (Tsikata, 1986).

Compounding Factors

"If the PNDC government was concerned with cheap popularity, we would not have presented you with such a budget. It is hard to ask someone who has already tightened his belt to the last hole to go and make an additional hole to tighten even further... [but] the steady economic decline which has affected the country over the past decade has had to be arrested and the longer we wait, the harder it would be."

- Chairman Rawlings commenting on austerity measures imposed under Economic Recovery Program (Shillington, 1992: p 100).

To fix the economic situation in the country the PNDC, with support from the WB and International Monetary Fund (IMF), outlined an Economic Recovery Program (ERP) in 1983 (Shillington, 1992). The core objective of ERP was to devalue the Cedi (local currency) and to do this PNDC would need to engage in core elements of neoclassical approach to economic development (Debrah, 2009). These measures took the shape of state divestment from agricultural and industrial sectors to attract private investments to increase production, as well as an austerity budget, which took away subsidies and sought to increase efficiency in collection of revenues (Shillington, 1992).

Without having to contend with democratic elections, the PNDC were able to impose the unpopular measures under the ERP within an increasingly fragile socio-economic situation. A direct result from the removal of state subsidies was the rocketing of commodity prices by 100-300% (Shillington, 1992). Other exogenous factors would increase the stress on the situation. From a socio-economic aspect, factors from Nigeria led to the expulsion of Ghanaians, and in under month Ghana had to reintegrate almost 10% of its population adding further pressure to the strenuous economic situation (1992).

Compounding this situation was the advent of the 1983-84 droughts across the Sahel. The droughts represented the end of a buffer period in Ghana’s rainfall regime (Owusu, Waylen & Qui, 2008). As figure 8 shows, the previous rainfall regime set between 1951-1970 is known to have had more rainfall and the buffer period roughly between 1970-1980 was characterized by reducing rainfall across West Africa. Resultantly, a new rainfall regime between 1981-2000 of lower rainfall, particularly for the northern parts of the country, was ushered in by the severe droughts (Owusu & Waylen, 2009). These biophysical processes drastically reduced inflows into the Volta Basin’s catchment since “diminished rainfall towards the end of the rainy season leads to prolonged dry season with increase evaporation,” which correspondingly reduced Akosombo dam’s power output to 2,095GWh in 1983 and 1,469GWh in 1984, less than half of the expected (Owusu, Waylen & Qui, 2008: p 206; VRA, 2016).

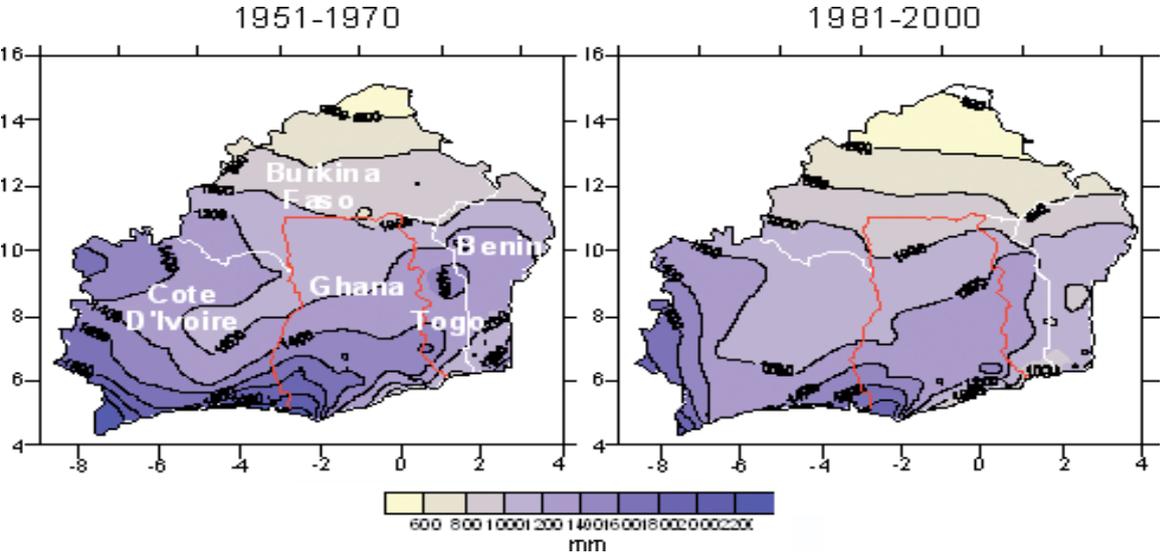


figure 6. Showing rainfall distribution in millimeters across Ghana (Red outline) and its immediate neighbors from 1951-1970 period and 1981-2000. Source: Owusu & Waylen, 2009

It is within these biophysical, and socio-economic conditions that the PNDC determinedly sought to induce economic recovery, and a crucial aspect to its achievement was the renegotiation of the 1962 Valco Agreement with GoG.

VALCO-Renegotiations: Undoing Nkrumah's Legacy (1982-85)

The new political regime under Rawlings would bring a determined government willing to change the nature of electricity supply in the country to better fit Ghana's developmental aspirations.

By the time renegotiations had started it had become common knowledge in Ghana that the 1962 Ghana-Valco agreement was unfavorable to Ghana's interests (Tsikata, 1986). Firstly, since the signing of the agreement, prices of energy in the world market had soared due to the oil crisis in 1973 but Valco had continued to pay roughly the same amount, which was already below aluminum industry standards (1986). This meant that Ghana was not earning anywhere near the potential amount in foreign exchange from Valco, with the only other foreign exchange earner in the electricity sector being VRA's sales to its neighbors Togo & Benin's distributor Communaute Electrique du Benin (CEB) (1986). Secondly, the energy requirements for Valco's operations left a surplus of less than 40% for other customers meaning that it was restricting development of other industries and wider electrification of the country, constraining potential socio-economic growth (1986). The negotiating team was more than aware of the significance of a successful renegotiation to the hopes of Ghana every achieving the goals set in the ERP.

By 1985, the negotiations had been concluded and Ghana had a more favorable agreement with Valco. It seemed that the PNDC's will to reach a favorable agreement at whatever cost amplified with the growing resentment in Ghana towards Valco's oppressive rates enabled the negotiating team to earn a better deal for increasing the rate and decreasing the amount of power Valco received from the VRA (Tsikata, 1986). Under the new agreement extra net revenues to government was \$43.2 million a year, with higher taxes and potential revenues to VRA also increased to around \$22 million a year (1986). Crucially, in relation to the evolution of the ES, VRA could now designate more cheap hydroelectricity to Ghanaians, rooting interdependencies of electricity supply with socio-economic development.

Economic Recovery and Electricity Supply Options

By 1985, positive macro-economic indicators showed that the ERP was working to some degree. The PNDC had focused the ERP on revamping the agriculture and industry and growth in these sectors were paying dividends (Shillington, 1992). Inflation had fallen from 120% in 1983 to 37% in 1984 and

10.5% in 1985 and GDP maintained an annual growth rate of 5% (1992: p 116). PNDC was now able to attract loans from the WB and extra foreign exchange available allowed investments in infrastructure paving the way for a NES in 1989, firstly by electrifying all the major district capitals through the newly established distributor Northern Electricity Department (NED) as a subsidiary to VRA in 1987 (1992).

Before the establishment of NED, VRA in 1985 conducted a generation expansion study to outline the options of keeping electricity supply ahead of demand. The droughts of 1983-84 had shaken the hydroelectricity system and it became apparent that VRA needed to diversify its option in electricity supply (J. Wiafe, Personal Communication, 2017). However any new PP constructed would act as a complement since the combined installed capacity of Akosombo and Kpong dam was more than enough to accommodate the electricity demand at the time (VRA, 1985). The options listed in the study included hydroelectric, thermal generation with the need to import fuels since Ghana had no proven reserves, solar, wind and nuclear (1985). Solar and wind were dismissed for being too small while nuclear were too large to be appropriate in Ghana for the next 20 years (1985). Thermal generation from coal-fired steam or combustion turbine would be the best candidate according to the study (1985). Overall though, the socio-economic climate in Ghana was deemed not conducive to bring any major PP online until 1996, so a plan consisting of short, medium and long-term options was plotted with the rehabilitation of the 30MW Tema Diesel PP, later in 1991, being the immediate consequence (1985).

First Glimpse of Light

It became apparent that the forecasts VRA was basing its plans on had grossly underestimated the rapidity of GDP growth and electricity demand. In light of the potential supply-demand imbalance PNDC created the National Energy Board (NEB) to oversee a nationwide strategy for the energy sector (Energy Research Group, 1987). Amongst its task was to research RE technology and its conduciveness to Ghana's socio-economic situation with the overall aim of reducing Ghana's recurring "drain on balance of payments due to energy imports" (1987: p 1). This was symbolized in a 1987 Symposium on RE (1987). During the event the prospects for solar, wind, biomass and indigenous hydrocarbons were assessed with solar drawing the most attention seeing that Ghana received sizable amount of solar daily at a 4.4KW to a high of 5.6KW for every square meter (1987).

The benefits of SE technology and its function in Ghana were well understood by those in the energy sector (Energy Research Group, 1987). However, the discussion on its application was primarily for rural development as part of government rural electrification project or decreasing end-users

demand for grid electricity (1987). But even with this narrow application for SE there remained barriers to its proliferation.

Institutionally, a lack of a central planning body in charge of solar technology implementation was identified since most of the solar technology remained in laboratories and/or in their pilot phase (1987). There were also multiple delays and cumbersome bottlenecks from the initial stages that inhibited progress in solar or any RE projects (1987). Because of this and subsequent lack of follow up, the public in Ghana remained unaware of solar technology's benefits (1987). The lack of commercial consultants and private sector involvement kept any solar technology applications merely as rural developmental projects (1987). Finally, there was the issue of financing the high upfront capital cost of solar (1987). Outside of that funding mechanisms toward RE projects were practically non-existent, and there was no formal recognition of RE in the ERP development agenda (1987).

Internationally solar technology had not matured enough and it seemed that its chances of contributing significantly to Ghana's grid supply were slim. As one speaker at the event put it "I am convinced that until and unless a comprehensive energy policy is evolved, a bold plan employing a commercial orientation to proliferation and utilization aimed at sustained technological development, renewable energy tech in this country will remain a dream" (Energy Research Group, 1987: p 236).

Electricity and Socio-Economic Development (1985-1993)

The growth of the electricity sector from the Valco renegotiations resulted in positive feedbacks with SED in Ghana, which in turn increased the demand for electricity and lay foundations for a transition to democracy (VRA, 1990; Shillington, 1992). The mining sector experienced positive growth rates, of which cheap available electricity from VRA was crucial, which attracted foreign businesses, while the government's NES inducted in 1989 continued to lead infrastructural development across the country and growth in electricity demand (VRA, 1990). Over the course of the ERP, manufacturing's high growth rates reduced while mining and electricity averaging 8.5% and 22.7% respectively outstripped it (ISSER, 1995). By 1991, the stabilized economic situation enabled Rawlings and the PNDC to lay the groundwork for a return to multi-party democracy, with elections to be held in 1992 (Shillington, 1992). Rawlings' newly formed National Democratic Congress (NDC) duly won the elections, and would retain power till 2000. However, incidences of government overspending to attract votes were observed and this mentality would extend to keeping tariffs below economic rates, to not disrupt the cheap electricity the voters were used to and cause unpopularity (Debrah,

2009; K. Wiafe, Personal Communication, 2017). Even though the second half of the ERP resulted in economic stagnation (due to drop in manufacturing performance) continued growth in the electricity sector made it an integral contributor to GDP at 1.5% of (ISSER, 1995).

Consequently, the mining and electricity sector became key to Ghana's SED. The two sectors were major foreign exchange earners bringing in much needed additional revenue at a time that other key sectors of Ghana's economy were failing, specifically manufacturing and agriculture, with low output from cocoa subsector due to poor rainfalls in the early 90s (ISSER, 1995). With electricity exports to CEB and Compagnie Ivorien d'Electricite, the Ivorian distributor, at 5 times domestic bulk tariffs and electricity sales to Valco ongoing, Ghana's ES generated significant revenue for GoG (Opam, 1995). This enabled re-investments into developmental programs such as the NES, which had successfully extended the grid to the northern capitals by 1990 (VRA, 1990). As a result of the availability of power the district capitals experienced immediate improvements in the quality of life especially growth in agricultural and commercial centers (1990). These relative improvements went a long way in assisting PNDC/NDC to win the 1992 and 1996 elections (Debrah, 2009).

As Ghana's socio-economy grew in tangent with electricity expansion, VRA's need to insure electricity supply for the burgeoning demand (10% average between 1985-1993) pressured it into seeking funds to develop the plans it had outlined in its 1985 Master Study (Edjekumhene, Amadu & Brew-Hammond, 2001). The droughts of 1993-94 struck the operations of VRA's hydroelectricity resulting in a power crisis and curtailment of power to VRA customers (2001). Though not as severe as the 1983-84 crisis, it again displayed the fragility of undiversified electricity supply system and prompted VRA to consider further thermal complement. Government had already sponsored oil and gas exploration and the potential of gas utilization for thermal power generation seemed promising (VRA, 1990). However, VRA was a long way away from securing funds for the development of any thermal plants seeing that the traditional international donors and the WB were unwilling to fund power sector investments "unless recipient countries demonstrate some commitment towards reforming the sector" (Edjekumhene, Amadu & Brew-Hammond, 2001: p 8). Fortunately, the guidelines for such reforms were similar to those proposed by the WB in the ERP which Ghana had instituted with policies such as the Statutory Commissions Act of 1993 that had already assisted in the conversion of 35 state-owned companies into limited liability companies (Opam, 1995). The liberalization reforms that had followed the ERP were now directly transforming the power sector in Ghana, and we see that it was only through this policy directive that Ghana could increase the supply of electricity and continue to power its SED.

Power Sector Reform and the Thermal Complement (1993-1997)

The objective of the reform was to satisfy WB's conditions, mainly liberalizing ES to attract IPP, for relinquishing credit for construction of thermal PP. The immediate results of the power sector reform saw the unbundling of VRA into just a generator and transmitter of electricity, with the creation of the National Grid (GridCo) as first step toward an "open access" grid, NEDCo to distribute to northern consumers, and Takoradi Power Company (TAPCo) handling the Takoradi Thermal Power Project (TTPP) which would see the construction of thermal PP at Aboadze (VRA, 1998). A regulatory board was established in the same vein as the NEB, but renamed Energy Commission (EC) (J. Essandoh-Yeddu, Personal Communication, 2017).

Since the 1985 Master Study, VRA had realized that coal-fire plant would not be the most suitable for Ghana's SEnv, and rather opted for Combined Cycle Gas Turbine. Coal required large economies of scale that Ghana did not have at the time to support the socio-technical system for coal-fire plant (K. Wiafe, Personal Communication, 2017). Also, GoG's exploration into indigenous oil and gas supplies hinted at a possible domestic source of gas, and with plans to incorporate cheap gas from Nigeria through the West African Gas Pipeline (WAGP) in the near future, it seemed logical to construct a plant that could utilize these sources (VRA, 1985). Environmental perspectives were not prominent during the decision-making, but natural gas was considered the cleaner, more reliable and efficient of the energy resources (Edjekumhene, Amadu & Brew-Hammond, 2001). In 1995 construction of the Aboadze thermal PP commenced and the first phase of the project was completed in 1997 with a 330MW capacity (VRA 1998).

True Price of Electricity and Power Crisis (1997-2002)

The long-term availability of cheap hydroelectricity in Ghana had resulted in a positive feedback with Ghanaian culture, leading to nation-wide inefficient applications and gross malpractices of electricity, which negatively impacted on the supply system. In Afrane's (1995) ECG endorsed short fictional story of electricity use in Ghana, called *Sorrows of Electricity*, he highlights the many malpractices of users of electricity users. The gist of the story revealed how electricity was perceived and misused, and this could be traced back to the traditionally low prices that hydroelectricity generated (J. Wiafe, Personal Communication, 2017). By the time thermal generation had been introduced to the supply system and VRA was importing crude oil from Ivory Coast it was inevitable that the price of electricity would increase (Edjekumhene, Amadu & Brew-Hammond, 2001). However, there were political implications for raising tariffs and this complicated the matter to the detriment of VRA's revenues,

which contributed in reducing the billed revenue collected from 89% in 1997 to 62.5% in 1998 (VRA, 1998).

If Ghana's power sector utilities were to remain financially viable and attractive for IPPs the tariffs would need to be economical. Before the power sector reforms, the Ministry of Mines and Energy was responsible for setting electricity tariffs in consultation with the VRA and ECG (Edjekumhene, Amadu & Brew-Hammond, 2001). WB during the reforms pressured GoG to raise tariffs to attract foreign private investors and the resulting price increases led to national public outcry, led by the Civil Servants Association (CSA), Trades Unions Congress (TUC) and Association of Ghana Industry (AGI) in 1997 (2001). These events accelerated the formation of the 'semi-autonomous' Public Utilities Regulatory Commission (PURC), as part of the ongoing power sector liberalization (Edjekumhene, Amadu & Brew-Hammond, 2001; J. Essandoh-Yeddu, Personal Communication, 2017). The task of the PURC was to transition electricity tariffs to economic levels but still make provision for universal access in keeping with GoG's developmental agenda, which not only included the NES, but a new VISION 2020 agenda (2001). PURC's 1998 tariff reviews, which saw a 300% increase, were deemed inadequate by the VRA (1998), which reported substantial losses during the year in comparison with 1997 losses (Edjekumhene, Amadu & Brew-Hammond, 2001).

The region wide shift to a low rainfall regime that precipitated the droughts of 1983-84, and lesser drought of 1993-94, now contributed to the drought of 1998 which struck another blow to Ghana's electricity supply system, and because of the interdependencies of the socio-economy to available hydroelectricity, this had considerable ramifications to key productive sectors and SED. By this time, the droughts of the 1980s were recognized in causing drastic changes in rainfall variability in Burkina Faso and Mali, which tellingly impacted on Volta basin's hydrology (Gyua-Boakye & Tumbulto, 2000). Additionally, global climate change had induced increases in temperature by 1 degree Celsius across Ghana (Gyua-Boakye, 2001). This increased rates of evaporation, due to increased capacity of air to hold water vapor at higher temperatures, and contributed to drying of streams and rivers across Volta's hydrological system reducing Volta lake levels and electricity output from Akosombo to 3,166GWh by end of 1998 (Gyua-Boakye, 2001; VRA, 2016). The industrial sector was particularly vulnerable during the crisis. In a joint research organized by TUC and AGI (2000) the main effects of the crisis were outlined as; a reduction in competitiveness due to increased cost of production leading to reduced output and market share, and lay-off or temporary reduced pay of labor. The document emphasized how the stipulations of VISION 2020, that placed indigenous industrial growth as being the engine for Ghana's move into a middle-income country by 2020, were far from being met due to the problems the electricity supply system were causing (2000).

Transition from Hydro Dominance (2002-2006)

The disturbances to VRA's hydroelectric system saw a significant tilt toward thermal generation, eventually leading to crude oil having a higher percentage as major source of energy by the mid 2000s. As figure 9 demonstrates, the sharp increase in crude export in 1998 reflect the power crisis at the time which required LCO to run the thermal PP, and eventually surpassing hydro as major primary fuel in Ghana's electricity supply. Increasing demand, which had already exceeded the Long Term Average yield of the hydroelectric system by 1991, prompted VRA to pursue the second phase of the TTPP to build an additional 300MW (Momoh, 2000). However, securing funds was difficult for the VRA given the lack of traditional financiers, its own lack of internal funds that could be partly attributed to the below economic tariff ECG and NED customers were paying for electricity services, and income lost to the purchasing of energy imports from Ivory Coast with the price of fuel almost tripling on the world market (VRA, 2000). However, the power sector reforms were beginning to bear some fruit. With government legalizing and encouraging the participation of IPPs, the VRA was able to confirm a joint venture (JV) with TAQA an Abu Dhabi firm to create Tema International Company (TICO), and CMS Generation of Michigan were contracted to build 220MW single cycle plant (Edjekumhene, Amadu & Brew-Hammond, 2001). The plant was commissioned in 2000, bringing thermal generation combined installed capacity to approximately 600MW (including Tema diesel) and hydroelectric at 1,072MW.

The shift to a thermal PP system had negative impacts for Ghana's balance of payments. The PURC and the VRA had both been banking on the availability of cheap gas from the WAGP with Nigeria to relieve pressures on the ES (Edjekumhene, Amadu & Brew-Hammond, 2001; VRA, 2000). The expectation was that the readily available cheap gas would power Ghana's thermal PPs and reduce the cost of electricity production thereby reducing end-user tariff (Edjekumhene, Amadu & Brew-Hammond, 2001; VRA, 2000). However, the WAGP had not been constructed by end of 2002 or 2004, so imports of LCO soared and VRA (and by extension GoG) foreign exchange financed the imports to keep up with electricity demand (Yakubu, 2002).

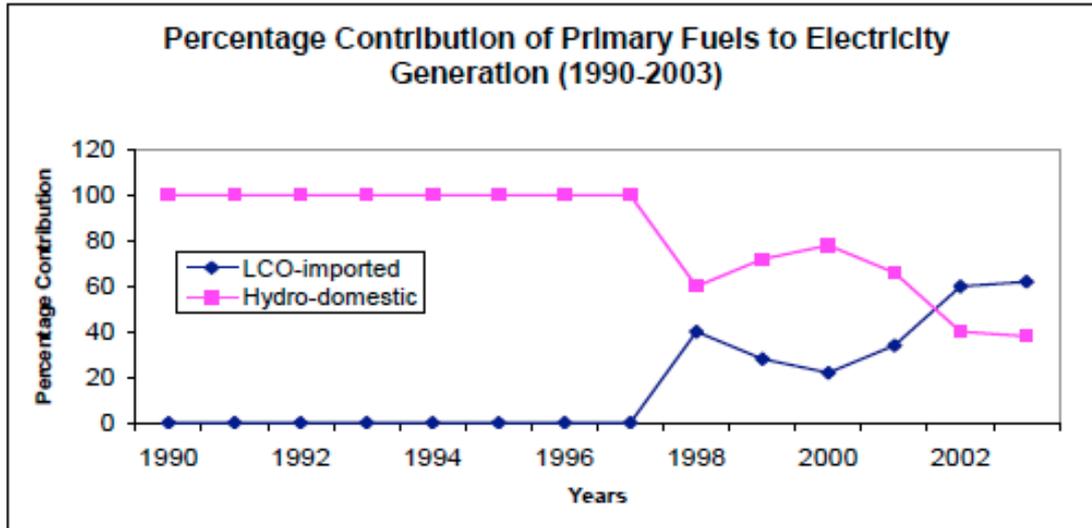


Figure 7. Showing the percentage contribution of crude oil imports increase in relation to decreases in hydro. Source: Kusi, 2005

To a large extent the thermal complement was failing to assure reliable and secure supply of electricity and these brought to question the whole idea of centralized electricity generation as the energy sector sought a different approach of realizing its target of universal access by 2020. The thermal additions to Ghana’s ES had already failed during the power crisis in 1998, with the VRA only meeting 89% of the domestic load forcing nation-wide power rationing for the first time since 1983-84 (VRA, 1998). After the crisis Ghana’s combined installed capacity was enough to accommodate the demand around 1500MW to 1150MW respectively, with operationalized capacity at 1360MW, but the percentage losses from ECG’s distribution system (20%) were causing erratic supply to its consumers (TUC & AGI, 2000). Plans to update the distribution infrastructure of the ECG were hampered by the issue of revenue collection, which was increasingly becoming more difficult as more ECG and NED customers were joining (legally and illegally) the national grid, making the privatization of ECG difficult (VRA, 1998; VRA, 2000; Yakubu, 2002).

Even with the PURC’s 400% increase in the electricity tariff in 2001, it was still well below an economic tariff as prescribed by the VRA and ECG (Yakubu, 2002). Given these problems of centralized electricity supply, the prospects of a decentralized electricity generation system were explored under various projects, such as the Rural Energy Services Project (RESPRO), utilizing RE technology (2002). An unforeseen benefit from the power sector reforms was the creation of an Embedded Generation Facility, which enabled power producers to connect directly to a sub-station for retail to local users as long as the capacity did not exceed 50MW (Edjekumhene, Amadu & Brew-Hammond, 2001). Initially meant to supplement electricity supply from diesel generators during the

1998 power crisis in remote areas, it provided the framework for deployment of off-grid RE technology (2001). However, most of the projects fell under the framing of a developmental project since commercialization was expensive in comparison to the heavily subsidized conventional fuels (2001).

By the end of 2005, Ghana's ES supply was still dominated by hydro generation at 5,629GWh, and thermal PP contributed 1,159GWh with a peak of 2,237GWh occurring in 2002 (Energy Commission, 2014). This peak coincided with the peak in oil imports at 1,146GWh (2014).

Results

The thermal complement's contribution to the barriers to SE stem from (a) the creation of an expensive thermal supply system, (b) transition to multi-party democracy and (c) rural development framing of SE.

(A) Significant disruptions to Ghana's hydro dominated ES caused by shifts in rainfall regime across West Africa, and on a national scale the Volta Basin's hydrology, altered the SEnv and forced the VRA to consider a complement to its supply. Thermal PP were identified as the best option even though they were expensive to run given that most of the primary energy resource (gas & crude oil) would need to be imported. However, continued coevolutions between socio-economic growth and electricity supply demanded that Ghana's installed capacity be increased to keep up with demand. The deteriorating financial position of the VRA rendered it incapable of internally funding new PP and a liberalization program was introduced to secure funding from the WB, breaking VRA's monopoly in electricity supply. However, the introduction of the thermal PP into Ghana's ES immediately demanded Ghana to purchase expensive crude oil and therefore set path-dependencies in securing further thermal sources leading to the current prominence of thermal over SE as primary energy resource.

(B) PNDC achieved a certain level of political and economic stability through the ERP setting up the basis for a transition to democracy. On the global level, the end of the Cold War and wider movements toward democracy pushed the date for Ghana's elections to 1992 and the NDC under Rawlings won the election. However, the new dimension of multi-party elections resulted in a shift in ES governance, in regards to the price of electricity and keeping political power. Seeing that the hydro era had fostered interdependencies between Ghana's socio-economy and cheap electricity, any price increase consequently caused civil uproar. But the expenses incurred in running the thermal PPs coupled with failure of the hydroelectric system meant that the price of electricity

needed to increase to reflect the costs and sustain the ES financially. This was not achieved largely because of political interest to keep the price uneconomic to retain a favorable image for re-elections, contributing to the deteriorating financial position of the current ES which is unable to attract SE IPPs because of the uncertainty of investing. On the other hand, the same mechanisms that keep electricity prices uneconomic have also contributed to the perpetual electricity crisis Ghana is facing, reducing GoG's will to invest in SE and rather opting for conventional PPs to solve the crisis.

(C) The Southern and urban focus of the national grid during the hydro era had resulted in an imbalanced distribution of electricity in Ghana. The NES sought to change this dynamic by extending the grid across the country, but the task of universal access demanded a supplementary plan to increase access of electricity to the remote rural centers which were disproportionately under electrified. The promise of decentralized SE as an answer to this problem gained prominence, since SE was readily available across the country and the technology allowed for a small increase in electricity generation. However, this original framing of SE as a rural development tool, kept the application of SE outside of commercial and private interests and has contributed to current low awareness of its ability in complementing grid supply.

5.3 Thermal Dominance (2005-2017)

Sub-RQ 3: How has thermal dominance in the supply mix contributed to barriers to SE in the current Selection Environment?

Introduction

Thermal generation in Ghana began on poor footing. Right from the start, shocks caused by 1998 power crisis on Ghana's socio-economy revealed the insufficiency of the thermal complement. After the crisis, continued growth in electricity demand and the lack of cheap indigenous or regional thermal sources forced Ghana to increase imports of light crude, placing pressure on Ghana's foreign exchange earnings and constraining broader developmental goals. In 2000, the New Patriotic Party (NPP) had won the elections and imposed a new developmental agenda under the banner of the Ghana Poverty Reduction Strategy (GPRS), as socio-economic growth was to be accelerated to eradicate poverty (GPRS, 2003).

“But then going forward in the short to medium term our system will most likely be thermal dominated because one we discovered gas, and two for us that is most cost effective, and you know solar has its own issues of intermittency...”

(K. Wiafe, Personal Communication, 2017)

Another Power Crisis

The interdependencies of Ghana's electricity supply system to its SED were severely strained during the 2006-2007 power crisis.

Even though Ghana had taken steps to complement its hydroelectric system with thermal PP, the electricity supply was still reliant on hydroelectricity and therefore the hydrological processes of the Volta Basin. It is hard to tell how much global climatic changes, associated with GHG emissions, were having an impact on the inflows to Akosombo, but reduced rainfall and increased evapotranspiration were major contributing factors (Kabo-bah, Diji, Nokoe, Mulugetta, Obeng-Ofori, & Akpoti, 2016). From figure 8, even though there was an upward trend in rainfall over the course of 1990s from the 1980s, by the 2000s this trend was decreasing as we see from the changed color variations, with low rainfalls over the northeast and southeast of the country.

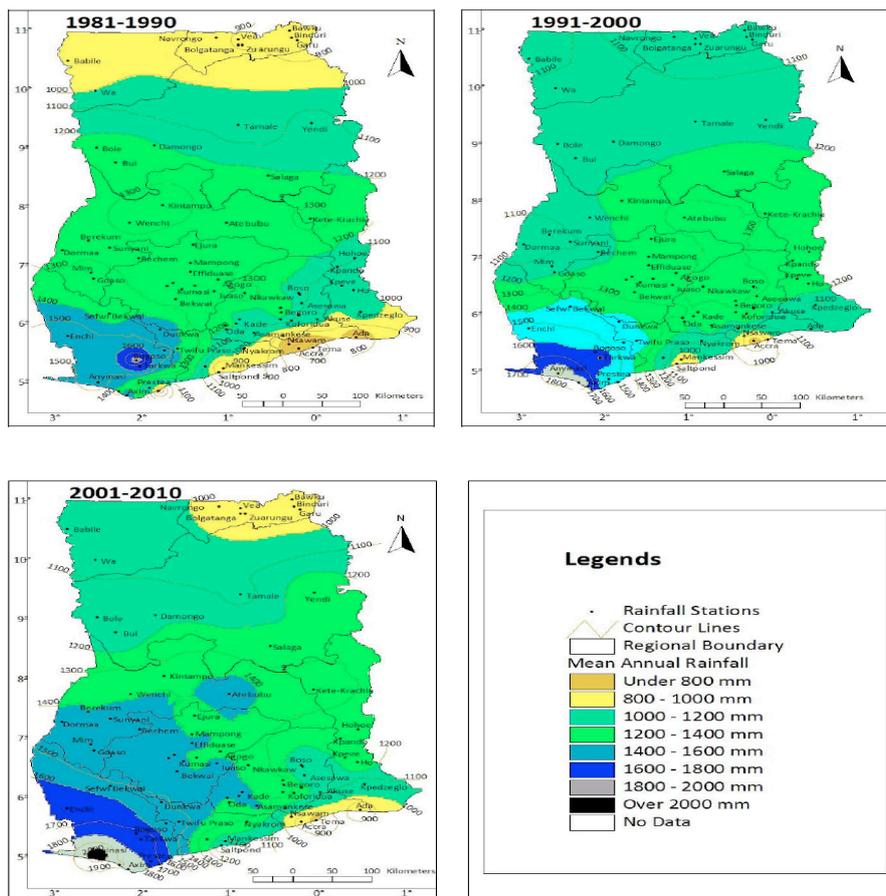


Figure 8, showing rainfall in millimeters across Ghana represented in different color schemes with yellow depicting less rainfall and blue showing more rainfall. Source: Logah, Obuobie, Ofori, & Kankam-Yeboah, 2013.

Compounding the shortfalls from hydro ES was the under-utilization of thermal PPs due to the high costs of importing crude oil. As was observed from the early 2000s increasing price and reliance on crude oil imports for electricity generation were costing Ghana (Energy Commission, 2006). Therefore during the crisis government was unable to secure the needed crude oil imports to run the thermal PPs causing a drastic fall in supply (CEPA, 2007).

The result of the crisis necessitated, what was described as an “expensive and embarrassing” loading shedding schedule, which caused adverse impacts across Ghana’s socio-economy (CEPA, 2007; p 6). The category of consumers dependent on VRA’s centralized ES had increased, particularly the service sector, which had experienced rapid growth and, consequently, demand for electricity since 2005 (Amoako-Tuffour & Asamoah, 2015). However, the sectors hardest hit were the mining and manufacturing sub-sectors which saw an increase in the cost of production and reduced competitiveness which the WB estimated would reduce overall real GDP growth between 0.7 and 0.9% (CEPA, 2007). Other industries dependent on local manufacturing feared being priced-out given the prevalence of cheaper imported goods in the market, VALCO closed down its operations impacting on other aluminum industry players, and PURC removed the pro-poor element of the utility tariff in an effort toward full cost recovery for VRA and other utilities (CEPA, 2007). The final cost to GDP growth of the 2006-2007 power crisis was estimated to be 1.5% (Amoako-Tuffour & Asamoah, 2015).

Even though electricity accounted for just 9% of end-user energy use, the crisis was damaging the NPP’s GPRS agenda of ushering Ghana into a middle-income status country by 2015, so plans to expand electricity generation were considered (Energy Commission, 2006). In the EC’s Strategic National Energy Plan (SNEP) (2006), coal-fired steam and combined cycle PPs were determined as most competitive sources of grid electricity, while solar PV, and waste incineration were deemed most expensive.

GoG put forward its short-medium term actions to deal with the crisis, which included a 300MW power plant to be installed in Tema by 2009 (TT1PP), continued work on the WAGP, the mining companies to supply 80MW plant by 2007 (MRP), and Bui dam at 400MW to be built using funds from Chinese government (CEPA, 2007). The above-mentioned actions were just a few of the proposed points to deal with crisis, but they were the only ones to come to fruition. Overall, the crisis had dealt Ghana a big blow to its development aspirations, and even provoked government to actually separate GridCo from the VRA in 2007 (J. Essandoh-Yeddu, Personal Communication, 2017).

A New Hope (2007-2012)

The discovery of oil, and associative gas, in Ghana and the following year's democratic change in government led to a new developmental agenda based on the full utilization of the hydrocarbon sources, particularly for supplying Ghana's thermal PP systems, altering the socio-economic dynamics in the country.

The impact of oil and gas discovery in Ghana and its resulting influence on development strategies was far reaching. In 2007 it was announced that Kosmos Energy had founded 'a significant oil accumulation' in two off-coast wells (McCaski, 2008; p 320). President Kufuor and the NPP had planned for the associative gas to serve as another commodity which would be extracted, processed and sold in the market by a third-party international, but NPP lost power in the 2008 elections and the NDC's President Mills was sworn in with a different perspective of how the resource would benefit Ghana's development (D. Hagen, Personal Communication, 2017). Under the NDC's Ghana Shared Growth and Development Agenda (GSGDA) that replaced the NPP's GPRS I and II programs, the problems of fiscal deficit and macroeconomic instability due to high inflation, of which crude oil imports for electricity were conspicuous, were to be addressed (National Development Planning Commission, 2010). GSGDA emphasized that to fully realize oil and gas development the industry would need to integrate into the local economy (2010). Seeing that 69% of modern energy used in industry and service sector was electricity the document outlined the need to expand generation from 2000MW to 5000MW by 2015, ensuring universal access, reliable supply and foreign exchange earnings through electricity supply, of which domestic gas was key (2010).

By this time, the plans to construct additional PP in response to the 2006-07 crisis had been realized along with additional capacity from IPPs to be served with incoming WAGP and domestic gas supplies. Of the PPs that came under the VRA's ownership were the 126MW TTT1PP and 80MW MRP which had been commissioned in 2008, then 50MW Tema Thermal 2 Power (TT2PP) plant in 2010 (VRA, 2010). Till this date, TICO was the only IPP PP online (2010). But the potential available cheap supply of gas for electricity generation led to the 200MW gas-fired IPP Sunon-Asogli PP (SAPP) in Tema, owned by China's Shenzhen Energy Group (Oxford Business Group, 2016).

Within a short period after the discovery, Ghana's electricity supply system had become dominated with thermal PPs, with two major clusters in Takoradi and Tema, however the importance of hydroelectricity was still relevant to the ES and broader SED. Since the crisis, Akosombo dam had resumed normal service with positive hydrological processes around the Volta Basin helping to reduce the need for crude oil imports, since domestic natural gas was not in production at the time and WAGP was finally about to start supplying gas in 2010 (VRA, 2010). PURC also managed to raise tariffs for the first time in two years by 87.8% (2010). These events helped in stymying VRA's financial

slide over the last decade, fostering hope of a more financial viability (2010). Industry demand for electricity rose modestly between 2008-2011, while non-residential and residential demand experienced quicker rates of growth hitting 16.5% average growth in 2010-2013 and above 12% by 2013, respectively (Amoako-Tuffour & Asamoah, 2015: p 7). Contributing to these percentages was the resurrection of Valco under GoG ownership and the NES extension to 4813 towns by 2010 (VRA, 2011). And after decades of being in the pipeline, the 400MW Bui Dam on the Black Volta river was completed in 2013 with funding from China's Export Import Bank and GoG, capping the continued significance of the Volta Basin's hydrology to Ghana's ES (Urban, Nordernsvard, Siciliano, & Li, 2015). The Bui Dam, along with SAPP, also symbolizes the change in the international scale of the SEnv as China's increasing influence in Africa through its non-interference policy comes up against the Washington Consensus directive of conditional aid (Aidoo & Hess, 2015). This marked involvement of China in Ghana's developmental programs can be slightly attributed to the discovery of oil and altered Ghana's potential funding streams for ES infrastructural developments (2015).

Burgeoning Light (2011-14)

Before the Bui dam was completed significant progress had been made toward RE development when the Renewable Energy (RE) Act of 2011 was signed with the purpose of realizing RE potential in fulfilling national developmental agendas. In line with evolving power sector reforms from the mid 1990s, Ghana Energy Development and Access Project (GEDAP) was established to pull funding from the WB towards improving; the operational efficiency of ECG (which had declined over the years), increasing population's access to electricity and helping Ghana transition to a low-carbon society (GEDAP, 2015). GEDAP carried out RE assessment reports and capacity building activities for the varied sources in Ghana which enabled the RE Act of 2011 to be passed (2015). Wider national and international concerns for GHG emissions and Climate Change were also influential in passing the Act.

RE Act aimed to encourage power generators and utilities to invest toward RE penetration in energy mix to 10% by 2020 in support of Ghana's development (SREP, 2015). The VRA outlined plans for installation of up to 150MW of wind and 12MW solar for both grid-connected and mini-grid systems, and aimed to use international finance mechanisms such as Clean Development Mechanism from Kyoto Protocol to fund the projects (VRA, 2011; J. Walker, Personal Communication, 2017). The Act's main goal, however, was to attract IPPs by setting guaranteed prices for RE electricity generation through a PURC controlled Feed-in-Tariff (FiT) mechanism to help mitigate high cost of RE (Amoako-Tuffour & Asamoah, 2015; VRA, 2011; J. Essandoh-Yeddu, Personal Communication, 2017). FiT consisted of RE purchase obligations to a distribution utility in accordance with the utilities mandate

of securing at least 10% RE in its mix (VRA, 2011). These measures were identified as fixing the problems of the first GSGDA (2010-2013) by contributing to GSGDA II's main objective of securing sufficient and reliable supply of electricity for economic growth and development in Ghana for 2014-2017 (SREP, 2015).

Despite the IPP focus of the Act, VRA was first to connect its 2.5MW solar PV system in Navrongo to the grid in 2013, making it the first non-large scale hydro RE to add to the supply (Energy Commission, 2014). With technical support from Kreditanstalt für Wiederaufbau, VRA planned to develop a 12MW solar project in incremental phases using internally generated funds (SREP, 2015; J. Walker, Personal Communication, 2017). NEDCo would be the off-takers (purchasers of electricity) of the RE electricity (J. Walker, Personal Communication, 2017). Navrongo, in the Upper East region, was identified as the first site because of the irradiation, available connection to grid, and demand in the area (5MW demand in the township) (2017). After 3 years of planning the VRA wholly owned solar PV plant was connected in 2013 (2017).

Around the same time of Navrongo's completion, plans to build the biggest solar park in Africa at Nzema in the Western Region of Ghana were stifled. The 150MW project was to be an IPP, owned by Blue Energy a UK based company and licensed by the EC as part of its mandate to ensure development and utilization of RE toward the 10% target (Amankwah-Amoah, 2014; J. Walker, Personal Communication, 2017; Energy Commission, 2015). Twenty-nine utility scale solar projects had been given provisional licenses in 2013, and their combined capacity was 2155MW (Energy Commission, 2015). However, the EC was unsure of how the grid's stability would be impacted by such a large intermittent source and decided to suspend issuance of licenses in 2014 and review the RE-FiT guidelines, putting the Nzema project on pause (Energy Commission, 2015; SREP, 2015). The new principles for the FiT clarified the maximum of 20MW per solar PV plant without grid stability and a total nationwide capacity for Solar PV without grid stability limited to 150MW, with PURC to gazette the new rates (SREP, 2015). Additionally, power purchase agreements for RE were set for 10 years even though the typical number of years for a RE is 20 years (SREP, 2015). These factors played a role in halting the 150MW solar PP, combined with generally increased perceived risk for other investors due to poor financial position of Ghana's power purchasing utility, the ECG (Scaling-Up Renewable Energy, 2015). In fact, the ECG's financial situation was negatively impacting the entire electricity supply system's ability to attract much needed investments laying the groundwork for the next power crisis.

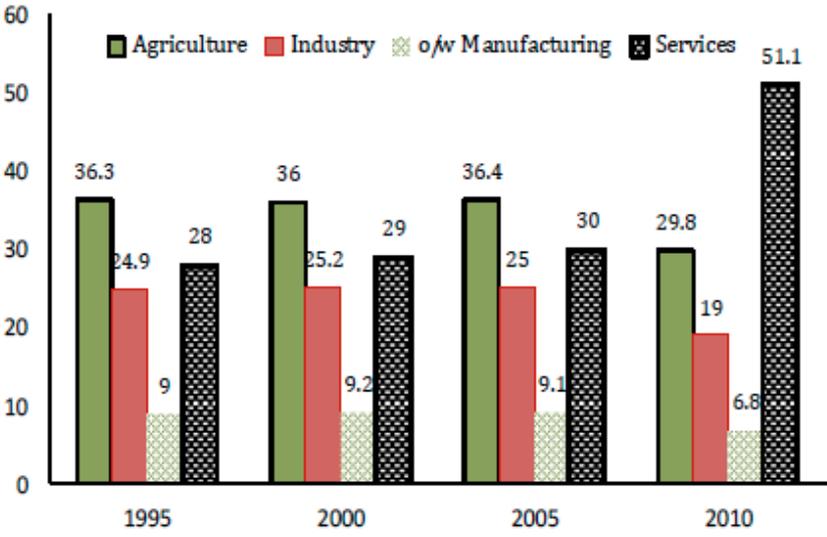
Dumsor (2012- present)

The underperforming thermal PP systems and rapidly increasing demand for electricity across all sectors of Ghana’s economy, mainly service and residential sector, would spark the beginning of the current power crisis, locally known as ‘Dumsor,’ with detrimental effects on SED.

“It is a cascade, VRA is just bearing the brunt. I mean we don’t sell directly to the customer it is the ECG that does, it is ECG that collects the money for everybody, all of us, from the gas to generation to transmission no interface between us and the customer. It is the customer that pays, and ECG can only pay back to us what they have collected. So if there is a shortfall it occurs first at the consumer end.”

(K. Wiafe, Personal Communication, 2017)

Ghana’s socio-economic dynamics had been working against the ES, as the makeup of the consumers changed, negatively impacting on effectiveness of electricity utilities to provide services. Firstly, the exponential increase in urbanization increased the demand for electricity in major urban centers (Amoako-Tuffour & Asamoah, 2015). Coupled with the general trend of population growth and increased standards of living, was higher penetration of technology in everyday economic activities placing more need for electricity (Amoako-Tuffour & Asamoah, 2015). As mentioned earlier the service sector had experienced a boom in its share of GDP, some extent due to available electricity, rising to almost 50% by 2010 (2015). As figure 11 shows service sector share of GDP steadily rising then experiencing a boom between 2005-2010, while shares of GDP for other sectors reduce, drastically altering ECG’s customer-base.



Graph 1 Showing the share of GDP in percentages for the main sectors of Ghana’s economy from 1995-2010. Source: Amoako-Tuffour & Asamoah (2015)

The problems of having a predominantly residential and non-residential customer base (70%) mainly have to do with issues of pricing, revenue generation and cash flow to make ES financially viable (2015). However, none of these issues had been dealt with satisfactorily. Electricity pricing had been kept artificially low by government or by government influenced regulators for political reasons (PURC), ECG was unable to collect revenue from customers due to poor infrastructure (poor residential address system, no metering system), subsidies for low-income consumers were costly, and on top of all that the tariffs were still uneconomic (Amoako-Tuffour & Asamoah, 2015; K. Wiafe, Personal Communication, 2017). Actually, the tariffs had not been cost effective since thermal PPs were first introduced (VRA, 2011).

On the supply side, the thermal PP system's inability to operate at full capacity endangered the supply-demand balance, which would eventually tip toward a shortage causing the crisis. The increase in electricity demand over the 2010-2013 narrowed the gap with supply, reducing the reserve margin, meaning that any short falls in energy generation from the installed capacity would exacerbate the gap (Amoako-Tuffour & Asamoah, 2015). The shortfalls would eventually occur due to inadequate gas supply to the thermal PPs. Ghana Gas (state-owned), established in 2011, was mandated to perform the role of aggregating Ghana's discovered domestic gas for electricity generation, however what became apparent was the unsatisfactory level of gas reserves (D. Hagen, Personal Communication, 2017; VRA, 2011). In fact, the reserves of oil and gas in comparison to Ghana's demand was small, and the added problem was that if the gas was not associative (with oil) there was little incentive for multinationals to invest in gas extraction infrastructure, so a while after oil began production in 2011, almost 7 billion cubic feet of gas was flared (D. Hagen, Personal Communication, 2017; VRA, 2011). Even with the WAGP and Ghana gas supply combined it would remain below the demand for gas for power generation (VRA, 2010). In 2012, Ghana's thermal PPs required 300 standard cubic feet of gas per day (mscfd) to run, but the supply from the operational gas fields was 100mscfd, and WAGP supply was below its contractual obligation of 120mscfd, resulting in a fuel shortage that rendered gas-fired 200MW SAP underutilized causing the supply-demand upset (Oxford Business Group, 2013). Additionally, the unavailability of gas forced government to import about 5 million barrels of expensive LCO to power the dual fuel thermal systems, increasing the budget deficit and prompting subsidy removal on hydrocarbon fuels causing price rises across the socio-economy (2013). Exacerbating the financial problems of electricity supply was VRA's own revenue collecting shortcomings due to ECG's poor performance. Table 2 displays the average dependable capacity of PPs, all category of electricity supply was below its installed capacity, consequently leading to erratic power outages and a costly load-shedding program (Oxford Business Group, 2013; Amoako-Tuffour & Asamoah, 2015).

Generating Station/ Plant	Nameplate Capacity, MW	Dependable Capacity, MW
Hydro		
Akosombo	1,020	900
Kpong	160	140
Bui	400	342
Thermal		
TAPCO	378	300
TICO	252	200
TT1PP	126	110
TT2PP	49.5	45
MRP	85	80
T3	132	120
Sunon-Asogli	220	180
CENIT	126	110
Embedded Generation		
Genser Power - IPP	5	2.1
Renewables		
Solar	2.5	1.9
Total	2,956.0	2,531.0

Table 1 Showing the installed capacity and the dependable capacity of PPs in Ghana. Source: Energy commission (2014).

The extent and severity of the recent power crisis on Ghana's SED would prompt plans to install mostly thermal PPs as a medium and long-term solution. WB had estimated that the direct cost of power outages in Africa were approximately 2% of GDP, and for Ghana the consequence of these losses translate to about \$320 million per year since 2008, meaning a significant "amount of potential economic growth" was negated (Amoako-Tuffour & Asamoah, 2015: p 10). These costs had significant impact across the socio-economy, which consequently led to further financial instability of the ES (Amoako-Tuffour & Asamoah, 2015; Energy Commission, 2015). Overall, real GDP growth declined from 7.1% in 2013 to 4.2% in 2014 and was expected to drop to 3.5% in 2015 (Energy Commission, 2015). Plans for increased installed capacity were in the pipeline but the problem was most of them were thermal and required reliable gas infrastructure, which was not readily available (2015). As a result, GoG turned to 'emergency' power in the form of mobile distributed power rentals, signing contracts with thermal generating IPPs of which the Turkish company Karpowership was first to materialize with an initial 225MW in 2015 running on oil for the most part due to gas shortages (2015). In the longer term the expected 523-703MW of additional thermal capacity and medium term from emergency power will require Ghana to invest in infrastructure to bring in reliable amounts of hydrocarbons to keep up with demand (2015). It is projected that Ghana would

need to increase installed capacity by about 3500MW to eliminate load-shedding and given the current dynamics it can be expected that imports of LCO would power a large portion of these PPs (2015).

Silver-Lining

Awareness for climate change and its impacts on Ghana has recently been playing more of a role in determining the SEnv for PPs. The impacts of climate change have already been observed in Ghana with the increases in temperature over the past decades, unpredictable rainfall and increased frequency of climate extremes (Riede, Posada, Fink & Kaspar, 2016). In its first Biennial Update Report submitted to the UNFCCC, detailed observations were made on Ghana's contribution to climate change, and even though Ghana's emissions are relatively low, its population growth of roughly 2.4% per year (one of the highest in West Africa) coupled with rising emissions from its energy sector (second largest emitter), primarily electricity generated from crude oil-fired thermal plants, give rise for concern (Ministry of Environment, Science, Technology and Innovation & Environmental Protection Agency, 2016). But strong regulatory practices ensure that with each PP constructed there is a need to obtain a construction permit from Ghana's Environmental Protection Agency (Urban, Nordensvard, Siciliano, & Li, 2015). On another front, the Ghanaian Youth Environmental Movement were vocal in halting the VRA's plan to construct a coal-fired plant, referring to how the plans contradicted the global move away from fossil fuels established in the Paris Agreement (Knott, 2015; J. Essandoh-Yeddu, Personal Communication, 2017). Finally, despite the harsh climate for RE IPPs BXC, a Chinese company, completed the construction of a 20MW SE PP in the Central Region which has recently come online, showing that the RE Act may be enough to ensure SE gains more of a foothold as a viable source of electricity in Ghana's electricity supply (Energy Commission, 2015; J. Walker, Personal Communication, 2017).

As of 2015, Ghana's supply mix was mostly hydro powered with 5,844GWh while thermal contributed 5,643GWh, with solar yet to register (VRA, 2016). However, the trend in generation shows a continued growth in thermal generation, almost doubling from 2,810GWh in 2006 (2016). On the other hand, the construction of the Bui dam saw Hydro hit its peak generation at 8,387GWh in 2014, but following year's low rainfall contributed to a significant drop by 2015 (2016). The discovery of oil and gas resulted in reduction in oil imports, making the thermal complement the era with highest amount of crude oil imports for electricity generation (2016).

Results

The Thermal Dominance contribution to the barriers to SE stem from (a) the discovery of oil and gas (b) deteriorating financial position of the ES, (c) the perpetual electricity crisis and (d) SE issue of intermittency.

(A) The establishment of the thermal complement steered Ghana's ES toward further path-dependencies with thermal sources so by the time oil and gas had been discovered the opportunity to exploit domestic thermal sources for electricity generation seemed the best option for the supply to keep up with 10-15% annual growth in demand. The most attractive feature of utilizing domestic thermal was the potential to reduce the costs of running the thermal PPs and thus GoG sought to setup the necessary infrastructure to exploit domestic gas reserves for electricity generation contributing to the prominence of thermal sources blocking SE uptake in the current SEnv.

(B) The unresolved problem of uneconomic tariffs, stemming from the clash of democratic interest against the need to increase revenue across the ES, had resulted in further financial deterioration of the ES. Additionally, the lower than expected reserves of domestic thermal sources meant that the mechanisms which created the uneconomic tariffs continued to negatively influence the perceptions of potential IPPs constraining the needed increase in PPs on the national grid. These mechanisms have contributed to two barriers to SE. Firstly, the inability of Ghana's liberalization agenda to attract IPPs meant that there is a shortfall of electricity supply in relation to growing demand contributing to the perpetual electricity crisis Ghana has been facing and reducing GoG willingness to invest in SE PPs. Secondly, the deteriorating financial position of the ES has not only detracted conventional IPP but has also contributed to low financial incentives for SE IPPs entering the ES, given the uncertainty of investing in the economically unstable sector and lack of guarantee on return of investments.

(C) The multidimensional factors that have contributed to the electricity supply shortfalls in keeping up with the growing demand has resulted in a perpetual electricity crisis which has severely stymied Ghana's socio-economic development. The shortfall of electricity supply mainly stems from the failure of Ghana's major PPs to secure their primary sources of energy, namely hydro and thermal sources. Simultaneously, Ghana is still in pursuit of its developmental goals of increasing economic growth and alleviating poverty, and these goals have fostered interdependencies with Ghana's electricity supply which have made the supply shortfalls problematic to socio-economic development. The combination of these mechanisms has contributed to reduction in political will to invest in SE because of its inability to provide a quicker resolution to the current electricity crisis, further pressuring the SEnv to prioritize conventional thermal PPs.

(D) The original framing of SE as an off-grid rural development technology has failed to realize the use of SE as a potential source for grid electricity, despite the maturity of the technology. Small-scale developmental applications of the technology in rural regions have done little to incentivize commercial interests in utilizing SE contributing to the low awareness to its potential for utility-scale operation. Additionally, inexperience in dealing with intermittency issues of SE has also contributed to low financial incentives for SE IPPs seeing that there is already problems of revenue collection from ECG customers. Interestingly, the failure of the thermal and hydro PPs to keep up with the demands of the SEnv and the consequent electricity crisis has actually resulted in SE being cost competitive given that electricity tariffs have been soaring. The establishment of Navrongo and BXC SE PP reveal that there are pathways for SE developing in the current SEnv.

6. Discussion

To answer my overarching RQ, my research intended to use a CF to unravel the socio-ecological mechanisms that have produced the barriers to SE contributing to Ghana’s grid electricity supply. By answering the sub-RQs, the processes that have determined the decisions to establish hydro and thermal variations of PP and its relation to the barriers to SE were identified. Figure 9 acts a summary of the results and illustrates the linkages between mechanisms across the three phases. My discussion is broken down into (a) main findings (b) situated-ness of findings to larger discussions on energy and sustainable development and (c) reflection on my CF I applied to produce those results.

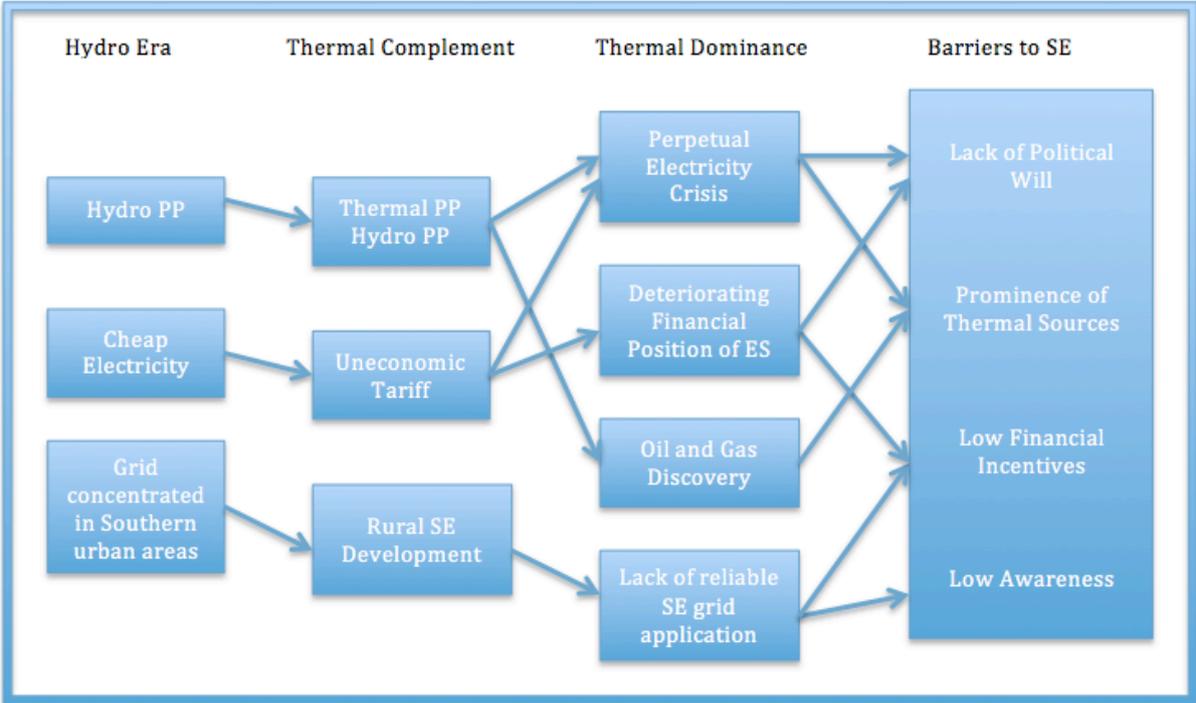


Figure 9 showing the results of the coevolutionary narrative of Ghana's ES and how the mechanisms have produced the current barriers to SE. Source: Own.

(A) The findings of my research confirm that underlying socio-ecological mechanisms have produced barriers to the uptake of SE for grid application in Ghana.

The main socio-ecological mechanisms stem from the Hydro Era, whereby Ghana's entire electricity supply was dependent on the biophysical processes of the Volta Basin. The regional hydrological shift to a lower rainfall regime that occurred across West Africa during the 1970s to 1980s, significantly altered inflows into the Volta Basin. This shift precipitated periods of drastically low rainfall and reduced electricity output, consequently leading to the thermal complement phase. However, during the thermal complement and most of the thermal dominance phase, a majority of Ghana's installed generation was still dependent (hydroelectricity contributed 65% to supply mix) on the hydrological processes of the Volta Basin (Asumadu-Sarkodie & Owusu, 2016). By the time of the thermal dominance, it seems that climate change was influencing the hydrological processes of the Volta Basin, as rising temperature and varying rainfall fostered even more unpredictable rainfall patterns over the Volta Basin. These processes would result in supply shortfalls causing a perpetual electricity crisis since 2012 that has pressured the GoG to prioritize conventional thermal PPs to resolve the crisis.

The other main finding from my research originates from cheap electricity the Akosombo dam provided to Ghana's domestic customers during the Hydro Era. The vast source of hydroelectricity from the Volta Basin enabled ECG to provide cheap electricity to its customer base. This mechanism evolved to include an even larger customer base after the renegotiations of Valco contract and the commencement of the NES. However, with the shift in rainfall regime and subsequent shortfalls in electricity output, coupled with an expensive thermal complement, the price of electricity needed to reflect the increasing costs of production. But political interests in keeping the price uneconomic contributed to the electricity crisis which has rendered the ES unable to attract SE IPPs because of low financial incentives and uncertainty of investment.

(B) These underlying socio-ecological mechanisms are important because they reveal the extent to which Ghana's ES is embedded in biophysical processes to do with the Volta Basin's hydrology, but also demonstrate the problems of applying SE, or RE in general, while a country is still developing its ES to secure supply for socio-economic development.

The findings confirm that issues of securing supply are set within wider energy scarcity issues, which further constrains ability for developing countries to develop alternative sources of energy

(Bradshaw, 2014). Specifically, for the case of Ghana's ES, what Bradshaw (2014) defines as environmental, economic and physical scarcity seem to agree with the findings of my research. That is the increasing disruptions caused by climate change on the Volta Basin's inflows and subsequent reduction in electricity output are causing environmental scarcity to the supply mix. On the other hand Ghana ES suffers from vulnerability to economic scarcity, whereby light crude oil's price volatility contributes to insufficient electricity generation from thermal PPs, while physical scarcity in this case refers to the limited reserve of natural gas Ghana has for powering its thermal PPs (2014).

GoG's prioritization of thermal sources over SE agrees with Bradshaw's (2014) energy dilemma problematic for developing countries. The links between access to reliable and available modern energy services to economic development are well understood, but in strengthening these links, GoG has fallen victim to trade-offs that, as Bradshaw (2014) explains, developing national governments face. That is; favoring of urban areas first, increased fossil fuel emissions against environmental sustainability because of relatively cheap and easier to obtain thermal sources compared to SE, and movement toward privatization and therefore prioritization of return of investment for incoming IPPs (2014). In the case of Ghana, the trade-offs have not paid off in securing electricity supply and this raises the question of how Ghana can hope to achieve socio-economic development without fossil fuels playing a significant role in the supply mix?

(C) What Bradshaw's (2014) dimensions of energy scarcity fail to do is draw explicit connections between the different forms of scarcity with problems of transitioning toward a lower-carbon society. My CF might have been able to explain how the underlying socio-ecological mechanisms have hindered SE for grid supply, but it also doesn't propose any pathways to overcoming the current barriers.

7. Conclusion

"As a poor person you know at times some food you have no option but to eat, but as you become rich you move away from all that, the junk food and all those things."

J. Essandoh-Yeddu, Personal Communication, 2017

My research sought to unravel the underlying socio-ecological mechanisms that have produced the barriers to on-grid SE supply. By applying an originally designed CF, I was able to develop a coevolutionary narrative of Ghana's ES and thereby identify the processes which produced the underlying mechanisms that have hindered SE's uptake for grid application, mainly stemming from cheap electricity and overreliance on hydro PP. The above quote also alludes to the problem of

increasing sustainability in electricity supply, without achieving broader developmental goals first. Further research should build on this study, by identifying pathways to overcoming the barriers to SE, particularly the case of SE's cost competitiveness within the current SEnv and the construction of BXC's SE PP.

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9. Appendix

1. Search criteria for Document Analysis

The search criteria for the document analysis was based on the creation of the timelines for the hydro era, thermal complement and thermal dominance in section 3. Through preliminary research a rough picture of narrative of Ghana's electricity system was understood, it became a task of finding literature on these events. A Google search was conducted using a combination of the key words, Ghana, development agenda, electricity, Energy Commission, renewable energy, electricity crisis, GridCo, history. For the archival material, I looked for VRA annual reports for the years of electricity crisis, and any form of government literature on energy and electricity in Ghana, specifically over the thermal complement phase. Once I began categorizing the data within the material, the major events were highlighted and a secondary timeline was drawn. I then searched for relevant literature via Google Search and LubSearch typing key words, Ghana, Akosombo dam, Nkrumah, Bui dam, thermal energy, power sector reform. All the literature compiled was subject to a brief categorization based on the whether it added in describing the Selection Environment (Socio-technical, socio-economic, biophysical). Literature which either repeated already known information and/or provided no direct relation to the SEnv and subject of study was discarded.

2. Full Transcripts of Interviews

I conducted four interviews, two of which were with personal from the Volta River Authority, one from the Energy Commission and the other from Ghana National Gas Company. Before the interview I informed the interviewee of the purpose of the interview and asked for consent on whether I could tape record the conversation.

2.1. Interviewee: Kwaku Wiafe (K)

Date: February 27th 2017

Interviewer: Abdallah Smith (A)

Position: Manager of Business Development and Power Trading

Purpose of interview: The interview with Mr Wiafe functioned as a way to corroborate the other sources of data on the developments of Ghana's electricity system and to gain insights into the current electricity crisis, and confirm the connections between the historical factors and the barriers to solar energy. Seeing that Ghana's recent electricity system history has no one document to refer to, his insights were significant in making the connections between the factors of economy, politics and crucially the culture, which had not featured enough in the other sources of data compiled for this research.

A: if you can just introduce yourself

K: OK Im kwaku Wiafe in charge of business development at VRA, but before I was an Engineer, I am an engineer by training. Masters in policy, worked in engineer for a while in head office, now in charge of business development, wasn't here in the 80s, but I have I came to vra in 99, it's a period I have read about cause when I had got into engineering there had been a number of studies that had been done in the period, but more like consultancy assignments so not published and not online, but probably when you go to our library I can give you some references and we have a public library at the head office and there are references I can point you to. Hope they would have it there, first one being **Ghana Generation planning study**, I think it was in 85 thereabouts, gives some background on some of the issues we discuss and im sure if you go onto the World bank, dunno if you have read the documents on national electrification project, and the national electrification project started somewhere in 87, 88 thereabout and resulted in electrification of whole country- those documents of course start by giving a general overview and some background information of the sector. But since your interest is on the environment and of thermal, I think that mm Akosombo was completed in the 65 and after Akosombo was completed a study was, no, Akosombo was designed by a company called Kaiser engineers, an American company, and immediately after they were asked to develop a master plan, a master plan looks at the long term development of a sector, what are demand growth like, infrastructure requirements all of that, they actually recommended that the first plant we build should be a thermal plant. Coming online somewhere in the late 70s, even before we build kpong dam and bui dam. And the reason was that the rainfall in this part of the world is inherently variable and therefore you needed thermal as insurance, so thermal was meant to serve as insurance whilst, even though hydro was providing base load. And difference between Africa and lets say Sweden is that in Sweden rain falls are slow and get stored naturally and summer snow melts, but here it just flows (expression to indicate the faster speed of rainfall), so you are more vulnerable to weather here than in the temperate regions, so the idea was lets if you are gonna be so reliant on electricity and I mean every country is reliant on electricity, lets build a thermal plant. Unfortunately at the time, I wouldn't say unfortunately, at the time the thinking in those days was that, I mean the 70s also coincided with the period of the Arab embargo on oil and oil embargo, so telling people to depend on diesel fired generation wasn't really politically acceptable – so essentially their recommendation was ignored, not in those strong words, but then government chose another path and decided to develop kpong dam first because they felt hydro was more suited in terms of the cost and other things, and developing country that would build a thermal plant at such high cost, even though the idea was not to run it, but to provide some security so that in the years, because drought doesn't happen every year so maybe one in five years once in ten years we would be secure. And so the kpong dam was build somewhere in the 70s and by 1980 it was finished, the year it was finished was the start of the serious drought period

A: 83-84

K: exactly, so even though drought was built it didn't bring much relief, which highlighted the rationale for the thermal plant if it had been built would have been a better complement to hydro, so we had to endure three years of pain -

A: Would the thermal have been able to supply the same amount, the Kpong supplies how much?

K: About 140MW, the thermal plant they were asking for was about 50MW or so, you have to check exact numbers when you go to the library you hopefully get the document, maybe not but would have reduced it. Because the extent of the drought was far beyond what we could've anticipated, I mean that drought in 1983, is estimated to be 1 in 10,000 year drought so an extremely rare event and you don't plan for such rare events, it would be full hardy to plan for such events. But at least it would have minimized the cost. So another study was done immediately after. Again the study recommended, so the study looked at all options looked at coal, gas turbines, looked at combined cycle actually that study in the mid 90s recommended thermal, either coal or gas turbine, but later the study was refined and the project was reconfigured into a combined cycle plant because in the 80s, again, when the study was finished in the mid 80s, the same principles as the case in the 70s, the thermal plants were going to serve as insurance, but again the mid 80s going on, don't know how much of history you know, that also coincided with the economic recovery program of the government and economic growth went

through the roof and it wasn't anticipated - and when you do a study you assume history is going to repeat itself so maybe you project 4-5% gdp growth which was the norm at the time, but you hit 13-14% so by 1990 the growth is expected in 2000 had already happened, so the plant wasn't needed as insurance was needed to support but really to support the load so it had to be reconfigured into a combined cycle plant which is more efficient as base load.

A: So before then the economic recovery plan, supply of electricity was little more than the demand?

K: Yes, at that time it was thought that Akosombo could meet demand fully, and all you needed was thermal to sit there and wait when akosombo dropped because of natural variability of hydro. But under normal circumstance you would get enough from Akosombo. But demand went to appoint where under normal circumstances you couldn't get enough from Akosombo, so needed a supplement, but the process of getting a new plant delayed because we had to rely on the World Bank, didn't have money ourselves, back and forth, studies upon studies, this and that, so the first plant came online, and the reason this particular combined cycle was deemed to be most cost effective, I mean other options were reviewed, and combined cycle was deemed to be most cost effective of all the options. Coal technology has significant economies of scale which our system could not support, gas turbine were inefficient, and combined cycle had become mature technology and there was also the potential of gas from Nigeria and so we started on crude oil and we are stilling running on crude oil so the idea lets have a crude oil fired plant and hopefully along the way we convert to gas, when we develop the infrastructure to bring gas from Nigeria.

A: And this is during a time in the world when there is movement of coal to oil in general.

K: Yes, but that wasn't a key driver. One of the key drivers was that in the 90s the price of oil crashed. So oil price went as low as 10\$ in late 90s, so cost of running combined cycles which has much higher efficiency compared to coal difference wasn't much, and you know coal had its issues with environment, but that time green house gas movement hadnt taken off especially in our part of the world, so even though it was in peoples minds it wasn't a key driver, environmental issues were not a key driver, it would be today but not then. So that's how thermal came introduced into Ghana (**10 mins**), and since then once we brought in the gas pipeline and we discovered gas then automatically technology that use those resources available become more competitive and more desirable. Of course now there is talk of renewable and there is a lot of effort to bring in solar, but we have not made a lot of progress, and it has noting to do with the technology, but institutional framework is not supportive and therefore money is there, people are there, willing to come as long as we create supportive environment. The sector is in financial difficulty but that is self inflicted and has nothing to do with lack of interest from investors, so once we get our act together we can see more – I think we can see more investment on that side to complement the thermal. But then going forward in the short to medium term our system will most likely be thermal dominated because one we discovered gas, and two for us that is most cost effective, and you know solar has its own issues of intermittency, and solar is really the main - when you look at wind its baya (expression to show have much potetial) very small areas, you cant do wind, 300-400 mw is I think the maximum we can do, that can sustain, so solar has its own issues. So that is where we are and that is why we chose thermal, at the time most cost effective solution and given where we were in terms of size of our power system, technology we chose was the one that best suited our needs at the time. That's what I can tell you.

A: So in terms of our commitments in Paris, I know we said we would do 10% RE by 2030, how realistic is that for us to fulfill that?

K: It is very realistic, I mean as I said it all about creating the conditions, in the past solar was considered expensive and therefore needed special incentives, but as of today from what we are hearing and seeing that isn't necessarily the case, solar can really compete with the conventional sources at least on a per kw basis. As a country we need what happened in Germany and the rest, where subsidies were used to support growth of solar and really they have driven down the cost for us, Chinese and everyone, and they have done the hard work but we need to take advantage of that but as I

said we need to create the environment as long as private sector is going to put their money into a project they must be assured of payment, all those things, that today is not happening so unless we get those things working. So yes its realistic and yes there is a lot of interest. And we had discussions with the mining companies, everybody is interested in solar, so I don't think the challenge is whether, 10% can easily be exceeded if you ask me, that limit has no, it has no scientific basis and economically if it makes sense to build more than that people would build it if conditions are right. And government to say, the reason why they said that 10% because the fear that too much of it will cause prices to increase but if it isn't coming at a price that is quite competitive with existing technology which doesn't require any massive jump in electricity prices, there shouldn't be any limits, it should just be economics and the economics needs to work in the right social framework.

A: In referring to other initiatives for solar, I know there was the AREED project, and one before that...

K: I mean those were pre-economic solar days, I mean areed run by kite and the rest, those were the days when we thought you needed special incentives to bring in solar. So areed was trying to provide subsidized financing in a way for clean energy projects, they even did LPG, they didn't really do any massive RE project per se, but today who needs incentives to bring in LPG, I mean 20 years ago or 30 years ago when LPG started government was given away cylinders because the thinking was that people wouldn't switch cause most people, I don't know if you came to meet those days, people were using electric cookers, middle class was using large electric cookers and rest was using charcoal and kerosene. Electric cookers because at the time power was so cheap akosombo was there so when we started going thermal and realized power wouldn't be as cheap government started to switch people off, and so government tried creating some incentive and that is what they did. So areed and the rest is what people did in the past, but today I don't think they have any place in – where - such funds I better spent on helping the public sector companies streamline processes of bringing them in rather than trying to support the investor. Investor has no problem of raising money, and investor can make good return on investment even at raised prices, electricity prices in Ghana are very high by virtue of fuel we use, you know we are buying crude oil unlike you go to Nigeria gas is just coming out of the ground, gas cheap, maybe not widely available for other reasons but for now not economic reasons. In Ghana issue of competitiveness is not an issue if we can get gas if we can get solar at 10-12 cents. Areed and the rest have outlived their usefulness if you ask me

A: So you talked about cheap electricity at the time, how much has that influenced, cheap electricity for the consumer, the culture and the society, how much have they gotten used to cheap electricity – sort of blocked more expensive- not more expensive but blocked more...

K: I think it has been a cause of our problems to be honest with you. We have been used to it, cheap electricity, for so long that any increase becomes a big deal. Any increase becomes big deal any part of the world. But Ghana is unique in the sense that Ghana, to Ghana electrification rate is almost 80%, among highest in the world, few countries in SSA have it the same. So it is widely available, people take it for granted, people are used to it being cheap, but unfortunately the cost is going to increase, because any technology we bring in is going to be expensive so the weighted cost is going up until some point it levels off, but it hasn't got to that point yet. So all things being equal prices will still have to go up in Ghana regardless of what we do, and unlike in other, in Ghana assuming we started with thermal, then we ready start with the high price like Burkina and the rest, so they are used to the high price, its there, most countries like the Senegal and the rest, French countries rely on diesel so they are used to it, but when you are starting on a low level. So culturally we havent been used to high prices and politics, the time that thermal came into coincided with when we became a democratic country and of course politics is about winning power.

A: now specifically when a plant is being constructed, the funding, what is the processes of bringing in funding for different plants we now have for supply to our national grid, I know world bank has participated in helping in bringing in funds

K: I mean today there is no WB involvement in bringing in funds, no multilateral involvement. Now it is a purely commercial venture. The private sector is now driving most of investment at least in generation, VRA is doing a bit of it, and there are juniors going to commercial bank going to collect money to build their plants. There are difficulties but they are still able to do it, tells you for the committed there is still room for you to come in. Nobody, there has never been, today people are still knocking on our doors with money available, if you wanted, to build plants. Just like investing in any other thing, only difficulty is just that ECG and other entities in sector are state owned the requirement is that government provide certain guarantees and those guarantees are due to our own created difficulties, if government doesn't come and pay ECG, then of course if you are selling to ECG you are concerned that they won't pay. If government was paying then of course then there would be no reason for ask for guarantees, or if PURC is unwilling to increase prices even when there is justification for that then of course the guy would want guarantees that he would get paid in the event that for political reasons you don't increase his prices. So those are the political risks and other policy related issues that they would want to protect themselves against. Once they do that, issue of raising money is not a problem, money has never been in short supply never has been never will be, its all about you putting yourself in a position to be attractive as an investment. A lot of people out there who know how to do that.

A: In terms of generation right now, how much does VRA own?

K: Now we own about 50% there about, because we are now about 4000MW and VRA has 2000MW, so just around 50 – 55% based on how you look at it.

A: And the other half is a mixture?

K: Private sector.

A: So private sector is getting more and more.

K: [21 mins] VRA in the medium term is going to be a minority player, because the private sector, should I say, has gained momentum and also gained an advantage. An advantage in the sense that they aren't concerned about financial problems and private sector not weight down about those sort of costs. Bottom-line, we supply to ecg and IPP provides to ecg, ecg will pay the IPP first, before it pays to VRA. So they will be indebted to us, but they wouldn't be ___ if IPP and VRA go into the market, iPP would receive money first.

A: I don't know how much you can comment on the debt issues, but is it VRA or ECG, which is in debt, and exactly how does that work?

K: It is a cascade, VRA is just bearing the brunt. I mean we don't sell directly to the customer it is the ECG that does, it is ECG that collects the money for everybody, all of us, from the gas to generation to transmission no interface between us and the customer. It is the customer that pays, and ecg can only pay back to us what they have collected. So if there is a short fall it occurs first at the consumer end. It can occur in two ways, either tariff not enough to cover how much they have bought cost of what they are supply or they aren't collecting the money. So if they don't – what ever the cost, if it is a short fall, they are collecting the money, if it were you, you will take your part and then pass it on to the next guy then the next guy and ultimately someone will be short changed along the line.

A: And that is VRA? And that is what has happened over a long period of time?

K: That is VRA. VRA. I mean they owe us billions of, and we also owe Ghana Gas for example, another state-owned entity over 500 million \$ now, cause if we don't also have money we cant pay them, then, government once in a while will come in, like if we owe WAGP, government will step in and pay, but government will not bother paying Ghana Gas cause they owe Ghana gas and wouldn't bother paying VRA because they own us. But they will pay an IPP, because they are a foreign investor, and see Ghana government doesn't want its name and the international price to be soiled

because I mean you are trying to trumpet Ghana as an investment destination you don't want to be messing up with the few people who put in their money, typically they want to appease them. We are one of them so what is the point.

A: what could be the implications then if VRA, ECG, people further up stream and there is too much debt in the system, is privatization a real thing?

K: Privatization hasn't solved the shortage problem; it solves the shortage problem to the extent that the shortage is a result of poor performance, and that is why ecg is being privatized. If ECG privatization is thought to bring in a little more efficiency and you know in the sense of being able to collect the money, reduce technical losses, because they all factor into your cost. Currently ECG losses about, depending on who you talk to, 30-40% of their money some of them as technical losses, some as stolen, some as money they don't even bother to collect. Don't even bother to show up. I mean my meter hasn't been read in one year. So I can choose to pay or not pay, so even though it is metered and they can come and bill me, they aren't bothering to. Eventually those inefficiencies, feedback because it is money you aren't collecting. I mean I can go to the customer service and pay on my own but not many would. So there are too many leakages, and the thinking is if private sector person has put his own money into a venture he isn't going to let you get away with it, and if you are state owned entity you get paid no regardless what you do. So incentives to perform are greater for private sector, so idea is to create greater incentives for performance. So privatization from my point of view it isn't an ideological issue, its really an issue of who has the greatest incentive to perform and more likelihood to perform. Just changing the incentive structure. People don't perform because, you don't work hard because you are happy to work hard but because there is something in for you.

A: In short term, privatization in the short term may help in bringing in some small money but then as you said before the supply side is still inefficient in covering.

K: You see it has to be holistic. The thing is you can't look at the sector in bits in pieces, you cant fix ECG without fixing the other aspects of it, if the you haven't gotten the prices right no private sector guy can help you with it. Even if it is efficient you still need to get paid for the investment and for the people to be efficient, and everyone down the chain must also get paid and be efficient. And he is at the forefront of the money but also at the back end, any problem with gas, generation transmission affects him. It is a symbiotic relationship that works both ways. Not only a matter of they paying but must work two ways.

A: And more on the societal front in terms of the sort of illegal taking of electricity not paying of electricity – is that a major factor?

K: I don't know the extent; if you look at the commercial losses they say it is about 14%, I don't know the truth. But if you go to our neighboring countries they don't lose as much. So is it an African problem? Why is it not happening in Senegal? If you talk to people who live in Senegal before they will tell you how strict those guys are. You even have to put deposit down before you even get meter connection, and 'lord help you' if you don't pay. You will not even last. Cote D'Ivoire all those countries Togo Benin have fixed that problem of stealing I don't see why we cant fix it ourselves.

A: When did the metering system, when was that introduced, how has payments from that side to ECG been working, has it always been the meter system. Or has it been that you come pay your utilities.

K: I don't understand your point but mm I mean the meter is what determines the amount you pay. So now they have pre payment, in the past it were all credit meters, so someone has to come and read and give you a bill. So if that cycle is long, because most people wont pay bill until they see a bill on their doorstep. So if you come and read my meter and it takes 6 months before you come to deliver my bill to tell how much I owe, means for 6 months I'm not paying any money and you aren't getting any money, meanwhile we are buying power and selling so how are you going to pay for that. So metering cycle is important in terms of how quickly you recover your money after you bought and sold power. And also your effectiveness in making sure people don't steal and make illegal connections and also

ability to, I mean elsewhere I don't know how it is in Sweden and the rest, they even analyze, they have software that check your consumption every month and if it goes beyond a certain level they will come and check, it could be that you are an old lady who is dead. And you aren't using your heater. Or anything. Automatically there are internal checks, so if you are doing 10 10 10 then one month you do 2, they will come, or if your neighborhood is doing 10 10 10 cause everyone has same equipment you know heater, and you alone are doing 5, what is so unique about you? It is management by exception. And they will find exceptional consumption patterns, and use that to follow it isn't blank and universal, just go round randomly going round checking people, its wasteful, in todays world of data-mining you don't waste time doing that. And ECG can do this, they have a wealth of information they can gather and analyze it, it is a matter of commitment, that's what it is about not rocket science.

A: I think I have gotten a lot --

K: If you want to deal with ECG issues I don't know if you have talked to anyone in ecg, but they will give you a different perspective which is useful, they will give you an idea of why all these things persist.

A: I havent talked to anyone in ECG, so it would be good if you could refer me to someone.

K: a guy called aminu

K: Number of documents you can ask for. During that period. We have annual reports, financial reports, usually there is a whole narrative. You know during those times VRA is alpha omega. Everythin about VRA is about the sector. Maybe get a few snapshots, 85, 90 get a sense of what was going on. But there is a lot of information and you can ask him for the study I talked to you about. Or any world bank reports on any of the projects and flick through them and see if they can be of use to you. Hopefully that will help you. At that time vra...

A: So there are a two, simple comments.. So I read about BPL global and they are doing something about smart grids and they just signed something with VRA. I don't know how much you know bout that. Read it somewhere online, smart grids.

K: Oh ok! Ah well, Broadband over power lines, what I know about them I know about the BPL company, they been around for a long time and I don't know if they are doing it in VRA. They are using the grid, they did a pilot in akosombo and they use the wires, broadband over power lines, use the wires to also send out for communication and there tellers, and they will use it at sekeda system and they can also use it for internet. So what they did at akosombo they could connect a wire to your home, like a normal telephone wire, just that on the pole there is some interface that converts signal from powerline to turn it into – im not an electrical engineer. I think it is technology that is available, eh we actually we used PLC in the past, so its technology that can eh, what is your background, engineering?

A: No im -

K: No you said you were a political scientist. All I know is that they did the pilot and they wanted to work with ECG and VRA to deliver that service, I don't know how far they got, because you know NEDco, they work with distribution company and you see our distribution company is a separate so have their own management, subsidiary, but separate and mainly operating in the north, but all I know is because they used to come – but I don't know how far they have got.

A: Second question: are you aware of this term lock-in. Where for instance there is carbon lock in – like in the West they have a situation of carbon lock in where their whole system of energy is based on fossil fuels and that is one of the problem for them in transitioning to renewables, how much is that a problem for Ghana?

K: When you say carbon log in or lock in?

A: Lock in. As in they build their infrastructure and then you have the institutional framework, and behind that you have the market who are profiting from that system and because of that there is inertia, so RE cant enter-

K: Oh I mean I don't know, because we don't really have market and institutional framework is underdeveloped. I don't think – carbon issues is just talk, we have talked the talked but not walked the walk. I don't think there is any vested interest in keeping any new technology for coming in. Difficulties have been in general and it is not only RE which are having problems coming in, but also conventional, some RE have come in, there are two grid scale solar projects in Ghana, one by VRA and one by BXC, chinese company, and they have a lot of others who want to come in who have a lot of difficulties. I don't know much about this carbon lock in principle, but then I don't think, you know RE, environmental issues have really not been a driver of what we do, it really has been necessity and crises, and our system is driven more by crises than any deliberate plan to develop the system in any other way. You know the crisis hits, everybody scrambles, something gets done, then everyone goes to sleep then the next crises hit then we scramble. Not about cost effectiveness not about long term planning there is no objective function that somebody sitting around that says these are the variables we should look at to get this outcome. So that is what maybe you finish school and come back to Ghana, then you can do it. Which I don't think you would.

A: That is why im writing this paper.

K: You would want them to pay for your vacation.

2.2. Interviewee: Douglas Hagen

Date: March 1st 2017

Interviewer: Abdallah Smith (A)

Position: Learning and Development Manager for Ghana National Gas Company

Purpose of Interview: The function of this interview in regards to my overarching research question was to gain insights into the processes that have enabled thermal sources of energy to become more prominent and therefore act as a barrier to solar. Specifically I was interested in understanding the prospects for Ghana using its domestic sources of thermal energy seeing that it was a crucial element in the continued path-dependencies of using thermal in Ghana's electricity supply. Mr Hagen's insights provided crucial data and corroboration with other sources in piecing the gas aspect of the narrative.

A: We can start by you telling me your name, your position how long you've worked here, those type of things.

D: So my name is Douglas Hagen, I am the learning and development manager for Ghana National Gas Company, and ive been here for nearly five years, since 16th of May 2012.

A: Ok, that is basically a good introduction. Ok, so I have already told you the general theme of my research paper, but maybe we can start from the discovery of oil in Ghana, and the issue of thermal plants being supplied with crude oil. So now that we have discovered oil and gas that has sort of figured in the government's mind, and that is a way to fix the problem of thermal plants and the crude oil supply. So could you just talk about that and I know the thermal plants changed from crude oil to gas, to the double cycle – not too familiar with the technical –

D: That is right. The combined cycle.

A: Yes.

D: Ok, so let me make sure I understand the focus and the purpose of your research first before I give you the correct information. So you want to see how Ghana's energy mix, will change or has changed since 1957 up to now, particularly you want to look at how the discovery of crude and oil and gas, will affect the energy and electricity generation.

A: That is maybe one aspect of it that is maybe more the contemporary aspect of it. The more historical aspect is that we had relied on centralized hydropower and those institutions and culture have evolved around that and now we have gone through a transition and we have thermal to complement but maybe with this complement we are going to a lock-in, if you are familiar with that term and that might prevent renewable energy. That is what I am trying to see if it is the case.

D: So the interest in renewable energy and efficiency and around the mix and its impact. Ok. So if I start with the discovery of the oil and gas one of the fundamental problems that we have had with our development in the country has been the cost of electricity and also its availability. This is no recent problem, I mean the dumsor, anybody who has lived in Ghana know we have experienced several times along certain lines. So when crude oil was discovered and because we were fortunate to have an associated gas with it, that is crude with gas, the idea was that we must commercialize the gas to support the rapid industrialization of Ghana, by using it to produce cheaper energy and electricity. So various options were done, I mean the original form of the agreement taken by the government of President Kufuor at the time, was to commercialize the gas in the same way they commercialized the crude oil so that a third party multinational will come who will process and sell the gas. Then when the Mills' administration came he set up a task force to look at how we could re-commercialize the gas, how we would make money from the gas. And the task force came with the understanding that instead of just thinking of the gas as just a commodity, as a way for the nation to make money, we should think of it as a way to industrialize the country by using the gas to produce electricity. Now let me make this analogy to you, the environmental impact of hydro in the long term is lower than the environmental impact of thermal, over the long term. But even in thermal sector if you think of the environmental impact between gas and light crude diesel, it's a significant difference. So the idea is if we continue to produce electricity with light crude, then we are going to destroy our environment quite faster than if we did it gas, so that was a driver for it. But the primary factor was this, if we produce electricity with hydro, it will cost us about 2 cents/ kilowatt energy. If we produce it with diesel, or you hear people call it light crude, it will cost us about 15/50 cents, this is cost before you have actually transported it and had distributed, so by the time you add those costs to it, it will be more. Now if we weight all of these (5:03) with gas, then we are looking around 6 cents, depending on the amount of hydro and the amount of light crude, but if we continuously look at reducing the amount of light crude and increasing the amount of gas then we are thinking of 6 cents/ kilowatt hour. Because you can actually reduce it to 17 cents per kilowatt energy if you weight hydro with light crude, that means you have more coming from hydro and a little bit coming with light crude. But if you have hydro and most coming from natural gas you can bring it down to about 6 cents per kilowatt. So if you speak to people in industry, nobody wants to pay \$50, 50 cents per kilowatt energy. I mean in England they pay about 40 cents per kilowatt energy at peak time. But in England they dont have a fixed amount charge. If you use more energy at peak time you pay more, if you use more energy at down time, even though you may be using a lot of energy, you will be paying less. So the community that thought they were washing at night, so when you are going to bed, you turn on your washing machine because its cheaper for electricity at that time, rather than to compete with the industry and use them at day time. Unfortunately for us, we haven't developed our market to that level, but at least we know that nobody here wants to pay 50 cents. Now the history, if you go around now you will know we are paying around 40 cents which is interesting but the price we are trying to avoid. If you can go only for crude, I mean only for water hydro and gas, based on those two alone you can actually reduce to 6 cents depending on what kind of contract you have. Some of our contracts may not be efficient in terms of the charges we pay, but if you have your own generation center and your working very well, very efficiently you can pay 6 cents. So the driver for the gas for Ghana, was really to use it to generate electricity and that is the whole purpose of Ghana gas being set up by the government. It was to say that we would put a national entity that would can aggregate all the gas, process it, and sell it to

our own generation centers to generate electricity, make some money for the company, but really the impact is about developing. So if at least from 2006, 2007 till now the focus, cause that is when we started commercialization of the gas field, the focus has been we generate electricity using our own gas and to be able to reduce the electricity, the problem we've had is that we don't have quite as much gas as we use, we rely on Nigeria to bring gas, and we have had problem with the constant supply of gas. So very often we have had to buy crude oil more than we expected and that then means our fuel our energy prices have gone up. Cause obviously diesel prices are more expensive so our energy mix, in terms of electricity generation, to the consumer is around 40 cents, 45 cents per kilowatt and that's because also some our transmission and other things are inefficient and they add on to the cost. So in terms of giving you a brief background my understanding of the industry has been fundamentally gas. Our energy mix is around trying to currently over reliance on maybe light crude and water or hydro, pushing toward more reliance on hydro and gas, natural gas from our own so we can choose our energy.

A: So you were talking about our reserves of gas and you said that we might, like how much do we have and how can it sustain like this strategy of keeping the price of electricity and if it can, how long can it do that? From our reserves.

D: The reserves are very important, but also not that important cause you may have it sitting down but it will cost you 4-3 billion to put the wells together to bring the reserves on. Do we have the money to actually make the wells, through which we get the gas in the first place? And if we don't, do we have the legal and institutional framework in the country to bring a multinational who will come and do the wells, knowing that there will be resources to pay them, and over the period and lifetime of the project they will recoup their money in time to make a profit. So if you've been in the industry you will understand that the gas, the ministry of petroleum, now back to the ministry of energy put together what they call the **Gas Master Plan** and within that gas master plan there was an agreement and a plan about what the gas cost will be to entice people to come and make those wells for us. So we do have more than 4000 billion standard cubic feet of gas, which is significant but in the grand scheme of places it is not. Saudi Arabia can process our gas and finish in maybe under 2 years. Do you understand?

A: Yeh

D: But even that we are not commercializing all of that. I mean from the jubilee field, which is up and running, we get about maximum of 120 million a day –

A: Of gas?

D: Of standard cubic feet of gas. That is the peak capacity. (10:30) We've never reached it. Because of the torrid/ Tullow bearing and all the issues we have on the jubilee fields, but we go around 80-90-100, I mean when you are 100 – you never really work to capacity anyway, but if you can get to a 100 consistently you know we are going to have enough to produce electricity. But that field has a lifetime of 25 years, it started in 2007 so you work the maths –

A: So about----

D: its done about 10 years but the gas only the commercialization started in 2014, so you just give it 20 more years, but there are other fields. So like from the end of March we should be getting some other gas from the TEN field, which has happened and it is going to add about 15 million to it, so we have 120, which we are working to about 100, and then we have 50 if we get regular 45 from that field, so that is an addition that is going to the field. There is also other fields which are purely gas, which are owned by again the same ENI company that is doing the TEN. Now, have we got enough incentive for them – remember normally when they go for the associative, when I say associative that is a field of both gas and crude, their prime focus is not the gas. They are not interested in the gas as much. They go for crude, but in the associative it means there is a limited amount of gas. But the non-associative is where you have pure gas and plenty of gas for us, but they have no interest to dig wells

there because they are more interested in crude. So does the Gas Master Plan, does it have enough incentive for those people to want to go and do that and give us the gas. So Jubilee field has about, lets say it has about a 1000 bcf, lets say the TEN will have similar. There are others, there is Jacta, which actually has more than that but it is non-associative, so it is much harder to get. So there are more fields that should come online, that should come on stream, that should extend the life of the project but there is that political and institutional framework that must be put in place. The government must show, and when I talk about government I mean actually the civil service, the people that work in those places, that stay after elections, they are far more important because in this area the decisions all have long term impacts. The politicians tend take about 4 years, that is the longest they can see. But the technocrat, the professionals who work in those departments must be able to think long term and must be able to support who ever is in power to come up with programs that will incentivize these people to come.

A: Ok. So there are two things now and they are on different ends of the spectrum. So one is more on the technical aspect of getting gas. You talked about associative and the problems of if it is just gas by itself - there is really no interest because the main thing is crude, so how often is it that gas is just by itself – how does that work cause im not too familiar with oil and gas. Cause as far as I know when you have oil you can also get gas, is that always the case, or can gas stand by itself.

D: Yeh, and you can actually have crude with no gas (14:37) you can have it in all different things. So what it is, is that you know I want you to think about – have you seen a well before, a normal well with water. Think about this as the same thing but much more technically than, bigger, longer or deeper. So a well will go maybe 70 feet, 80 feet this will go maybe more than 1000 of kilometers, you can have a well that is as long as driving to Kumasi, down to Cape Coast to get crude. So that is the first thing I want to think – and to think about how the hydrocarbons form. Every dead living things have hydrocarbon. So basically you have them everywhere, they aggregate together billions of years make that – they break that process when they are actually digesting to form part of the soil depending on the conditions that they come together they can release a certain amount of carbon that forms together, that forms this. And we don't clearly, I mean the science is there but you can force it, it takes forever to do. Now depending on he environmental nature when these things come up, they can come up with gas or not. And when they come up with gas it is very good because you know as you dig to the ground, theres gas there it pushes it up, and you suck it easily. When there is light crude or crude oil down without gas, basically you now need to go and get your own gas to pump it there to push it out and it makes it more expensive. Until recently there wasn't even enough viable technology to extract them because obviously depending on the price of crude oil, if crude oil is \$10 then buy the gas and pushing it there is – when crude oil gets to \$100 per barrel, even shale gas becomes viable. Do you understand? So depending on the price and how things work, but yeh the gas forms from living things and they can form either with gas, without gas or gas alone, depending on the conditions at the time. When the digestion and everything happens. And when it comes without gas, its harder to extract because you have to push gas down there to push it up. When it comes with gas it is quite easier because the gas is always looking to escape, so in trying to escape it comes with some of the crude itself. And then sometimes when you have gas alone, its also easy to do because you dig into it, as soon as there is a way the gas is coming and you can. Very often the gas comes as liquid anyway, so you have to process it. So after you process it, the lighter gas will go and then the heavier gases will stay later and then you have some slight amount of liquid. So those are just the initial technical, just to try and help you understand.

A: And the problem with what we have in Ghana is that the interest are in crude, so even if we did have gas, there wont be any commercial interest in extracting that, unless it is with the crude oil.

D: It depends on the incentives you give to the multinational, they will do anything that makes them money, so countries like Trinidad and Tobago they had the same issue as we had and they developed a program that allowed them to export gas to the US. Now they are struggling because US is now a net exporter because of shale gas. They developed the infrastructure, they actually incentivized the companies to come and in the first 20 years they give an international company almost a monopoly

and actually helped them make a lot of money just bringing up the gas and selling it on their behalf and they get a little bit of royalties. Then after 20 years when that contract ended the next negotiations they were a lot tougher, because they had now gained the technology themselves to be able to do it and they had put in place infrastructural and mechanisms for the state-owned company to do the project if the company would do. And the thing is after 20 years even though the company had built the infrastructure the ownership transferred to the government. Do you understand? So it is about how you incentivize them. It is almost like dangling an apple in front of them and while they bit – do you understand? So all they are always looking how can we increase the amount of money they make. So once the government comes in and is investing along with that, is the government also bringing in other things to make sure production quality and other things – do you understand? And they would have made enough money to cover their costs in the first 20 years. So everything else is profit.

A: So coming to the case of Ghana and how we need to develop these institutions, how far are we from developing these institutions that will enable this environment for the extraction of crude and natural gas

D: I think we have come a long way, there is a lot of room for growth and for improvement. I think looking at the kind of industry we have here, the amount of gas and the amount of crude, I don't think we are ever going to be like the Norways or other countries. We have gas we have crude, but we don't have a lot, I mean even compared to Nigeria we are nothing. Do you understand? So I am not a big fan of investing the whole countries effort into this to say that we have to be self-sufficient because by the time you finish training the people we might now have any crude for all those people to work in. I think fundamentally what we need to do is to make sure that, in commercializing the products, commercializing the crude, commercializing the gas we get a better deal. So it is about strengthening institutions that petroleum commission, energy commission and the other places for them to enforce the laws about localization, the laws about local content, the laws about structuring a development so that when the multinationals come, there is a lot of benefit for Ghanaians as well. And I think for me those are the areas that we need to focus on. Cause even if you go and buy a block, you can buy a block in Nigeria that is far more lucrative than all the blocks in Ghana put together. So it really doesn't make sense unless you really don't know what other discoveries we will make, so we should always have people in the industry who know what the industry is about, and that is why localization is important. Localization is a simple, simply means that for every role that we have a foreigner doing it, we must be training a Ghanaian who with time will be capable of also taking up the role. For me it is a job and lucrative job for a Ghanaian but it is also a competency training, that somebody somewhere from will get certain expertise and understanding. So lets say we get a huge discovery somebody understands the industry now to move into the job, who will be thinking Ghanaian, who will not be thinking how can I make as much money as possible and go and spend it in the States or in the UK or somewhere else.

A: To some extent we have something like that, kind of going on –

D: We do, I mean if you speak to the petroleum commission, they are doing a good job. So there is a legal framework expresses a certain level of localization and they implement it through the visa systems and its not perfect, but I think they are doing a good job.

A: So now that we have talked about these institutional things that are needed to allow the gas to be beneficial for us, coming back to this idea of lock-in. Are you aware of the term carbon lock-in, institutional lock-in.

D: I think about it and I think it is a very beautiful term that will probably not apply to us. If you look at what we have done, you know you cant just turn your infrastructure that you is used for say processing crude into just gas, I mean that is just essentially the explanation we talk about, when we talk of lock-in, it is to say, we you structure all your energy generation infrastructure to use a particular fuel, a fuel that you may not have in the long term, you might find out that it may not be the best fuel or it becomes expensive then all of a sudden you still have to go and buy it and that is the fear. When

we are talking about having that carbon lock-in. The way I see it, unless we are capable enough to go nuclear and I would strongly object on personal reasons of my view of our attitude towards doing the right thing and doing the right thing all the time and our attitudes toward maintenance I don't think we develop those capacities in those people who are going to run it for me to feel comfortable. And I think the most energy efficient way we can do it is with gas. Anyway I think so far we don't have, looking at the list of the other hydro projects that can be done, and on cost to benefit that will be sustainable, I don't see them. All our rivers are drying up, even when we did the research and it came up with a lot of rivers that could have had small mini hydro, that could have serviced local areas, when you go back to those rivers I don't think your view of them will be the same because most of them, we haven't looked after our environment, our rivers and things, so I think apart from what we have done at Bui, there may just be one little dam that may be able to be done very little dam. So if we move away from hydro, the most environmentally good way of doing anything is with gas, in my opinion. So, reconfiguring our infrastructure to process with gas is not necessarily a bad thing, but we must also keep in mind that we may not have the gas, then what do we do? And so if you look at, I mean sometimes I think we haven't shown a lot of foresight as a country in that area, but one of the things we have done is that most of the infrastructure can switch between light crude and gas, and I don't think that is an accident, I think that is well thought in saying that, we must reconfigure all your activities to be able to do this. There are specific gas turbines that can not take light crude or gas which we need to look at, I mean some of the plants were supposed to be short term and then Asogli could not use light crude but actually one part has been reconfigured to use light crude, so those are things we are looking at trying to avoid in that kind of lock-in. There is also recently been a talk about more environmentally friendly coal and new coal technology, that is not as bad as what we used to. And so there has also been the talk about people trying to offer that to us saying that it would give us cheaper and a better source of power for your industry and clearly one analysis I heard somebody with a doctor in front of his name say that he has never seen any country that has developed from third world to a near developed country that never had a coal plant. So the argument for that is also being done strongly. I think there are a few people who probably know they can make money by being brokers for coal and I don't particularly, I mean I think that is how our world works. People's interest must collide with the interest of the bigger social enterprise and that's when beautiful things happen and I think that if there is a coal that can be proven to be more environmental friendly, then there is nothing wrong in experimenting and having an understanding. Knowing that we don't want to destroy our world, at least we must leave our world, if not better than we found it, at least the same. So I think it is a beautiful term, I think we need to be aware but I think it is the least of our worries.

A: Ok and when we talk about sustainable and having sustainability within our energy sector, would it be fair to say that it would be good if we have a larger share from renewable energies, lets say solar because solar is the most viable one at this time, if we can have a nice mix, lets say a 30-40-30, between gas, hydro and solar – that could be a potential aim for us to have, in terms of sustainability and since energy is so crucial for development. Wouldn't that be something realistic we can aim for

D: I think it would be beautiful to increase the renewable aspect of our, the mix. I think the research that was done using wind turbines under the river and the seas. You go to Ada, where the river meets the water, they actually have a high turbulence level when the sea comes really fast and the river kind of comes into the sea and that is very fast, and we did some projects, I mean Ghana, the people that came with funding to do the project there, and they actually researched on how much energy could we produce with an underwater turbine using the natural – and I think that project is still on going, funded by – sorry you are hot?

A: no it is fine, I sweat...

D: Yeh so they did that work using the natural current of the sea, to see if we can generate a good amount of electricity. There is some work done, that has also been done on using some of the windmills locally to see that. And you know about the Navrongo project as well. So we have experimented and we have to keep looking at that, I mean we cant just keep destroying the world just

for the purpose of industrializing. So far the significant challenge has always been the initial capital required to build wind farms of good size that can stand –

A: Or Solar?

D: Yeh or any of the renewable ways. So one of the things I have been following is the technology has actually been improving so the capacity of the panels that were done a few years ago compared to now the generators and other things, I mean I have a friend who has convertors, solar convertors and the batteries used to be packed in a separate room, several batteries and they took all that and put two new batteries and are far more efficient than the about 15 batteries they used to have before. So the technology has improved. Even the cost is coming down, if you look at how much of the EU funding has gone into the technology, how much the Chinese have also invested in the technology and various projects have happened but it seems that all the time the initial capital seems to put the state off. I also think that when you are under pressure you tend to go for what you know and because most of our decisions are driven by pressure and fear because unfortunately with our energy mix for the last 7 years, from 2010 till now, it has been relentless problem with energy and so we have made decisions from position of need, which hasn't encouraged innovation in my view. So we've – we haven't done as much in renewable in terms of the mix but I think if you look at the amount of sun we have we should be doing a lot better. But it is always the initial capital outflows. It is quite high. You know I was wait- I was looking for like the world, you know when they do the Davos convention, when they met in Paris recently before Obama went, and they are talking about the carbon footprint and others and people paying the fines – I was actually looking forward to a project or funding for these projects and actually working on it in an industrial area in an economical way so that they fund the projects and manage the projects for the projects to pay back the cost of those projects. You know there's a lot that people in government, in my view, can learn from the churches. You see they are able to tell people to give them money without doing anything for them, because even if God makes a miracle its not the pastor im given the money to, its God and I cant give god money so it shouldn't cost us anything. But there are other things I see them do. There is one church in Ghana here that will, has a fund, they build their satellite churches and then the other churches pay back the fund. So they don't wait for the satellite churches to do collection and take forever they go to an area, build a nice beautiful house that will cost, lets say half a million dollars. Significantly higher than it would cost to build that kinda house, but the satellite church will do contribution and tell people that they need to pay this money so another satellite church can help – and I was expecting some fund like that, that says we are going to developing countries where there is a lot of you know – if you go to China, I mean, they are destroying the world far more than anybody else, with a lot of crude and a lot of coal – do you understand – and significantly a lot of developing countries in Africa will follow that thing cause there is a limit to how far they will listen to the Europeans and the Americans telling them that this is not right, this is destroying the world, this is going to do this, when they themselves in their own countries are having an argument about even the impact of global warming and whether global warming is as bad as we think, or whether we can control it, or we can not control it. But if we had a fund that clearly stated we can do this for you in your country, we will project manage it for this years so that you can't, you wont corrupt me and siphon the money and we will pay for the cost of project before we hand over, then that would help. Until such a project like come – I was striving to see how countries like Ghana can put their money into renewable energy. They would do small projects. Navrongo 2.5 and underwater not negligible, I am sure they are using it adding it to a few things. But I also think that one of the important things that we have to try to do is localize generation if its possible. Because generating all the electricity in Tema and Takoradi, and travelling all the way to Tamale doesn't make sense, you lose so much of the power and I think that is one of the things China do very well they build those generation centers near the location. Because you save on the environmental impact, you become more environmentally sustainable.

A: And in Ghana this issue, most of the rural is still not electrified – I think it is 30% that has been electrified-

D: The data is quite interesting because the data that the politician gives is that they have electrified 65% of everywhere including the villages. But when you go to the villages most of them they do have street lights, but most of them haven't taken power into their homes, because they don't want to pay the bills. So it depends on what you call electrification. Do you say the homes of 65% of Ghanaians has electricity or do you say that they have the wires? That if they choose they can tap and pay for the bill and if you want to say that the fact that there is wires passing in front of your home that is within access to you, then the government could be right by saying we got 65. If you want to say it is in the house and the people have access to electricity, then you will think of 35, so you choose which one.

A: But even regardless of that situation, the way the make up of renewable is – is that it works well for decentralized, so it makes sense when you are building a solar field to do it in the north and supply northern consumers, whereas building one in the south and trying to move it all the way to the north and that –

D: It doesn't make sense to transport electricity over long distances, doesn't make sense –

A: No, so that is one of the benefits that renewable can help in electrifying those parts of the country

D: But let me ask you a question then, do you believe renewable is the way to go? From your studies.

A: I think there needs to be a mix, because renewable is intermittent, cause the sun is not shining all the time and it doesn't have the same capacity to do as gas and coal to give energy, so we need a mix I think, and the more diverse our mix the more secure our energy supply, cause we do need to develop. So that is what I would say, that renewable energy is just a third of the answer.

D: You have answered my question, of what you see the percentages as –

A: Yeh like

D: It always makes sense to use the raw materials that you have, and at the moment the raw materials we have is gas, we just have to be open to the fact that we will not configure our infrastructure to use gas only. In the long term the raw material that we also have in abundance is a lot of air for our seaside and a lot of light

A: Solar

D: So we also have to find a way to use it. It is whether we want to invest in the technology itself and I think that my way the most viable option I see that if we selected lets say a 100 technicians in a government sponsored project and trained them through a program within your ___ like Germany, China those countries are really like appreciating the renewable technology. Germany does very good solar panels and stuff, France and of course the Chinese and the Chinese are actually very well- they had a state sponsored thing, so even their panels were cheaper in Europe than the ones made in Europe because they were subsidizing and I think the Europeans were very unhappy. But I think the only way for us is that we build and invest in the technology itself, so that with the raw materials we have the men to do it. So that we can have, and a government policy that says we are going to build this thing we have the people. So if you train a 100 people and you bring them back, then you are moving these 100 people plus another 200 people who are working from areas building plants and maintaining them. But the approach has been to buy the technology all the time and then you buy the maintenance technology because obviously it needs to be maintained, then you buy the operating technology, you will not be motivated because you are going to spending more, because the cost of maintaining it has become higher than the cost of maintaining the gas infrastructure, the cost for building it is higher than cost of building gas. Then the downside of it, cause most of our electricity, most of the peak time in Ghana in the use of electricity is between 6 and 9, during that time you have no solar, very little power comes and during that time, you know electricity is funny, you cant store it, I mean – do you understand? During even your peak time and your whole solar doesn't give you as much. Of course if we have a lot of offices in the area, those are the areas you want to build more solar for using. In the

offices the day time they are there, when the ACs and others are on, the Sun is also high and it is powering. So yes, we must aim for, in my view 30% 25% something like that, people think we should aim for more, for wind, for the renewable activities, and we must if we are going to be successful we must invest in it as a country and it should be government policy – state policy and we must invest in the technology and not the products. If you want to buy the technology, make somebody build it or come and build it for your- you don't get anything at all – but I doubt, you know you are making the decisions under pressure, I mean if you are at the ministry of energy, that is a job nobody should want – and im surprised I heard that the man they suspected that he would have bribed people for that job. I think the person who gives you that job, either trusts you very much or they want to give you a poison chalice. And I don't know which one it is. Because it is a job that you can not win

A: I was even looking at one of the news papers – says ECG needs 1 billion dollars investment to clear the debt and you know make power supply and we also own Cote d'Ivoire for gas-

D: For electricity, we are buying electricity from them.

A: it is almost like a

D: it is a job no one should want I don't understand why

2.3. Interviewee: Johnathan Walker

Date: March 13th 2017

Position: Planning and Business Development

Purpose of interview: The general purpose for interviewing Mr Walker was to get specific details on the development of the VRA Navrongo Solar power plant. Originally, I planned to study pathways for solar energy, and through conversation with Mr Walker I got an idea of the processes seeing that he had worked personally on the project. The function of the interview, in regards to my thermal dominance research question, acted as a way to clarify the barriers to further installations of solar power plants in the current selection environment. Toward the overarching research question the interview provided key insights into a part of the narrative that I needed to supplement with someone who had worked in the field.

J: PV panels, at the time polychrsytaline wasn't bad, you know Ghana has a very high irradiation so poly would perform good, it wont be bad, so we chose poly-. Although people felt we should do mono. But –

A: What's the difference between the two?

J: Mono is more efficient, but it has its advantages and disadvantages. But looking at our, in terms of price, poly wasn't, at that time poly wasn't as cheap as it was now, but we weighed all our options, and we decided for the poly. Mono was also proven, but poly was more widely used world wide, so we went in for the proven and widely used technology.

A: In terms of the project itself, the actors, was VRA the main actor and then which other actors?

J: This project was solely funded from VRA's internally generated funds, at the time we were quite profitable I wouldn't say we had the best of resources, but we were ok, and that is why decided to do it so small. 2.5MW peak plant isn't as big as what you see elsewhere. In terms of stakeholders, when the law was passed Energy Commission came in with the Renewable energy requirements we were supposed to go for permits, you have to do your ESI, Environmental Impact Assessment this plant was quite small so they call it a preliminary environmental report, so basically yes, we licensed our plant with the energy commission. You know the licensing process has a number of stages from provisional to siting permit, construction permit and so forth.

A: But in terms of like institutional framework and stuff, there is definitely something in place for renewable projects. For VRA to continue to do projects like Navrongo or-

J: Yes. VRA has its own plan, and its plan as I said is 10%. At any point in time our installed capacity we have, we are to do 10%. So we did the first phase which was from 2010-2015, the plan was to do 12MW of solar and 150MW of wind. However, we are slacking, we have only done the 2.5MW, we also done some wind measurement because of the wind projects we intended on undertaken. You know for wind you have to be certain of your site and so we identified 8 sites in Ghana we procured meteorological mast, we have done a whole year of wind measurements. So now we are sure of what we are looking at, but funding is an issue for the wind, but we are still engaging with investors. The plan is to have a joint venture with whoever is interested. But for the solar we are planning a 12MW project now, its going to be in the North, we started way back in 2012, we were in discussions with the German development bank (KfW?) they agreed in principle to fund the project to initiate the project we did siting at _____, we did an environmental studies, we have done our shortlisting of EPC contractors. The loan agreement between Ghana government and the development, you know the development bank in Germany. So it is between two governments, Ghana government and German government. The loan agreement was signed just last December. Its gone to parliament, parliament has approved it so we are going ahead to the selection of an EPC contractor. It is a German development bank project, we have a consultancy we are working with whose also helping us with some other studies for it. So if everything goes according to plan we have another 12MW in Kaleo Wewara (location in Ghana), coming end of next year. That one we are looking at either poly or mono. We have done some initial assessments and the mono will give us more yield and the poly is also ok. But is a tradeoff between cost and energy. So the EPC contractor in its quotation we will see which one we will eventually go for.

A: PV is not on the table for this project?

J: No, that's poly – so between polycrystalline and mono.

A: Going back to Navrongo what goes into the process of picking a particular site, is it just irradiation or are there other factors?

J: Irradiation, grid availability, demand in the area, eventually who is going to buy it.

A: So who is going to buy the electricity from the navrongo farm? Is it ECG?

J: No Navrongo feeds directly into a distribution system, I told you already it's a 2.5MW, very small, at that time when we did our analysis the load in Navrongo township itself was about 5MW. So the plan was to feed directly into the distribution system of NEDco, so Nedco, even though we don't have a PPA yet, are the eventual off takers. However for the upcoming ones, we have two sites Kaleo Wewara sites is, the Kaleo Site is 8MW, the Wewara site is 4MW. So we are planning to put the 8MW plant into the high voltage, the 161, which will make it possible to sell to anybody, however the 4MW will go into the distribution system similar to Navrongo, so NEDco possibly will be the uptakes-

A: So what is the possibility of getting Solar projects onto the grid – is it a problem of capacity, or geography of things. What are those problems of getting solar onto the grid?

J: Onto the grid, ours aren't too big, in terms of capacity but remember you have to look at your eventual market and the demand in the area because you cant size it too big that when you are eventually targeting local people, I mean the distribution, then you know it will be too much for them but if you are looking at bringing it to a bigger market lets say ECG, then I guess you can go ahead and, so its all about the grid connection.

A: So are there any plans in place to have Solar project on that scale that does that goes into –

J: Like 50MW?

A: yes.

J: VRA is planning 50 MW plant in Bongo also in northern part of Ghana where we have acquired sites, so yes we are planning it. And eventually when it is being implemented the plan is to put it directly into high voltage 161 where we can sell to ECG or anybody else.

A: But then it will be in the North so it will go through NEDco and then –

J: No, you know GridCo the transmitter also has substations, so we take it directly to the 161 substation, where they can step it up and send it to the high voltage.

A: So that is one of the things that is needed, those high voltage lines.

J: Yes, and I don't think Gridco is doing a bad job when it comes to that. They have a couple of substations widely spread in the areas. But as you are saying it is something you have to look at before setting up a solar plant. Because you don't want something that is a stranded asset which you can't evacuate. But we, every time we are acquire a site we consider that. So all our sites are close to substations or we engage GridCo to see their plans for substations and we factor it into it.

A: So how much coordination is there between GridCo and VRA? I mean GridCo was part of VRA then-

J: But then it is a requirement. Even before you are given (10:11) a construction permit you need to know your evacuation. The construction permit by the energy commission you need to know how you are going to evacuate power. You initially have to engage Gridco, so you discuss how this will be done.

A: And then in terms of Solar projects that VRA have taken on, or plans to take on. What has been the funding ?

J: Funding has really been a big issue. Like I was saying we did the 2MW. We started the whole program in 2010, so Navrongo was completed in 2013. We started planning the Navrongo concurrently with the Kaleo Wawera, and we are in 2017 and the loan agreement was just signed a month ago. So yes funding sometimes leaves a project – it is not easy getting funds well in this part of the world. My boss would say money is accessible, but structuring the project to get the funds, that what you get.

A: What about those Climate Defense Mechanisms the UN has put in place. Is that a realistic option or it depends on the scale of the project?

J: Initially, I remember for Navrongo (11:32) it wasn't, we considered CDM, Clean Development Mechanism. We initially started with the local authorities, they call it designated national authority – I wasn't really too much involved so I really cant say much. But then for this Kaleo and Wawera project we were also targeting CDM. But unofficially or officially I wish I wouldn't put it on record, the German government felt – you know Clean development Mechanism will earn you some credit which will improve to be profitability of the loan – the loan we are getting from the German government is very cheap, quite concessionary so then if they are given you a cheap loan and you are doing carbon credit which you would eventually sell back to them, they weren't too much in support of it, because the carbon credit it is the western market which divides/requires it because they are more polluting than we are. And for now carbon credits the value of it has fallen so bad that its not even (inaudible word) now.

A: Going back to Navrongo. Navrongo doesn't feed into the grid, it helps the Navrongo township.

J: Yes

A: And you have the other project which 50MW, I mean is 12MW -

J: The 12 is two different sites and the 8 we plan on taking into the grid and the 50 is on paper. So far nothing much has been done on the 50

A: Other from the funding aspect of this project, what other problems are there?

J: Well I think in my opinion the priority of renewable has gone down. Cause you know Ghana at that time we are just coming out of a crisis for a need for base load commercial plant was there more than renewable energy. Nobody was paying attention – cause you know we have the law that gives renewable energy purchase obligation and like I said earlier as part of the purchase obligation, every customer every user or bulk consumers is supposed to have a percentage of its generation from renewable. However this law has been there since 2011, thereabout. Most of the bulk consumers don't have 10% of their energy from – and nobody is penalizing them, so it doesn't motivate developers because they feel when they come in it will be difficult to have a buyer. At that time renewable was very expensive it is recently solar is going down – at that time, even the first feed-in tariff which was advertised was 20\$ cents has been reviewed to 18 or 16- if you are going by the feed-in tariff nobody nowhere bulk customer would want to pay that for an intermittent source. So I think reliability (unsure) framework is also an issue the law has been there for a long time, purchase obligation isn't being enforced so it is something they need to look at.

A: And then when we look at, when we talk about this sort of crisis that comes in a changes the priorities and then we have natural gas, domestically available, that also comes in. How much does that come into the projects that are for renewable and solar projects?

J: Well, it does affect it a lot, because people tend to lose focus on it. Hopefully if we get out of this crisis and then all these natural gas fields, we have the Sankofa and the rest start flowing and we have a stable power supply, maybe the attention will come back to renewable. Maybe.

A: In terms of – I don't know how much you know of the Karpowership, their power barge, and they are an IPP right? How much do you know about how that came into existence –

J: What I know is what I also hear in the media, but since I am also here I hear slightly more than you do. But well it was an emergency, well so-called emergency, even though the Karpower people didn't say it was an emergency. It was a plant needed to help solve the dumsor as it was happening then. I hear they contracted for 2, the first 250 is in town I hear another 450 is also coming, running on engine fuel, heavy fuel oil. I am just looking at generation from Karpower, that's a year – its not doing bad in terms of energy production its not doing bad at all.

A: So is the likelihood that such projects, IPPs, like Karpower will continue to happen?

J: I doubt it considering the number of agreements the ministry has with other people, even with Karpower, as I said this is the first one of 250 and I hear there is talks of bringing the 450, there is GE 1000, there is LE Power, there is AXAR. So as I speak to you there is a lot of independent power producers contracted. I doubt in the short term we will have new ones, well I am saying new ones, because there are already plans that have been contracted that have not been developed yet, a number of them. Asogli has already moved from 180 to about 560, we have about 360 sitting down which is not running. We have people on the ground, Senpower, which is constructing and hasn't even come into operation yet. We have AXAR, so we have a number, and till now to 2020, I doubt we will be getting brand new as in outside the AXARs, the Amandies, the Jacobsons already plans that have been contracted and which havent been put into operation yet.

A: And most of the IPPs, the contracts that you know, and have signed, are they mostly renewable or more conventional?

J: More conventional. However when you go to the energy commission even from their website you can see that a lot of people have obtained licenses for renewable energy plants but, as independent, but it doesn't look like its going to happen.

A: Why?

J: First of all the priority is on the conventional ones, and I think the independent renewable energy projects are being frustrated, some got very high tariffs, way back then. 20 cents 18 cents, 15 cents, now people have realized solar is becoming cheaper and cheaper by the day so there is no way they are going to make that plant happen if its going to be a 20 cents plant. Maybe it is going to require, if they have a PP, it is going to require some renegotiations, I cant really speak much to that. Like Solar now, the ministry of energy lands and tender, last year and they were getting prices around 11 cents WE power also did a similar thing and they are getting prices around 8 cents. So if you have a contract you signed a year or two ago saying 20 cents, I doubt it will happen – it has to be renegotiated.

A: So from both the independent, private sector and the government sector renewable energy has not been the focus because of some certain number of factors that have come into play. And that is threatening the amount of renewables that will be forecasted to come int-

J: Because the cost of renewable has always been a problem –

A: Even though now the price has come down –

J: For solar, I wouldn't say for wind, cause our wind projects is what is mainly stalling negotiations is the cost of the energy. We think its too high, investor thinks its ok for him because he is bringing his own money and he is assuming so much risk, but for solar it is ok, but for other technologies it could be challenging.

A: How much do the public play a role in this renewable, solar – I know maybe it is not in your field exactly but if you could just

J: In my opinion, you see the energy commission is running a program where I think you are supposed to install your balance of plants for the domestic system and they will give you free panels, but I think the cost of the balance of plants is still quite expensive. Public and most people, I think out of ignorance do not understand why we have so much sunlight and we aren't doing solar. So I would say the public is not well informed about what goes into a solar plant, but I think they do play a minimal role

A: I think that is mostly about it,

J: So then renewable has always been on the table for everybody. The law has passed it is left with enforcing it, because if we were mandating every consumer to have 10% renewable energy in its supply and we were penalizing them. It is either they buy or they get penalized so the framework has to be reviewed even though their talks are implemented in every year, its not really there –

A: Sort of going back into the past a little bit, how long has solar been on the table in terms of producing electricity for not just the grid, but in general in Ghana –

J: in Ghana I didn't really hear much of solar until the renewable energy law was passed around 2010, but that is my opinion maybe some people had found some solar and – I really really didn't hear much until the law was passed and VRA started getting into it, and now we have an IPP, BXC who have done a 20MW, but even some time back there was an announcement all over BBC that Ghana was going to get the biggest solar plant..

A: Yeh the Nzema.

J: I don't think it is going to happen.

A: That was conducted by the Blue company.

J: Yeh Blue

A: That too, what happened to it?

J: I think it got a very high tariff, so they are ready to do it if they get the necessary approvals like the PPA and everything but you know the system will frustrate you. People will come to the realization that the tariff is quite high, even some people will say we don't even need 150MW at the particular location, probably has to be widespread

A: Cause that project isn't planned to go into the grid –

J: it is planned to go to, but it is planned in the Western region, where we have our thick rain forest. So all those things are factors

A: So if you are building a solar farm you are taking away forest

J: And at that time, we had only done the 2.5MW and people were really skeptical and having 150 on the grid, there were fears of having grid instability, in terms of intermittency, but I doubt it is going to happen and even if it is I doubt 150 will happen at a go. Probably happen in phases –

A: And as we move on in changing our grid system and transition, how realistic is it for us to have a smart grid? (J chuckles) I know we talked about it briefly the last time, there were some plans to bring in Smart grid technology to Ghana. How realistic is that?

J: All I can say is GridCo is working on it, and that is the target but I don't know how soon.

A: And Ghana's commitments for renewable energy as well, how realistic is that, that we will achieve those as well?

J: Ghana only said 10% of it, but we are lagging behind –

A: And this is not just Ghana, it is other countries

J: Well I would say one thing we really took the focus off renewables was the load shedding, so the need for emergency and instant conventional base load superseded the need for renewable

A: And also we got involved in the WAGP

J: And also found gas, and investors came in and we have gas, so we have to make use of it

A: yes, somehow. And the gas too has limited supply, so when that also reaches its limit we will get into trouble again.

J: There are talks of LNG too. So going forward the focus is on conventional, and renewable is about meeting some climatic impressions

A: I think that is about it

2. 4. Interviewee: Dr. Essandoh-Yeddu

Date: March 2017

Position: Director (Strategic Planning & Policy)

Purpose of Interview: The meeting with Dr. Essandoh-Yeddu was primarily meant to provide an overview of the development of Ghana's electricity system, particularly the liberalization program introduced in the beginning of the 1990s and the general discussions on the barriers to solar energy and possible pathways. Seeing that Dr. Essandoh-Yeddu had been involved with the energy sector for over 20 years he acted as a great source to corroborate other information and provide critical insights

to the narrative. More specifically, I was interested in finding out about his views on this sustainability versus development debate and where he positioned himself within it.

A: I can think we can start with just your name background and position now, just for the starters.

E: My name is Dr Joseph Essandoh, I am the acting director for policy and planning for the commission, in the commission we do really provide the advisory note on mandated to advice the minister on energy issues.

A: When was the energy commission established.

E: You know it was established, the energy commission itself I would say, they would say depending at time 1997 or 8 that kind of thing. But the key, yes 1997, but it started operating in 1998. Yes, fine. But the whole commission started as a board in as far back as 1986, it became operational in 87 or 89, something like that

A: And as far as the EC (energy commission) goes, why was it created, under what initiative and what were the main architects for it-

E: Good, if you are young maybe you were not born then, but then 1983 or early 80s there was a global drought affecting a lot of continents, including Africa. In fact, it was very severe in East, the Horn of Africa, particularly Ethiopia where in fact there were a lot of people dying. In fact, to a certain extent a group of singers led by Michael Jackson then Lionel Ritchie and others came and put a song together called 'We are the world'. *We are the world*. You've heard it?

A: Yeh I know that song.

E: Just for that, it was a global current thing. So there at that time our only source of power was hydro. Hydropower from the Akosombo that was likely covering the southern part of Ghana you see. Next to that, cocoa was the Ashanti region all other spots beyond Ashanti region at the Brong-Ahafo was largely distributed (unknown word) that is diesel, yes diesel and all that, fine. And even the electricity was likely in a few commercial centers, capitals. You see you go up north you likely the new thermal plants, diesel plants – so here was a time when power was just now built with 900MW of course feeding likely the VALCO aluminium smelter. But in fair the dam, the reservoir, the main was a 240, it fell to below 240 the power was very small. So we realized we were over relying on the hydro, so then we consulted or as usual the donor party contacted us and 'you need to broader, larger scope of energy use even including renewables.' In fact that was the first time renewables, officially renewables in Ghana. So energy board was set up around 1983, but it start operating 86/87 and I joined 89. So you see energy board were supposed to be the planning body for the energy sector. Beginning it was VRA hydro that was planning largely for electricity in Ghana, largely coming from the hydro and you have ECG doing the distribution and having some few thermal, you know all the diesel plants were really belonging to ECG. Then, so when it happened like that, you know you cant just leave the planning of the hydro power in the hands of VRA we prefer to have a more independent group to look at it, so energy board was formed. It was Energy board that we start looking at broader sources of power. Not only the hydro, but we also look at thermal, we also look at renewable like solar and others even though at that time solar was on the high side. So with time, in that time you have a number of promotion of renewable energy sources, in fact I was the first solar project – so if you go to the ministry to solar on the roof, I put it there. Where you there? Maybe you were not there?

A: Ministry of Energy, yeh I have gone there but I didn't see the roof—

E: oh on the roof you can see the solar panel on the roof

A: I think I remember seeing –

E: On the car park

A: Yes, I remember

E: So that was, I did that one. We documented a number of solar projects in the country and Ghana telecom then had a program to connect telecommunications place throughout the country and achieve 100% coverage, so they were largely based in using solar stand alone systems for the repeater stations. Ministry of health also in the rural areas using it for vaccine refrigeration and so for the big health centers a few points for lighting and for surgery, particularly the military hospital lighting was using solar. You see, and which institutions again... and most of them were largely used for communication, remote communication systems, wireless communication.

A: But these were mostly off the national grid.

E: Yeh they were all largely off the national grid, that kind of thing

A: So the EC operates, so the energy commission operations extend beyond the grid

E: Yeh when energy commission came we weren't only looking at power, but at other energy uses. So we introduced, also that time we were looking at wood fuels that could also contribute to the drought, desertification so introduced, improved woodstoves to reduce consumption of wood and also improve _____ if you are using charcoal to improve the production of charcoal, and then later on we introduced LPG as a complement to wood fuels used in the home-

A: So getting back to when the EC was created, it was sort of part of this larger program of breaking down the VRA to more decentralized and

E: Yes that was the beginning but all what we were largely doing is to look at other sources of energy not necessarily power. You see and we also introduced energy efficiency programs

A: More on the consumer end

E: Yeh more on the consumer side, we tried to introduce, trying to educate the industry on this energy efficiency use, power factor improvement cause at that time we were all relying on hydro power, **Akosombo** it was very cheap so the power fell very low for a lot of industries, paying very little for electricity you see. So when we introduced, so for it now we have energy efficiency conservation programs. So but of course the VRA was still doing the power planning and all those things, and the interesting and during the latter part of the year they introduced Thermal power as complementary to hydro and that was the **Aboadze Thermal** Plant you see. Then it got to a certain point, you know with all these public sector institutions, government sponsored, finance and what we realized is if things are on government side a lot of inefficiencies and all that. So we decided that we can make more, or we can improve the coverage when you allow the private sector to come in. But for private sector to come in, they would need to have a **referee**, so now the referee and it means the grid must be autonomous, you know VRA was controlling the grid, so you can imagine, they can decide, I won't allow yeh I won't allow – they can dictate the pace so it means we have to find ways of splitting and taking away the grid from VRA you see, but they also resisted for a very long time and so in 90s is when all these things were proposed, in the 90s. You see they resisted and still hook on, so it was to a certain extent that any other power would come you have to align yourself with VRA you see, that is why TICO aligned with VRA because they don't have the land and the grid will still be operated from by VRA, so the monopoly was still very strong. So somewhere along the line the government still needed money, could not raise all the funds so we have these **power sector reforms** coming in to look at all these things and some of the recommendations said to separate the grid from VRA you see. And had really strong independent planning institutions, but if you wanted to have an independent group to handle the grid, then you needed a facilitator, an umpire, so energy commission, energy board has to be formed and also the tariff center has to be independent somehow, you see. So energy commissions was formed, but then energy commission that was to replace the board, you see. But the government decided to split the technical regulation from the fiscal regulation. So it placed the technical regulation under the energy commission which is still under the ministry of energy. But they placed the fiscal,

tariff under the PRC, PURC. Both were started the same year, but the PURC is still under, I would say under the Presidency. So it will not take instruction from the ministry of energy that kind of thing.

A: So all in all, this program of breaking down the different components of the electricity system was trying to make the security of energy more – better

E: Better – bring in private sector participation. More investment and all those things, you see normally people would say - VRA resisted furiously so when we had a first ___ out of it, so even in the 90s still we were not out of the woods, we were still having some challenges once in a while, load shedding and all those things. So we decided to be serious and we got the Danish support, and they developed the first transnational energy plant for the country

A: That is with the Danish support

E: That is the SNEP 1, so when you read the SNEP and there has been changed in government. So Danish were also saying ‘well we have produced this nice report,’ fine but you are an advisory body, you see. Changed of government and advisory body so you just give it to us. So it was pick and choose from the recommendations. The interesting, you know for the **petroleum** side, they more or less **implemented** most of the recommendations and so you see there is no shortage of petroleum products that kind of – you see that kind of thing. But electricity side was not easy, still had VRA on system until we have another power crisis I think 87, 2007 – sorry – and this time the government himself, the minister took somebody physically as the boss of GridCo and then GridCo was established, out of VRA that is how it was.

A: So now there are two things I will ask for. So it is kind of successful now the breaking of the monopoly-

E: since GridCo became independent, we have now more private companies coming online

A: And so now, with the overarching aim of securing energy how successful has the decentralizing program helped energy security-

E: Now even! In terms of capacity fine now you have ____. The challenge now is tariff, not reflective enough, not transparent enough, you see. And that is what we have to work on. In other countries certain tariffs are being set, to regulated – we should all sit down and share ideas – but not here.

A: Even though PURC—

E: PURC we don’t know the formula they are using, but it comes out. You can tell what goes in there but you know humans we can make mistakes you see, so I think – so you see – I see that the challenge over here now in the power sector you know the value chain is being the tariff side

A: And you think the supply side has more or less been-

E: If the tariff side improve, the supply side will improve significantly

A: Because the IPPs will be coming in because there are better prices

E: Yes, cause the pricing structure is just not very good, see and that kind of thing, so these are so far the challenges we have.

A: You mentioned the SNEP, then the influence of the oil

E: SNEP is the strategy national energy plan

A: And you mentioned the influence of crude oil, and the oil and gas in the document. How much has crude oil and natural gas discovery changed the dynamics

E: In actual fact that was the recommendation in the SNEP, I remember when we were developing the petroleum side, if you have time to read through the petroleum report. When they were talking they thought we wouldn't discover oil. Some even said they have had the confidential Brazil followed them and there is no oil here but we still made the recommendation you see, and we hit-

A: We hit oil, and so now-

E: Cause we felt that if you look at the geological activities, the rate were not close to discover oil and so maybe we have to intensify the drill rate and exploration – and look at the fiscal regime the conditions to make it more attractive, I mean if a company is coming to drill, what makes Ghana special? We have to look at all these things so I think the recommendations were picked and they were followed and once they were followed and low and behold we discovered oil

A; And also allowed us, cause we retrofitted our thermals plants to be combined cycle, we could use the natural gas and-

E: That was a very successful policy implemented by VRA throughout most of the plans were purely combined cycle, sorry not combined cycle but dual fuel basically from the beginning

A: And so now we have sort of put a lot of things in place to make sure that natural gas and the crude oil is not only good for our energy security, but there is still problems and for you it is from the PURC, the rates, the tariff rates. Now we will switch to talking about renewables and we start maybe with the renewable energy act which was drawn up 2010-2011, and how much has that changed the make up of our energy mix

E: Well it is going to take some time, but the key thing is the renewables first thing when the renewable energy act, we started the feed in tariffs you see, so whenever there is feed in tariff it can be subject to abuse, and I think that is what we had. But if it is competitive bidding, that is best, so it is the feed-in tariff somebody can participate and just front these companies come and put their margins on it and then hide, you see even- yes! To me I never liked it. You see but now, feed-in tariffs were introduced earlier because they thought that the renewable was way too expensive, new markets and so on. But you know with the rapid dropping of pricing there was no need for that kind of thing, some of these were coming down regularly and very competitive more than diesel and others, there is no need to have it. For most of us that was the situation but not all the technologies. But now we that the price has come down drastically, if we just feed-in tariff we don't do competitive bidding, somebody can just front a company and all those, you see a politician going under, and then force, ECG is a government company – it is a government entity you see, so they have to accept the price of PPA, the power purchasing agreement. But if competitive bidding, all that is happening in Gambia and South Africa, the price will come down. And even here, the one on the Bui, it came at 12 cents per unit

A: That is from competitive?

E: Yeh yeh. See it is like building any of these eh, competitive is not bad

A: So just explain for me the difference between, in like, the feed-in tariff and the way it works now

E: Feed-in tariff you set, feed-in tariff it means say feed-in tariff, say for solar you see for a certain price, what do we have the price now? Say maybe **20 cents per unit** after that you set up a portfolio so now you force companies to also produce, to prepare all their power to have a certain percentage from renewables. So it become a policy whether competitive or not you are costing that company to do that. But if it is competitive you can still have the feed-in tariff and you say now what? So compete, and some of these companies may even quote something below the feed-in tariff

A: And that was the idea? And people would try work towards that. So other from the feed-in tariff have there been any other reasons why solar in particular, because that is the main out of the other renewables, hasn't been able to pickup especially in contributing to the grid?

E: People just make noise it is not necessary that solar is picking up it depends on how you bend. Some are still conventional systems are still very high, but if someone install 100MW solar they make a lot of noise in the paper. That country will be behind secretly and not come on the air – 1200, 1000 megawatt of coal, you see – yes. Like for example, when we were in Paris for the Paris agreements that very week Germany put up, switched on 1000 megawatt something of coal plant you see

A: So everyone is doing back door things

E: Yeh cause the key thing is that yeh, you need cost competitive electricity, you don't produce power for power sake, it has to be competitive, withstand the market – you are invited –

A: Oh thank you

E: Otherwise, yes, your company will go bankrupt and your government and even the country. So the key thing I keep saying is that energy mix, is not just solar or diesel or no, energy mix, you look at the cost how affordable it can be and that is key, and with time as one become cheaper you bring it in

A: and now we have this situation where, going back to the whole energy mix, we have natural gas and all the things being done for natural gas, is that in some way taking attention away from renewable?

E: No no no. These are, when you want to run industry its not solar, are you getting me, we need a continuous, reliable, stable supply of power, and not solar. Solar can disturb your grid, you see, if you have fluctuations and all that. So these are all important in deciding. So as you introduce in particular the **intermittent renewable** like wind, you need to make sure it doesn't **disturb** your grid

A: So in that sense when we are intending on increasing renewable energy mix in our system we need to make sure our grid system is smarter to be able to balance it and how far are we from realizing this-

E: Gridco is doing some studies and all these things, so for that in fact the German, the GIS is helping to do some studies so we can insert our 20MW for different points around the national grid that you can bring this solar. You cant install solar, let say 300MW at one point, you know maybe here can take 40MW, and that kind of mapping they are trying to do now

A: And this planning, is it just one entity or is it between all the entities, the VRA, EC, ECG

E: In particular it is between ECG, VRA and Energy Commission, cause VRA is just one of the generators. The key person is GridCo because we are coming to connect to the grid

A: Because they know who is asking for electricity or who needs it, in the different parts of the country. Also what is the nature of the IPPs that have been coming on board, what is their main source of energy that they use.

E: Depending, some of them are having solar, or biomass. Some of them have come in but none of them have started yet. Because you know solar it is easy to install, you can just pack the panels and the models behind a truck pull them and go and put them somewhere. And also wind, **wind** has huge mass so you need a **huge** infrastructure equipment and building equipment. So usually when they come to countries they do, if you like for example, if there is oil like the off-shore you go to the oil drilling and all this they employ huge infrastructure then you combine, then they also help you to install the mhm. Hydro and solar and those kind of companies they will just come in and just install the – you know – no no no – they don't do that. Then they have to go find other jobs, you see so at least is becoming more cost competitive. that is why I believe you havent seen any wind project yet.

A: And so for you, how realistic is, you know we have this 10% commitment for the INDC for the Paris Agreements

E: Oh that one is because the 10% is for renewables including hydro below 100MW, are you getting me. So if you take all hydro including the large at Akosombo and Bui, then it is far beyond 10%

A: But for now that consideration is for the small hydro. So how far is it realistic that we can achieve that 10% renewable energy penetration

E: Yeh, depending on the programs you put in place, that's all-

A: And as of now the way we stand with what we have

E: Oh we have some number of mini hydro grid projects, micro-grid projects that is coming online, based on solar and others being sponsored by world bank under the Climate Investment Fund, if they were costing, we wouldn't have such projects, so they are there but it takes time.

A: And then hopefully the idea is that it will help the market, then you have different suppliers and you can feed-in to the grid. So as of now how developed is our market for renewable energies to be taken up? Is it just now picking up or?

E: You know we say we are a middle income country but we are still developing countries structures, still energy deficient. Most mid-income countries consume power around 1000 or something like that and our per capita we are still around 350 or something like that. So that tells you we are energy deficient. We need injection, but it depends on cost, not too expensive and in line with slow growth

A; In regards to sustainability, is there a realistic threat of our system becoming too reliant on hydrocarbon sources of energy and facing the same sort of problems that the western world is facing-

E: Yeh but we are still nowhere when it comes to economic growth. So it is a balancing act, as you grow you try as much as possible to, as China is doing. Yes you still breathe and as you grow you increase the quality and all that. You can not just go and destroy your industry and just keep on importing. Then what are you doing to yourself, rather serving other economies, other countries economies. So you look at the balancing act

A: And in Ghana right now are we prepared to do this-

E: Yeh that's what we are doing, that is why some of us are here, to make sure it is done. If left to a lot of people like NGO, a lot of people need education – its not just like that, when you say energy it is not just like that- you have to look at the cost, cost competitiveness of it. When you go to and you are buying things from China, you are happy but you re also destroying the economy. And their economy is booming and your economy is dying. So who loses, it gets to a you cant even buy from them. So it is a balancing act, making sure to make sure your economy is not destroyed just because of the sake of the environment. Mind you the environment is not only the atmosphere and climate change. There is no technology that is environment free, you always going to have environmental challenges with any technology

A: I guess the idea is to choose the ones that are least –

E: Yes that is why we have the balancing act, and also we call it automization- we automate

A: Electrify and all those

E: As a poor person you know at times some food you have no option but to eat, but as you become rich you move away from all that, the junk food and all those things

A: yeh then you have salad

E: so that is how economies, not just someone says so and you also follow, you become a laughing stock in future. And those are the young people we have to advice who study your program. We had a

similar challenge, I remember when I was in Sweden doing my masters, I was really you know in terms of solar I was the solar. You know how were our people still using coal, Germany in particular, Germany – yes. When they are ok now, they say oh lets now reduce it, and meanwhile they use the same money from coal to support the renewables but we don't have it.

A: No we don't have that

E: Because were they have used coal for a very long time, they have had power 1.5 per cent 1 cent per unit and all those things – this kind of thing. So if you have renewables they are very nice but bring down - take a lot and make it competitive

A: So other from the pricing aspect, what are the other challenges of achieving this balancing act for Ghana?

E: Then it will probably be infrastructure particularly for wind, if you don't have that infrastructure, but solar yes fine. But when you install one big plant it is about installing 5-10 solar plants, of course depending on the

A: And in terms of, you know like how, the Akosombo dam during that period in time it was clear political agenda moved and got the Akosombo dam against some sort of odds. Now we have kind – but not really a similar situation in some ways we have this energy need

E: We need visionary leadership, I keep saying, in Africa. I keep saying a good example is Niger they have a lot of deposits of yellow cake (uranium), yellow cake is uranium

A: Yeh uranium (chuckles)

E: France has a company called ARIVA, ARIVA used a coal plant, put about 200 or 400MW coal plant, mined the yellow cake to send it to France to get 100% coverage-

A: Because they are also trying to secure their energy-

E: There are about 2-4 million people in that country

A: In Niger

E: Yeh, only about 20% electricity covered and no use, we say whose a fool. Are you getting it. Then even France, France has about 75% coming from nuclear and they also have some coal in there and the coal, some of the clean coal, they import it as far as from Columbia. Why would they waste their time with Colombia, why do you think - eh what is their motivation for coal, importing coal. Can you tell me?

A: Maybe it is cheaper

E: What do you think makes it cheaper to import coal

A: Not as available as your own

E: No, what do you think makes it- what is the motivation for importing the coal?

A: For France?

E: No , for any country

A: For any country

E: Yes, now if coal, if you put a cargo of coal in the ship a tanker, no security, which of them will be attacked

A: What did you say one with cargo one with what?

E: Oil tanker

A: Oh ah the oil tanker will be taken

E: Now if you come and put it down, put it there, sorry no security, which of them will be stolen the following day? And you have them in barrels

A: Oh the oil

E: You see along the coal value chain you reduce costs. So if you are able to handle the emissions, you are gone. So that is how things are measured.

A: Didn't Ghana also build a **coal power plant**

E: That is what we want to do. If there are people who can understand then. NGOs they go and read and some of them get subversions from some of these international and try and sabotage some of these things.

A: So it was blocked?

E: It was not blocked only that it is still in the pipeline. Now we have a new government, they have come so we will see what government will say

A: So the coal power plant it was meant to supply the grid or was specific to industrial

E: no no- grid it is a grid project. You can ask for coal, this is a huge plant-

A: And we will import the coal

E: Yeh from South Africa

A: And as far as other, ok, so basically also all the other technologies are on the table because now we have decentralized, so anybody coming in with an idea that's the – so what is looking like the best option?

E: The best option is to have an energy mix, and optimum energy mix

A; Yeh simply, let me see if there is anything else, let me think for one second