

Status and challenges of wood biomass as the principal energy in Sierra Leone

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Abstract

The availability of energy in developing countries, especially in Africa is still a great challenge, affecting the standard of living and investment in the Continent. The absence of adequate energy supply in both urban and rural areas in Africa since the colonial era has given wood biomass energy the advantage among other energy sources. In this paper, the literature and reports were synthesised to assess the wood biomass energy usage status, production, consumption, economic benefits, pitfalls and future trends in Sierra Leone. The combined the energy supply from all sources in Sierra Leone accounts for less than 30% of the country energy needs. The massive reliance on wood biomass energy in Sierra Leone is as a result of poverty, a high cost of alternative energy source, weak economy and underdevelopment of the state, previous civil wars and a low standard of living. The exploitation of other forms of renewable energy such as modern bioenergy, solar, wind, and increased hydroelectric production could improve the access of power and diversify Sierra Leone's energy profile in the future.

Keywords: *renewable, natural, power, Africa, charcoal, fuel*

1 Background

The Republic of Sierra Leone is located on the coast of West Africa, bordering with the Republic of Guinea in the Northeast and Republic of Liberia in the Southeast and North Atlantic Ocean at the west. Sierra Leone has a total land area of 72, 326 km², over 80% of which was initially moist high tropical hardwood forest that predominate the more heavy rainfall areas, but only some of them remain [1, 2]. Sierra Leone is divided into four regions, namely the Northern Region, Southern, Eastern and Western Region [3]. The geographical location of Sierra Leone ranges between 6°55'–10°14'N and 10°14'–13°17'W. Most of the 7.2 million people are residents in the capital city and nearby [4]. Agriculture constitutes the key economic activities, accounting for about 65% of the country's Gross National Products (GNP) [2]. The tropical climate has a distinct dry and rainy season. The rainy season extends from May to November, with precipitation ranging from 2,000 mm in the north to more than 5,000 mm along the coast [5]. About 90% of the population has insufficient purchasing power and depends mainly on wood as fuel for cooking and kerosene for lighting, which have negative consequences on the environment, health and to the quality of life, especially of the rural poor [6].

Biomass is briefly described as an organic matter renewable over time, and can be used as a renewable energy resource, either directly by combustion to produce heat or indirectly, after conversion into various forms of semi-processed bio-fuels (such as wood pellets or ethanol). Woody biomass potential abounded in stumps, tree branches, residuals of sawmill and sawdust lops

[7]. A previous report that an estimation of [8] 81% of Sub-Saharan African (SSA) households depend on wood biomass energy mainly from fuel wood and charcoal for domestic cooking. This degree of reliance is far higher compared to any other regions [8]; and solid fuels for food is an indicator of energy poverty [9], with South Africa having the highest biomass energy consumption in Africa [7]. AFREA stated [8], wood-based biomass energy continues to be the primary energy source for hundreds of millions of urban and rural residents in almost all social segments in Africa as a whole. Wood fuels play a dominant role in the energy balance of countries in Sub-Saharan Africa, but shortages of wood fuel exist or are perceived to exist in many areas [9]. In Sub-Saharan Africa available evidence suggests that the use of biomass for energy has increased roughly in proportion to population growth [10].

With growing urbanisation, the biomass energy sector is becoming more commercialised, and consumption of charcoal is increasing (which leads to a higher biomass consumption, given the low conversion efficiencies in most charcoal production). Wood, charcoal and agricultural wastes make up the bulk of the traditional biomass resources in SSA. The consumption of wood is the predominant source of biomass energy and represents the largest single source of energy for most families in the SSA with charcoal recently becoming an increasingly dominant energy source for urban households. In most countries within the SSA, about 70-90% of their primary energy supply is from biomass energy. By the year 2030, it is expected that nearly one billion Africans will depend on traditional biomass to meet their energy needs [10]. Wood biomass is the principal domestic energy source

in Sierra Leone. However, the non-availability of comprehensive data on its consumption and production at a regional and national level is challenging the consumption rate and the sustainability of wood biomass energy countrywide. Here, the researchers synthesised the status, potentials and trends in the production and utilisation of wood biomass energy, to propose rotational management strategies for promoting it in the future.

2 Review of wood biomass energy production and consumption in Sierra Leone

Research conducted by Gotfried and Hall [1] investigated the biomass energy for Sierra Leone where the terrestrial above-ground biomass production and utilisation in Sierra Leone were analysed from 1984 to 1990 (Table 1). The total production of biomass energy was estimated at an annual average of 131 Primary energy (PJ), (39% from agriculture, 51% from forestry and 10% from livestock). Out of the 117 PJ produced from agricultural and forestry operations, 37 PJ was harvested as firewood and burnt (10.9 GJ or 0.72 t wood per capita per year, supplying 80% of the country's energy). The total amount of biomass (fuel wood, residues and dung) used directly to provide energy, mostly in households, was estimated at 40 PJ (11.8 GJ per capita per year or 0.79 t fuel wood equivalents). A previous study [11] investigated the household use pattern of firewood energy in terms of marketing and production in Sierra Leone. It was concluded among others that Sierra Leone is likely to face a problem of firewood depletion caused by a large number of households which depend upon it to meet their daily energy needs. The researcher further noted that since there are no national energy accounts or empirical energy research, energy policy decisions are based on inadequate information.

Meanwhile, the energy consumption will increase at the expense of the declining number of forests, and the workload of women related to firewood collection will also rise. Furthermore, previous researchers investigated the socio-ecology of firewood and charcoal on the Freetown Peninsula [13]. It was concluded that the socio-ecology of firewood and charcoal on the Freetown peninsula remains mostly an unknown entity despite plans for its imminent restructuring and wood-fuel consumption comprises of two separate but related components.

Additionally, a study investigated the domestic trade in timber and fuel wood products in Sierra Leone [14]. The researchers conclude that the trade in wood-based products in Sierra Leone is an essential and vibrant livelihood activity that brings a significant revenue of cash in poor rural areas and that its impacts on forest cover are less than previously claimed. A good number of researches also have been carried out within the Sub Saharan region including Sierra Leone by previous scholars [13-26] on firewood and charcoal as sources of energy, especially in the rural settlements.

Previous studies by numerous researchers [1, 3, 14, 27, 28, 29] have all confirmed that wood biomass energy is indeed superior and will continue to be shortly in Africa and Sierra Leone in particular.

3 Method of data collection

Data was collected from the wood biomass capacity, production and utilisation report across Sierra Leone over the past decades for writing this paper. Predominately, close attention was paid on the use of wood biomass energy as the primary source of energy for cooking and other functions. Pitfalls, renewable

Table 1 Annual production of primary biomass ($m^3 10^6$) for 1984 to 1990/91 [1]

Production of forest biomass for 1984/85 to 1990/91										
Years	1984	1985	1986	1987	1988	1989	1990	Average Annual Production $m^3 10^6$	Average annual production $10^6 t$	Annual forest crop energy potential PJ)
Annual prod	3.150	3.232	3.316	3.402	3.490	3.581	3.674	3.406	2.49	37.3

Footnotes t = tones of biomass.

Another study assessed the solid wood fuel situation in Sierra Leone and Burkina Faso [12]. The researchers realised that when the use of wood for energy is systematically planned taking into account maintenance of forested areas, the continuum of forest vegetation on specific areas can be secured, and the wood collection (most typically done by women) can be rationalised.

energy status, economic benefits of wood biomass trade and trends were reviewed and recommendations made for effective wood biomass energy use in the future. The data for this review has been obtained from various sources including Food and Agricultural Organization (FAO), United Nations (UN), Sustainable Energy for all (SE4all), International Renewable Energy Agency

(IRENA), United Nation Development Program (UNDP), Sierra Leone 2015 and 2004 Census reports (SSL), Government energy reports, published articles, conference proceedings, workshops and other energy-related reports and news articles about Sierra Leone. Furthermore, metadata from existing literature for biomass production, utilisation and potential availability of biomass resources were collected for the review.

4 Wood-based biomass energy status in Sierra Leone

Currently, the country per annum megawatts of installed power generation capacity is about 90 megawatts (MW) which is far lesser than the estimated 300-500MW that is needed to light the whole country [30]. As a result of this gap, wood biomass energy is the primary source of cooking energy in most of the households in Sierra Leone. The biomass energy is basically in the form of fuel wood charcoal and with little of crops residues. It has been estimated that 86% Sierra Leone primary energy is from wood fuel, in which firewood accounted for 79% of energy and 7% for charcoal with other shares of 13% and 1% originating from petroleum products and electricity respectively [5, 31, 3]. Another study [32] contradicted other reports estimates and suggested that charcoal and wood make up 90% of total energy consumption in Sierra Leone because biomass potential is high, particularly from forest resources. In 2011, it was estimated that the public consumed 1,262,000 tons of wood biomass [31], while in 2012 and 2013 the consumption was 3,394 and 3,622 tons respectively [33]. The 2011 quantity is equivalent to 14,674GWh (based on population baseline of 3.52 million, growth rate of 3.3% in 2011, per capita consumption of 0.42m³/cap/ annum and 0.11m³/cap/ annum for firewood and charcoal, respectively [16, 34, 31]. Based on reports of Kamara, [35] the total primary energy supply of 2013 was 3.9 million toe. According to a recent study [27], it was stated that tens of thousands of rural families had earned their living from producing these fuels.

sector has not received the attention it deserves based on its major role in energy provision across the country. However, recently, the government is embarking on a mission to ensure the electricity reaches at least to all districts headquarter towns, but this initiative is still in the early stages. If successful, this move could reduce the amount of firewood and charcoal produced and consumed in Sierra Leone.

Over the years, wood fuel energy has enjoyed superiority because it's affordable and available to all citizens regardless of social and economic status. Most of the firewood consumption is in the rural areas while the charcoal is mostly consumed in urban areas. The Government of Sierra Leone reported that about 97% rural household in Sierra Leone use wood for domestic cooking as compared to 74% of the urban family with Western Area households using 30% charcoal [28]. The absence of electricity in most rural areas of Sierra Leone from time to time has made the use of firewood a way of life and the only source of energy especially for cooking in rural areas. The insufficient electricity supply in the country has been increasing since independence, and this has placed an enormous burden on wood fuel to cater for the energy requirements (for the domestic purpose) of 7.2 million people thereby leading to massive deforestation. Currently, the electricity sub-sector in Sierra Leone faces challenges, with less than 13% of the population having access to grid-based electricity in 2013 [3]. Most of the energy production 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 [6]. The annual production of forest biomass (m³10⁶) for energy from 1984 to 1991 is presented in Table 1. The average yearly production was 3.674 (m³10⁶) while the annual output in tones was 2.49 (10⁶t). The annual production of primary biomass increases with the increase in population.

Wood fuel is the most dominant, affordable and cheapest fuel available in Sierra Leone with its production, sale and transportation solely on the responsibility of individuals in the

Table 2 A trend of Biomass Consumption in Sierra Leone (2006 –2013) 10⁶ tones [27,42, 52]

Biomass	2006	2007	2008	2009	2010	2011	2012	2013
Fuel wood	1.111	1.126	1.136	1.144	1.156	1.161	3.394	3.622
Charcoal	0.043	0.049	0.061	0.074	0.085	0.101		
Total	1.154	1.175	1.197	1.218	1.241	1.262	3.394	3.622

Commercial wood fuels are now the largest cash crop in Sierra Leone and producers have increasingly formed organised associations such as (Charcoal and wood sellers' association) to produce, transport and sell commercial fuels (wood and charcoal) mainly in the capital city. Nevertheless, the solid wood biomass

private sector [36]. The increase in population and poverty level in Sierra Leone is believed to stimulate the trend of biomass consumption in Sierra Leone. Both (Table 1 and 2) show the increase in production and use of biomass over the years. The pattern of biomass consumption in (Figure 2) supports the

increase in biomass every year as seen in (Table 1 and 2). There has been a steady increase in biomass consumption in both wood and charcoal from 2006 (1.154×10^6 tones) to 2013 (3.622×10^6) respectively.

This trend of consumption is likely to continue until 2030 as projected by SE4all [3]. Currently, the population of Sierra Leone is estimated at 7.2 million and expected to increase [34], while the economic recovery rate is low. This imbalance will put a high pressure on wood biomass to meet the energy need for the country both now and shortly.

The diverse functions of wood biomass energy in Sierra Leone are presented in (Figure 1). The main purpose ranges from cooking to blacksmithing. Wood biomass is an affordable energy source in cooking and ironing for both low- and middle-income earners. A report highlighted that wood is also used in food cropping and other food processing, cooking, preservation, artisanal activities lighting at night time social events, and heating purposes during the wet season [32].

Biomass from wood is the primary source of energy in the SSA with more than 80% of households depends on it daily compared to any other region in the world. Nevertheless, not much attention is given to its economic, social, and environmental importance as well as its roles in development such as charcoal and electricity both at the international and national scales [8].

4.1 Wood biomass as the principal cooking energy in Sierra Leone

In Sierra Leone, wood biomass energy has been and continues to be the most available, affordable, useable and reliable source of energy for cooking across the whole country. Wood fuel is the traditional form of energy and is used almost exclusively by households for cooking and craft and other conventional activities [31, 32], 80% of the country total energy use being traditional biomass [37]. It was reported that only a small percentage of available modern energy services, non-biomass renewables, and electricity petroleum products are used in Sierra Leone [6, 31]. Wooden stoves are rare, while three stone fires predominate in both rural and urban firewood using households [27]. Biomass is the primary source of energy in Sierra Leone, especially for homes, and it has excellent prospects because the country is an agricultural state [38]. Nationwide survey on the fuel use for cooking by the only certified statistical institution in Sierra Leone [34] is shown in Table 3. This survey clearly showed that the leading role played by wood biomass energy in all regions and Districts. A majority (64.7%) of Sierra Leoneans use fuel wood as their source of energy, while (32.2%) minority use charcoal for energy (Table 3). Electricity, Gas and Kerosene account for 0.5, 0.8 and 0.7% of energy respectively and are mainly utilised in the capital city.

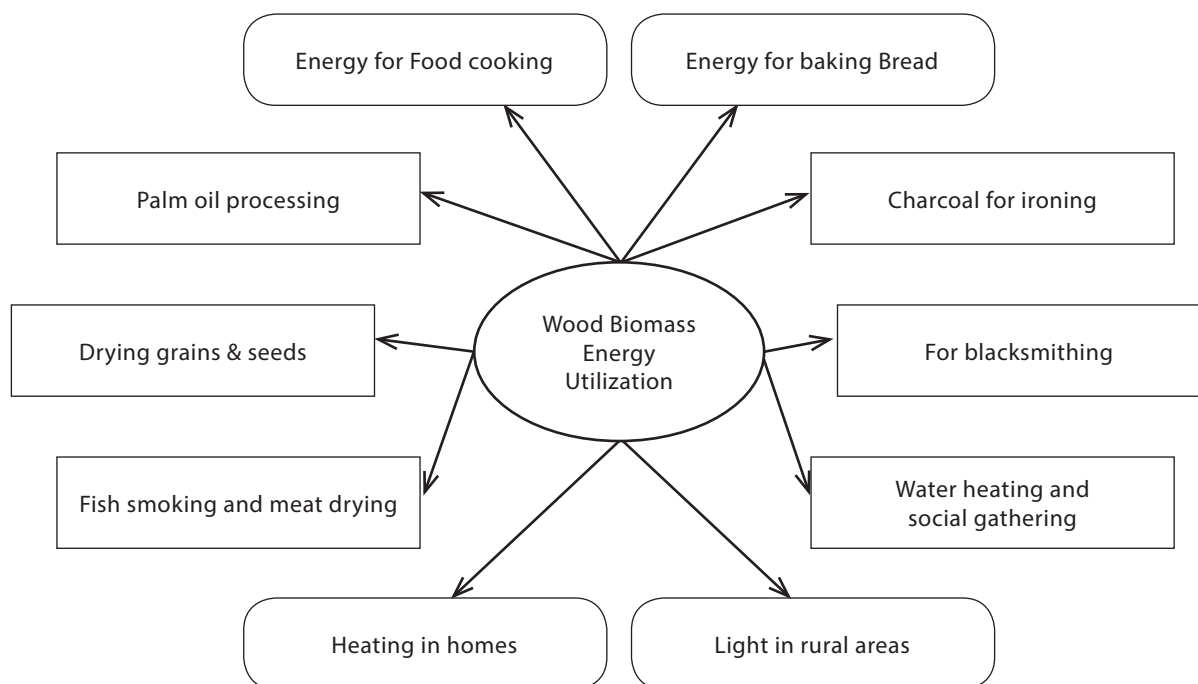


Figure 1 Some primary uses of wood biomass energy in Sierra Leone [32]

Table 3 Household by principal sources of fuel (Energy) for cooking by region, districts and area residence [34]

Regions/ District	Total	Electricity	Gas	Kerosene	Charcoal	Wood	Crop residue	Saw Dust	Solar	Animal Waste	Others
Country total numbers	126,5468	6,445	10,546	8735	406,875	818,185	1628	1604	1594	592	9265
Percentage	100.0	0.5	0.8	0.7	32.2	64.7	0.1	0.1	0.1	0.1	0.7
Region											
Eastern	281, 201	502	443	919	47,962	229, 420	320	388	287	96	864
Northern	414, 377	618	1010	2480	63,156	343, 851	679	692	550	219	1122
Southern	248, 655	418	601	1078	28,032	216, 399	413	215	301	107	1091
Western area	321, 235	321, 235	4907	4258	267,725	28, 515	215	309	456	170	6188
Urban/ Rural											
Urban	697, 706	226	992	2716	21, 182	668, 078	1179	1097	919	363	954
Rural	567, 762	6219	9554	6019	385, 693	150, 107	448	507	675	229	8311

A report shows that the dominant form of fuel (energy) for households in Sierra Leone is still firewood 78.76% followed by charcoal 20.22%. On a regional basis [39]. Table 4 shows that the Northern region 96.25% used more firewood than the South 93.15%, followed by Eastern 90.02%. The Western area accounts for 28.50% of fuel wood consumption but the highest in charcoal consumption 70.39%. At the provincial level, about 97.23% uses firewood as their main source of energy while at the urban level only (50.09%) uses firewood. The result shows an increase in charcoal consumption in a metropolitan area of 48.83% as compared to 32.20% in 2004. At the national level, the 2011 result shows more dependence on firewood 78.76% than the 2004 report which was 64.70%.

Table 5 shows that fuel wood was the primary source of cooking energy from 1963 till 2004 in the capital city, Freetown. By 2013, however, charcoal became the primary source of energy for cooking surpassing fuel wood and other sources of energy in urban areas. Alternately, kerosene has been the third option for energy in the city, but by 2013 it uses decline to 0.6%. What is clear from colonial days to now is that energy availability is still a challenge and the shortage or absence of electricity in homes especially for cooking has increased the pressure for wood biomass.

Table 4 The proportion of cooking fuel by Region and Rural-Urban in Sierra Leone [39]

Fuel source	Eastern	Northern	Southern	Western	Rural	Urban	National
Firewood	90.02	96.25	93.15	28.50	97.23	50.09	78.76
Charcoal	9.59	3.04	4.82	70.39	1.79	48.83	20.22
Kerosene/oil	0.04	0.14	0.26	0.64	0.15	0.14	0.25
Gas	0.00	0.08	0.00	0.13	0.02	0.11	0.06
Crop residue/sawdust	0.26	0.33	1.54	0.01	0.78	0.10	0.51
Animal waste	0.03	0.02	0.15	0.11	0.03	0.15	0.07
Others	0.05	0.14	0.07	0.22	0.00	0.31	0.12
Total	100	100	100	100	100	100	100

Table 5 Freetown Population and primary Cooking Energy Census, 1963 to 2013 [27, 40, 41, 42]

Year	Freetown Population	National Population	Freetown as % NP	% Freetown Household Primary Cooking Source					
				Charcoal	Wood	Kerosene	LPG	Electricity	Others
1963	127,917	2,180,355	5.9%	1.0%	91.0%	7.0%	n/a	n/a	n/a
1975	276,247	2,735,159	10.1%	18.0%	68.0%	12.0%	n/a	n/a	n/a
1989	469,776	3,515,812	13.4%	30.0%	60.0%	8.8%	n/a	n/a	n/a
2004	764,484	4,976,876	15.4%	32.2%	50.7%	10.8%	1.0%	0.1%	5.2%
2013	1,019,744	5,989,623	17.0	72.7%	26.0%	0.6%	0.2%	<.05	0.5%

In Africa, the majority of the population, especially in rural areas, is dependent on traditional biomass harvested directly from the forests for cooking and heating [29]. Only 14% or less of the country's population has access to another form of energy such as electricity and are mostly from the upper class of society. The rest depends on free wood biomass energy to help them cook their food and other functions.

4.2 Reasons why wood biomass is the primary energy source in Sierra Leone

The recent history of the civil war, corruption, natural disasters such as flooding, Ebola outbreak, landslides and bad leadership has placed Sierra Leone at the bottom of the human development index for decades as seen in the trend from 1990-2015 [43] and hence dependence on wood biomass greatly. Since gaining independence in 1961 from Britain, the past and present governments have not lived up to the expectation of the agenda and focus after independence. As a result, the country lagged behind nations such as Singapore, Ghana, Kenya, Malaysia, etc. that were once considered as socioeconomically equal. There are still big towns in Sierra Leone that have never had electricity connection since the independence of the country. Therefore, rural communities are now habitual of biomass energy usage daily without any interruption. The current economic and international debts of the country comes a high illiteracy rate, unemployment, corruption, and poor infrastructure are signs that wood biomass energy usage will continue to dominate the energy sector shortly. Significant and sustained population growth of 2.2% in Sierra Leone implies that a more considerable amount of energy will be required [29]. Another important reason is the irrational government policies, weak implementing institutions, inadequate monitoring of all environment and natural resources management policies and regulations.

Based on statistics, Sierra Leone wood fuel production (wood for charcoal) amounted to 5,749,270m³, with 421,577 tons of charcoal was produced in 2014 [44]. Various statistics reports have confirmed that wood biomass forms the major bedrock of energy for cooking and other domestic household chores in Sierra Leone and it has dramatically supported rural livelihood.

Additionally, wood biomass production has created a lot of jobs and has been a source of income for rural farmers especially those living along highways and near the city. Though wood harvesting has been ongoing from time to time for energy purposes, the vegetation carrying capacity of Sierra Leone still prove to be resilience enough to support the growing population. However, the combination of rapid population growth, mining and shifting cultivation practices and urbanisation pose an environmental threat shortly.

4.3 Wood biomass energy trend in Sierra Leone

The use of forest biomass for energy is still increasing and is expected to continue [29]. As long as the economic situation in Sierra Leone continues to grow at a snail pace, wood biomass energy will remain the main source of energy for another decade or more [45]. The biomass consumption from 2006 to 2011 period in '000' tonne, showing a yearly progressive increase in the use of fuel wood and charcoal is shown in (Table 2). It could be seen that biomass consumption increase from 1.154×10⁶ tons in 2006 to 3,622×10⁶ tons in 2013. This means with the absence of sustainable and affordable energy in Sierra Leone, biomass energy consumption will continue to increase as the population increases. The way forward to reduce biomass consumption in Sierra Leone is by bringing together all energy development partners and the Government to sit down and map out sustainable short and long terms solutions using successful models from countries like China, Singapore, Japan, Ghana and other countries in Africa that had similar challenges previously.

In 2004, a comprehensive household survey on biomass energy consumption was conducted by Statistics Sierra Leone (Figure 2). Except for the urban area "Freetown" (Table 4), the rest of the country shows that more than 80% of households were using biomass energy for diverse functions. Almost every region in Sierra Leone use fuel wood as the main source of energy for most rural homes and access to sustainable and secure the supply of fuel wood is essential for the survival of rural households [32]. The data presented by statistics Sierra Leone 2004 shows that 98% of Koinadugu District residents depend on wood biomass for energy. Except for Western Urban, Western Rural and Kono

District, all the other eleven Districts wood biomass dependence was above 90%. This could be attributed to the facts that Western urban is the capital and have some access to electricity, gas cookers and other forms of energy. On the contrary, the other Districts are facing challenges with underdevelopment, electricity availability, high unemployment rate and the sources of income are limited. However, recent electricity supply reforms made by the Government across the country will help reduce the dependence of wood biomass for energy shortly.

it stands, biomass energy source carries the highest volume of consumption for both cooking and lighting in many households in Sierra Leone. Due to the adequate rainfall in Sierra Leone and the growth rate of vegetation, domestic availability of wood biomass seems sufficient for consumption for the next decades to come. The annual supply of wood fuel from the forest is estimated at 5 million m³, about 20% of which is consumed in Freetown [32]. Biomass will remain as the main source of energy for the foreseeable future in Sierra Leone [31].

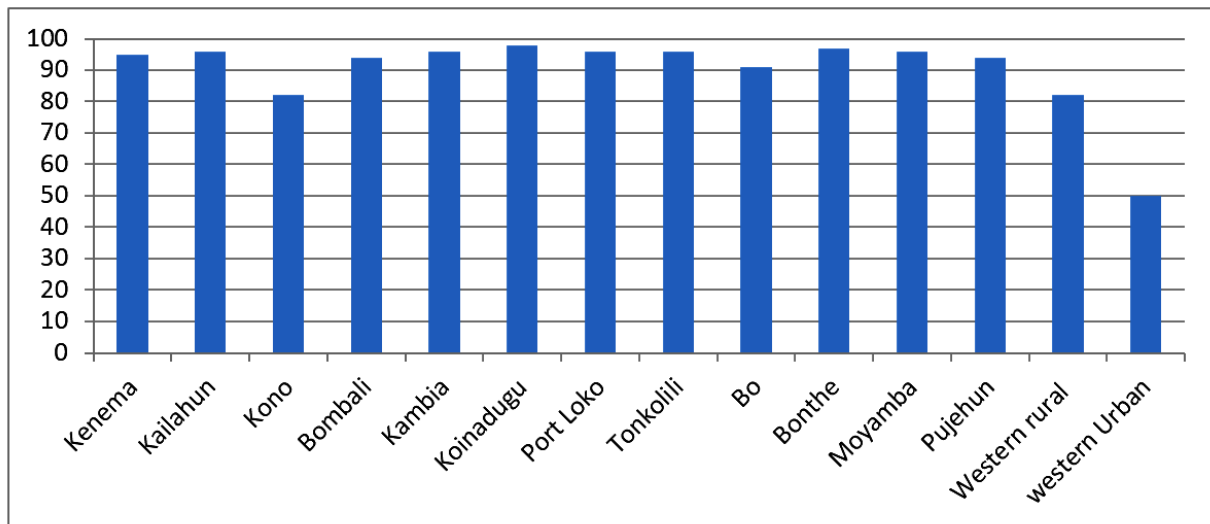


Figure 2 Percentage of fuel wood consumption in all Districts for 2004 [44]

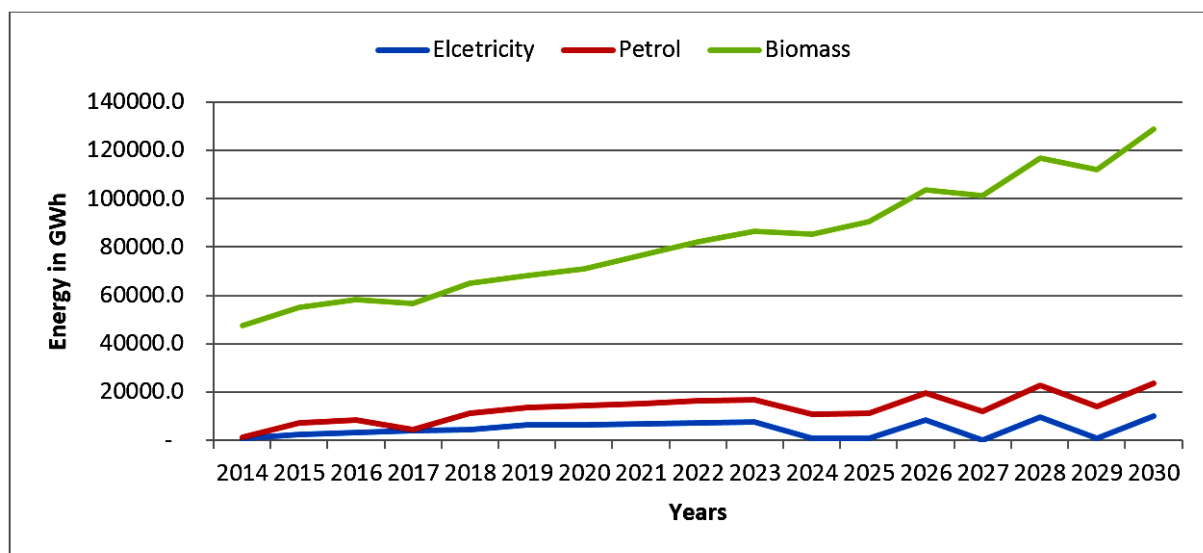


Figure 3 Total energy supply trajectory of Sierra Leone from 2014 to 2030 in GWh [3]

A report [3] predicted that the trajectory on energy supply from 2014 to 2030 gave biomass energy a comfortable lead ahead of other energy sources (Figure 3). This prediction implies that biomass energy is difficult to replace in Sierra Leone and might take years to provide its alternative means or match. As

4.4 Economic benefits of wood biomass production and trade

After the civil war in Sierra Leone, electricity and infrastructures were utterly destroyed especially in rural areas and the only

reliable source of energy was the wood biomass energy. Traders took advantage of this gap and motivated local farmers to sell the wood on their farms and make money while waiting for their crops to reach a harvesting stage. This activity quickly turns into a lucrative business that motivated all rural farmers and youth to engage in the industry. The situation further aggravated when the refugees from neighbouring Liberia sought charcoal burning as their source of income and profession. Since then, firewood and charcoal trading has provided a self-employed job for thousands of people in Sierra Leone. In rural towns and villages along or close to the highways, bags of charcoal and bundles of wood could be seen throughout the year. Earnings from these sales have provided income for the majority of these subsistence farmers and jobless youths. Today we have a formidable organisation like wood sellers association as well as the charcoal sellers association in the country. These associations look after the welfare of producers and buyers in the trade. According to CEMMATS [46], the sales of firewood and charcoal provide income for about 400,000 rural residents with virtually quick investment and returns.

4.5 Pitfalls of wood biomass energy overexploitation in Sierra Leone

Consequently, the total dependence of wood biomass energy by over 90% of the population has impacted Sierra Leone negatively. According to a report, Sierra Leone's forest area is declining as the demand for forest products and wood fuel increases [47]. Also, a report warned that the current high deforestation rate, due to harvesting of traditional fuels, can lead to environmental, health and social impacts on the 65 % of the population living in rural areas [31]. Besides fuel wood for energy, the reduction of living trees for charcoal burning is causing immense environmental problems which leads to a more significant loss of biodiversity and land degradation. Slash-and-burn agricultural practices are also playing a role in the destruction of natural habitat and soil degradation [48, 47].

Other reports warned that the absence of management schemes to regulate wood fuel harvesting in Sierra Leone is causing the forests to shrink rapidly thereby making it difficult to meet the domestic demand of wood fuel and wood fuel export cumbersome [49, 47]. Additionally, indoor air pollution caused by the inefficient use of charcoal or fuel-wood contributes to respiratory diseases, mainly among women and children [27]. Fuel-efficient wood stoves can be introduced in such area as it may be popular among the people, as these stoves increase the fuel efficiency while using the traditional biomass fuel. Most of these stoves are smokeless and will help address the health issues caused by indoor pollution by burning of fossil fuel.

4.6 Renewable energy capacity and potential in Sierra Leone

Sierra Leone poses great renewable energy output, but its harnessing is minimal countrywide [50]. In general, the Sierra Leone energy sector (power) is small compared to other nations with AV power output less than 150MW of operational capacity for the whole country, and it is accessible mainly in Freetown. According to recent statistics, it estimates that [37], barely 10% to 12% of the urban population and only around 2% of the rural population approximately have access to electricity. A report showed that renewable energy capacity in Sierra Leone is 88MW, out of which 56MW is generated by Hydro Power while 33MW is generated by Bioenergy [51]. At present, the solar and wind energy potential of Sierra Leone is still untapped but has a high potential based on our climatic patterns (Table 6). The reports also showed that Sierra Leone has a capacity of 33MW, generated mainly from Biomass [51]. According to the recent reports [37], around 8471 solar street lights have been distributed by Government to the fourteen districts main headquarters in the country, but only a few are in operating conditions at this moment.

Table 6 Renewable energy capacity statistics of Sierra Leone from 2007-2018 [51, 52]

Renewable Energy type (e)	Period and their capacity in (MW)										
Years	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total renewable energy	4	29	29	54	54	54	54	88	88	90	92
Renewable & Hydropower	4	29e	29e	54e	54e	54e	54e	56e	56e	58e	60e
Medium hydropower	4e	4e	4e	4e	4e	4e	4e	6e	6e	6e	
Wind energy	-	-	-	-	-	-	-	-	-	-	-
Solar energy	-	-	-	-	-	-	-	-	-	-	-
Bioenergy	-	-	-	-	-	-	-	32	32	32	32
Solid biofuel & energy waste	-	-	-	-	-	-	-	32e	32e	32e	32e
Bagasse	-	-	-	-	-	-	-	32u	32e	32e	32e

Note: "u" is used by International Renewable Energy Agency (IRENA) to signify figures obtained from unofficial sources such as industry, associations and news articles. The symbol "e" follows figures that have been estimated by IRENA from a variety of different data sources.

The renewable energy capacity of Sierra Leone shown in Table 6 highlights the past and current renewable energy capacity of the country based on 2007 to date. Renewable energy such as bioenergy, bagasse and solid biofuel & waste energy started producing energy in 2014 and has since reduced the immense energy pressure especially in the capital city. Based on the Ministry of Energy report [39], the overall electrical power generation of the country has increased from 2014 to 2017. However, more need to be done to actualise the full potential of renewable energy across the country in the next couple of years.

5.0 Conclusion

The use of wood biomass energy in Sierra Leone is not by choice but when there is no alternate energy. If there is an alternative, then it seems to be preferable. Wood biomass is the only reliable energy available throughout the country and is cheap for all classes of Sierra Leoneans. The possible alternative to wood biomass energy usage shortly is electricity especially hydro-energy. The utilisation of other forms of renewable energy such as modern bioenergy, solar, wind, and increased hydroelectric production could improve the energy access and diversify Sierra Leone's energy profile. Policies that decrease dependence on traditional biomass and encourage environmental sustainability will deliver a vast range of benefits. Investing in future energy is the touch-stone of economic development in Sierra Leone, and it will help to fast track the rapid infrastructural investment while still meeting the felt needs of citizens sustainably. The provision of energy is vital for the realisation of sustainable economic growth and human development. The limited availability of electricity in rural districts is partially responsible for the congestion in Freetown as well as the deterioration of rural areas. The government should prioritise access to electricity as this brings investors and development in any nation. With this, the government must act trustworthy for international donors and other supporting organisation to finance a massive sustainable energy project throughout the country. The government should copy the success model in terms of policies and strategies of countries once struggling with the energy issue but are now energy sufficient and stable.

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