

Availability, Accessibility and the Road Map for Clean, Affordable, Effective and Efficient Energy for Sierra Leone; A six years Analysis from 2006 to 2011

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DOI: 10.29322/IJSRP.8.5.2018.p7769

<http://dx.doi.org/10.29322/IJSRP.8.5.2018.p7769>

Abstract- Sierra Leone has long been struggling to achieve zero energy poverty, but the main obstacle in this struggle is the technical and technological availability. However, the energy situation currently is far better than in the early 2000s. The economy of the country was estimated to have grown by approximately 7 percent in 2011 from 5 percent in 2010. Domestic revenue was believed to increase during the past years, mainly as a result of tax collection efforts and one-off payments of signature bonuses from the energy products (petroleum) exploration activities in the country. Our focus on this paper is to evaluate the range of accessibility of electricity in the country. A period of six years from 2006 to 2011 of energy revolution was carefully studied, which revealed that there is a significant improvement in the energy sector. In compliance with United Nations Sustainable Development Goals, the previous government instituted and implemented energy sector as a priority in the agenda for prosperity in 2012, which inculcated private sector companies in the provision and implementation of solar lantern and solar small home systems. This initiative led to the formation of renewable energy association in Sierra Leone.

Index Terms- Accessibility, Energy, Electricity, Implementation, initiative, policy, solar lantern

I. INTRODUCTION

Access to clean and affordable energy is a major challenge in Sierra Leone, where a majority of the population lives below the poverty line and does not have access to affordable modern energy (electricity). According to the Ministry of energy, electricity in Sierra Leone was 3%, 4%, 7.4% and 9% in 1999, 2005, 2008 and 2011 respectively. Ancient uses of biomass, in the form of charcoal and firewood still take over the energy accessibility blended with serious impacts on economic activities, livelihood, human health and environment as a whole[1]. Energy policy in Sierra Leone, is always been

impacted by insecurity in hope of resource accessibility and cost, the unpredictability of gas prices and oil prices in the world market only emphasize the critical link[2].

Understanding and determining the cost of energy roadmap as a full may change the policy formulation format over time and allow policy to be directed to address persistent aspects of the energy market in Sierra Leone. Aims of the term sustainable development and the developmental ideas of frameworks for its effective application in confined and global contexts has always been struggling to survive in Sierra Leone[3], most specially in the energy sector. Debates have been going on in expectation of the post-2015 targets for sustainable development, Millennium Development Goals (MDGs), as set out in the Sustainable Development Goals (SDGs) target for 2030, to provide clean and affordable energy for all.

A comprehensive investigation of the interconnections among energy options, and protection of the natural environment and ecosystem services for Sierra Leone as well as potential social welfare highlights an unquestionable vision for the development and implementations of renewable energy technological capacity to promote the so called green economy[4]. Sierra Leone as a small country, with less than 7.5 million population depends about 90% on fossil fuel and bio energy for its primary energy consumption.

There is consciousness in the world that the challenges linked to the assertion of renewable energy technologies for the diffusion of green energy require appropriate evaluation and dimension of the environmental and social impacts associated with the

installations, operation and maintenance. But yet still the country has a long way to achieve in a stable energy provision even in the capital city, Freetown.

Presently, like other countries, such as Saudi Arabia which produces oil and have enough energy, have introduced a new concept of water desalination to solve the fresh water problem in Saudi[5] which requires a very high energy input. The balance between the growing demand of water and energy in Sierra Leone is progressively becoming a serious challenge nationwide. The main focus of this is to assess energy situation, accessibility and the road map for clean, affordable and efficient energy for Sierra Leone; A six years Analysis from 2006 to 2011

1. BACKGROUND

Sierra Leone is located in Western Africa with a total land region of 72,325 sq. km. Statistics Sierra Leone (2012), the population is projected at 6.0 million in 2011 with a growth rate of approximately 3.4%. The capital city of Freetown is placed in the western area of the country and is home to approximately 1.25 million people (~21% of the total population in Sierra Leone). Sierra Leone has a temperate climate with hot and humid weather in the wet season, which habitually start from June to November and a waterless (dry) season, which typically start from December to May. Sierra Leone has an ambient temperature range of 20°C - 35°C and relative humidity varying from an average of 75% in the wet season to about 45% in the waterless (dry) season.

Sierra Leone is measured by the UN classification as a Least Developed Country (LDC) with considerable inequality in income distribution among its people. While Sierra Leone has substantial minerals, agricultural, and fishery resources, its economic and social roadmap are not well developed, which hampers the country's economic progress.

The economy was estimated to have grown by approximately 6 percent in 2011 from 5 percent in 2010. Home revenue increased during the past year, mainly as a result of tax collection efforts and one-off payments of mark bonuses from the energy products (petroleum) exploration activities. Inflationary pressures were however high during the first half of the year on account of the

continued raise in the international prices of food and energy (fuel) and consequently pass through into domestic prices. However, the pressures eased in the second half of the year as international prices of commodities (goods) stabilized as financial and economic policies were tightened.

2. SIERRA LEONE ENERGY SCENARIO

The input priority of government in 2009 was to build up the energy sector with the endeavor of motivating both the small, medium and large economic activities in Sierra Leone. To effectively accomplish this dream, the Government switched the funds of the Ministry of Energy and Water Resources in 2009 from recurrent to domestic development expenditures in 2009. The total revised funds for non-salary/non-interest recurrent expenditures allocated to the Ministry of Energy and Water Resources amounted approximately to Le72.6 billion in 2009. Despite the fact that looking at the linkages among energy, water and land resources comprehensively[6], with the aim of improve the living standard in the country.

The government flexes the funds of the Ministry specifically for the Emergency Power Project, when it was well-known that the completion of the national hydro (Bumbuna Hydro) Electric Project would be delayed for a period of months in 2009. As a result, the funds implementation rate of the Ministry was close to the revised target with a difference of only 5.6% below the revised budget in 2009. The multipurpose utilization of water and energy from multiple sources in the country is a reality in rural settings of developing countries[7].

The total non-interest persistent expenditures in the Ministry amounted roughly to Le68.9 billion in 2009 compared to the revised funds of Le72.6 billion. The emergency power project was to be discontinued around half in 2009 after the completion of the national hydro (Bumbuna Hydro) electric project in 2009. But government resolute to broaden the emergency energy project programme to the end of 2009 as appraise when it became obvious that the full commissioning of the national hydro (Bumbuna Hydro) Electric Project would be delayed. Governance theory can help to fill the basic needs of a country, taking into account the wider governance setting, the processes that take place within it and how they influence the

acquaintances between technical information and implementation[8].

The electricity grid production increased nearly 3.2 percent to 175.9 GWh in 2011 compared to 170.4 GWh in 2010 as a result of government commitment. Industrial utilization of electricity increased toward 32.1 GWh from around 25.6 GWh in the preceding years, an increase of 22.9 percent. Line losses remained highly projected at about 42 percent of unit generated from the generation source.

The European Investment Bank disclosed plans to team up with other donor associates namely: the World Bank, African Development Bank and Kreditanstalt für Wiederaufbau in the region of Sierra Leone's energy sector, in the course of the West Africa Power Pool Project which upon completion will elevate the energy situation in Sierra Leone.

The global human requirement for energy is expected to increase significantly with the raise in world population that is estimated to arrive at 9.4 billion by the middle of this century, according to the intermediate modification of the 2012 Revision of World Population Prospects, the official United Nations (UN) population projections arranged by the Population Division of the Department of Economic and Social Affairs (UNDESA, 2013)[9].

2.1. RENEWABLE ENERGY IN SIERRA LEONE

Renewable energy has become popular and intensively utilized in Sierra Leone by both government, and private individual companies with the aim of achieving clean and sustainable energy. Despite the energy poverty in the country, the demand for solar energy for the past years has grown on a very high scale. The uptake of solar PV has been growing rapidly which led to the formation of renewable energy association (REASL) over the past few years, driven largely by the need to reduce greenhouse gas emissions from energy generation[10]. Photovoltaic (PV) systems convert the radiation coming from the Sun to the Earth's surface into electricity which is used by the consumer.

The human life needs energy (electricity) to accept the desired instruction to brand sure energy safety and environmental superiority[11]. At the end of 2013, the global installed capacity

of solar PV reached 138 GW, with 37 GW added in 2013 alone, a 35% increase on the previous year. Achieving clean energy globally is one of the aims of many countries including the organs of United Nation (UN) such as UN-Environment (UNEP), food and agriculture organization (FAO), United Nations Development Program (UNDP) and UN-Energy.

It is unclear how the impacts connected with the fabrication and application of solar pv components (batteries, pv panels, and charge controllers) would affect the environment in comparison with the conventional supply of electricity from the grid. Solar energy has involved almost all the countries for the advantages such as clean, carbon free and inexhaustible cultivation[12].

It is suggested that renewable energy production has a very large outlook of growth, stand-alone photovoltaic (PV) system is one of the most significant applications in renewable power production, and has high realistic value in the regions which are un-electrified by national power grid, such as remote areas, desert and border outpost. However, the power of PV cell is significantly influenced by the climate of the region such as light intensity and temperature.

The optimum solar way out resolve contain a strong cyclic component which reflects the daily request profiles of electricity power consumers and the variation in the solar production. A feature of community power bank (battery storage) systems is relatively minute figure of customers which often falls into the array of 20 to 200 households[13]. Among all sustainable and renewable energy resources, solar energy has potential to fulfil these needs in Sierra Leone, because it is free and clean.

Therefore, photovoltaic cells are extremely important for the conversion of solar energy into electricity in Sierra Leone. According to the latest surveys, 90% of the solar photovoltaic products in the world market are based on first-generation crystalline (monocrystalline and polycrystalline) silicon (Si) wafers with power conversion efficiency (PCE) between 15 and 20% on the module level of 1.6 m²[14]. Sierra Leone has struggled to installed solar street light in the capital city Freetown and the entire district headquarters towns.

2.2. ENERGY UTILIZATION IN SIERRA LEONE

Energy (electricity) utilization in Sierra Leone is conquered by fire wood and charcoal (biomass), which accounts for over 82% of energy used most specially in the poor communities. The largest supply of biomass energy is from wood fuel followed by charcoal. Imported energy Products (Petroleum) such diesel, petrol, kerosene and gasoline are the next leading sources of power at approximately 14%. National grid-generated electricity the books for the rest of the power supplied to the country's general public. Any major political change at a national level can have serious implications on the broad range of energy sector in Sierra Leone[15].

Wood fuel is known as the traditional form of energy in Sierra Leone and is used more or less exclusively by households for cooking, lighting at night in the poor rural communities and craft activities. Petroleum products are the most significant source of energy for the modern industrious energy sector including transportation and personal electricity production. Recently, foreign exchange difficulties had restrained Petroleum products importation, which were subsidized by Government. Just like in other countries, the environmental tribulations by fossil fuels and scarcity of these energies cause many governmental organizations to put motivation, encouragement conditions to create a center of attention for private companies to invest in renewable energies[16].

Presently, the Electricity sub-sector in Sierra Leone faces challenges with less than 15% access in the city and the major towns across the country. good organization and access are constrained by high technical losses on the transmission and distribution network, which are additional compounded by low voltage quality due to overburdening of infrastructure by criminal users in the city and the three regional headquarters[17]. The stockpile of energy efficient appliances and equipments also remains low in the country. Additionally, the growth and use of Renewable Energies from Hydro, Solar, Biomass, wind and other facilities has been a slow process in Sierra Leone.

The level of energy utilization in the Sierra Leone has grown significantly between 2005 and 2011 from 1,249 ktoe to 1,865 ktoe respectively[18]. On the other hand, there remains a huge gap of suppressed demand for energy especially in the electricity

sub-sector across the country. Economic expansion in mining, agriculture, trade and industry is also accelerating demand for electricity.

2.3. SIERRA LEONE ELECTRICITY SITUATION

The electricity division in Sierra Leone is rigorously challenged across production, transmission and distribution due to the poor energy infrastructure development[19]. It is estimated that less than 12% (Ministry of Energy report, 2012) of the population have access to electricity in Sierra Leone. production capacity is inadequate and transmission and distribution networks are largely not enough and aging since the colonial time which leads to massive lose of power[20]. The largest part of the energy (electricity) network suffered harm during the eleven years civil war in Sierra Leone. Actions in recent years have determined on bringing the accessible network back to action to serve the massive demand for energy (electricity). The present energy (electricity) system covers mainly the western region (capital city) of the country and some major districts head quarter towns namely Makeni, Kono, Bo and Kenema. The bulk of energy (electricity) utilization takes place in Freetown, the capital city due to the high population concentration.

The Western area, is supplied by the Electricity Distribution and Supply Authority (EDSA) through the Electricity Generation Transmission Company (EGTC) using the national hydro (Bumbuna Hydro) Power. Bo and Kenema, two major cities in the southeast of Sierra Leone, are served by a hybridized system, the Bo-Kenema Power Services – BKPS from the generation to distribution of electricity with the rationale to alleviate energy poverty[21].

The generation capacity of BKPS consists of a thermal power plants with an installed capacity of 5 MW (Ministry of Energy report, 2012) located in the city of Bo town and a hydro power station with approximately 6 MW (Ministry of Energy report, 2012) situated in the region of Dodo village in Kenema district. Originally, there were provincial systems consisted of nearly 12 independent isolated systems located in district headquarter towns across the country. But, most of these systems were shattered during the eleven years civil war, with the exception

of the Bo-Kenema Power Station - BKPS; some of the isolated systems have been restored such as Kono town.

Transmission and distribution lines are more than 52 years old and are poorly maintained, as a result, these networks are presently not capable of transmitting more than 37 MW of power. This poses a serious restricted access for additional generation capacity being added to the grid or in planning[22], with Particular attention paid on the rising strategies to improve the abilities of electricity.

1. RESULT

Sierra Leone is extensively enriched with renewable energy potential such as (biomass, solar, hydro and wind) which is estimated at approximately 1,362,000 toe (UNDP Sierra Leone Energy profile, 2012) for the year 2011 and has a capacity of producing closely 15,674 GWh based on population baseline of 3.55 million, growth rate of 3.5% in 2011, per capita expenditure of 0.32m³ /cap/ annum and 0.13m³ / cap/ annum for fire wood and charcoal respectively. Most of the energy (electricity) generation and use in Sierra Leone is concentrated in the household sub-sector, where biomass, in the form of fuel wood and charcoal is used for cooking and kerosene is used for lighting by the poor rural local villages. Only around 10% of the population has access to electricity from the national power grid in Sierra Leone (2012 report on survey of charcoal businesses in urban centres of Sierra Leone).

The fact that the key energy (electricity) supply of Sierra Leone at the end of 2011 consisted of over 80% renewable including biomass and hydro and about 16% oil further adds pressure on the forest resources. The Sierra Leone possesses vast potential in renewable energy which remains virtually un-invested. The new exploration activities of oil are being proposed by the government in the country.

Table 1; development of energy utilization in Sierra Leone from 2006 to 2011

Year	Biomass Consumption'000'toe	Petroleum Products Consumption'000'toe	Electricity (Grid Connected) Consumption'000'toe	Final Energy Consumption'000'toe
2006	1,254	196.7	4.4	1,455.1
2007	1,275	176	4.21	1,455.21
2008	1,297	199.4	16.79	1,513.19
2009	1,218	165.5	17.26	3,109.5
2010	1,241	189.3	19.22	1,449.52
2011	1,262	189.8	20.15	1,471.95

Source; Ministry of Agriculture and Food Security (MAFFS), 2012

1.1. THE ENERGY UTILIZATION PATTERN IN SIERRA LEONE

The structure of the energy utilization in Sierra Leone by sectors and energy carriers as reported by the national energy strategic plan of the Ministry of Energy and Water Resources (2009), it is noticed that numbers for the year 2008 and 2011 have been extrapolated from original records given in a reading by the World Bank for the year 1986 energy structure in Sierra

BIOMASS	2006	2007	2008	2009	2010	2011
FUEL						
WOOD	1,212	1,128	1,146	1,154	1,166	1,171
CHARCOAL	44	55	66	78	86	121
TOTAL						
'000'toe	1,256	1,183	1,212	1,232	1,252	1,292

Leone. Fire wood still represents the main power source in Sierra Leone[23]. The mass of fire wood utilization takes place in the household sector, mainly for cooking and lighting in poor rural communities. Charcoal is also devoted in the residential sector and little percentage in the commercial sector such as bakery and fish smoking. There is some minute utilization of fuel wood and charcoal in the manufacturing sector which is normally difficult to account for.

Table 2; Energy utilization pattern in 2011

Sector	Fuel	Char	Petroleum	Elec	Tota
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	wood	coal	Products	tricity	1 %
Agriculture, Forestry, Fishing	3%	0%			2%
Mining	0%	10%	5%	2%	4.5%
Industry/Commercial	3%	10%	11%	60%	21%
Transport	0%	0%	49%	0%	12%
Household/Residents	94%	80%	25%	30%	60.5%
Total	100%	100%	100%	100%	100%

Source: Ministry of Agriculture and Food Security (MAFFS), 2012 annual report

1.2. RATE OF BIOMASS CONSUMPTION IN SIERRA LEONE

Biomass is the major source of energy used in Sierra Leone for cooking and lighting in many households and a minute percent in the commercial sector[24]. This energy source carries the highest volume of consumption in the whole energy system, representing over 80% of total energy consumed in Sierra Leone.

Table 3; Trend of biomass consumption in Sierra Leone from 2006 to 2011 ('000'toe)

Source: Ministry of Agriculture, Forestry and Food Security 2012

1.3. UTILIZATION AND SUPPLY PETROLEUM PRODUCTS IN SIERRA LEONE

Petroleum products (diesel, Petrol, gasoline and kerosene) importation has been done through refined products like Gasoline or Petrol, Diesel, Marine Fuel Oil, Kerosene and Jet A-1 due to the nonattendance of a refinery plant in Sierra Leone. The Petroleum Products are utilized mainly in the transport, industrial and residential sector. Sierra Leone at present importing all of its petroleum products, the only refinery plant in the country is no longer in operation. As shown in the table 4, Petroleum Products importation volume per annum decreased by more than 100%

between 2006 and 2011. Petroleum products utilization averaged 185,295toe per annum

Table 4; Imported Petroleum Products 2000 to 2011 in (MT)

Year	Kerosene/Jet Marine				
	Petrol	Diesel	Jet A-1	Oil	Fuel Total
2006	69,317	150,902	38,089	28,825	287,133
2007	45,792	125,597	20,631	8,699	200,719
2008	50,424	150,136	12,933	17,324	230,817
2009	41,368	89,151	11,320	6,343	148,182
2010	78,197	99,545	11,093	23,251	212,086
2011	76,620	144,224	14,011	89,100	323,955

Source: National Petroleum Unit (PU) Sierra Leone, 2012.

Table 5; Consumption development of petroleum products from 2006 to 2011 ('0000'toe)

PRODUCTS	2006	2007	2008	2009	2010	2011
GASOLINE	78	50.6	70.3	71.6	90.7	93.2
LPG	0	2	2	3	3	4
DIESEL	98.4	94.2	101.7	78.2	95.2	78.1
FUEL OIL	10.3	22.4	20.4	16.1	9.6	8
KEROSENE/						
JET	35.5	25.8	18	10.6	6.8	4.5
Total	222.2	195	212.4	179.5	205.3	187.8

Source: National Petroleum Unit (PU) Sierra Leone, 2012.

Table 6; Grid generated electricity utilization from 2006 to 2011 ('000'toe)

POWER STATION	2006	2007	2008	2009	2010	2011
KINGTOM	2.72	2.4	11.2	6.5	3.55	1.18
BLACKHAL						
L ROAD	n/a	n/a	1.8	1.5	n/a	0.91
BUMBUNA	n/a	n/a	n/a	3.52	12.8	14.5
BKPS	0.67	0.69	0.89	0.98	0.95	0.99
Total '000'toe	3.39	3.09	12.09	12.5	17.3	17.58

Source: Ministry of Energy, 2012 annual report

Table 7; Power capacity installed as of may, 2012

Type of	Installed	Number	State	Grid
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power plant	Capacity in of Plants	Owned,	Connected
MW		Private,	
		Mixed	
Thermal Oil		State	Grid
Plant	38	Owned	Connected
Large	7		
Hydropower		State	Grid
plants(>10M		Owned	Connected
W)	55		
Small	2		
Hydropower		State	Grid
Plants(<		Owned	Connected
10MW)	6.75		
Auto-	4		
Generators(1			
35MW) plus			
two years			
import	135+39 =		
(39MW)	174	Private	Isolated
Mining	33,000		
Company			
Gen.	88.5	Unknown	Private
Photovoltaic	0.025	Unknown	Mixed
TOTAL MW	356.3		

Source: Ministry of Energy and National Revenue Authority, 2012

Table 8; right to use to grid connected electricity from 2006 to 2011

POPULATI

ON	2006	2007	2008	2009	2010	2011
Freetown	38,262	47,291	54,126	64,406	67,522	83,551
BO-Kenema	8,752	9,078	9,555	10,280	11,309	12,693
Makeni	315	530	621	696	602	1,050
Total						
Customer	47,469	56,889	63,202	75,092	79,426	87,284
Population						
connected	284,57					
Grid	4	340,734	378,612	450,492	475,956	523,104
Population	4,937,4	5,009,265,	116,385,173,	505,294,64	5,478,89	

without Grid26	6	8	8	4	6	
connection						
% ACCESS	5.52	6.52	7.48	8.79	8.28	8.7~9.8

Source: Sierra Leone Statistic, 2012.

CONCLUSION

Generation capacity of reliable electricity is still too little as compared to potential require in Sierra Leon. Insufficient production capacity in combination with the poor capacities of the transmission lines led lots of industries as well as commercial and residential consumers to purchase imported diesel generators for self energy support in the country. Small generators cost on average US\$350. These small generators are costly to run, because fuel costs are at present is too high in Sierra Leone.

Several private investors are forced to self-generate power in order to meet their own power requirements. for example, cement manufacturing, mining companies and mobile phone operators are currently generating their own power requirement to meet the power demand of their factories, which make the living standard too high for the poor and average Sierra Leonean. The power capacities installed by these private investors are substantial ranging from 180 to 300MW when compared to the total national installed production capacity. The necessity to self-generate makes it more costly for these companies to run company in the Sierra Leone.

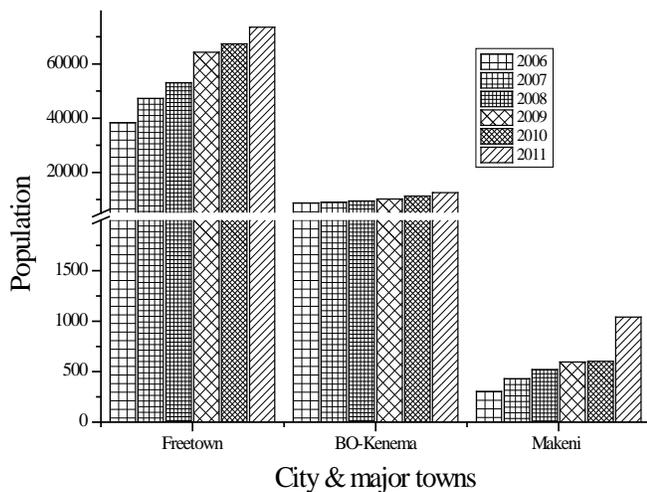
In 2009, additional generation capacity was added, the Bumbuna I hydro plant about 55 MW installed capacity, about 20 MW firm production capacity in the dry season entered into operation late 2009. The Government of Sierra Leone 2009 signed a Heads of Terms with Joule Africa to further develop Bumbuna II and the additional room of Bumbuna I and a pre-feasibility study was done which reveals that the project could generate power up to 390MW with a firm capacity of 115MW in the dry season to the main national distribution system.

The government was pursuing more options to add more production capacity to enhance adequate energy for the country. Major power plants projects for power production were being developed; these power plants will run on an amalgamation of natural gas and heavy fuel oil. These projects were expected to partly tackled grid reinforcements, in order to reduce the grid

power outage that would put a stop to the electricity from reaching potential households.

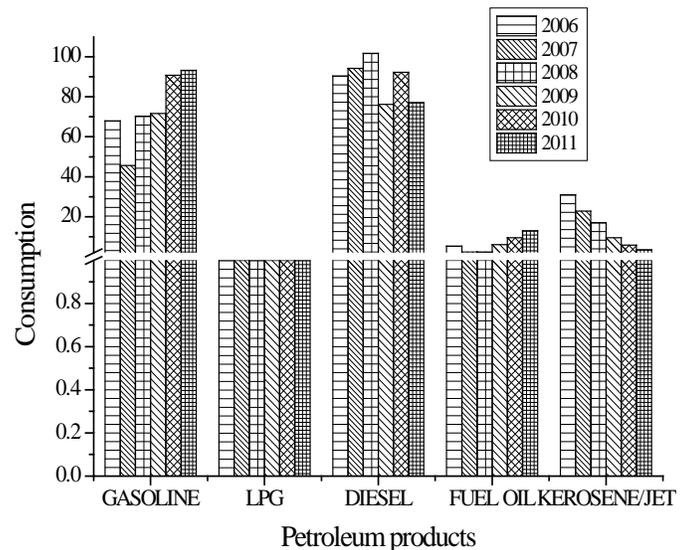
Improving the country's energy (electricity) sector was one of the Government's principal objectives from 2007 to 2012, this critical priority was expressed in the Government's Agenda for Change, which was unveiled in 2008. Further than political support, the Government anticipated to devote financial resources to improve the energy (electricity) sector because of the clear positive impacts on social, environment and economic growth in the country. The Government was committed to work with the private companies, International Energy improvement Programmes and the donor society to accomplish these essential dream in the energy sector.

Figure 1; DEVELOPMENT OF ACCESS TO GRID CONNECTED ELECTRICITY FROM 2006 TO 2011



However, from the graph there is an enlargement in the access to electricity in the city and the three regional administrative headquarter towns. The increase of the population in Makeni in 2011 was as a result of the mining companies that were located in the district. As a result, the access for electricity in Makeni town was increased. The populations in Freetown keep rising as it is capital city of Sierra Leone.

Figure 2; PETROLEUM PRODUCTS UTILIZATION FROM 2006 TO 2011



As the country depends solely on petroleum products and biomass for primary energy consumption, gasoline and diesel keep raising in demand. However, the liquefied petroleum gas (LPG) consumption is still low in the country. The decrease in the consumption of kerosene from 2006 to 2011 could be as the result of the introduction of solar lantern lamps in the country in 2010 under the implementation of the renewal energy policy, which inculcated private sector companies in the provision and implementation of solar later and solar small home systems. This initiative led to the formation of renewable energy association in Sierra Leone.

1. RECOMMENDATION

As the world is moving toward a green economy, renewable energy is one of the pillars that is used to achieve this big dream. Therefore Sierra Leone should endeavor to follow the route that most countries in the world are using. As one of the poorest countries in the world, Sierra Leone has renewable energy potentials across the country throughout the year.

Hence government should implement the renewable energy policy and set indicators in achieving the set energy priorities. Efficient and affordable energy accessibility in the country will aid the living standard and economic growth. Government should empower the energy sector by investing in the technology and providing adequate skills to carry out the administrative and technical affairs of the energy sector.

ACKNOWLEDGMENT

Special thanks to Professor Zhiqiang Zhang of College of Environmental Science and Engineering Tongji University, Shanghai, Yanpu District 200092, P.R China For his mentorship throughout my master's program

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