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Energy Framework and Policy Direction Guidelines: Ghana 2017–2050 Perspectives

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ABSTRACT Ghana currently has no future energy strategic plan or framework for its generation system apart from the Energy Policy developed by the Energy Commission (EC). The EC based its research on the year 2000 parameters and estimated the energy system up to 2020, which cannot entirely address the current challenges facing the energy sector. The main objective of this paper is to develop an integrated energy planning (IEP) framework for Ghana as a guideline for addressing energy challenges, to promote energy efficiency in both demand and transmission, CO_2 emissions reduction, and the utilization of renewable energy sources (RES). The methods used are content analysis, multiple case study, and procedure for IEP framework development. The primary computer tool used for the analysis and future energy projections was Long-range Energy Alternative Planning. The demand forecast was performed using key input parameters, including Gross Domestic Product, population change and urbanization. The overall results of this study suggest 40% of non-conventional renewable energy resources into the country's energy mix, proposed energy efficiency promotion in both demand and transmission, and the utilization of RES integration to save the nation up to about 40% CO_2 emissions reduction. The paper recommends strategies to reduce losses in the transmission and distribution systems of Ghana. The paper again recommends the revenues accrued from the carbon tax for maintenance work on the existing equipment, and finally, an integrated energy planning framework was developed to serve as a roadmap for Ghana's energy sector up to the year 2050.

INDEX TERMS CO_2 emissions, energy demand, energy efficiency, energy policy, installed capacity, integrated energy planning, renewable energy sources.

I. INTRODUCTION

The choice we make today on energy production and consumption will determine how sustainable a future energy system can be progressed in socio-economic endeavors. To attain the universal access to affordable and reliable energy supply, the model of Ghana's energy has gone through tenacious and active policies with ambitious attainment goals of renewable energy, energy efficiency enhancement, and technical innovation support and development of the industries [1]. Policy evaluation should be undertaken to ascertain the impact of the existing policy on the country's generation system. This will lead to the identification of the lapses of these policies. Also, the development of a uniform policy framework to promote the future development of the energy system. The Republic of Ghana, an energy policy contract, currently will expire in the year 2020 [2]. Ghana appears to be crawling closer in the direction of universal electrification. As in the case of many developing countries, many challenges remain unsolved. In an attempt to solve those challenges, the IEP framework is, therefore, necessary to make sure that energy service requirements for current and future are met in the most efficient, affordable, and sustainable means and be mindful of avoiding any negative influences on the

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environment [1], [3]. In [68] the authors present state-of-the-art survey on hybrid renewable energy system operations and planning.

To ensure adequate, secure, optimal, and reliable energy supply, it is indispensable to have a coherent, comprehensive, and workable IEP framework. This framework eventually becomes a guide for maintainable energy expansion, effective utilization of the natural resources, and provision of reliable energy supply to the citizenry. The activities of the previous policies developed by the Energy Commission of Ghana didn't assess the ecological effects of the future pathway on energy generation with regards to the reduction of the CO2 emission policies entirely. The EC's study again did not make any provision for identifying the optimal cost model for energy generation development in Ghana [3], [4]. This paper, therefore, examines and reviews policy options for promoting energy efficiency, reducing transmission and distribution losses, promoting clean energy through CO_2 mitigation, promoting bilateral, regional, and international cooperation in Ghana's energy sector, localization, and job creation potential and renewable energy development. It is essential to consider all these factors when investment policies on RES systems are made [5], [6]. Sub-sectorial strategies, however, are developed to reflect the individual perspective of every sector. To avoid policy conflicts, it is, therefore, imperative to develop an integrated energy planning framework for the country. The paper recommends strategies to be implemented for reducing losses in the transmission and distribution systems of Ghana to improve energy efficiency and reliable supply of energy. Finally, an IEP framework was developed for Ghana's energy system as a roadmap to achieve sustainable energy from 2017 to 2050.

II. MATERIALS AND SIMILAR STUDIES

Five African countries were selected based on the similarities in energy generation in terms of their evolution and nature as reference for the Ghana IEP framework development. They include Uganda, Togo, Democratic Republic of Congo (DRC), Nigeria, and Egypt. IEP frameworks developed by Denmark and South Africa were also put in perspective as a guide for the development of Ghana's IEP framework.

A. ENERGY POLICY IN UGANDA

The electricity Act of Uganda was promulgated in 1999. The policy aimed to reform the power sector with the introduction of IPPs to compete with the National electricity industry. The target of improving electricity access to 12% in 2012, 26% in 2026, 51% in 2030, and 100% in 2040 funded by the World Bank and the Global Environmental Facility through Energy for Rural Transformation could not be met as a result of the diversion of funds to other projects than the intended purpose [7, 8]. The state of renewable energy in Uganda as of 2015 was less than 8% capacity [9].

B. PROPOSED ENERGY POLICY IN TOGO

Togo currently has no energy policy guideline for its energy sector [10] the draft energy policy which was expected to be adopted in 2014 is still under consideration at the Energy Ministry. The draft document has a comprehensive policy on renewable energy development, off-grid energy supply for isolated and remote areas, and an incentive package for IPPs to provide energy for the national grid. The draft policy again contains an investment code on tax exemptions for energy providers to ensure reasonable revenues on the investment made on energy production. [11], [12].

C. ENERGY POLICY IN DRC

DRC's population currently stands at about 70 million people, only 6% of the population has access to the reliable electricity supply. The entire energy system in DRC is disjointed; the country has no energy policy in place [12], [13]. Electricity legal code for DRC was adopted in May 2009 in Kinshasha workshop. Even the generation of electricity has increased by 15% in the last 10 years. Subsequently, the population growth has seen an astronomical increase of 41% in the same period, according to CNE. Government buildings and public enterprises consume about 50% of the power generated in DRC annually [14], [15]. The elaborated policies in the framework are gradually reducing CO_2 emissions in non-ETS sectors such as.

D. NIGERIAN ENERGY POLICY

Nigerian policy on energy was promulgated in 2003 to serve as a framework for energy development in Nigeria to ensure energy security to the year 2020. The renewable energy master plan (REMP) was developed based on this policy in 2005 [16], [17]. REMP was a joint program between UNDP and the Nigerian Energy Commission. The vision 2020 which was released in 2009 contained the government's ideology of increasing the GDP from less than 10% to 13% and RE contribution from 2% to 15% [18], [19].

E. ENERGY POLICY IN EGYPT

Egypt has a comprehensive plan for its energy sector; currently, the total installed capacity as December 2017 stands at 45,192 MW with a maximum load of 30,400 MW [20], [22]. The transmission grid stands at 45,000 MW, and the generated energy is 186,320 GWh. Apart from the statistics listed above, Egypt is blessed with an abundance of renewable energy resources. Egypt has neither an energy policy nor an integrated energy planning framework for its energy sector. However, there are various laws and regulations which form guidelines for the energy sector such as laws on RE development as enshrined in article 32 of Egypt's national constitution, electricity law, first-round Cabinet decree on Feed-in-tariff, second round Prime Minister's decree on feed-in-tariff for RE projects. The current energy plan for the country from 2016 to 2035 is illustrated in [23], [24].

F. SIMILAR STUDY ON IEP FRAMEWORK

South Africa and Denmark were selected based on the similarities in energy generations and natural resources for the development of renewable energy as a case study for Ghana IEP framework. The two IEP frameworks were thoroughly reviewed, and some methodologies were adapted in the Ghanaian context.

1) IEP FRAMEWORK OF DENMARK

Denmark has a long-term strategic plan of achieving 100% RE supply of electricity by 2050 in all sectors of the economy [25], [26].

The country has a roadmap to complete the elimination of energy generated from coal by 2030, RE shall be used for heat and electricity supply by 2035 and ultimately, reaching total independence of fossil fuels energy by 2050 as shown in Table 1 [27]–[29].

TABLE 1. Roadmap to 2050 IEP framework for Denmark [27].

No.	Type of Energy	2015 %	2020 %	2025 %	2050 %
1	Wind	41	54	61	70
2	Solar PV	2	5	9	10
3	Fossil	44	21	10	0
4	Biomass	10	18	18	19
5	Others	3	2	2	1
6	**Total RES**	**56**	**79**	**90**	**100**

Agriculture, transport, waste, and parts of the industry, households, and the energy sector from 2013 - 2020. This is under the EU energy package and climate target for its countries to reduce CO_2 by 20% in 2020 [30], [31]. The phasing-out of fossil fuels will further reduce total CO_2 emissions in line with this strategy, and Denmark will be put on track for 80-95% CO_2 reductions by 2050 [32], [33]

2) IEP FRAMEWORK OF SOUTH AFRICA

The supply of South Africans energy is dominated by coal which represents about 70% of the total installed capacity; crude oil contributes about 22%. Natural gas, renewable energy, and Nuclear power, including biomass and hydro, contribute only 9% of the installed capacity [34], [35]. A further check-in [36], [37] discloses that coal contributes about 90% of the power generated, 5% of nuclear and 4.5% hydro in that order. Natural gas, Petroleum diesel, and other RES such as biomass, wind, solar, bagasse, and landfill gas together contribute only 2%. The IEP in South Africa only consolidated the energy production pattern with a little on RES and CO_2 reduction [38], [39]. The country aimed at reducing CO_2 emissions to 40% but still maintained coal-power generation as the primary source of energy up to 2050 [40], [41]. The scope of the South African IEP framework consisted of the following: Primary energy sources and Demands for energy services. Key sectors of the economy captured in the framework were transport, industry, commerce, residential, and agriculture with energy forecast to 2050 [38], [42].

G. OBSERVATIONS FROM SIMILAR ENERGY POLICIES AND IEP FRAMEWORKS

The review made on the energy policies of the selected countries shows that none of the selected countries has an integrated energy planning framework. Egypt has a comprehensive plan for its energy sector, but there are no policy guidelines for the plan. It is the only country among the selected countries which has the most extended and well-distributed plan to cover all energy resource in the country. Nigeria had an energy policy up to 2020 to increase the contribution of RE from 2% to 15%. The Nigerian policy didn't put measures in place to reduced CO_2 emissions as well as how energy efficiency can be improved. The entire energy system in DRC is disjointed; the country has no energy policy in place. The proposed energy policy written by the Togo's Energy Commission (EC) in 2008 is yet to be adopted by the central government. The implementation stage of the document was slated for December 2014, but the final document is still under consideration stage at the EC's office. Togo's draft energy policy is expected to address various challenges in the energy sector and also to promote energy efficiency in the areas of generation, transmission, and distribution of electrical energy. The state of RE in Uganda as of 2015 was less than 8% capacity. To attain the MDGs RE capacity, the country has set for itself 30% target of RE to augment the Uganda's installed capacity as stated in their 1999 energy policy document. Uganda has a target of improving electricity access to 12% in 2012, 26% in 2026, 51% in 2030, and 100% in 2040 respectively, however, there are no policy guidelines to achieve these targets in their energy policy documents. All these documents from the selected countries were used to serve as a reference in our attempt to develop an integrated energy planning framework for Ghana.

III. METHODOLOGY

Multiple case study method was used for the paper. The data analysis techniques as indicated in Figure 1 focused on method used to achieve the needed target on research work done in Ghana RE and grid integration: issues, challenges, and solutions with a taxonomic review and technological approach to obtain the needed results [43]. Long-term Energy Alternative Planning (LEAP) was applied to perform the analysis for energy projection modeling from 2017 to 2050. Descriptive statistics and frequency tables were built for displaying the outcomes following the main objectives of the paper. To make accurate projections on the country's energy needs from 2017 to 2050, LEAP software was used for the projections [44].

A. CASE STUDY OF SOUTH AFRICA'S IEP FRAMEWORK

The SA IEP framework, unlike Denmark, was extended across all sectors of the economy. The primary purpose of the South Africans' IEP is to make sure that energy service requirements for the current and future are met in the most efficient, affordable, and sustainable means. Ghana and South

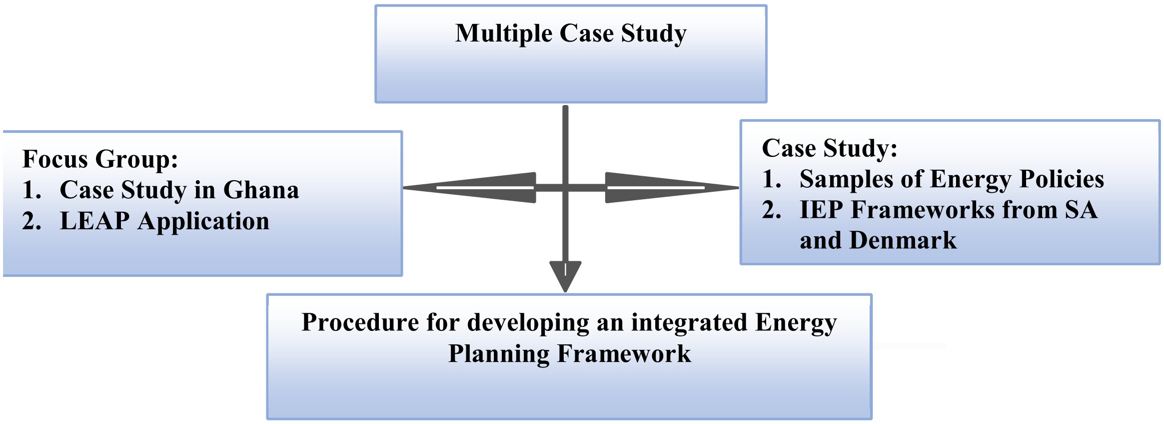

FIGURE 1. Procedure Ghana's IEP development.

Africa have some similarities in terms of energy production. Again, Ghana can adapt SA's approach to climate change, supply, and demand in the Ghanaian context.

B. CASE STUDY OF DENMARK'S IEP FRAMEWORK

Comparing Denmark's situation with that of Ghana shows two different scenarios. In terms of RES per area and per capita, the comparative analysis puts Denmark ahead of Ghana. Ghana's energy now is dominated by fossil with 55.7% and hydroelectric power of 44%. RE contributes as low as 0.3%. However, Ghana can adapt Denmark's systematic approach to the development of numerous RES potentials in Ghana. The development of Ghana's IEP framework was achieved through broader consultations from all energy policies and IEPs from the selected countries discussed earlier, coupled with the current energy situation in Ghana. Figure 1 illustrates the procedure used for Ghana's IEP development.

IV. DATA, RESULTS, AND ANALYSIS

The technology adopted here is to help to put all the data gathered and use LEAP application to forecast the energy required up to 2050 and use them as a benchmark for the IEP development. The year 2010 was chosen for designing Ghana LEAP model as the base year for the analysis of the projects in the developmental structure of the energy generation systems of Ghana up to the year 2050. 2010 again was chosen as a base year because of the accessibility of data. The Statistical Service of Ghana conducted the last national population census in 2010 [45], and Ghana Energy Commission also conducted a national energy survey in the same year [46]. These two national activities provide reliable data for the model. The year 2010 selection for this study also provided seven years (2010 to 2017) to validate the results with real data. The growth population trend of Ghana was estimated at 2.4% annually, according to Ghana's Statistical Service (GSS). Ghana's population and housing census were estimated at 24.7 million people [46]. Ghana's population growth is related to Sub-Saharan African growth rate of 2.5% as compared to 1.6% in other middle-income countries [45].

Table 2 shows a summary of the 2010 population and housing census. The consumption of electrical energy trends in Ghana varies between urban and rural areas.

TABLE 2. Summary of 2010 population and housing census [46].

No.	variable	value	Percentage Increase
1	Total population	24, 658, 845	
2	The rate of population growth	2.4% Annually	
3	Total population in urban areas	12, 545,229	50.9%
4	Household	5, 467, 136	
5	Urban Household	3,049,438	55.8%

The access to electricity in the urban areas was 83.8% in 2010 as against 16.2% of the rural areas. The population of the urban areas as of 2010, which was 55.8% is expected to increase to about 60% in 2050 [46]. Gross Domestic Product (GDP) plays a vital role in the energy planning process; the growth rate from 2005 to 2009 averagely was about 6% and rose to the highest of 14% in 2011. Table 3 indicates Ghana's GDP characteristics from 2010 to 2017 [48].

Crude oil production in commercial quantity in 2010 boosted the country's revenue, and as a result, the country's growth of the GDP dropped drastically to 4% in 2014 but increase to 6.1% in 2016 as indicated in Table 3. The increase of GDP was as a result of power shortage that bedeviled the country in 2014 and 2015 [48]. The energy situation improved due to the Government's intervention in 2017, and a result, the GDP growth then moved to 8.3%. Table 4 illustrates the trend of GDP share at necessary economic activities in Ghana from 2010 to 2017.

The manufacturing and mining sectors in Ghana are most consumers of the country's energy. The government's agenda of industrialization will pose a great challenge for the power sector since the growth in industrialization will increase the electricity demand, and the country needs to produce more energy. Modeling the demand of the industrial sector, 1.0 was anticipated which indicates that, the increase of

TABLE 3. GDP characteristics from 2010 to 2017 [48].

YEAR	2010	2011	2012	2013	2014	2015	2016	2017
GDP (MILLION US$)	16848	18158	16615	16790	11402	9221	9879	19223
GDP GROWTH RATE (%)	7.9	14	9.3	7.3	4	3.9	6.1	8.3

TABLE 4. Delivery of GDP at rudimentary fiscal activities (%) [48].

YEAR	2010	2011	2012	2013	2014	2015	2016	2017
AGRICULTURE	29.8	25.3	22.9	22.4	21.5	20.3	23.4	24.5
INDUSTRY	19.1	25.6	28	27.8	26.6	25.3	27.3	28.1
MINING	2.3	8.4	9.5	9.4	8.0	6.3	7.1	7.0
MANUFACTURING	6.8	6.9	5.8	5.3	4.9	4.8	4.1	4.0
OIL AND GAS	0.4	6.7	7.7	8.2	7.2	5.8	6.0	5.9
CONSTRUCTION	8.5	8.9	11.5	12	12.7	13.2	14.2	15.4
SERVICES	51.1	49.1	49.1	49.8	51.9	54.4	56.8	56.3

TABLE 5. History of Ghana's generation and demand [46].

Year	Demand		Peak		Generation	
	GWh	% Growth	GWh	% Growth	GWh	% Growth
2005	6935	19.7	1325	26.3	6788	12.4
2006	7838	13	1393	5.1	8430	24.2
2007	6822	-12	1274	-8.5	6978	-17.2
2008	8043	17.9	1367	7.3	8324	19.3
2009	8385	4.2	1543	12.9	8958	7.6
2010	9232	10.1	1506	-2.4	10167	13.5
2011	10565	14.4	1665	10.6	11200	10.2
2012	11620	10	1729	3.8	12024	7.4
2013	12127	4.4	1943	12.4	12870	7
2014	13678	12.8	2061	6.1	12963	0.7
Last 5 Years		9.6		7.3		5.5
Last 10 Years		9.7		5.6		9

energy demand of 1% should correspond to 1% growth of the GDP as indicated in the national energy policy [49]. Adoption of 8% growth of GDP as a base case projected the energy needs from 2010 to 2025. And 12% growth was projected from 2026 to 2050, which is expected to increase the energy supply [49].

A. GHANA'S ENERGY DEMAND FORECASTS

In [49] the authors present techno-economic and environmental analysis of power generation expansion plan of Ghana. Ghana's electricity demand increases at the rate of 9.7% every year, and this trend has been consistent for the past decade alongside 5.6% growth in peak demand. Table 5 illustrates the history of Ghana's generation and demand from 2005 to 2014. But the growth of peak demand rate in the past five years has improved to 7.3%. But the demand rate stayed at 9.6% for the same period. Comparing the 2014 value of generation and that of 2005, according to Table 5, indicates a significant boost in generation growth.

Table 5 further indicated that the last five year's generation is nearly half of that of demand. This is a clear indication that Ghana energy consumption does not correspond to its generation, and that trend must be addressed immediately to avoid future energy crises.

B. TECHNICAL RESULTS ON RES TECHNOLOGY DEVELOPMENT

The technical results in the LEAP model indicated the need to maximize the utilization of any available.

Renewable Energy Resources (RES) of the country as against the utilization of energy produced by fossil fuels. Aside from two additional hydro plants which are to be constructed in 2025 and 2035, the results further consolidated the relevance of RES development. About 78 TWh is expected to be generated by 2050. The strategy adopted to expand RE succeeded in a significant reduction of thermal energy generation to as low as about 50 TWh as illustrated in Figure 2. With this development, renewable energy in Ghana will increase to 55% from 2017 to 2050.

The agenda of increasing the RES deployment has yielded positive results, as predicted, non-conventional RES share has increased to a peak value of 45 TWh in 2040 from PV, wind, and hydro sources but slightly declined to 42 TWh at the end of the study period. Figure 3 illustrates the percentage input by plant type.

Contrasting other developments, RES capacities peaky at closed values and these values confirm the real maximum of all available resources of the plant type. These outcomes, therefore, are a clear indication that the country can generate over 50% of RES to meet its growing energy demands.

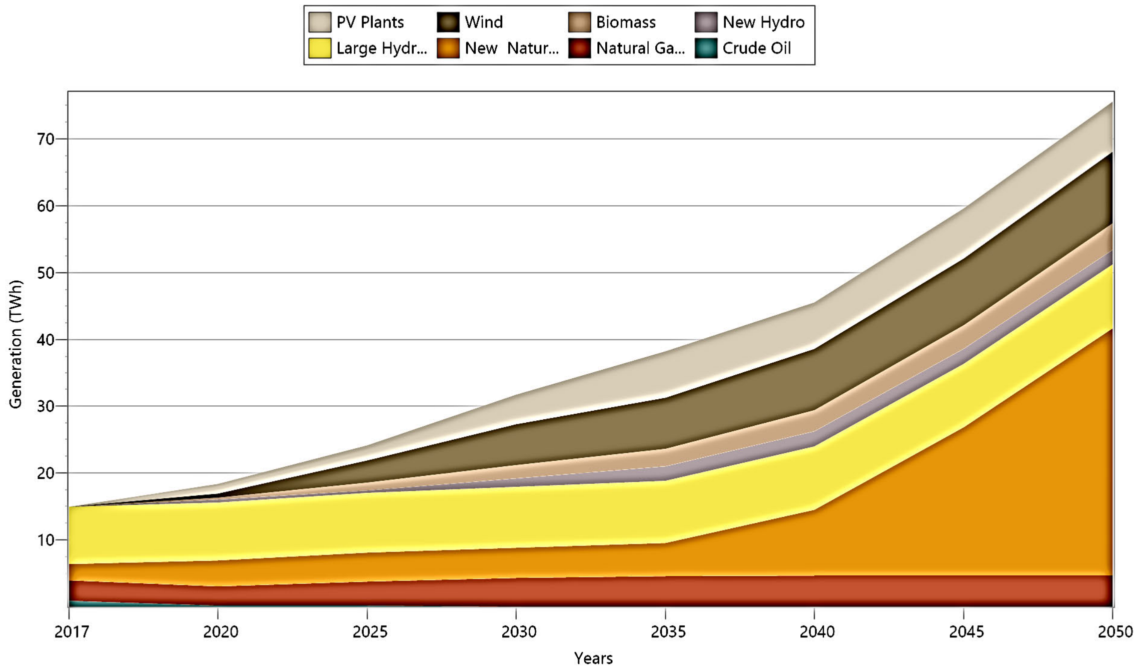

FIGURE 2. Renewable energy development.

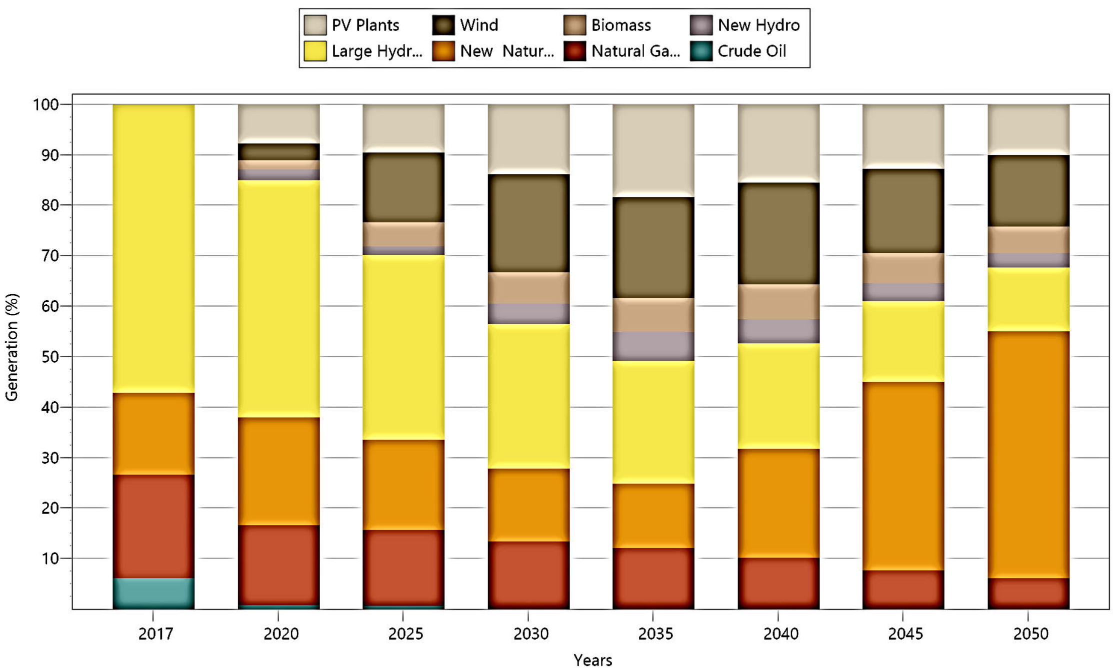

FIGURE 3. Energy generation by plant type.

The results also considered the various challenges of integration of RES in large quantities into the grid system and suggested possible solutions.

C. FUTURE ENERGY DEMAND FORECAST

Energy security and sustainability should be the focus of a long-term integrated energy planning framework. Many researchers have used various methods in an attempt to forecast Ghana's energy demand and supply. Bekoe and Adom [47] used ARDL and PAM, and an estimated 12% growth from 2000 to 2020. Abledu [48] used ARIMA and estimated 8% growth in demand. Awopone *et al.* [49] used LEAP and projected 7% increase from 2014 to 2040 on the condition of a stable economy within the study period.

TABLE 6. Authentication of the demand side of the leap model.

Real Data versus LEAP								
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Real (TWh)	9.23	10.57	11.62	12.13	13.97	14.32	15.46	16.03
LEAP (TWh)	9.91	11.01	11.69	12.40	13.17	13.09	14.01	15.71
Error (%)	7	4.2	0.6	2.3	-5.8	1.9	2.2	2.3
GRIDCO versus LEAP								
Year	**2015**	**2018**	**2020**	**2023**	**2026**	**2029**	**2032**	**2035**
GRIDCO (TWh)	13.93	16.30	18.15	21.39	25.29	27.21	31.41	35.89
LEAP TWh)	13.98	16.73	18.88	22.58	27.04	30.89	34.12	38.56
Error (%)	0.3	2.66	0.4	5.6	6.9	7.6	8.9	9.5

Ghana grid company adopted a similar approach of Abledu and forecasted 7% to 9% range of growth from 2000 to 2020 [52]. The bottom-Up approach of LEAP model was adopted in this study. The 2010 energy consumption survey conducted by Ghana's Energy Commission was adopted for the development of the intensity model. The outcome of the energy demand forecast from 2010 to 2050 is shown in Figure 4.

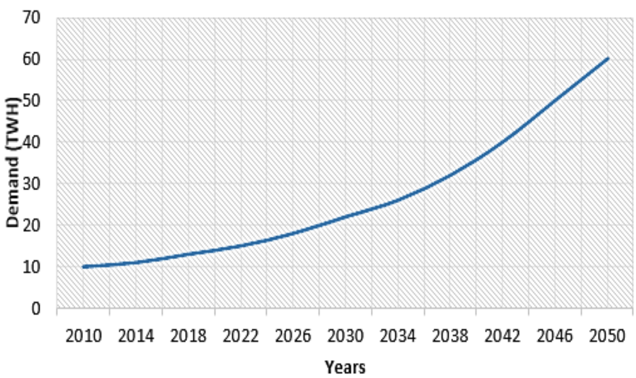

FIGURE 4. Forecast of energy demand from 2010 to 2050.

From Figure 4, the outcomes indicate that demand forecast will rise at an average growth rate of 12 TWh from 2010–2018, 6 TWh from 2018–2026, 8 TWh from 2026–2034, 14 TWh from 2034-2042 and 20 TWh from 2042-2050. The growing rate follows the past growth in energy demand, and they are reliable with the official load forecasts of the country [52]. Ghana will need a total of 18 TWh as energy requirement by the year 2026. This value is projected to be increasing to 60 TWh by 2050. Ghana can only achieve this target by exploring every available energy source in the country to meet this future energy requirement.

All projections in this paper are made based on the past demand as well as GDP values which may not be seen in the real demand, so it is significant to understand that the real demand may be higher as compared to the forecast made in this study. The historical trends alone for energy forecast is not enough to capture the actual future energy demand because the inadequate power generation, as well as low rate of rural areas electrification, may lead to repressing future energy demand [53]. That is why Ghana recorded negative demand growth in 2014 during the period of the energy crises, as shown in Table 6. This demonstrates that energy generating capacity always relates to the official demand forecast.

This study aims to find probable paths leading to the maintainable generation of energy to embark on economic and ecological analysis in the current state of Ghana's energy situations and to develop an integrated energy plan framework for the country. Thus, this demand will be used for all the framework development. Actual figures and official load predictions from 2010 – 2017 from the EC's database was used to authenticate the results generated from the demand side of the LEAP model in this paper. Table 6 further illustrates the comparison between the real data with LEAP results in the upper part of the table, and the lower part shows the official load forecasts with model results.

The official load demand forecasts carried out in Ghana are only two, the EC's forecast which projected the future demand from 2000 to 2020, and that of GRIDCo which projected from 2012 to 2035 [54]. For this study, GRIDCo's forecast was adopted because it represents the present trend in energy demand and supply in Ghana, which is also in line with the IEP framework development. The real data and the LEAP forecast have moderate differences in all cases except the year 2014 where the LEAP forecasts are a little higher than the official forecast with the maximum 7% error that occurred in 2010. This means that the highest error that might occur in this study should be approximately 7%. This is a clear indication that the LEAP demand model has the needed ability to the model trend of Ghana's future energy demand in the development of the IEP framework.

D. LEAP APPLICATION FOR MODELLING GHANA'S ENERGY GENERATION SYSTEM

The dependable installed capacity in 2010 was 1866 MW [55]. The system was modelled by aggregating all power plants in the country individually, including energies produced by the IPPs [56]. The characteristics of various generation plants and their operations are from 2010 to 2017, as illustrated in Table 7.

Actual plant operative data from 2010 to 2017 [57] were used in Table 7 this is as a result of the government's plans to convert all energy generating plants into combined cycle plant, all of them were modelled as such [58]. Almost all thermal generation plants in Ghana use either light crude oil

TABLE 7. Characteristics of generation plants in Ghana from 2010-2017 [56].

Dependable installed capacity (MW)								
Plants	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Thermal	765	765	875	1130	1130	1376	1671	1667
Hydro	1040	1040	1040	1420	1420	1420	1420	1420
PV				2	2	2	2	2
Available Average Capacity (%)								
Thermal	46.77	46.77	47.45	46.8	46.8	46.7	46.8	46.8
Hydro	76.78	83	88.6	66.2	67.4	47	64.3	61.7
PV				20	20	20	20	20

TABLE 8. Comparison of leap model and official data results, 2010.

Generation (GWh)				
No.	**Plant**	**Official**	**LEAP**	**Error (%)**
1	Hydro	6,994.84	6,995	0.0
2	Thermal	3,134	3,134	0.0
3	**2010**	**10,128.84**	**10,129**	**0.0**

TABLE 9. Comparison of leap model and official data results, 2011-2017.

Generation (GWh)									
	Hydro			**Thermal**			**PV**		
Year	**Official**	**LEAP**	**Error (%)**	**Official**	**LEAP**	**Error (%)**	**Official**	**LEAP**	**Error (%)**
2011	7561	7562	0.01	3134	3134.24	0.01	-	-	-
2012	8071	8071.81	0.01	3639	3637	-0.06	-	-	-
2013	8233	8234.75	0.02	4635	4632.69	-0.05	4	4.38	8.5
2014	8387	8384.75	-0.03	4635	4632.64	0.05	4	4.38	8.5
2015	8390	8389.76	0.01	4635	4635	0.0	4	-	-
2016	8432	8431.80	0.01	5706	5735	0.0	4	-	-
2017	8622	8621.90	0.01	5726	5722.75	0.01	4	-	-

TABLE 10. GDP of Ghana from 2010 – 2017 [60].

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
GDP (Million US$)	16848	18158	16615	16790	11402	9221	9879	19223
GDP Growth rate (%)	7.9	14	9.3	7.3	4	3.9	4.1	8.3

or natural gas for their operations. For lower environmental impact and low cost, the preferred fuel is national gas when accessible, but due to inadequate supply of natural gas, light crude oil still contributes about half of the fuel feedstock [51]. The ratio of fuel feedstock from 2010 to 2017 is 45% and 55% for light crude oil and natural gas respectively. The ratio after 2017 was interposed to 80% natural gas and 20% light crude oil by 2020, and it is expected to reach 100% natural gas by 2035. These projections agree with the National Strategic Energy plan of Ghana's bids to use only natural gas to run the thermal plants [59]. To determine the capability of the LEAP model, the installed capacity of 2010 was modelled, and the results were compared with the official results, as illustrated in Table 8.

The results were accurate and were much close to the data recorded in Table 8. The results further revealed that the values of thermal in both LEAP model and official data are the same, and 0.0% of simulation error was recorded. However, LEAP model for Hydro was a little higher than the official value, but the same 0.0% of simulation error was recorded. The LEAP model results from 2010 to 2017 were compared with official data, and the details are presented in Table 9.

E. ECONOMIC CHARACTERISTICS IN GHANA

The GDP (Gross Domestic Product) play an essential role in the energy planning process, the growth rate from 2005 to 2009 averagely was about 6% and rose to a highest of 14% in 2011. Table 2 shows the GDP of Ghana from 2010 to 2017 [60]. Ghana began production of crude oil in profitable quantities in late 2010, and because of crude oil production, it is observed from Table 10 that the GDP growth dropped to 4% in 2014 after a peak of 14% in 2011. This is mainly due to the load shedding that was experienced between 2014 and 2015 because of insufficient generation [60]. It was however increased to 8.3% in 2017 the highest in last five years. Damage to the West African Gas Pipeline resulted in a shutdown of the pipeline for maintenance cutting out supply to the gas turbines. Even though the agriculture sector serves as the primary source of employment, especially in rural areas,

TABLE 11. Distribution of GDP at basic economic activity (%) [60].

Year	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture	29.8	25.3	22.9	22.4	21.5	20.3	23.4	24.5
Industry	19.1	25.6	28	27.8	26.6	25.3	27.3	28.1
Mining	2.3	8.4	9.5	9.4	8.0	6.3	7.1	7.0
Manufacturing	6.8	6.9	5.8	5.3	4.9	4.8	4.1	4.0
Oil and gas	0.4	6.7	7.7	8.2	7.2	5.8	6.0	5.9
Construction	8.5	8.9	11.5	12	12.7	13.2	14.2	15.4
services	51.1	49.1	49.1	49.8	51.9	54.4	56.8	56.3

the service sector is the backbone of the economy, accounting for 51.1% of GDP in 2010. The trend of GDP share for the various sectors of the economy of Ghana is illustrated in Table 11.

The most energy-intensive sectors of the economy include the mining and manufacturing sectors. Growth in these sectors will, therefore, lead to a significant increase in demand for electrical energy. For Ghana to benefit from its oil industry, there is a need to expand its electrical generation sector. To model the industrial demand, the GDP elasticity of demand of 1.0 was assumed. This means a 1% increase in GDP yields a 1% increase in energy demand. This is to conform to the official projections presented in the national strategic plan [51]. Thereby increasing the future power supply of Ghana [61].

F. DATA ANALYSIS AND DISCUSSIONS

The development of IEP framework for Ghana has been categorized into three main stages: the first stage as a base or reference point, the second stage as Moderate Renewable Energy Sources (MRES), and the third stage as High Renewable Energy Sources (HRES). The development of the IEP framework for Ghana is built on the Government's planned for increasing the capacity of electrical energy to meet the demands of its growing population and projected extenuation alternatives. The formulation of the stage is presented in the National Strategic Energy Plan [51].

The present addition of generation capacity in Ghana is concentrated mainly on thermal power which is operated mainly on crude oil (oil) and natural gas (NG). This development tendency was expected to carry on in the first stage (2010 – 2017) development through the inclusion of Renewable Energy Sources (RES) on the Ghana's master plan of energy generation expansion programme [54]. Some dedicated systems that are presently granted permits for construction or still under construction were also considered in the IEP framework. LEAP application was applied endogenously to add to some extent extra thermal plants value of 300 MW power in units to meet the increasing energy demand and specified reserve margin. Eighteen percent (18%) of reserve margin was interposed for increasing from the base year (2010) to 20% in the study period (2050).

The reliability of the generation system depends typically on the reserve margin. The reserve margin also is the difference between the percentage system peak load and the operational installed capacity [62]. Ghana has been operating at a negative reserve margin in the past seven years due to insufficient capacity addition, inadequate fuel supply, coupled with increasing demand. GRIDCO has, however, established stability criteria, including an 18% reserve margin [63]. Accordingly, for this analysis, a minimum reserve margin of 18% was adopted. The main summarized characteristics of the IEP framework development are stated below:

- The country has no limitations on the usage of fossil fuel instead of electrical power generation.
- There were no targets for the reduction of CO_2 emissions.
- The energy expansion programme was primarily based on the combined cycle of thermal plant construction.
- The upgrading of the existing single-cycle plants to combined-cycle plants.
- The country will continue on Natural gas as the primary fuel for the available thermal plants.
- The 10% target for increasing Non-conventional Renewable Energy Resources (NRES) by 2030 will be generated to the total generation capacity, this does not include large hydro generation.

The main focus of MRES development will be the promotion of renewable energy sources. Ghana has a substantial RES potential such as Wind, PV, wave, biomass, small Hydro, and MSW (Municipal Solid Waste) but the study concentrated on Solar and wind energies intending to expand RES to a maximum of 50% by 2050. HRES Development explores the full potentials of RES in Ghana. This development adopts changing of the existing strategy to lower emission technologies from high emission technologies by drastically reducing electrical energy generated from fossil fuel.

G. COST-BENEFIT ANALYSIS OF THE IEP

Table 12 presented the monetary outcomes of the developments in 2010 in US dollars. From table 12, all costs relating to the framework development were taken to allow the environmental effect to be quantified in the development. The cost includes Operation and maintenance (O&M) costs and Environmental Externalities (Env. Ext) costs. The cost of adverse effect from greenhouse gases which emanate from power generated from the fossil fuel and job creation potentials for the study period were also factored into the development. There is no carbon tax mechanism in Ghana as it stands now; nonetheless, ccarbon tax of ₵50.00/tonne

TABLE 12. Cumulative cost benefits from 2010 to 2050 for stage one development.

Item Cost in (Million USD)	The discount rate of 5%		The discount rate of 10%		The discount rate of 15%	
	Stage 2	Stage 3	Stage 2	Stage 3	Stage 2	Stage 3
Transformation	5134.47	13296.42	1787.35	5260.50	722.26	2468.90
Fuel	-107.14	-632.59	-82.98	-478.22	-63.94	-366.69
Env. Ext. Cost	-4.33	-25.03	-3.25	-18.29	-2.48	-13.66
NPV	**5023.00**	**12638.81**	**1711.13**	**4762.99**	**655.84**	**2088.56**

in 2020, ₵100.00/tonne in 2030 and ₵150.00/tonne in 2040 in that order. This model was set-up to examine the extent of damage carbons which emanate from CO_2 emissions can cause to the citizenry and the possible ways to eradicate or minimize it. The carbon tax was introduced to tightening energy generations that produce CO_2 emissions as developed by the LEAP model. As a result, RES increased from 32% to 39% representing about 47% of the country's total installed capacity by 2050. This is the highpoint consequences of the carbon tax introduction on the various developments. Table 12, therefore, summarizes the cost and benefit and circumvented fuel purchased, transformation cost, and cost of ecological externalities and as compared to base case development. The results may not give the exact cost value, but it can provide a convenient yardstick to compare with the fiscal performance.

Table 12 further shows that at the base reduction rate of 10%, an additional cost of $1787.35m and $5260.50m in capital investment will be needed to start the implementation of the stage two RES and the stage three RES developments respectively during the planned 30 year study period. A real discount rate of 10% was used based on the West Africa Power Pool generation and transmission master plan recommendations for member countries [64]. To consider the higher investment cost of technologies, the results were not surprising in the alternative developments. The RES developments were seeing much lower than the total Net Present Value (NPV) according to the results. This is as a result of the substantial cost savings in fuel that occur in the two RES developments. From the results shown above, Ghana needs long term savings in the cost of fuel by implementing the other development during 2010 – 2050 with the addition of RES into the energy generation plan.

H. ENVIRONMENTAL ANALYSIS OF THE IEP

The adoption of the Fourth Assessment Report (AR4) emission factor was in line with the IPCC's recommendation for consistency in reporting from 2015 [65]. The increasing values of CO_2 emissions shown in Figure 5 are as a result of the use of coal instead of natural gas for the thermal plants. The introduction of coal instead of natural gas contributes to higher emissions on the environment, which has a severe effect on the population. Cumulative emission of about 4.000 $MMTCO_2$ e, as shown in Figure 5 is a result of the introduction of coal in the generation plants.

Ghana currently has no limitations on CO_2 emissions on thermal plants for energy generation; that is why the country continues with the thermal power expansions. CO_2 emissions emanated from coal fuel is the highest globally, with about 73% CO_2 emissions of the total 11.8 GT in 2009 globally [65, 66]. Apart from CO_2 emissions, coal ash also has many toxins such as cadmium, arsenic, and selenium. CO_2 emission target, if introduced, will directly affect the growth of clean energy technology in Ghana. The introduction of this target resulted in higher growth of NRES. Comparatively, the optimum framework model forecasted 40% of NRES power of Ghana's total installed capacity by 2050, and that will correspond to about 40% CO_2 emission drop on the optimum framework.

The growth of RE generation systems has reduced the fossil fuel plant's share of generation capacity. The production of thermal power is expected to reduce from its current state of 62% of the installed capacity to 55% in 2035 and 42% in 2050 if CO_2 emission targets are introduced. The reduction of thermal power production will automatically reduce fuel import quantity for power generation. The suggestion of CO_2 emission target introduction will help the country to ensure energy security. This clearly shows that the acceptance of coal development will have an adverse effect on the environment.

The country, therefore, needs to consider introducing an emission standard by encouraging the IPPs to invest in renewables but to continue exploring more efficient combined cycle gas plants for thermal generation. The general idea of RES contribution to the reduction of CO_2 emissions was also confirmed in Figure 5. The results further indicated that the best way for the country is to follow the proposed stage three RES development generation expansion plan to avoid about 90 $MMtCO_2e$ and also to reduce about 40% as compared to that of the stage one plan. The LEAP model contains CO_2 emission factors required for environmental assessment. The practice will also help Ghana to reduce the transmission and distribution losses from the grid system and increase energy efficiency.

I. LOCALISATION AND JOB CREATION POTENTIALS

Overall job potentials in the IEP framework are in construction rather than operations. Hence, a prominent nuclear build programme makes for big employment [67]. The IEP does not only mention the undermining effects of mega constructional projects which create boom-bust local economies. Broader macroeconomic consideration needs to be taken to cover all sectors in job creation in order not to reduce the productivities of the long-term economic programme. Construction and operation jobs are expected to be created. The projections of

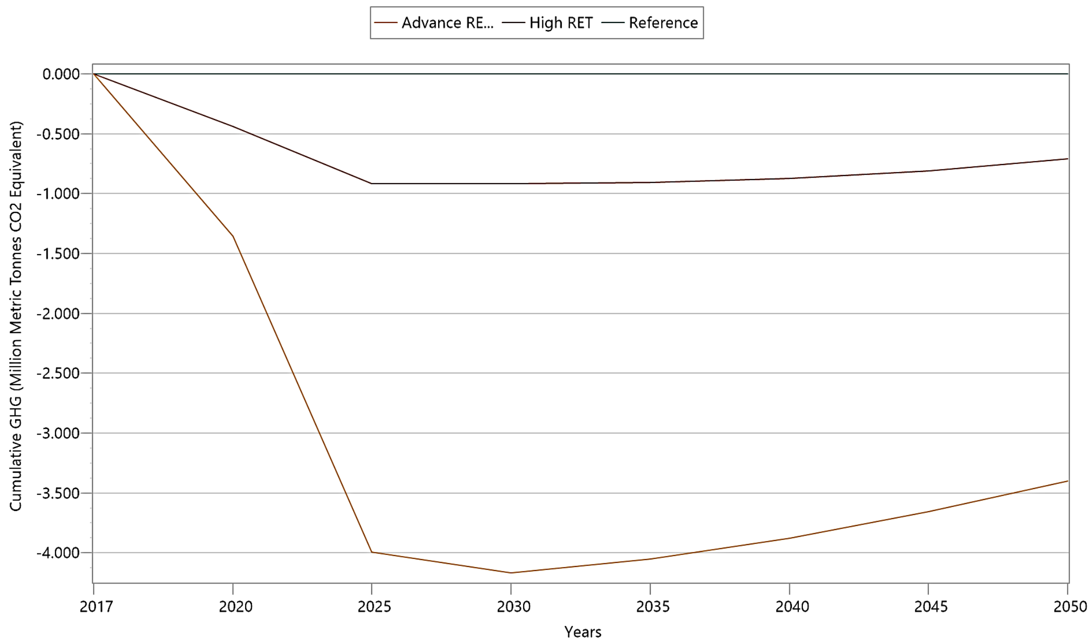

FIGURE 5. **Environmental analysis of the IEP framework.**

job creation were based on South African RE job calculator in line with the IRENA's more sustainable energy pathway.

V. IEP FRAMEWORK AND POLICY DIRECTIONS FROM 2017 - 2050

This section provides a summary of policy direction and framework for the future generation, transmission, and distribution systems of Ghana based on the outcome of the data acquisition and analysis made in the study. The focus on energy efficiency should go beyond domestic and expand it to cover that of industrial and other sectors. An energy audit should be conducted in the industrial sector to ensure performance standards, and the ban on old refrigerators and televisions should be enforced to the later. Transmission and distribution loss reduction strategies must be implemented. These should include both technical and non-technical losses.

The country should encourage the use of RES on domestic activities in places such as schools, hospitals, and local assemblies. CO_2 emission tax must be introduced, not only to create awareness but also for economic gains. Proceeds from this tax can be used for maintenance purposes and also to improve RES development. Emission targets must be enforced to inspire energy providers to explore other alternatives for energy sources. Development of an alternative energy source has slowed down as a result of over-dependence on fossil fuel energy. Locally available energy resources should be developed to serve as an energy alternative for the country.

Fuelwood and charcoal, which is the primary energy for the rural dwellers, contribute about 27% of Ghana's energy consumption. The imbalance of demand and supply of fuelwood is also a threat to the energy security of the communities in rural areas. The energy supply mix in rural areas needs to be diversified to avoid energy insecurity. The government of Ghana owns and controls all industries in the energy sector. The government's inability to provide the needed funds as a result of increasing demands from other sectors such as health, education, transport, and security has hugely affected the operations of the energy sector.

The established facilities in the energy sector had increasingly deteriorated whereas new capacity hadn't been added, despite growing demand. Deficiencies of management and funding are causing insufficient and unreliable energy supply. Private sector participation in this regard is necessary to attract new investment to the energy sector to restructure the sector. In contrast, the profit motive will be used to assist in finding solutions to operation and management challenges experienced under public ownership. Figure 6 illustrates the procedure used for Ghana's IEP development and listed below are the policy framework and directions.

A. HYDROPOWER

Hydropower is currently the second-highest producer of electricity in Ghana; it contributes about 42% of the country's energy mix. It provides one of the cleanest and the cheapest electricity, notwithstanding its high initial capital cost. Ghana is endowed with substantial hydro potential with an estimated production of about 3000 MW. Apart from Akosombo, Kpong, and Bui dams, several streams and small rivers exist can be harnessed as small-scale projects for the production of an additional 100 MW of electricity. The small scale hydropower projects have the potentials for the provision of electrical power for the rural dwellers in Ghana. The results of this study, however, indicated a downward trend slightly to pave the way for more renewable energy developments.

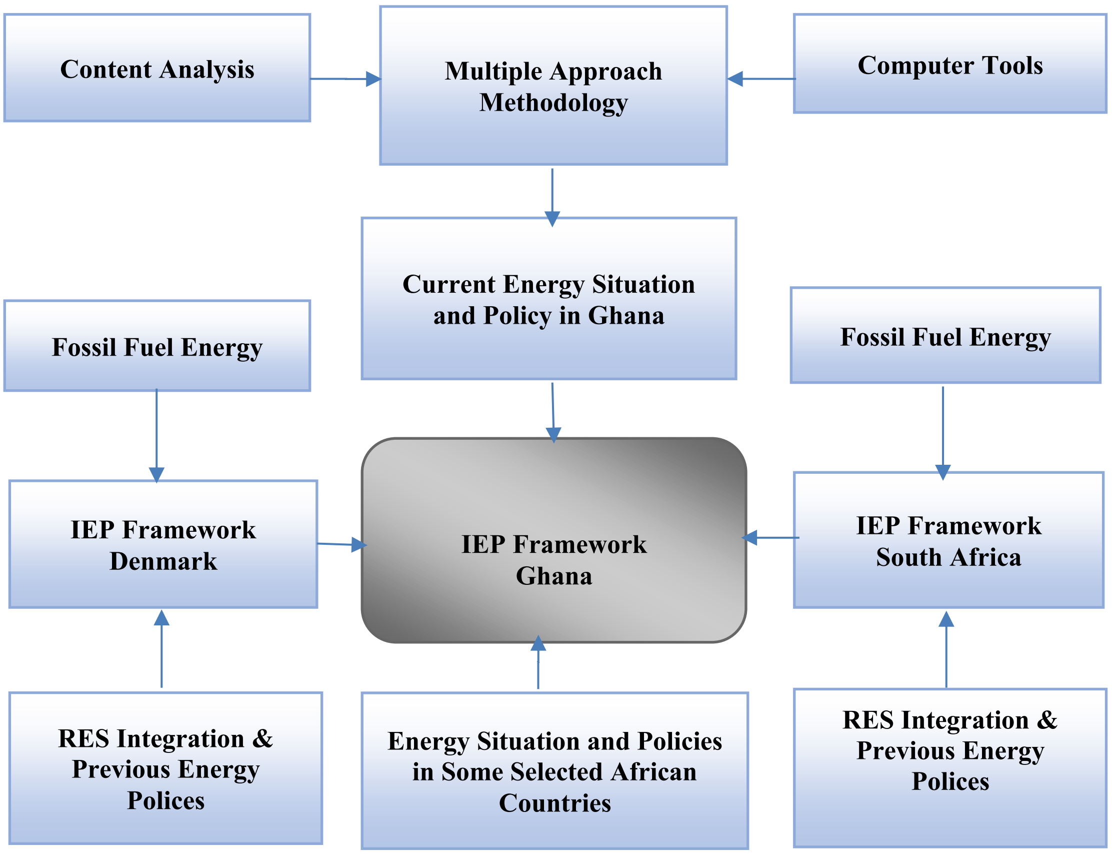

FIGURE 6. IEP framework development procedure.

i. Policies

- All available hydropower potentials shall be harnessed fully for the generation of electricity for the country.
- Particular attention shall be paid to the micro and mini-hydropower development schemes in Ghana.
- Ghana needs to promote the indigenous and private sector participation in the development of hydropower.

ii. Objectives

- To increase the percentage hydropower contribution to the nation's installed capacity.
- To increase the rural electrification project via micro and mini hydropower schemes.
- To entice private sector participation and investment into the production of hydropower schemes.
- To reduce damage to the ecosystem caused by the development of the hydropower schemes.
- To motivate the diversification of the energy resource base.

iii. Strategies

- Maintaining and establishing new multi-dimensional contracts to regulate and monitor the usage of water in global rivers flowing through Ghana.
- Increasing participation of indigenous in the designing, planning, and construction of hydropower plants.
- The government should provide essential engineering infrastructural accessories and equipment for hydropower plant development.
- The private sector, both foreign and indigenous, should be encouraged to establish and operate hydropower plant in Ghana.
- The private sector, both foreign and indigenous, should be encouraged to produce local accessories of hydropower plants.
- Hydro potential rivers data should be continuously updated to identify all possible dam locations in the country.

B. THERMAL POWER

Thermal power is currently the highest producer of electricity in Ghana; it contributes about 57% of the country's energy mix. The installed capacity at the end of 2017 was 2172 MW. The average dependable energy was 1985 MW, but the available power within the period was 1527 MW, the highest among producers. Light crude oil, natural gas, and diesel are the primary sources of fuel for Ghana's thermal power plants. Some of the plants can use more than one type of fuel, but natural gas is considered as a preferred choice because of its relatively low price. The inadequate supply of natural gas in Ghana is the main challenge for the operation of the thermal plants. 26% of the energy produced by thermal plants are produced from plants that use only national gas. The results shown in chapter four of this study suggested a shift from thermal energy to renewable energy to achieve the purpose of CO_2 emission reduction.

- All available thermal plants shall continue with their operations for the generation of electricity until Ghana attains its RES target in 2050.
- Ghana will continue to promote the indigenous and private sector participation in the development of thermal plants.

i. Objectives

- To maintain the percentage share of thermal power contribution to the nation's installed capacity.
- To entice private sector participation and investment into the production of thermal power schemes.
- To motivate the diversification of the energy resource base.

ii. Strategies

- Increasing participation of indigenous in the designing, planning and construction of thermal plants.
- The private sector, both foreign and indigenous, should be encouraged to establish and operate a thermal power plant in Ghana.

C. SOLAR ENERGY

Ghana is located between 4°44'N and 11°11' latitudes and 3°15' and 1°12' longitudes. The land area is about 238,539 km^2 with tropical weather; this weather is experienced in every part of the country. The country is endowed with abundant solar resources. These resources are mostly found in these areas: Navrongo in the northern part of Ghana, Kumasi in the middle part of Ghana, and Takoradi in the southern part of Ghana as shown the Figure 2.8. Conversion of solar energy into electrical energy has gradually become a primary renewable energy source in the world now, and many countries are tapping into solar energy to replace thermal and hydropower. Ghana is blessed with solar irradiation across the country with an average daily ground measure between 3.92 and 6.11 kWh/m^2. The duration of the yearly sunshine is estimated between 1800 and 3000 hours which can generate up to about 9.8 PWh. This clearly shows that the radiation level in Ghana currently is enough to generate energy more than the present energy needs in the country.

i. Policies

- Solar energy integration into the nation's installed capacity should be pursued aggressively.
- Ghana should keep up-to-date global developments of solar energy technologies.

ii. Objectives

- To increase the percentage of Ghana's energy mix through solar energy.
- To increase the market share of solar energy accessories and technologies.
- To develop solar energy technology conversion both locally and internationally.
- To increase the rural electrification project through solar energy.

iii. Strategies

- Increasing development and research in solar energy technologies.
- Encouraging training on solar energy and the development of manpower.
- Encouraging local solar energy products manufacturers by providing sufficient incentives.
- Initiating measures to encourage and provide adequate support for the local industry of the solar energy system.
- Providing financial support for the solar energy systems installation.
- Maintaining and setting up a complete information system on how to assess solar energy resource and technology in Ghana.

D. BIOMASS ENERGY

The only fuel in Ghana for cooking in rural areas are charcoal and firewood, but the country has not benefited from energy produced from biomass as practiced in other parts of the world. Even though the use of biomass in power generation will result in almost zero CO_2 emission, a comprehensive assessment made so far indicates that Ghana has biomass potential for electricity production, but the country is yet to benefit from the natural resource due to lack of technical know-how. According to M. H. Duku *et al.* [69], crop residue produced in 2008 alone was estimated to about 4.8 million tons which can generate 75 TWh of energy got wasted. In that same year, wood and logging processing, as well as MSW, was estimated to about 616,000 tons and 760,000 tons respectively were also got wasted. In conclusion, he stated that it's highly feasible for Ghana to consider biomass as an alternative source of energy generation.

i. Policies

- Ghana shall efficiently harness and integrate non-fuelwood biomass energy resources with other energy resources.
- The government should promote the practical usage of biomass conversion technology.

ii. Objectives

- To increase biomass products in rural areas as energy resources alternatives for the rural dwellers.
- To promote practical usage of all farming residues, human and animal trash to serve as energy sources for the rural dwellers.
- To minimize the combustion of biomass fuel hazards.

iii. Strategies

- Giving enough motivation to local entrepreneurs to produce biomass energy conversion systems.
- Starting pilot projects to produce biomass energy conversion accessories and systems.

- Educating capable manpower and provide them with necessary engineering skills to produce spare parts and components for biomass systems.
- Educating capable manpower to maintain biomass energy conversion systems.

E. WIND ENERGY

The fastest increasing RES worldwide currently is wind energy. However, Ghana is yet to harness wind energy for the country, despite the country's adequate wind potential. According to National Aeronautics and Space Administration (NASA) came out with three selected sites where the country can generate energy as shown in Figure 2.9 in chapter 2, and a wind resource map developed by National Renewable Energy Laboratory (NREL) also identified Ghana's wind potential to produce energy (Figure 2.9 in chapter 2). However, it is sad to note that Ghana is yet to make good use of these blessed natural resources. It was further revealed in Figure 2.9 that, the eastern border with Togo has wind conditions of 7.8 to 9.9 m/s which can produce energy density between 600 and 800 W/m2 but that one too has not been attended to. All these are a clear indication that wind potential in Ghana is enormous, but not a single wattage energy has been produced to the national grid.

i. Policies

- The practical usage of wind energy technology should be promoted by the government.
- Necessary measures shall be taken to ensure that wind energy is developed at the maintainable cost to consumers and suppliers in the rural communities in Ghana.

ii. Objectives

- To develop Ghana's potential wind energy to serve as an alternative source of energy.
- To develop Ghana's potential wind energy to provide power for rural communities that cannot be connected to the national grid now.
- To develop wind energy technology at places where it is financially and technically practicable.

iii. Strategies

- Developing and encourage research on wind energy utilization in Ghana
- Educating capable manpower and provide them with necessary engineering skills to produce spare parts and components for wind power systems.
- Starting pilot projects to produce wind energy accessories and systems.
- Training of local skilled craftsmen to operate and maintain wind energy systems.
- Giving suitable motivations for wind energy developers, producers, and consumers.

F. ENERGY EFFICIENCY

Energy efficiency offers a cost-effective way of achieving sustainable energy in the future. Efficiency also reduced energy bills and increased disposable income for consumers. This includes a reduction in the cost of fuel and energy infrastructure. Improvement in efficiency will also have a positive macroeconomic impact, including increases in GDP. Currently, the utilization of energy in Ghana's economy cannot be described as efficient. Aside from direct losses, the effective use of energy has its inferences on the economy. Either investment made on infrastructure will be more than the required or the ecological challenges may be compounded; as a result, high prices of goods. Ghana has massive potential for energy conservation in every sector; studies have shown that about 24% of the energy used in Ghana's industries go waste due to lack of simple housework measures. It, therefore, necessary to encourage the effective use of energy and the need to conserve energy.

i. Policies

- Ghana shall encourage the adoption and development of efficient utilization of energy.
- The promotion of energy conservation at all levels of misuse of energy resources shall be encouraged.

ii. Objectives

- To improve the security of Ghana's energy and self-sufficiency.
- To ensure judicious misuse of non-renewable energy resources in Ghana.
- To remove preventable investments in the energy supply sub-structure.
- To lessen the production cost of energy-dependent chattels and services.

iii. Strategies

- Giving institutional motivations to promote energy conservation and application of energy efficacy methods.
- Lessen the consumption of energy by increasing mass communication and transportation system in every part of the country.
- Taking steps to ensure that all machinery and equipment imported into the country are energy efficient.
- Taking suitable measures to lessen the storage of energy, transmission, and losses in the distribution system.
- Keeping the public informed about the needs and benefits of energy efficiency development.

G. BILATERAL CO-OPERATIONS

Ghana currently has collaborations with local and foreign energy industries within the context of its monetary relations with some other countries and bilateral establishments. The aim of this cooperation is to accompaniment local efforts to ensure energy security for the country. Joint management, energy supply, and fair-play participation in energy sources development form part of the multi-lateral collaboration with our local and foreign partners. Ghana's involvement in international organizations offers an opportunity for it to champion its cause in its energy agenda. In this regard, Ghana's energy sector can benefit from mutual opportunities for small and medium projects through bilateral cooperation.

i. Policies

- Energy sources in Ghana shall be positioned in enhancing and promoting international collaboration for the general technological and economic expansion of the nation.
- Ghana shall emphasize on strengthening and promoting energy integration and cooperation within the sub-region.

ii. Objective

- To improve Ghana's active involvement in international organizations concerning energy.
- To enhance the use of the sub region's energy resources.
- To expedite the attainment of necessary technology for the expansion of the energy sector.

iii. Strategies

- Promoting the formation of the instrument in both local and foreign to promote trading and exchange of related information and technology in the energy sector.
- Enhancing favorable interchange relationship with ECOWAS and AU member countries for secure funding of the energy-related projects.
- Mobilizing local capital in the community and promoting favorable investment weather to attract international funding for energy projects development.

Safe-guarding

- Ghana's active involvement in an international organization on energy.

H. FUNDING

Funding necessities for the whole energy sector is considerable. The country needs new investments for exploitation and exploration accomplishments. The necessary funding needed should be long-lasting with support from both local and foreign funding sources. But national earning and foreign investment capitals together can offer the needed financing in a greater proportion. Due to the risk element in energy projects, every investment made in the sector must be made to yield a higher rate of returns to pay back in due cause to attract more investors. The government alone cannot provide the needed funds for the activities in the energy sector due to other obligations and competing needs. This calls for private sector inputs, both local and foreign. Hence, financial performance must be improved, and a favorable environment must be provided to attract investors.

i. Policies

- Ghana should adopt and explore feasible funding possibilities from domestic and foreign partners for the development of its energy resources.
- Energy sector investment should be given the needed attention and priority it deserves in the financial sector.
- Private investors, both local and foreign, must be encouraged to invest in Ghana's energy sector.

ii. Objectives

- To provide the needed funds for the energy sector.
- To continue providing funds for the projects in the energy sector.
- To position the energy sector to attract both local and foreign investors.

iii. Strategies

- Dedicating portions of the national budget to cater for the energy sector in the areas of research, training, and technology acquisition.
- Providing economic motivations for potential investors in the energy sector.
- Revising the current laws governing the energy sector operations and include private participation.
- Ensuring realistic returns on all investments in the energy sector via the cost-effective pricing of the energy.
- Creating an enabling environment to attract local and foreign investors in the energy sector.

I. LOCAL PARTICIPATION

The government's dominant role in the energy sector is crippling the sector as a result of its inability to meet the sector's substantial capital demands coupled with advanced technology. Ghana's wealth creation capabilities of the private sector and the level of local participation in the development of the energy sector is not encouraging, for meeting the needs of the energy sector. Local private sector participation must be encouraged by the inclusion of ordinary Ghanaian citizens to participate and vie for investment opportunities in the energy sector. Indigenous participation will help the nation to secure a healthy energy sector development and also to provide decent jobs for the local people in the country.

i. Policies

- Individual Ghanaian citizens and local companies shall be integrated into possession participation in the privatized and deregulated energy sector.
- Local participation in the development of the energy sector shall be promoted to a higher level with financial support from the government.

ii. Objectives

- To ensure the active participation of indigenous private companies for the development of the energy sector.
- To attain a higher level of value-added within the local content of the activities of the energy sector.

iii. Strategies

- Founding a funding scheme that can support the local investment in the industries of the energy sector.
- Making a percentage share for local companies to acquire in the privatized energy sector.
- Encouraging the local investors to establish in the production and service in the energy sector.

J. ENERGY PLANNING

The multi-dimensional nature of energy issues demands effective planning, to deal with the factors affecting energy demand, supply, and consumption. It is, therefore, imperative to adopt an integrated and comprehensive approach to avoid discrepancies in the planning process. Other sectors of the economy also must be considered in the planning process.

i. Policies

- The development of the IEP system shall involve all program concerning the energy and actions of other sectors of the economy.
- The IEP system shall be all-inclusive to cover the activities of the exploitation of the resources, development, and consumption.
- The IEP system shall be reliable with the entire development goal of the nation.

ii. Objectives

- To ensure consistency in the IEP system with the activities of the other sector of the economy.
- To ensure consistency in the IEP system with national development plans and policies.
- To ensure enough energy supply to other sectors of the economy.
- To sustain the environmental development in the energy sector.

iii. Strategies

- Reinforcing the collaboration between the Energy Commission and the other agencies working for the energy sector.
- Encouraging official cooperation and dialogue between organizations whose activities are inter-related to the energy sector.
- Creating energy planning and implementation agencies to cater to energy-related issues.
- Introducing effective and accelerated manpower expansion programme.
- Developing a master plan for the energy to ascertain the demand-type, categories of consumers, energy supply, and also to study the interaction between energy, economy, and the environment.

K. POLICY IMPLEMENTATION

Without proper implementation, no policy can succeed. To accomplish the specified aims and effectively implement the strategies, several instruments such as financial measures, education, judicial measures, information, and formal arrangements need to be applied. Lengthy administrative procedures and delays hampered the realization of policy programmes. These challenges need to be addressed effectively before we can successfully implement this energy policy.

i. Policies

- The Energy Commission of Ghana shall coordinate and monitor the implementation of this energy policy.
- Any other government-related policies on energy should be developed from the national energy policy to ensure consistency.

ii. Objectives

- To ensure proper implementation and management of the national energy plan.
- To ensure that the expected role by the energy sector shall be performed effectively in order to achieve the main aims of the national energy plan.
- To ensure all sub-sectorial plans on energy-related matters should be in consistent within the national energy policy framework.
- To reinforce the coordination and monitoring of the core functions of the energy commission.

iii. Strategies

- Ensuring proper forum be provided for periodic dialogue among departments and agencies who are connected to energy production and usage in the country.
- Promoting the participation of the private sector on energy production while the government also plays his role by providing necessary energy substructure.
- Ensuring effective implementation of policy strategies, proper monitoring, and valuation of the implementation procedure.
- Ensuring regular checks on the implementation of the policy of the energy sector.

VI. CONCLUSION

The paper explored the various policies and interventions for promoting grid and renewable energy integration as well as energy efficiency deployment. The paper also analyzed the various energy policies and the barriers to renewable energy development in Ghana. The section identified barriers and explored options to promote the deployment of renewable energy grid integration and energy efficiency activities in Ghana. It emerged from the study that in Ghana, many barriers related to the implementation. Implementation phase barriers include a lack of clear policy and capacity to regulate. Other barriers related to lack of finance, inability to operate, and maintain energy equipment after installation; as well as the weak capacity to undertake energy efficiency projects. There is, therefore, the need for capacity building and establishment of dedicated government agency solely for renewable energy development. This will go a long way to streamline the various policies, create public awareness, and facilitate the development of the vast renewable energy resources in the country. Such an agency will also lead to the development of a long-term generation plan taking into consideration all the available energy resources in the country. It is believed that the proper implementation of this policy will encourage investment in the substantial renewable energy potential that will meet the energy needs of the country.

The energy landscape in Ghana's future projections depends on the achievement of the main objectives of the IEP framework. The security of our energy supply must be guaranteed in all sectors of the economy with timely decisions and proper investments in new energy infrastructural projects and proper maintenance care. The security of supply in the liquid fuel sector must be ensured by moving away from imported fuel and concentrate on local production. The cost of energy in all sectors should be managed following the planned projections. This paper concluded the IEP framework and policy directions for Ghana from 2017 to 2050 about the overall results and factors presented.

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