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| RESEARCH ARTICLE

Energy Transition in the Context of Electricity Power System and Climate Change Reality: A Macro Evidence from Ghana

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| ABSTRACT
Whereas energy transitions have received global energy governance attention over the few decades, it appears research on this important subject is either new or unclear in terms of the direction and the quantum of changes in Ghana. The study was about an analysis of the phenomenon of structural electricity energy transitions in the context of climate change reality in Ghana to inform sustainable energy policy. The study used the desktop research methodology, including retrieving and analyzing secondary qualitative and quantitative materials from various sources. The results show two significant structural changes in Ghana's electricity energy subsector. Firstly, the results show a significant transition from the previous hydro dominant electricity generation to a hydro-solar-thermal mix. However, crude fired thermal plants account for about 69.56%, compared to 43.33% and 0.49% respectively for hydroelectricity and solar plants in 2020. Secondly, the state monopoly of electricity supply structurally and significantly changed into a state-private-partnership supply mix, with approximately 57% of total generation supplied by independent power producers in 2020. Based on the results, the study concludes that electricity transition from a broad perspective of structural changes in the economy's electrical power systems has taken place based on the available data from Ghana. However, a low-carbon energy economy transition in the context of transitioning into climate compatible energy-climate-sustainability nexus has not yet taken place. Therefore, further interdisciplinary studies are imperative to appreciate both theoretically and practically why Ghana's renewable energy policy agenda and the observed strategies of implementations appeared contradictory.

| KEYWORDS
Ghana Electricity Systems, Energy Transition, Climate Change, Renewable Energy Resources, Desktop Research Methods

JEL Classifications: L94, P18, P28, Q01, Q4

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1. Introduction and Background
Energy transitions (past, present and future) and human civilizations are co-evolutionary phenomena. That is, from our primitive journey as hunters to agrarian society and progression to a more sophisticated modern industrialized society, the world continues to transit from one form of exosomatic energy resources use and their underlying carrier technologies to another (Gallo et al., 2016). These transitions are influenced by either biogenic, anthropogenic or interactive factors. The energy transitions experienced by economies have common characteristics. Firstly, energy transitions are seldom complete - that is, they represent a complex and episodes that usually happen over a long period of time, may take decades or centuries. Secondly, energy transitions are paradoxical, in that in spite of the energy system composed of durable infrastructure networks with high costs of investment in technologies and resources, they notwithstanding change over time (Bridge et al., 2018). Thirdly, energy transition and social-political changes are inherently interwoven (Miller et al., 2013; Rohracher, 2018; Stephens, 2019). Fourthly, energy transitions are a function of socio-environmental movements, locally, nationally, and globally and cascading effects. For instance, the ongoing demand for energy systems democratization in some parts of the world, as detailed in (Benander et al., 2017; Feldpausch-Parker & Endres, 2022; Renn et al., 2020). Fifthly, energy transitions are parts of the dynamics of national and

global political ecology (Sovacool, 2021) systems. However, these characteristics of energy transitions may not necessarily be independent.

Hitherto, energy transitions were interpreted as phenomena of individual economies and cultures. However, since the promulgation of the concept of the green economy following the world financial crisis in 2007/8 (Yang & Chen, 2009), the notion of the energy transition has emerged in the discourse of the governance of national and global energy resources and technologies, particularly in such interdisciplinary areas as energy-growth-poverty nexus, environment, and energy governance policy and academic literature. This is taking place contingent upon the sustainment of the growing social, and political mobilizations and movements against the past and contemporary unsustainable fossil energy led industrialization. These movements appear as a negative socio-political obligation in favour of a low-carbon economy as a means of attenuating greenhouse gas emissions, especially carbon dioxide (CO_2), limiting the impact of global warming (World Energy Transitions Outlook: 1.5°C Pathway, 2021), while also addressing the problems of poverty and inequity within and across economies sustainably (Höffken et al., 2021; Kumar et al., 2021). For instance, within the framework of energy democracy, Germany is reputed to have developed the notion "Energiewende", reflecting a national agenda for energy transition, which among other things, include phasing out nuclear energy plants, increasing the proportion of energy mix with green reputations; decentralization of energy systems to ensure higher local participation; prohibition of vehicles with unacceptable levels of emissions; and the banning of diesel-powered vehicles from accessing some geographical locations (Gründinger, 2017b; Oei, 2018; Sturm, 2020). Following the literature (Bashmakov, 2007), it appears energy transition follows a neat path, which includes transition by "changing patterns of energy use" (for instance, from the dominant solid biomass to liquid energy resources to electricity); "changing energy quantities use" (for instance, from scarcity to abundance, or from abundance to scarcity or reduction in consumption due to energy efficiency practices); and "changing in energy qualities" (for instance, from firewood to electricity). In some economies, solar and electric-powered vehicles are already taking the position of fossil energy commodities in intra-inter-city transport systems.

The literature on energy transitions, unfortunately, is rather inconclusive. However, it is believed that "*If governance of the energy transition is to be exercised effectively and efficiently, a common understanding of 'energy transition' seems to be helpful and necessary*" (Pastukhova & Westphal, 2020). Notwithstanding, a number of researchers agreed on a common denominator of energy transition: as involving a historical drift away from an economy's economic production, consumption and waste disposal processes based on a particular energy resource to an economic system based (wholly or partially) on different energy resources(s) (Urban, 2019). The Dictionary of Energy defines energy transition as "*a change in the primary form of energy consumption of a given society*" and further classifies energy transition as "Social Issues" ("Energy Transition," 2015). It is important to reiterate here that energy transition is not only "Social Issues"; as energy resources, and their usage from a critical perspective is an interplay of social, economic, political, environmental and geopolitical challenges facing the world (Hochstetler, 2020; Sioshansi, 2011; Wallimann, 2013). Energy transition resonates with the logic of an economic systems' repentance from the "sin" of using energy resources that continue to exert an existential threat to the absorptive and carrying capacities of the social-ecological systems for both present and future generations. The extant literature pertaining to the notion of energy transition provides two main conceptual views on "energy transition". The first view postulates energy transition in the framework of structural change in the economy's energy systems (Guan et al., 2018). The use of "structural change" means a significant transformation in a country's energy systems and not temporal change (Guan et al., 2018). This view of energy transition resonates - with that put forward by Neuman et al. (2014) of the World Energy Council, that is, energy transition is "*a long-term structural change in energy systems*" (Hauff et al., 2014). Neuman et al. (2014) view though general, has a reputation of inclusiveness.

Table 1: Various frames and worldviews on the international political economy of energy

Frame agents	Dominant worldviews	Prioritized component of energy security	Energy Security for Whom?	Underlying values and goals
Neo-liberalists	Technological optimism, free-market libertarianism	Geopolitical affordability	Economy	Welfare, freedom
Neo-mercantilists	Defence of national security	Geopolitical availability	State	Political interdependence & territorial integrity, respect of nature
Environmentalists	Environmental preservationism, conscientious consumption	Environmental sustainability	Earth	Equity, justice
Social green	Justice, neo-Marxism	Social acceptability	Society	Respect dfor nature
Ubuntu Philosophy	"I am because we are."	Human-nature unity	The collective/society	Collective well-being

Source: Author's own compilation from various sources: (Mugumbate & Chereni, 2020; Sanusi & Spahn, 2020; Van de Graaf & Zelli, 2016).

Again, it draws our attention to the view expressed on energy transition when it was first coined in the 1970s, especially as can be found in (Naill 1977).

The second view on energy transition defines the term from the perspective of energy qualities and reflects the international community's over-ambitious goal of achieving "Zero-Carbon-Emissions" by half of the 21st century. In this context, energy transition is seen as a transition towards a low-carbon economy or greener energy systems (Gibbs & O'Neill, 2015). The above school of thought pertaining to energy transition is fairly a demonstration of different frames and goals of global energy policy and governance. For instance, the International Renewable Energy Agency conceptualizes energy transition as a "*pathway towards the transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century*" (World Energy Transitions Outlook: 1.5°C Pathway, 2021)[1].

This definition, in comparison to Neuman et al. (2014), is specific. In either of the two definitions, we are presented with a common understanding. That is, energy transition is a complex sociotechnical process. We are therefore challenged to provide frames and heuristic worldview constructs that address the national and international political economy of the energy transition. Table 1 paints a picture that energy transition is fairly a function of the dominant economic and political ideologies; prioritized components of energy security; those for whom energy security is for; underlying goals and values to be maximized (Van de Graaf & Zelli, 2016). Whereas Table 1 is an oversimplification of what realities may suggest, they provide an economic-political-social-environment-philosophical-geopolitical heuristic construct of the various contexts in which energy transition should be analyzed, and accordingly, policy solutions proposed. For instance, the Ubuntu, social greens and environmentalists and their corresponding worldviews, energy security priority, targets of energy security and underlying values and goals are fairly compatible with the current goals of the global energy transition. Furthermore, based on Table 1, other related energy governance essentials such as affordability, universal access, sustainability, reliability, social equity and justice are critical issues. The study integrates these elements in the broader analysis of the phenomenon of electricity transition from the macro-level in Ghana.

Further review based on the work of Sovacool et al. (2020) provides a comprehensive perspective from sociotechnical landscapes for better appreciation of an economy's energy transition processes. These authors differential between "interim-energy transition". This is where there is the existence of governmental green energy policies; however, there is no public support and acceptance (Edomah et al., 2020). The second view proposed by Sovacool et al. is "Deliberate energy transition", of which energy end-users or citizens, in general, propel sustainable development transitions notwithstanding the absence of state policies. This can be exemplified by the massive German citizen's movements forcing the government to phase out nuclear power plants following the 2011 Fukushima Diaiich nuclear plants meltdown in Japan (Gründinger, 2017a). The third landscape of energy transition, as opines by Sovacool et al. (2020), is "Transformative energy transition", which is a hybrid of the first and second views. With the "Transformative energy transition", there is, sustainable energy transformation ignited a hybrid of state policy and public

[1] See also Energy Transition by IRENA (2020) https://www.irena.org/energytransition).

actions (Edomah et al., 2020). Other researchers have also offered insightful conceptual discourses that distinguish energy transition in low-income economies and those of developed economies (York & Bell, 2019). The view expressed by York and Bell is particularly relevant to low-income countries (the global South), whereby electricity infrastructure service gaps drive continued state investments in renewable energy technologies and resources. In this context, their question of the policy puzzle is: whether developing countries' policies and investments in renewable electricity generation mix is really energy transition or just additional investment to close the energy infrastructure gaps in these economies (the global South).

The existing literature provides clear but complex drivers of energy transition both spatially and temporally. Firstly, in the United States of America, energy transition is motivated by the quest to attenuate import energy dependency (Krane & Idel, 2021), especially following the first world energy crisis in the 1970s. And in the four of the BRICS (Brazil, Russia, India, China and South Africa) economies: Brazil, China, India and South Africa, energy transition is motivated by the need to expand - energy infrastructure networks to meet the growing demand following rapid industrialization, rising middle-income classes, the current egalitarian principle: 'leaving no one behind' (Homi et al., 2020), in sharing the coast and benefits of using energy resources. Secondly, energy transition is motivated by the growing knowledge about the risk of anthropogenic climate and environmental degradation. For instance, environmental concerns played- a major role in the energy transition in Germany (Gründinger, 2017b; Hauff et al., 2014). Similarly, Hauff et al. (2014) have mentioned two potential drivers of a country's energy transition. Firstly, the government of state policies, for instance, the country's renewable energy policy targeting, improvement in energy efficiency in both demand and supply sides management, incentives for innovations and research and development. Secondly, innovations and research by energy companies can also drive the energy transition. For instance, the famous U.S. "Shale gas and hydraulic fracking have a revolution" is largely contingent upon shale gas technological innovations (Middleton et al., 2017). In all the two potential drivers suggested by Hauff et al. (2014), it is clear that government policies and initiatives are critical inputs in driving an economy's energy transition (Bridge et al., 2013; "States, Markets, and Energy Transition: Good Industrial Policy?" 2020). This is understandable giving that energy systems are a critical component of a country's national security concerns (see Table 1). For the purpose of looking at energy transition from the prism of long-term economic, social, environmental and climate change realities, the work of Igor Bashmakov (2007) hypothesized energy transition as three laws in the study titled "*The Law of Energy Transitions*" is insightful, and should be relevant to Ghana's energy transition thinking. Bashmakov (2007) proposes three general energy transition laws, including:

> *the law of stable long-term energy costs to income ratio; the law of improving energy quality; and the law of growing energy productivity. These laws are essential for shaping long-term projections and checking for their consistency. All three are rooted in amazingly stable in time and universal across the country's energy costs to income ratios.*

A strategy to derive a practical reality from Igor's hypothesis (energy transition) is, therefore, to develop indicators from which measurements could be made to provide science for policy in the energy sector in general.

Ghana, like many low-income economies, the energy transition as a research focus is fairly new. In addition, there is no conclusive epistemological appreciation of the concept of the energy transition, that is the question of *"what is energy transition"*?. There exist not also any clear understanding, as to whether the phenomenon of the energy transition has taken place or not, and if so, in what direction and forms has it occurred with specific reference to Ghana. Set against this ground, the study presented in this paper provides integrated insight into electrical power energy transition in the Ghanaian context by drawing references from international perspectives. In a nutshell, the study presented here attempts to contribute to the literature on energy-economy-environment-climate change literature by answering the following research questions: *How has electricity power energy transition evolved in the Ghanaian context?*

2. Indicators of Electric Energy Transition - Literature Review

This section briefly reviewed the significant literature on how indicators of electricity energy transition can most probably explain Ghana's electricity systems under the following three subheadings: changes in energy sources and technology; changes in demand and supply-side ownership and management and transition to cleaner (greener) transport systems (emphasis on vehicular transportations).

2.1 Change in Energy Fuel Type and Technologies: Transition from one type of energy to another requires a change in technologies or energy carriers and are integral parts of the overall social and technological changes over time. Therefore, energy transition involving a change in the use of the energy fuel type (resources) is an indicator that shows a significant shift in the previous dominant energy resources used in an economy over a period of time and corresponding technologies. It is important, however, to note, based on the Physical Law of energy: the Laws of Thermodynamics (law of the conservation of energy), that no energy source is completely "clean" as the quality of energy changes as it is transformed from one source and form to another (Dincer & Rosen, 2021). For example, a significant shift in the use of thermal energy resources and plants and nuclear energy to probably relatively cleaner (greener) energy resources such as solar or wind technologies. This indicator as a measure of the economy's energy transition has gained popularity in the literature (Gallo et al., 2016; Gürsan & de Gooyert, 2021; Şan, 2017). In some cases, depending on what is driving energy transition, there may be a transition that occurred technically within the same category of energy resources as new technologies are discovered. For example, a change from coal consumption in favour of natural gas as both are thermal energy resources (Bradford, 2018, p. 870), or a significant transition from the use of fuelwood charcoal since both charcoal and fuelwood are all biomass energy resources. Also amendable to this indicator of the energy transition, particularly in developing regions of the world, is the increasing shift from biomass energy resources and technologies to relatively environmentally benign energy resources such as LPG (liquefied petroleum gas) (Leach, 1992; Pachauri & Jiang, 2008).

2.2 Change in Demand and Supply Sides Ownership and Management:

The energy system of every economy may be analyzed from such subunits as technology, economics, markets and policy (Bradford, 2018). This can further be simplified into demand-side management (DSM) and supply-side management (SSM) (Hamilton, 2013). One important indicator of assessing if energy transition has taken place (or is taking place) is to observe the dynamic of change in the ownership of the DSM and SSM in an economy. Traditionally, the government enjoys a natural monopoly in terms of ownership and management of energy as resources strategic resources, and also, as a critical infrastructure network systems inherently integrated with the national security and geopolitical thinking (the reader may refer to Table 1 and text cited thereof). Thus, this indicator assesses the change to the ownership of the energy systems or ownership, for instance, from central state control to a more liberalized private control and management or the opposite (Burke & Stephens, 2018; Klagge & Meister, 2018; Melo et al., 2011; Rommel et al., 2018). Recent literature analyzing the bottom-up approach or decentralized energy systems which involves the transfer of ownership and management of energy systems to localized stakeholders, have termed this phenomenon as "energy democracy" or "democratization of energy" (Burke & Stephens, 2018; Greenberg & McKendry, 2021; MacEwen & Evensen, 2021).

According to Bridge et al. (2018), and as paraphrased here, the term energy democracy refers to shifting towards forms of local, community and municipal ownership and control of energy resources and technologies, and it is fuelled by the growing interest in challenging the traditional centrally or corporate ownership and control of energy infrastructure systems. Energy democracy is admissible to greater citizens' participation in the processes, implementation and outcomes of sustainable, ecologically, socially acceptable, and inclusive energy systems (Ibid.). Some authors believe that energy democracy aims at addressing the challenges of providing equitable, affordable, reliable and environmental sound energy services for all; by integrating the environmental and climate change movements within the larger umbrella of the movements for social and economic justice globally.

2.3 Transition into a Greener Transport System:

This is a situation whereby an economy transits into low-carbon or greener transport systems, particularly the vehicular transport subsector. The world has been concerned about how to transit into transport systems that are equitable, climate-resilient and environmentally sustainable. Some studies suggest that electric power generation will "*open the door to fundamental changes in our modes of transportation*" (Miguel et al., 2010, p. 26). In general, the energy sector (electricity, heat, and transport) contributed to about 73.2% of total global anthropogenic CO_2 in 2020 (Figure 1).

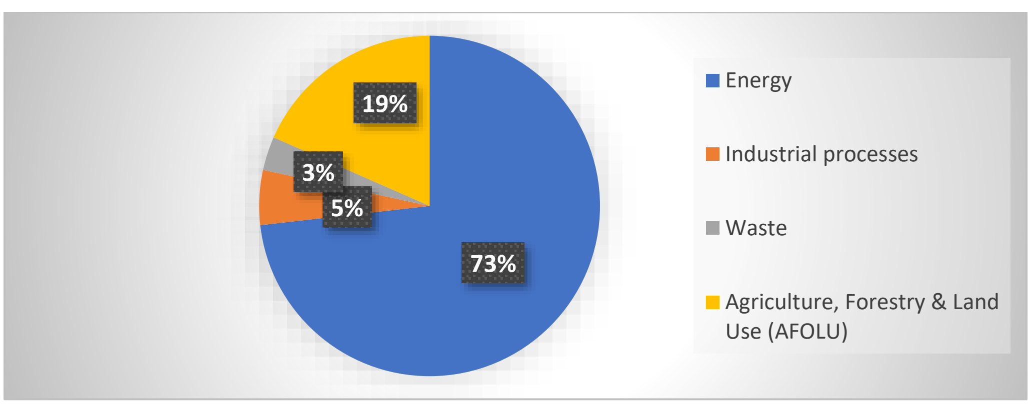

Figure 1: Carbon dioxide emissions by sectors (2020) Source*: Author's own using data from Our World in Data (https://ourworldindata.org/uploads/2020/09/Global-GHG-Emissions-by-sector-based-on-WRI-2020.xlsx).*

Further, at a high confidence level, the Six Assessment Report (AR6, 2021) of the United Nations Framework Convention on Climate Change (UNFCC) conclude that "*Fossil fuel combustion for energy, industry and land transportation the largest contributing factors on a 100-year time scale*" (Arias et al., 2021, p. 110). The current 23% of the contribution of global transport systems to CO_2 is projected to increase (Muneer et al., 2020), holding the COVID-19 possible impact constant. The road transport subsector is a paramount contributor and accounts for about 20% of total global anthropogenic greenhouse gases (especially CO_2) (Ibid.). For instance, a further sub-sectoral breakdown in terms of CO_2 emissions in 2020 shows that road transport accounted for about 12% as a share. Figure 2 illustrates the subsectoral contributions to global total CO_2 emissions by 2020.

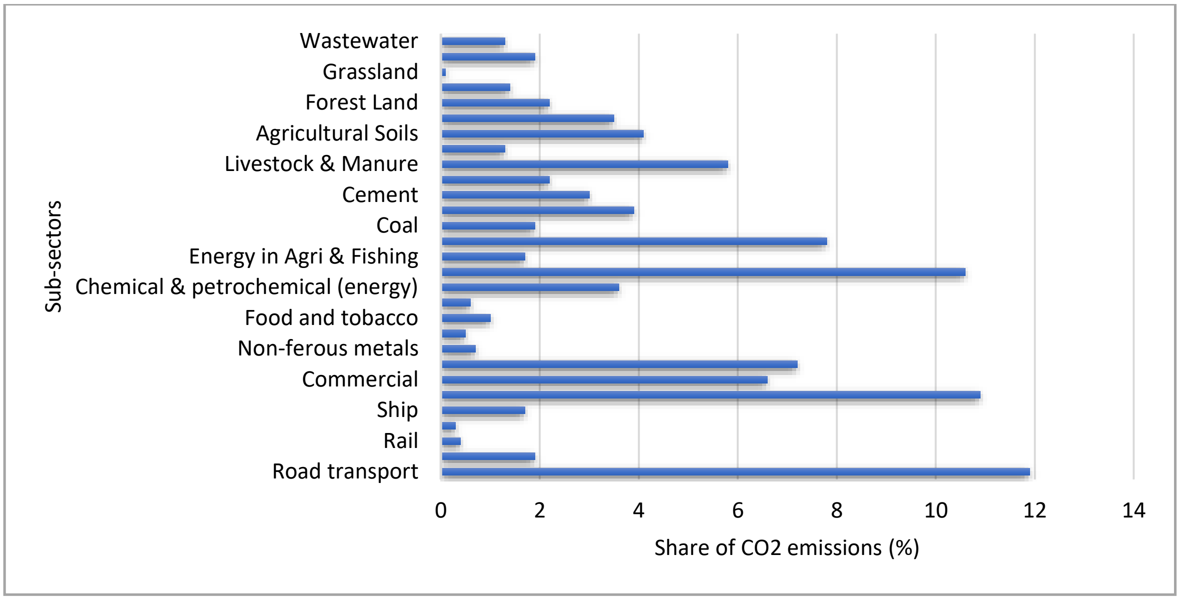

Figure 2: Carbon dioxide emissions by subsectors (2020)

Source: Author's own using data from Our World in Data (https://ourworldindata.org/uploads/2020/09/Global-GHG-Emissions-by-sector-based-on-WRI-2020.xlsx

In Ghana, the energy sector outstripped the contribution by land-use change and forestry from 2016 (Figure 3).

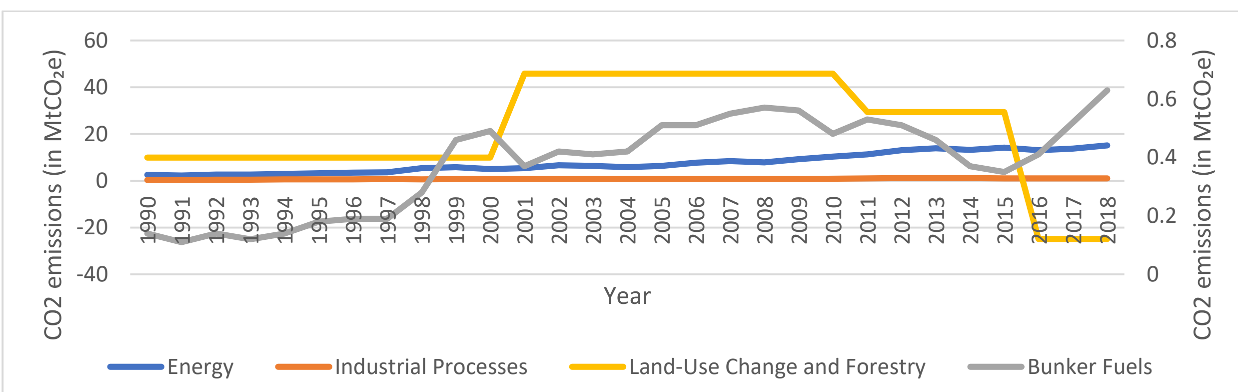

Figure 3: Historical CO2 emissions of Ghana (1990-2018)

Source: Author's own calibration using data from Climate Watch[2]

Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change shows that between 1990 and 2016, total carbon dioxide emissions (in Mt CO_2e) increased by 66.3% (Ghana's Fourth National Communication to the

[2] Data available from https://www.climatewatchdata.org/data-explorer/historical-emissions?historical-emissions-data-sources=cait&historical-emissions-end_year=2018&historical-emissions-gases=co2&historical-emissions-regions=GHA&historical-emissions-sectors=energy%2Cindustrial-processes%2Cagriculture%2Cland-use-change-and-forestry%2Cbunker-fuels%2Cenergy%2Cagriculture%2Cland-use-change-and-forestry%2Cenergy%2Cagriculture%2Cenergy%2Cindustrial-processes%2Cagriculture%2Cland-use-change-and-forestry%2Cenergy%2Cindustrial-processes%2Cagriculture%2Cland-use-change-and-forestry%2Cbunker-fuels&historical-emissions-start_year=1990&page=1.

United Nations Framework Convention on Climate Change, 2020). Thus, a country's transition into low-carbon and consequently greener transportation should be an indicator of the bulk of greenhouse gases, especially CO_2 lies with the vehicular transport system (Yin et al., 2015). A comparative empirical study between China and Mexico concludes that". The transport sectors of both countries are significant contributors to the overall greenhouse gas emissions" (Mendoza & Jiahan, 2020). Ghana is becoming an energy-intensive economy due to population growth, urbanization, energy consumption, industrialization, increasing private acquisition of cars, and the need to acquire and use electrical appliances to adapt to the increasing temperature due to climate change. In addition, the country must meet its commitment to the Nationally Determined Contributions (NDCs) of emissions-cutting under the Paris Agreement of 2016. Greener vehicular transport systems are therefore indispensable in this regard. Research on the country's state of affairs regarding electricity sector energy transition is needed for science policy.

3. Methodology

In relation to the methodology used in this study, it has largely involved desktop research in gathering significant information for the study. The science of desktop research is defined as "the process of assessing published secondary data"(Jackson, 1994, pp. 21-22). It mainly depends on finding, assessing, synthesizing and carefully analyzing the secondary data from multiple relevant sources, for instance, review of literature, published data, reports, proceedings, legal documents, etc.; and have been applied in (Jorge & Andreea, 2016; Langa, 2014; Van Logchem, 2019). Based on the literature, existing information pertaining to electricity power transition in Ghana by examining thematic areas in renewable energy reports and documents, Electricity Supply Plan (2018, 2019, 2020, 2021), the Ghana Renewable Energy Master Plan (GREMP, 2019), the Ghana Renewable Energy Act (2011), and information from the official databases of institutions such as Electricity Company (ECG), Ghana and the Northern Electricity Distribution Company (NEDCO), Energy Commission of Ghana, the Volta River Authority (VRA), and relevant articles. The retrieval and organization of the relevant information were structured under the following thematic sections: (i) the share of power electricity generated from hydroelectric power (HEP), thermal plants and solar plants; (ii) share of electricity generations managed by the state and private power producers (private and state-owned electricity company's ownership); and (iii) Structural transformations that most probably have occurred in Ghana's electricity power sector over the past years. Based on electricity power generation statistics as part of Ghana's annual energy sector statistics and reports, Table 1 demonstrates the various sources of electricity power categorized as state and private ownership based on literature. Based on the National Energy Statistics provided by the Energy Commission of Ghana, the various sources of electrical energy sources include solar plants, hydro and thermal plants. Furthermore, the protocols of electricity power transition illustrated as "Indicators of Electric Energy Transition" in the literature review section offers guidance for drawing a conclusion as to whether electricity energy transition has occurred (or not) with specific reference to Ghana's electricity subsector the country's energy systems.

4. Results and Discussion

4.1 Electricity Generation and Supply in Ghana: History and Essential Highlights

As have largely been global, the commencement of electricity supply in Ghana is historically linked to state monopoly of the industry. Ghana's electricity should be analyzed from the colonial era and post-colonial independence in terms of ownership and management. From the colonial era, the electricity sector was owned and managed by the state (the colonial administration under the British), and it dates back to 1914. Two things worth considering in terms of environmental sustainability and equitability of electricity management during the colonial era. From the angle of environmental concern, electricity power generation plants were fired by fossil fuels (Eshun & Amoako-Tuffour, 2016). In terms of equity, Accra, Kumasi, Takoradi, Cape Coast, Winnaba and Tema were the only locations with electricity access, as these towns largely served the political and natural resources interests of British colonial imperialists, leaving the majority of the rural folks behind at the time. In fact, historical accounts indicate that electricity production during the colonial era was powered by isolated diesel plants, in which the largest plant was stationed in Tema with 35,298 kilowatts.[3].

As part of the post-independence developments to drive industrialization, the first grid-based system of electricity transmission was installed in the year 1963. However, the first installed capacity was just about 161 kilovolts (kV), which transmitted electric power from the Tema to the larger parts of Accra. In 1966, the Akosombo Hydroelectric Dam on the River Volta was inaugurated during Dr Kwame Nkrumah's administration, a mega-project that serves as the turning point of Ghana's post-independence energy infrastructure development. With a distance of about 500 km and 8500 km^2 coverage area, the Akosombo Dam is reputed as the largest artificial lake in the world (Gocking, 2005; Smil, 2015; Twineyo-Kamugisha, 2012).

The Akosombo Hydroelectric power plant has about 1000 megawatts (MW) capacity for electricity generation. About 60% of electricity generation output at the inauguration of the Akomsombo Hydroelectric power was utilized to fire the smelter at the Volta Aluminium Company Limited (VALCo). The 30% remaining power was provided electricity mainly for the urban and political centres through the national grid project. Compared to about 30.8 million population today[4], the population then (in the 60s) was

[3] Link to data: https://www.ide.go.jp/English/Data/Africa_file/Company/ghana02.html

[4] Link to data: https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20Provisional%20Results%20Press%20Release.pdf

about 6 million people. Paradoxically, whereas a large population in the rural communities were not electrified, surplus electricity supply was exported to the neighbourhood economies: Benin, Burkina Faso, Mali and Togo. The electricity geopolitics and diplomacy strategy of the government of Ghana in exporting power to the nearby countries while the majority of its populations, especially in the Northern part of the country, are underserved, is still less under-researched. With the recent increase in demand for electricity services due to the rising middle class, urbanization, population growth, industrialization, as well as the need to bridge the rural-urban and north-south access gaps, the power supply capacity from the Akosombo Hydroelectricity power plants failed to match supply. The situation is exacerbated by the fluctuations in the water volume of the Volta Lake Volta Reservoir due to climate change (Gyau-Boakye, 2001; Miescher, 2021).

Various regimes of Ghana have tried to address the electricity supply-demand disequilibrium using various policy instruments, including the resort to "prayers and chanting" to command rainfall on Lake Volta. What is relevant to science policy as interventions include the addition of mini hydroelectric and thermal plants to the existing national grid. However, the expansion of thermal plants fired by light crude oil (LCO) imposes serious environmental health problems due to high greenhouse gas emissions, and it is incompatible with Ghana's efforts to reduce energy-related emissions and climate change mitigation. For instance, in what is titled: "***Updated Nationally Determined Contribution Under the Paris Agreement (2020 – 2030)***", the government of Ghana mentioned "Low carbon electricity generation" as a policy action whose objectives are "climate change mitigation" and a "4,439.4 Kt" of emissions reduction, sustainable energy transition as social-economic expected outcomes by 2030 (Updated Nationally Determined Contribution under the Paris Agreement (2020 – 2030) 2021). It appears the current expansion of thermal plants which are fired by LCO is inconsistent with Ghana's greener electricity energy transition strategies.

4.2 Ghana's Electricity Generation Mix: Current Trend

Since the inauguration of the Akosombo Hydroelectric power station in 1966, the electricity subsector of Ghana's energy sector is traditionally served by on-grid electricity supply network systems. However, the hydroelectricity supply, since 1984, has become less reliable partly due to climate change-induced erratic precipitation patterns (Adenuga et al., 2021; Eshun & Amoako-Tuffour, 2016; Sackeyfio, 2018). Consequently, Ghana, in recent years, has started experimenting an off-grid electricity generation as well as the rapid expansion of the thermal-based electricity generations.

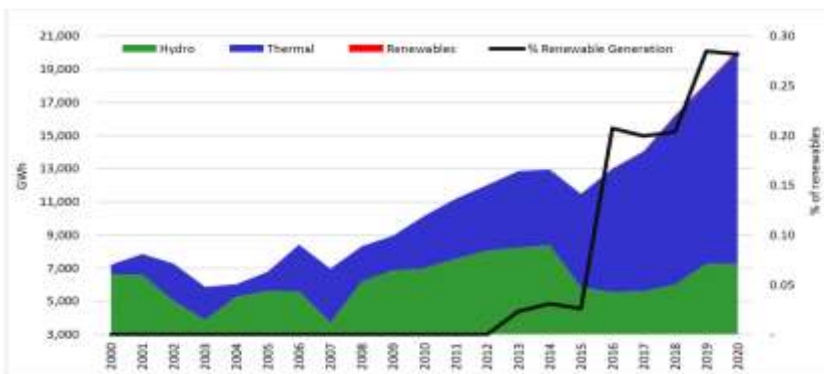

Figure 4: Electricity generation by fuel types of Ghana (2000-2020).

Source: Adapted from (National Energy Statistics, 2021, p. 22).

As can be inferred from Figure 4, in 2000, 6,610 GWh (representing 92% share of the total electricity generated) and 614 GWh (representing 8% of the total electricity generated) of electricity generation were fired by hydro (water) and thermal plants respectively. In 2020, however, out of the total 20,170 GWh of electricity generated, 7,293 GWh, 12, 820 GWh and 57 GWh were generated from hydro, thermal plants and renewable sources, respectively; representing respectively 36.2%, 63.6% and 0.28% shares of hydro, thermal and other renewables. As illustrated in Figure 4, whereas the thermal fired electricity generation mix appears progressive, the year marks the structural break, where thermal electricity generation mix outpaced the traditional hydroelectricity power supply. Furthermore, apart from hydropower, other renewable sources (mainly solar and waste to energy (W2E) contributes insignificantly to Ghana's electricity generation mix. As a result, Ghana has failed to achieve its 10% renewable electricity mix by 2020. For instance, whereas Ghana ambitiously targeted a 10% share of installed capacity from 2010 to 2020 in line with the SDG 7.2, which is to "*Increase the share of renewable energy in the global energy mix substantially by 2030*", only 0.3% was achieved (see Figures 4 & 5).

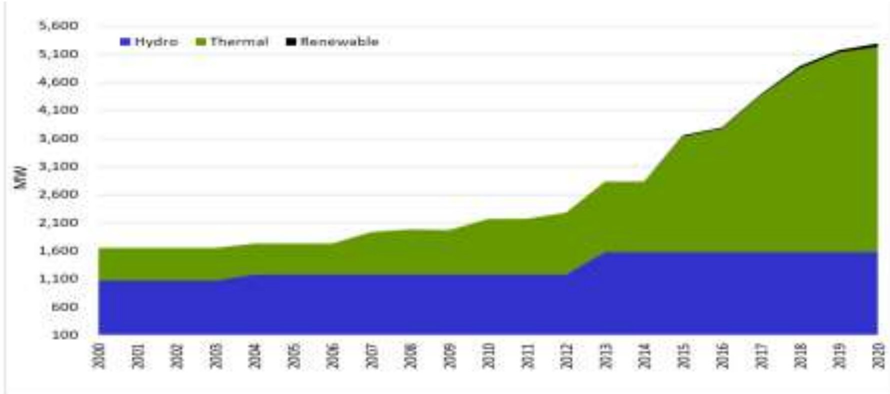

Figure 5: Ghana's installed generating capacity (2000-2020).

Source: Based on annual data from (National Energy Statistics, 2021, p. 18).

Notwithstanding, the on-grid installed renewable capacity grew significantly from 2.5 MW in 2014 to approximately 59 MW in 2020 (National Energy Statistics, 2021), representing about 2,260% growth between 2014 and 2020.

Table 2: Ghana's electricity generation in MW by sources (2020)

Electricity Plant	**Installed Capacity (MW)**	**Dependable Capacity (MW)**	**Type Energy Fuel Use**
State-Owned Electricity Generation Entity (The Volta River Authority (VRA**)**			
Akosombo HEP	1,020	900	Water
Kpong HEP	160	140	Water
TAPCO (T1)	330	300	Gas/LCO
TICO (T2)	340	320	Gas/LCO
TT1PP	110	100	Gas/LCO
TT2PP	80	70	Gas
KTPP	220	200	Diesel/Diesel
VRA Navrongo Solar Plant	3	2	Solar
VRA Lawra Solar Plant	7	5	Solar
Sub-Total – State-owned	**2,270**	**2,037**	
Bui HEP	404	360	Water
Ameri Plant*	250	230	Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LOC/Gas
KAR Power	470	450	LOC/Gas
AKSA	370	350	HFO
Trojan	44	39.6	Diesel/Gas
BXC Solar	20	0	Gas
Bui Solar	20	16	Solar
Cenpower	360	340	Diesel/Gas
Tsatsadu Mini Hydro	10	8	Water
Genser	60	60	Gas
Cenit Energy Limited	110	100	LCO/Gas
Amandi	203	190	LCO/Gas
IPPs - Sub-total	**2881**	**2663.6**	
Grand Total (State-Owned + IPPs)	**5,151**	**4,700.6**	

Source: Author's on construction using data from (2020 Electricity supply plan for Ghana: An Outlook of the Power Supply Situation for 2020 and
Highlights of Medium Term Power Requirements, 2021; National Energy Statistics, 2021).
Note: LCO = Light Crude Oil, HFO = Heavy Fuel Oil.

According to the recent electricity sub-sector reforms, there are three main entities dealing with demand-side management and supply-side management. They are: (i) generation entities (producers); (ii) transmission entities (transmitters), and (iii) distribution entities (distributors). These actors emerged in Ghana's electricity sub-sector as a mechanism to break the hitherto state ownership and monopoly in the electricity sub-sector. The power generation entity consists of private (independent power producers) and state-owned enterprises. The Volta River Authority is the state-owned company and manages the Akosombo hydroelectric power station, the Kpong hydroelectric plant, including thermal plants and two solar energy plants (the Navrongo and Lawra solar energy plans). In total, the state-owned and managed plants installed 2,270 MW capacity and 2,037 MW dependable capacity (Table 2); the reader may also refer to current data from (2020 Electricity supply plan for Ghana: An Outlook of the Power Supply Situation for 2020 and

Highlights of Medium Term Power Requirements, 2021). The Independent Power Producers (Table 2), representing power plants owned and managed by private producers, have become critical of the country's electricity sub-sector. The activities of these private companies can well be operationalized in the context of economics as 'foreign direct investments' (multinational corporations), abbreviated as here as "FDIs or MNCs". In that, the majority constitutes foreign entities operating in the electricity markets of Ghana. They impressively constitute the twelve thermal plants and two hydroelectric power stations in Ghana, with a total of 2881 MW and 2663.6 MW installed and dependable capacity respective in 2020 (Table 2). However, the electric power produced by the IPPs is sold to the government of Ghana to complete the main function of energy systems, that is, the transmission and distribution of useable energy services to end-users, see recent detailed discussions by Cambini et al. (2020).

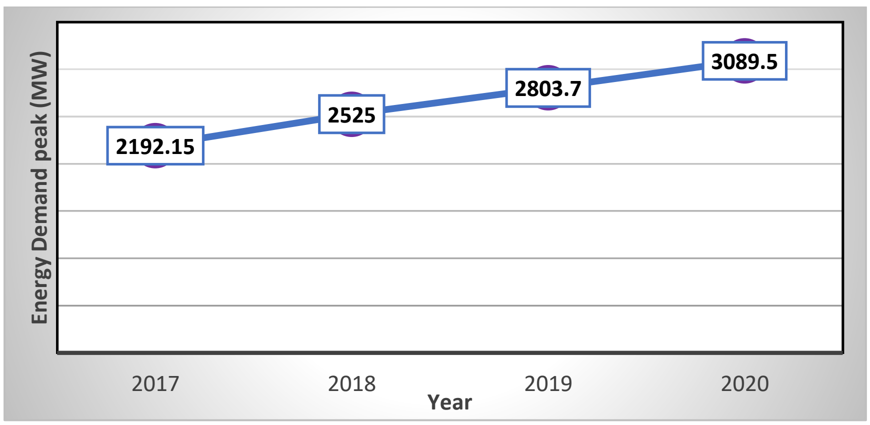

Figure 6: Ghana Electricity System Peak Demand (2017-2020).

Source: Author's own construct using data from (2020 Electricity supply plan for Ghana: An Outlook of the Power Supply Situation for 2020 and Highlights of Medium Term Power Requirements, 2021).

Table 2 further illuminates details of electricity generation by the state and IPPs in the 2020 fiscal year. For instance, in 2020, the electricity system demand peak reached 3,088.5 MW, compared to 2,192.15 MW, 2,525 MW and 2,803.7 MW in 2017, 2018 and 2019, respectively. This represents an approximately annual compound growth rate of 9% between 2017 and 2020 (see Figure 6). The total installed dependable generation capacity summed to 4,700.6 MW. This comprises approximately: 29.95% of hydro fuel, 69.56% thermal and 0.49% of solar power. In terms of ownership, approximately 43.33% and 56.67% respectively, for state-owned and private-owned (IPPs) plants in 2020 (see Figures 7 & 8).

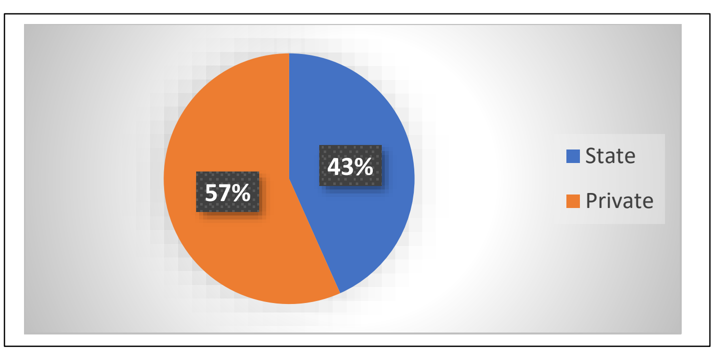

Figure 7: State versus Private Electricity Plants Ownership in Ghana (2020).

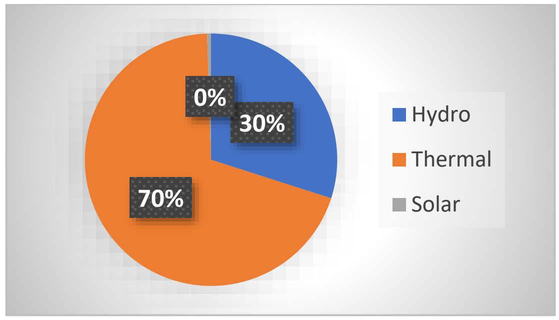

Figure 8: Electricity Generation by sources (2020).

Source: Author's calculations based on data in Table 2.

The large share of private participation (about 57%) in Ghana's electricity generation subsector resonates well with the growing need for a government-private partnership to deal with energy deficits and under investments in energy infrastructure networks. Whereas this is encouraging in terms of addressing in access gap, at least in the short-medium-term planning, a large proportion of investment been directed into fossil-fired thermal plants expansions contradicts an existing view that "*African governments, foreign investors and private investors are poised to roll out renewable energy projects across the continent*"(Simelane & Abdel-Rahman, 2011, p. 11). Moreover, the current position of the Government of Ghana is that climate change impacts such as high temperature and sea levels rising are occurring, therefore, the need to decarbonize the energy sector. The use of LCO and high fossil oil to fire thermal can increase greenhouse gas emissions, especially CO_2. It thus appears that, whereas the official long-term energy goals of the government of government are pursuing environmentalists, social green, ubuntu philosophical views that address human needs in a manner that is compatible with ecological systems health, its policy actions and results depict the worldviews of the neo-mercantilists and market liberalists who place the state and economy in energy policy actions over environmental concerns (see Table 1 and the referred text for details).

The electricity transmission subsector is a state-owned entity, that is, Ghana Grid Company Limited (GRIDCO). It is a subsidiary of the Volta River Authority, mandated to operate high-voltage electricity networks that transmit electric power from the generation stations across geographies where power is legitimately used. The electricity distribution subsector is made up of two entities: the Electricity Company of Ghana (ECG), which is mandated to distribute electricity services to end-users in the middle and southern belts of Ghana, while the Northern Electricity Distribution Company Limited (NEDCO) is responsible for the distribution of electricity to consumers in the northern belts of Ghana. In terms of operations, these two entities, ECG and NEDCO, are responsible for converting high voltages of electricity transmitted by GRIDCO to the acceptable consumption voltages, distributing useful electricity energy services to end-users in residential, industry, transport, agriculture and service consumption subsectors, as well as collection revenue/utility bills from their customers.

In 2019, following the various electricity market liberalization reforms, there was an attempt to privatize at least 50% of electricity distribution in Ghana as part of the Ghana Power Compact Projects financed by the Millennium Challenge Corporation (MCCs) (United States of America) to ensure efficiency in the distribution of power Ghana and the neighbouring countries. This led to a consensus agreement between the state-owned ECG and a consortium firm, Power Distribution Services Ghana Limited (PDS for short). However, various corruption risk assessments reviewed bleaches of conflicts of interests and lack of transparency in key political figures in the ruling New Patriotic Party were figured pointed. Consequently, the MCCs withdrew its $190m grant, ending the proposal to privatize parts of electricity distribution in Ghana. Some scholars have found that corruption, rent-seeking and bribery are inherent and fairly ubiquitous in a capital intensive investment like energy in developing economies and are usually "*associated with the sharing mechanisms*" (Jean-Marie & Geoffron, 2013). Future empirical works can help appreciate the 'corruption-energy transition nexus' to inform sustainable and resilience policies, especially, giving the importance of the energy-climate-poverty nexus.

If the current trend of Ghana's national grid electricity value chains – production, transmission and distribution are juxtaposed with a few decades ago situations, we are able to establish two significant structural changes. Firstly, we observed the evidence of a transition from the hitherto state natural monopoly of the electricity sector to a government-private-partnership regime, where the private sector accounts for about 57%, compared to 43% of state-owned entities. Secondly, there is an observed transition from the dominant hydroelectric power since the 1960s, to a hydro-solar-thermal generation mix, with hydro-fired electricity accounting for approximately 29.95%, crude fired thermal plants accounting for 69.56% thermal and 0.49% of hydropower (Figures 7 & 8).

These changes observed in the electricity subsector of Ghana's energy system are biogenic-anthropogenic factors and internal-external (domestic and geopolitics). However, these factors are not mutually exclusive. In terms of biogenic-anthropogenic factors, climate change coupled with extreme climatological events such as protracted droughts, erratic precipitation patterns, deforestation, etc., resulted in the decline of the water volume in the Akosombo Dam Reservoir (Gyau-Boakye, 2001). Some authors (Eshun & Amoako-Tuffour, 2016) believed that the first electricity crisis took place in 1984 due to climate change. However, in the face of fluctuations in the water volumes of the main hydroelectric dams, Akosombo Dame, Kpong Dam and Bui Dam, the country is expected to meet electricity demand-supply equilibrium by meeting about 10-15% annual increase in demand due to urbanization, population growth, industrialization and National Grid expansion. Moreover, the increasing integration of the private sector or parastatal organizations are largely part of the "quick-fixes-syndrome" to the major electricity crises since 1984. As already mentioned, Ghana's electricity crisis dates back to 1984. However, it peaked between 2014 and 2015, due in part to the protracted dry seasons resulting in a drastic decline in the generation of electricity from the Akosombo hydroelectric power plant, which supplies more than 60% of hydro-fired electricity in the economy. The electricity power outages intensified in 2015, coinciding with a political election year, in which the expression "dumsor", transliterated meaning, "power-off-power-on", became a domestic vernacular in Ghana.

Due to its reputation as a general-purpose technology, distortions in the electricity supply systems may yield serious political, social, economic, national security and environmental sustainability challenges, especially in multi-party democracies with periodic elections. For instance, some analysts argue that "*Power cuts are seen as the biggest test for John Mahama government ahead of the election in 2016*" (Umaru, 2015). As a result, the then ruling party, the National Democratic Congress, resorted to a 10-year contractual agreement with the TKEG (Turkey Karadeniz Group) for the supply of thermal-based electricity generation plants. According to the terms of the contract, the government of Ghana was requested to pay the initial investment cost for the two floating power ships. However, the cost of the approximately 450 MW electricity installed capacity is to be added to the national grid. In addition, the AMERI thermal plant was contracted by the then government to generate 24 MW power on a five-year construct, operate and transfer (BOT) arrangement and to be fired by natural gas produced from the Atuabo gas processing plant.[5]. In retrospect, the quest to fix the electricity crisis in Ghana, which peaked in 2014-15, superseded emissions concerns of the economy of Ghana, even though the government expression of worries about the devastating impacts climate change is ubiquitous in the government's short-medium-long-term energy policy. For instance, according to Ghana Renewable Energy Master Plan (GREMP, 2019), the overall short-medium-long-term goal is to provide *an " Investment-focussed framework for the promotion and development of the country's rich renewable energy resources for sustainable economic growth, contribute to improved social life and reduce adverse climate change effects*" (emphasis supplied) (Ghana Renewable Energy Master Plan, 2019, p. 6).

The rising addition of thermal plants for electricity generation has resulted in a number of social-ecological systems resilience challenges. From the social-economic angle, there has been a drastic rise in electricity tariffs, leading to disconnections, protests and even killings since 2017 because of the customer's inability to pay the rising utilities. For instance, on May 22, 2021, a young boy of 14 years who was selling sachet water was shot and killed by police personnel escorting the staff of the controversial PDS in an attempt to collect electricity bills which residents in Odumase in the Eastern region of Ghana, while several others sustained various degrees of gun wounds (KODJO & ODUMASE, 2019). Another social-economic impact of transitioning into thermal plants in Ghana has done with supply reliability and security, as crude and gas fuels used to power these plants are subject to price and supply fluctuations, especially in the Middle East that is plagued by political hostilities. Moreover, the use of gas fuel to fire thermal plants has led to a sharp increase in demand for gas between the energy and residential subsectors. Consumers who are conscious of their energy security has resorted to the use of firewood and charcoal as close fuel substitutes, with serious environmental problems such as deforestation, black carbon and carbon dioxide emissions. A number of studies have demonstrated a varying nexus between residential use of biomass fuels (fuelwood, animal dung, crop residue, charcoal) and environmental health problems such as respiratory diseases and premature deaths (Nawaz & Henze, 2020; Po et al., 2011; Yun et al., 2020).

Interestingly, however, there are no government official policy frameworks backing the transition from hydroelectricity to thermal plants, compared to the national Renewable Energy Act, 2011 (Act 832), which defines and presents the context of pursuing renewable energy development in the country. The rising development in the transition from previous state monopoly in the production of power to more private generation is supported by a number of general government policy instruments in the framework of the public-private partnerships for infrastructure network services and enhancing public service provision. This framework is codified in the National Policy on Public–Private Partnerships (2011).

4.3 Renewable Energy Development Agenda in Ghana

Ghana's national policy on renewable energy deployment dates back to the 1980s under the National Electricity Scheme (NES). However, following the various international environmental conventions and treaties such as the United Nations Framework

[5] The reader may refer to the full article at: (https://constructionreviewonline.com/news/ghana/newly-constructed-ameri-power-plant-in-ghana-to-start-operations-february/).

Convention on Climate Change (UNFCC, 1991), the Kyoto Protocol (KP, 1997), the Paris Agreement (PA, 2015), and the United Nations Global Agenda for Sustainable Development Goals (SDGs) (United Nations, 2015), renewable energy resources and technology deployment have attracted policy interests in Ghana. This is evidenced in the country's policy targets, for example, the country's 10% renewable energy mix in Ghana's energy generation mix by 2020 (Energy Sector Strategy and Development Plan, 2010) (Ghana Renewable Energy Master Plan, 2019). Additionally, the promulgation of the Renewable Energy Law, 2011 (as in Act 832) ("The Renewable Energy Act, 2011," 2011) aims at creating an enabling environment legal framework to attract private sector involvement in the following:

(i) Development;
(ii) Management; and
(iii) Utilization of renewable energy in an efficient and environmentally sustainable manner.

Moreover, the Ghana Renewable Energy Plan (GREP, 2019) has been revised to generate 1,000 MW off-grid electricity for communities by 2030. Also, Ghana is an active member of the United Nations systems; therefore, the country's renewable energy framework is in line with the Sustainable Energy for All (SE4ALL), a global initiative to mobilize resources on a global scale, governments, private sector and civil society organizations to undertake a concrete action towards three, but interlocking objectives of:

(i) Ensuring universal access to modern energy services;
(ii) Doubling the global rate of improvement in energy efficiency; and
(iii) Doubling the share of renewable energy in the global energy mix,

by 2030. The Ghanaian government so far domesticated the global SE4ALL initiative in 2012 in the country's Renewable Energy Master Plan to address the above global initiative through three objectives:

(i) Provision of Off-Grid Renewable Energy-Based Power Solutions for Remote
(ii) Communities;
(iii) Access to modern energy for cooking; and
(iv) Productive Use of Energy (PUE).

To achieve the above, the government of Ghana has introduced the **Mini-grid Electrification Policy** (MGEP, 2016) to integrate mini-grid electrification infrastructure networks into the country's National Electrification Scheme (Ghana Renewable Energy Master Plan, 2019). Under the MGEP of 2016, mini-grids constitute a public sector driven investment initiative with the Volta River Authority and Electricity Company of Ghana/Northern Electricity Distribution Limited, which are accountable for the generation and distribution of electricity, respectively. Under the MGEP (2016), customers connected to mini-grids benefit from the same electricity pricing policy same as customers who are connected to the national grid, particularly under the current rural communities electrification framework (Ghana Renewable Energy Master Plan, 2019).

4.4 Preliminary Discussions

Our analyses have so far shown that in the broad sense, there have been significant structural transitions in Ghana's electricity subsector of the country's energy systems. These structural changes take the forms of changes in electricity generation mix by fuel types and the status of ownership in terms relative to the demand and supply-side management of electricity supply value chains – generation, transmission and distribution. In terms of structural changes by fuel types, the study demonstrates a significant change from the post-independence hydro dominant grid electricity generation to hydro-thermal-solar mix, with thermal plants currently accounting for a large proportion of Ghana's electricity generation installed capacities. In terms of demand-supply sides management ownership, the study suggests a significant structural transition from an exclusive state monopoly in the electricity generation, transmission and distribution to the government-private partnership.

These structural changes are driven by multifaceted forces, biogenic and anthropogenic, in an interactive manner. Largely, the observed structural changes can be explained by climate change (Kuamoah, 2020), the need to expand access to the entire country driven by population growth, urbanization, industrialization, increasing middle class, and generally increasing capitalist-influenced social metabolism in Ghana. The government of Ghana has, in a way, responded to such increasing demand in the electricity services through government-private-partnerships for the related infrastructure investment and social service delivery

Ghana's structural changes in the electricity subsector of its energy systems appear to be akin to those observed recently in some of the BRICS (Brazil, Russia, India, China and South Africa) economies, especially that of China and South Africa (Hauff et al., 2014). Among these two BRICS economies, the observed structural changes in the electricity sectors, especially those that have to do with the fuel types, were largely driven by the need to equalize the growing demand with supply. Given the recent decades of international treaties and conventions on environmental sustainability and development and the need to transform the global energy systems from the fossil-dependent paths, Ghana's electricity transition to thermal plants is rather 'undesirable'. From the views of some scholars, there are a number of comparative advantages of increasing hydroelectricity compared to thermal plants fired by fossil fuels, in addition to the fact that, in some degree of consensus, the world is pushing for a lower-carbon economy or greener energy generation mix (Akpınar, 2013; Bagher et al., 2015; Bahadori et al., 2013; Miescher & Tsikata, 2009). A philosophical contradiction of Ghana's current transition into dominant thermal plants fired electricity generation systems can be mirrored from premises that the environmentalist, social greens, ecologism, survivalism, Ubuntu (Table 1) worldviews appear to be the current dominant worldviews shaping international energy systems and development agenda, see (Cherp & Jewell, 2011, 2014) for instance.

Aside from the relative advantages of the hydroelectricity power generation, one can also cite lower grid-related greenhouse gas emissions and other forms of pollution in communities where hydropower plants are sited, in addition to being cheaper in terms of delivering electricity services to end-users than thermal plants (Fakehinde et al., 2019). The main reasons are that hydropower plants depend on kinetic energy embedded in flowing water (Kutscher et al., 2018) to turn the turbines of the plants, compared to thermal plants that depend on volatile crude oil supply, expensive and can take a heavy toll on scarce and competing fiscal space in low-income economies like Ghana. This is because currently, most of the thermal plants rely wholly on high fossil fuel oil and light crude oil (see Table 2). In addition, the use of gas in thermal plants may increase scarcity and, for that matter, the unit price of liquefied petroleum gas for households. This may lead to households resorting to the use of charcoal and firewood as close substitutes energy fuel, leading to deforestation, environmental degradation and indoor air pollution-related premature deaths.

As it has historically been since the first industrial revolution, in low-income economies like Ghana, during the early stage of industrial take-off, economic growth and development are often seen as the most important concern for citizens, and environmental concerns subordinated to the former (economic growth and development). This is evidenced by excessive moves towards extractive activities in the mining sector (minerals and sand), notwithstanding the fact that these activities can contribute to serious environmental degradation (air, land, water pollution) and depletion of the natural base of the economy (35-39). That notwithstanding, it is expected the social and political costs and promoting the general well-being of citizens shall be primacy in deciding between development alternatives, taking into consideration the general low saving, wages and salaries in the economy. A leading scholarship from social-ecological systems (SES) thinking perspective argues that "*Fundamental issues for humanity like democracy, health, poverty, inequality, power, human rights, security and peace all rest on the life support capacity and resilience of the biosphere*" (Biggs & Maja, 2015, p. XIX). The validity and physical manifestations of the above quote are ubiquitous in Ghana in terms of the negative impacts of climate change in critical sectors of the economy such as energy, water, agriculture and infrastructure systems, as well as official adaptation and mitigation policy documents of the government of Ghana. It, therefore, piques our climate-energy-sustainability nexus curiosity as to why successive administrations and governments have resorted to the more ecologically and economically costly thermal electricity generation plants in attempts to address themselves Ghana's electricity crises. Instead of investing in comparatively cheaper alternative renewables and technologies. The answer, probably, is underpinned by the government of Ghana's tendency to resort to 'ambulance or quick fixes' in dealing with social-economic societal challenges. It is, however, worth noting that energy problems are inherently social, economic, environmental, political, and even geopolitical problems.

Generally, energy infrastructure networks, especially hydropower projects, are inherently capital intensive, involved in high social overhead costs, and require a number of years for an economy to realize returns to investment in micro, meso and macro levels (Bridge et al., 2018). Since the construction of the Akosombo Dam from 1961 to 1965, three more additional hydropower plants have been constructed (see Table 2). The most recent ones are the Tsatsadu Mini Hydropower Plants completed in 2021 to produce a 45 kW of electricity, and the Bui Hydropower Plant with an installed capacity of 400 MW completed in 2013, all constructed by the Bui Power Authority through the government-private-partnership engagement between the Government of Ghana and the Chinese-based Sino Hydro (Kirchherr et al., 2016). With its relatively large installed capacity, the Bui dam is a 622 million USD project and has taken Ghana five decades since its conception in immediate post-independence for completion in 2013. The high monetary cost, as well as the long duration of the project completion, makes the Bui dam less politically attractive to successive governments with four-year constitutional mandates and limited fiscal space. The heavy crude-powered thermal plants have been politically appealing to the 'homo politicus' over the past decades as they (thermal plants) offer a much quicker and short-termist 'ambulance fix' and comparatively reliable solutions. This is rather a political entrepreneurship approach to enable the electorate and general citizenry to acknowledge the government as if it has provided solutions to the electricity crisis during the four-year term, and therefore to yield for them some completive political reputation in order to capture power in the next election. For example, during the peak of the electricity crisis in Ghana between 2014 and 2015, the move by the then government to bring the two floating thermal power ships to attenuate the power crisis may be considered as a strategic decision to sail the ships to the shores of Ghana in a fortnight in order to be connected to the national grid system (Gyamfi et al., 2018; Kumi, 2017). However, such politically underpinning move towards addressing the electricity crisis in Ghana between 2014 and 2015 appears more pragmatic and scientifically meaningful, compared to the resort to 'prayers and chanting to command rainfall into the Akosombo dam' led by the government of Ghana in 2004 to address the same problem.

On the contrary, the structural change from the state-led monopoly in the generation, transmission and distribution of electrical power to end users is expected. Many advanced economies, including capitalist, development states and socialist economies, have already applied this model in the electricity sector. Thus, it has also become a general policy of the government of Ghana to engage the private sector in the country's quest to provide socio-economic infrastructure services, motivated by the limited and competing fiscal space in the face of high demand for public infrastructure and essential social services (Robert et al., 2014). On its ideal wisdom, government-private-partnership is expected to propel the government to make the provision of critical infrastructure services productively and efficiently (Clark & Hakim, 2019; Oliveira Cruz & Miranda Sarmento, 2021; Seleznev et al., 2020). These assumed perks had situated government-private partnerships globally, an appealing model of development, including Ghana (Jamali, 2004; Sapri et al., 2016). Notwithstanding, there is compelling evidence illustrating the fact that government-private partnerships have overwhelmingly failed to deliver their assumed benefits, that is, a secured and efficient public service (Pusok, 2016; Salman et al., 2019). In the case of Ghana, the recent government-private partnerships in the electricity sub-sector have ended in excess power installed capacities, whereby about 4657.37 MW was produced instead of 2957 MW demand peak in 2020. A number of concerned groups have questioned the direction state's decision pertaining to the contractual agreement with independent power producers, requiring Ghana to honour its obligation of paying for the excess installed capacities, whether they are used or not.

Some sources indicate that Ghana currently pays some $450m annually for the redundant overcapacity of power from the private power producers (Dzawu & Vuuren, 2019). For what could be considered as a negated just transition, the cost is transferred to electricity end-users, leading to a high cost of electricity since 2017. Notwithstanding the fact that can Ghana currently has an overcapacity installed power, the current is still suffering from intermittent power blackouts, as the government is unable to meet its debt obligation with the private power producers and supplies of light crude oil and heavy fuel oil to keep the thermal plants running. If the present overcapacity installation is projected into the near future, it constitutes a drawback towards low-carbon economy and greener electricity system transition. This is because it will become a daunting policy action to push further investments to electricity generation as there is already existing stock of over installed capacities in the economy. However, energy systems involve constant learning and corrections for past mistakes. Thus, the current excruciating costs of thermal electricity plants provide policy logic to invest in relatively cheaper and environmentally benign renewable energy technologies and resources. Given the likely political costs of running an expensive energy system and the country's accumulation of energy sector debt of over $750 million (Olero, 2021), it can be anticipated that the State would amend itself to provide electrical power from alternative sources that are affordable, reliable, resilience, and environmentally compatible with moving towards the 2030 Global Agenda on Sustainable Development Goals.

The 13th goal (SDG 13) of the 2015 United Nations 17 Sustainable Development Goals requires that the international community "***Take urgent action to combat climate change and its impacts***" (https://rd.springer.com/referencework/10.1007/978-3-319-95885-9), as well the temperature goal of the Paris Agreement in 2015 to limit "*Holding the increase in global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels*" (Klein et al., 2017) demand greater decarbonization of the transport sector globally. Against this logic, the Ministry of Energy, in conjunction with the Energy Commission of Ghana, launched the "Drive Electric Initiative (DEI)" in 2019[6]. However, in Ghana, the domination of fossil fuels in vehicular transportation modes is expected to extend well into the future. This is because, as the larger regions of sub-Saharan Africa, the battery charging infrastructure points needed to roll out electric vehicles (EVs) are almost not in place (Ayetor et al., 2020), even though greener vehicular transport systems can "improve air quality, offer benefits to the power networks, and aid renewable energy integration" (Collett et al., 2021). Moreover, currently, there is just not enough public awareness about the need to switch to low-carbon and greener vehicular transportation systems. For instance, a study conducted in Ghana on citizens' choice of vehicular transport modes preferences shows that income level, family size and status, perceived comfort and distance from the workplace were key factor determinants of vehicular transport mode choices (Abdul Muhsin Zambang et al., 2020; Ackaah et al., 2021; Sam et al., 2018). According to these studies, environmental consciousness among studied samples in Ghana appears not a significant determining factor. Meanwhile, vehicular transportation is a major contributor to the total anthropogenic carbon dioxide emissions in Ghana, as shown in Figure 2. Researchers have estimated that privately owned vehicles are accountable for the 83% of the CO_2 emissions of the total transportation sector (Maza-Ortega et al., 2021). Thus, in line with the global debates, the main purpose of '*defossilizing*' the vehicular transportation in Ghana should be a push " *to achieve a drastic reduction of CO_2, NO_x, and particulate matter (PM) in the atmosphere*" (Maza-Ortega et al., 2021).

5. Conclusion and Matters Arising

Based on the study's findings, matters arising, and discussions, we have both quantitative and qualitative reasons to conclude that significant, and for that matter, structural changes in Ghana's electricity subsector have occurred. However, the observed structural changes, though significant, are not complete. In a broad sense of transitions, two main observations can be made: (i) a transition from the dominant hydroelectricity power from hydro sources to the hydro-thermal-solar mix. However, presently, thermal plants

[6] See https://energycom.gov.gh/efficiency/drive-electric-initiative.

account for a higher share of Ghana on-grid electricity installed capacities (ii) the transition from the previous state monopoly in the ownership and management of electricity generation, transmission and distribution to government-private-partnerships, whereby independent power producers currently account for a higher share of electricity generation in Ghana. Important matters arising from the study include the need to understand the drivers of structural changes, both demand-side management and supply-side management in Ghana. Firstly, it can be concluded that the need to expand access and supply reliability are key motivators of electricity system structural changes in Ghana. This may largely be driven by the government of Ghana's policy reforms in the electricity subsector to bring on board government-private partnerships to improve both expansion and service delivery to domestic, and neighbour countries end users. Secondly, the need to avoid expensive political costs, such as losing elections, propelled quick fixes in the electricity crisis in Ghana, and thermal plants installations are more feasible in the short-termists political economy thinking and interests. Thirdly, climate change is a major driver of electricity structural transition in Ghana, as extreme climatological events, such as protracted periods of droughts, erratic precipitation patterns, etc., attenuate the reliability and resilience of hydroelectricity infrastructure network systems. However, the currently observed situation of the electricity energy transition, from the perspective of a low-carbon economy, lacked the reputation to be considered as transitioning towards a low-carbon or greener economy. For instance, the dominant thermal installed generation capacities of electric power mean higher grid greenhouse gas emissions. The above appeared incompatible with the government of Ghana's long-term plan of addressing the interlocking problems of poverty based on the national energy systems with low greenhouse-gas reduction reputation, as mentioned in the "***Updated Nationally Determined Contribution Under the Paris Agreement (2020 - 2030)***" document. An interesting matter arising in the study is that Ghana's electricity transition from hydropower to thermal plants-appeared both biogenically and anthropogenically circumferential, as demand-supply equilibrium management and climate change interact to drive the current structural change in terms of fuel types.

Therefore, further interdisciplinary studies are imperative to appreciate both theoretically and practically why Ghana's renewable energy policy agenda and the observed strategies of implementation appeared contradictory in terms of electricity availability, acceptability and reliability.

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