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Exploring Africa's Potentials of Biopower for Low Carbon Development

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Abstract

Clean and Improved energy access is the topmost priority in the African continent and the globe at large due to persistent energy demand rise and the challenge of climate change. The persistent increase in the energy demand arising from population exponential growth is particular more severe on electricity as more fundamental due to its multiplying impact on virtually all sectors of economy. This paper tries to explore the potentialities of Biopower for Africa's low carbon development. In doing so, the review of the electricity generation has been done for the continent with the analyzed chances of scaling up the power supply mix by high and efficient utilization of the lignocellulose biomass resource potentials for biopower, and in the same manner, lowering the depleting fossil fuel consumption for environmental concerns and benefits. Manual analyses were done as well as applying M.S EXCEL forecasting and also the incorporation of RETSCREEN Baselines thoughts. The result is obvious on the fact that for the 2014 baseline power assessment, a 50% reduction of fossil fuel uptake and incorporation of 90% of the explored total lignocellulose-based biomass resources for bio-power will ensure electricity increase by 79.9% with a high greenhouse gas emission savings of 171MT. Moreover, on basing the analyses to 2030 power projection scenario showed an electricity increase by 43.46% with the greenhouse gas emission savings of 194MT based on 25% reduction of fossil fuels with addition of 90% of total biomass resource. Therefore, this is obvious to the fact that Africa is fortunate with huge un-tapped Biomass resource of which having appropriate policies in place for their full utilization in a sustainable way as proposed, will give a better room for changing the story-line of energy deficit in the continent particularly as it relates to power sector being an area of most concern with multiplying impacts.

Key Words:
[Low Carbon Development, Energy Demand, Biomass, Biopower, Climate Change, Africa, Energy Deficit]

Contents

1.0: Introduction

Africa is the second largest continent following Asia in terms of land area, containing roughly 20% of world total land area with 54 countries [1]. Energy is generally a key pre-condition to sustainable development and also a fundamental human right hence, a critical concern. Africa is endowed with huge energy resources both conventional and renewables. However, with a very low level of access. It is quite unfortunate that beyond 50% of the population have been deprived access to modern final energy aid [1]. Despite of the high demand and huge resource endowment, the continent's portion of the global energy consumption has been obtained to be around 3.5% [2], and largely traditional biomass. To add further, energy efficiency in processing is also seen to be a challenge due to either low technical expertise or equipment underperformance as almost 10-40% of the continent's total primary energy input is lost on transformation to final energy [2].

Renewable energy resource is of greatest interest of exploitation to the continent of which a more specific focus is on Biomass as the heart of all the renewables. Biomass is quite distinguishable from modern bioenergy, as the latter is energy derived from the former through various technical and highly sophisticated processes such as thermal, mechanical, chemical, and bio-chemical depending on the product targeted. This energy could basically be in form of heat, power or biofuels (liquid and gaseous fuels). Bioenergy is a matured technology and also a renewable energy with the highest potential expansion among all the renewable energy technologies, hence, considered the heart of energy transformation [3]. However, this paper has been restricted to the Biomass resources dedicated to Biopower generation in the African context.

Production and utilization of modern bioenergy (Biopower) has been considered a fundamental requirement for rural development bearing in mind the clean energy service access from biopower industries [4]. It is evident that modern bioenergy (Biopower) development offers a golden opportunity in investment and infrastructural improvement in the agricultural sector. This is with a view of boosting the agricultural production with their further transformation to energy service and geared towards socio-economic development continentally and globally [5].

Unfortunately, most current biomass utilization level in Africa especially in sub-Saharan Africa is quite crude, unsustainable and inefficient hence, non-modern. About 65% of the population relies on traditional biomass (wood fuel) for cooking, heating, and lighting purpose mostly in rural areas of the continent [3]. Hence, leading to indoor pollution and resulting to increased health challenge and mortality. Forest devastation is also certain due to continuous deforestation with no proper plans or technical knowhow for replanting. This calls for proper action technically, jointly, judiciously, adequately and in a timely manner.

Finally, Biomass resource utilization in transitioning to low carbon development in view of modern bioenergy and particularly the Biopower targeted approach broadly speaks about sustainable development for the continent as virtually all the pillars of sustainable development are embedded and interwoven. This is in view of the fact that according to [6], Low Carbon Development (LCD) is understood as using low carbon substitute to fossil fuels in view of reducing emissions (pollutants and GHG), and at the same time improving economic growth and development significantly.

Lastly, this paper is aimed at evaluations and explorations of the potentialities of biomass for Biopower for low carbon development target in the African Continent, covering both the Northern region and the sub-Saharan region (i.e. critical region and of most concern) and with the scope of the research covering the sustainable development pillars.

2.0 Methodology

This research has focused on the Biomass potentials in seeing clearly the extent to which final energy supply i.e. biopower could be integrated in the continent's power mix with the associated benefits. This is due to the transformative role to which the biomass resource could offer being the heart or the mother of the energy transformation not only in the continent but globally. The methods or steps employed in the research paper are as mentioned below for the perusal of the readers:

Evaluations of Biomass Resources (specifically the Agro Residues and Forestry Productions) potentials for up-scaling the electricity mix of the continent while at the same vein, lowering a certain portion of the excessive fossil energy uptake has been clearly done by selecting a given baseline year which was 2014 as well as projecting the assessment to 2030 Business as Usual (BAU) scenario. The sole idea was to see the status quo on the continent power mix and the extent to which it could be possibly upgraded on a green transformation basis.

Following up with the power mix scale-up was the greenhouse gas emission assessment by quantifications of the base scenarios emissions as well as the proposed scenarios emission based on the established standard emissions factors for the concerned fuels. This was concluded by evaluating the GhG emissions reductions or savings on having the successful shift from the Base Cases to the Cases Proposed in both the baseline year i.e. 2014 and the projected year i.e. 2030 as a clear benefit for the worthy of the transformation.

Social and economic benefits have also been dealt with squarely on linking to economic growth and development at different levels of the continent i.e. domestic / levels, industrial levels and institutional levels. However, this aspect of the analyses is strictly qualitative hence, involved theoretical backgrounds and arguments from various experiences. Furthermore, it must be stated that any positive changes have to be accompanied with challenges of which some could be surmountable. The scope of this research paper included also the surmountable challenges discussions as well as brief enumerations on how they could be addressed effectively.

Lastly on the scope of the research was the discussions of some certain opportunity areas that are worthy of adopting in the process of the transitions for improved benefit. This opportunity areas where addressed as possible business model(s) and value chain extensions.

3.0: Results and Discussions

3.1: Electricity Up-scaling with Biopower

The Overall Energy Conversion Efficiencies (i.e. from chemical to thermal and to electrical energy) for Oil, Natural Gas, Coal, and Biomass power plants are as shown in the below table:

Table 1: Energy Conversion Efficiencies for Thermal Power Plants

Power Plants	Technique of Transformation	Overall Efficiencies ($\eta_{overall} = \eta_{th} \times \eta_{el}$)
Biomass	Combustion and Steam Turbine Generator Shaft-work for Power Generation	25%
Coal	Same as above	35%
Oil	Same as above	38%
Natural Gas	Same as above	45%

Sources: [7]; [8]

According to the above table, it can be deduced that Biomass is less energy dense than fossil fuels, hence, more of it energy is required than the fossils to produce the same final energy needs.

1) 2014 Baseline Power Analyses

- Base Case Assessment

The 2014 baseline installed and generation capacity mix as obtained from total shift project database is as follows:

Table 2: Installed Capacities and Electricity Generation Mix for Africa during 2014

Fuel Mix	Installed Capacities (GW)	Fuel Mix	Electricity Generation (TWh)
Fossils	113.6	Oil	91
		Gas	234
		Coal	241
Hydro	24.1	Hydro	120
Wind	2.1	Geothermal	32
Nuclear	1.9	Biomass	2
Others	4	Others	19
Total	145.7	Total	739

Source: [9]

From the above table, the Fossil Fuel Consumption could be established based on the overall efficiencies information for their respective power plants as follows:

Table 3: Calculated Fossil Fuel and Biomass Consumption for the Established Power Generations of 2014

Fuel Use	Energy Consumption (TWh)	Power Generation (TWh)
Oil	239.47	91
Gas	520	234
Coal	688.57	241
Biomass	8	2
Total	1456.04	568

- Assessment of the Proposed Case

The below table gives the quantified biomass resource obtained for the 2014 base year with the ascribed energy values calculated:

Table 4: Assessed Lignocellulose Biomass Resource Data for the 2014 Base Year

Domain	Item	Quantity	Cal. E.C (MJ)	Cal. E.C (TWh)
Agro Processing	Crop Residue	2490367870kg	3.2549×10^{10}	8.79
Forestry Production	Wood Fuel	656920317m^3	1.4347×10^{13}	3873.69
Total		N/A	1.4380×10^{13}	3882.48

Source: [10]

Note that the calculation of the energy content was done based on the breakdown of the crop residue different varieties for the whole continent during the specified year, their total quantity obtained and the energy content factor (i.e. Specific Energy) for each of the produced residues. This procedure is also similar for the wood fuel, in line with the obtained total volume produced and the Standard Energy Density.

Based on the energy information from the FAO Statistics database, as well as the electricity mix information obtained from Total Shift Project Database, it is quite obvious that the continent electricity generation could be scaled up by lowering the fossil fuel uptake and replacing with the huge biomass resource available during the baseline year. This will play a multiple role of lowering costs of energy generation, extending energy availability, and with enormous socio-economic, and environmental benefits that will be addressed latter on.

Reduction of the fossil energy by 50% and adding up 90% of the estimated total biomass available for the base year is a feasible approach as shown in the below table:

Table 5: Proposed New Electricity Generation Mix for the 2014 base year

Fuel Mix		Fuel Consumption (TWh)	Electricity Generation (TWh)
Fossil Fuel	Oil	50% of 239.47 = 119.735	50% of 91 = 45.5
	Gas	50% of 520 = 260	50% of 234 = 117
	Coal	50% of 688.57 = 344.285	50% of 241 = 120.5
Total for Fossils		724.02	283
Biomass in Mix		8	2
Proposed Biomass		90% of 3882.6 = 3494.34	3494.34 × 0.25 = 873.59
Total for Biomass		3502.34	875.59
Hydro		N/A	120
Geothermal		N/A	32
Others		N/A	19
Grand Total			1329.59

Concluding Assessment:

Proposed Electricity Generation Mix = 1329.59TWh

Conventional Electricity Generation Mix from Total Shift Project Database = 739TWh

% Electricity Generation Increase = $\frac{1329.59-739}{739} \times 100\% = \mathbf{79.9\%}$

- Total Biomass required (90% Proposed Use + Biomass for Existing 2TWh$_{el.}$) = 3502.34TWh
- Total Biomass Resource (Wood Fuel + Agro Residues) for the 2014 base year = 3882.48TWh

Therefore, Biomass Resource Left over = 3882.48 – 3502.35 = 380.13TWh

This huge Biomass resource left over of **380.13TWh** could then be utilized for other applications as reference for further considerations depending on the decision makers choices in all the concerns.

2) 2030 Projection Power Analysis

➢ Base Case Assessment

Below show the installed and generation capacities mix for 2030 scenario as obtained from [8]

Table 6: BAU Installed Capacities and Electricity Generation Mix Scenario (2030)

Fuel Mix	Installed Capacities (GW)	Fuel Mix	Electricity Generation (TWh)
Fossil Fuels and Nuclear (Use of Uranium)	440	Oil	216
		Gas	490
		Coal	570
Hydro	50	Biomass	40
Wind	22	Nuclear	35
Geothermal	12	Hydro	250
Others	2	Other REs	120
Total	526	Total	1721

Source: [8]

From the above table, the Fossil Fuel and Biomass Energy Consumption could be established based on the overall efficiencies information for their respective power plants:

Table 7: Calculated Fossils and Biomass Consumption for the Power Generation of the 2030 Scenario

Fuel Use	Energy Consumption (TWh)	Power Generation (TWh)
Oil	568.42	216
Gas	1088.89	490
Coal	1628.58	570
Biomass	160	40
Total	3445.89	1316

- Proposed Case Assessment

The proposed case energy analysis for the continent base on proper adjustment to the base case is as follows beginning with the biomass assessments of [10]:

Table 8: Agro Residues and Forestry Production Quantifications for 2014 and 2030 Forecasting

Year	Crop Residue (kg)	Wood Fuel (m^3)	Crop Residue Cal. E.C (MJ)	Wood Fuel Cal. E.C. (MJ)	Total E.C (MJ)	Total E.C (TWh)
2014	2490367870	656920317	3.2549×10^{10}	1.4347×10^{13}	1.4380×10^{13}	3882.6
2030	3752248609	801919796.1	4.8497×10^{10}	1.7514×10^{13}	1.7562×10^{13}	4741.74

Note that the 2030 forecasting was done using M.S Excel based on the obtained historical data trend from [10].

Therefore, from the table, the following could be extracted:

Total Biomass Energy Content (Agro Residues + Wood Fuel) for the Excel Forecasted / projected data of 2030 = 4741.74TWh

Based on the energy information from [10], as further developed in Table 8, coupled with the electricity mix information obtained from [9], it is obvious that the continent electricity generation can be feasibly scaled up by lowering the fossil fuel uptake and replacing with the huge biomass resource available as shown in table 7. This will play a multiple role of lowering costs of energy generation, improving energy access, and with enormous environmental and climate joint benefits that will be analyzed latter on.

Reducing the BAU fossil energy by 25% for each of oil, natural gas and coal, and augmenting with 90% of the total lignocellulose biomass resource available from table 7 is a proposal that is possible and worth doing approach as shown from the result table below:

Table 9: Newly Proposed Electricity Generation Mix for the 2030 Projection

Fuel Mix		Fuel Consumption (TWh)	Electricity Generation (TWh)
Fossil Fuel	Oil	75% of 568.42 = 426.315	75% of 216 = 162
	Gas	75% of 1088.89 = 816.67	75% of 490 = 367.5
	Coal	75% of 1628.56 = 1221.42	75% of 570 = 427.5
Total for Fossils		2464.405	957
Biomass in Mix		160	40
Proposed Biomass		90% of 4741.74 = 4267.57	$4267.57 \times 0.25 = 1066.91$
Total for Biomass		4427.57	1106.91
Hydro		N/A	250
Nuclear		N/A	35
Other R.E Sources		N/A	120
Grand Total			2468.91

Concluding Assessment:

Proposed Electricity Generation Mix Total = 2468.91TWh

Conventional Electricity Generation Mix from IRENA database (BAU) = 1721TWh

% Electricity Generation Increase = $\frac{2468.91-1721}{1721} \times 100\% = \mathbf{43.46}\%$

- Total Biomass required (90% Proposed Use + Biomass for Existing 40$TWh_{el.}$) = 4427.57TWh
- Total Biomass Resource (Wood Fuel + Agro Residues) for the 2030 Scenario = 4741.74TWh

Therefore, Biomass Resource Left over = 4741.74 – 4427.57 = 314.17TWh

3.2: Environmental Benefit Assessments (GhG Analyses)

The table 10 below shows vividly the GhG Emission factors applied for the emission analyses as obtained from RETSCREEN decision tool standards.

Table 10: GHG Emission Factors for Fuels

Fuel	GHG Emission Factors		
	CO_2 Emission Factor	CH_4 Emission Factor	N_2O Emission Factor
Oil	0.269ton/MWh	0.0029kg/GJ	0.0019kg/GJ
Natural Gas	0.179ton/MWh	0.0036kg/GJ	0.0009kg/GJ
Coal	0.338ton/MWh	0.0145kg/GJ	0.0029kg/GJ
Biomass	0.007ton/MWh	0.0299kg/GJ	0.0037kg/GJ

[RETSCREEN Standards]

1) 2014 Baseline Emission Analyses

➢ Base / Conventional Case Emission Analysis

According to Table 3 of calculated fossil fuel and biomass energy consumption with the power generation mix showcased in power scale up analyses, the table below incorporates the calculated GhG Emissions for the energy consumption based on the established emission factors of table 10:

Table 11: The Calculated Fossil Fuel and Biomass Consumption for the Power Generation of 2014 Base Year with the Calculated GhG Emissions

Fuel Use	Energy Consumption (TWh)	Power Generation (TWh)	Base Case CO_2 Emission (MT)
Oil	239.47	91	64.2
Gas	520	234	93.1
Coal	688.57	241	232.7
Biomass	8	2	0.056
Total	1456.04	568	390.26

➢ Emission Analysis for the Proposed Case

Table 12: Proposed Fossil Fuel and Biomass Consumption with the Power Generations for 2014 and Calculated CO_2 Emissions

Fuel		Fuel Consumption (TWh)	Electricity Generation (TWh)	CO_2 Emission (MT)
Fossils	Oil	50% of 239.47 = 119.735	50% of 91 = 45.5	32.2
	Gas	50% of 520 = 260	50% of 234 = 117	46.54
	Coal	50% of 688.57 = 344.285	50% of 241 = 120.5	116.37
	Total Fossil Fuel	724.02	283	195.11
Biomass in Mix		8	2	0.056
Proposed Biomass		90% of 3882.6 = 3494.34	3494.34 × 0.25 = 873.59	24.46
Total Biomass		3502.34	875.59	24.516
Grand Total		4218.36	1158.59	219.63

Therefore, the Overall CO_2 Emission Savings

= Base / Conventional Case Emission – Newly Proposed Case Emission

= 390.26MT – 219.63MT = 170.63MT

2) Emission Analysis for the Forecasted 2030 Year

➢ Base / Conventional Case Emission Analysis

The table 13 shows clearly the calculated GhG Emissions for the BAU 2030 Projected year as an extension of Table 7 and based on the secured standard emission factors for the fuels concerned:

Table 13: Calculated Fossil Fuel and Biomass Consumption for the Established Power Generation for the 2030 Projection with the Calculated CO_2 Emissions

Fuel Use	Energy Consumption (TWh)	Power Generation (TWh)	CO_2 Emissions (MT)
Oil	568.42	216	152.9
Gas	1088.89	490	194.19
Coal	1628.58	570	550.46
Biomass	160	40	1.12
Total	3445.89	1316	898.67

➢ Emission Analysis for the proposed or suggested case

In line with the previous exercise in the electricity up-scaling (see Table 9), the extension has incorporated the calculated GhG emission values and shown in the result of Table 14 below:

Table 14: 2030 Newly Proposed Fossil Fuel and Biomass Use with the Power Generation and Calculated CO_2 Emission

Fuel		Fuel Consumption (TWh)	Electricity Generation (TWh)	CO_2 Emission (MT)
Fossils	Oil	75% of 568.42 = 426.315	75% of 216 = 162	114.68
	Gas	75% of 1088.89 = 816.67	75% of 490 = 367.5	146.18
	Coal	75% of 1628.56 = 1221.42	75% of 570 = 427.5	412.84
Total for Fossils		2464.405	957	673.7
Biomass in Mix		160	40	1.12
Proposed Biomass		90% of 4741.74 = 4267.57	4267.57 × 0.25 = 1066.91	29.87
Total for Biomass		4427.59	1106.91	30.99
Grand Total		6891.995	2063.91	704.69

Therefore, the Overall CO_2 Emission Savings

= Base / Conventional Case Emission – New Proposed Case Emission

= 898.67MT – 704.69MT = 193.98MT

According to RETSCREEN Baseline, the **193.98MT** emission savings for the 2030 projection is equivalent to **35611305** Automobiles not used for the projected year.

Table 15: Overall GhG Emission Summary for the 2014 Baseline and 2030 Projection

2014 Emission Summary				*2030 Emission Summary*			
Base Case		*Proposed or Suggested Case*		*Base Case*		*Proposed or Suggested Case*	
Fuel	*Energy Utilization (TWh)*	*Fuel*	*Energy Utilization (TWh)*	*Fuel*	*Energy Utilization (TWh)*	*Fuel*	*Energy Utilization (TWh)*
Fossil	*1448.04*	*Fossil*	*724.02*	*Fossil*	*3285.88*	*Fossil*	*2464.405*
Biomass	*8*	*New Biomass*	*3494.34*	*Biomass*	*160*	*New Biomass*	*4267.59*
		Ex. Biomass	*8*			*Ex. Biomass*	*160*
390.2MT CO_2 Emission.		*219.63MT CO_2 Emission*		*898.67MT CO_2 Emission*		*704.69MT CO_2 Emission*	
***170.63MT** CO_2 Emission Savings on adopting the Proposed Case as compared to the baseline case, and is equivalent to **31325162** automobiles taken off-operations in the Baseline year*				***193.98MT** CO_2 Emission Savings on adopting the Proposed Case as compared to the Baseline Case, and is equivalent to **35611305** automobiles taken off-operations for the Projected Year*			

3.3: Socio-economic Benefits Breakthrough

Extending the power access through the bio-power tends to offer a lot of superb benefits on social and economic ground which will be highlighted as follows:

The benefits could be viewed critically from household level and to a larger extent the various sectors of development for the continent such as agricultural, educational, health, transport, industrial, and so on.

On the household level, the improved access to electricity will assist greatly in addressing a lot of household issues such as lighting, abundance in water supply, and above all, makes activities more efficiently and in a timely and less stressful manner. Hence, this ensures boosting of livelihood or the standard of living at the domestic level absolutely.

Moving on further to the sectors of development, starting with the agricultural sector, the improved access to energy / electricity assists greatly in enhancing more diversified and sophisticated agricultural practice thereby improving agricultural system efficiencies, quality and yield of produce to a greater extent. Therefore, agricultural transformation of the continent is only sound on greater access to stable and sustainable power supply which can only be made to reality on integrating the untapped biomass resources put forward.

The improved access to electricity is also very critical to the educational sector. This will assist greatly in modern schools' empowerment by improving the use of modern learning facilities for students' welfare. Access to all these facilities could be made more feasible only with the stable, sustainable and reliable power supply.

Moreover, the improved access to electricity is equally important to health sector of the economy. This is in view of having greater access and use of modern and sophisticated diagnostic facilities for proper check-up of patients. It is quite a pity to the continent that most hospitals in remote areas especially in the sub-Saharan Africa lack access to electricity, which subjects patients to life at stake.

Furthermore, Industrial sector is another key area of development to the continent which ensures improved access to processed goods. This sector could not function effectively on the base of unsustainable and unreliable power supply. Therefore, the improved power supply is also a critical concern to the industrial transformation of the continent.

On a final note, employment opportunities are made possible at all levels of implementation, starting from feedstock extraction to the power generation and to distribution levels for end use.

3.4: Challenges of the Biopower Massive Adoption with Viable Solutions

- The possible challenges in such undertakings have been outlined in brief with lucid explanations regarding how they may be seen as obstacles in the following outlines:
    i. Securities in Water: The continuous use of water for biomass growing specifically for bioenergy activities and more specifically on the bio-power generation subject matter offers a challenge of water shortage to regions with low level rainfall experience. This is in view of the fact that more stress will be on the water bodies for irrigation practices and power generations thereby resulting in continuous water bodies draining and severe drought. With the drought prevalence, further biomass plantation is impeded as well as the associated modern bio-power generation as water is needed for both. Above all, other activities very critical such as operations for consumption, food crops plantation and so on are also hindered, making the economy at stake. Therefore, biomass plantation practice for energy could be considered unviable in areas with such misfortune.
    ii. Land Use Challenge: Land resource is a fixed asset that could be either arable or non-arable. Arable lands are used for plantation (i.e. Biomass Plantation for either food or energy) or for grazing purpose. This land also permits activities such as power plants installation. On the other hand, non-arable land un-favors plantations but could be applied for other activities such as the power plants installations and beyond. Therefore, excessive use of lands for biomass plantation for energy as well as for power plants installation

renders land usage for other activities like food production and so on unfavored. Hence, this could pose a challenge to bio-power projects.

iii. Deforestation Impact: Continuous deforestation in securing biomass feedstock for bio-power generation is another critical issue disrupting the ecosystem by contributing to increased CO_2 Emissions, desertification and land degradation hence, affecting the successful implementation of bio-power projects.

- Addressing the challenges / Viable Solutions Discussions
    i. Addressing the Water Security Challenge: Addressing water issues to modern bio-power is very crucial in ensuring sustainable agriculture and forestry as well as the power generation. Sustainable water management is the only way out to tackling the water scarcity challenge to the associated locations such as setting up in place rainfall harvesting systems in conserving water for future use, the practice of expanded irrigation schemes coupled with use of sophisticated machines in having access to untapped water, and finally the efficient practice of water recycling and reusing. These are all in favor of sustainable agriculture, forestry and power generations.
    ii. Addressing the Land Use Challenge: to counteract what has been said concerning land use in the previous discussion for the challenges, it must be emphasized from what has been disclosed in the literatures that various stakeholders have accentuated land availability being an unlimiting factor to bioenergy development in Africa and Beyond [5]. This is because the continent is commended with abundant and unutilized lands both arid and Semi-arid most especially in the Sub-Sahara. Another study by [11] as revealed gives the 2050 scenario on a global perspective regarding the arable lands that could be harnessed i.e. 390million hectares, 1300million hectares, and 4000million hectares on low, medium and high bands of 0-100EJ, 300-600EJ, and >600EJ respectively.
    iii. Addressing Deforestation Impact: The aspect of Sustainable Forest Management majorly by Afforestation and Reforestation is strongly advocated for in neutralizing the effect of deforestation for the sustainable supply of biomass resource for modern bio-power projects.

3.5: Opportunity Areas on Implementation

i. Carbon Sequestration Model (CSM) or Carbon Capture and Storage Model (CCSM)**:** Biomass is considered carbon neutral on net basis focusing on direct emissions only. This is because the amount of CO_2 captured during the growth and manufacturing phase i.e. photosynthesis is what is equally released on transformation to final energy. However, opportunities exist in transitioning from the carbon neutrality to a more environmentally friendly approach which is carbon negativity in ensuring a more de-carbonized economy for tackling climate change challenge more severely. The carbon negative strategy in this regard is termed Carbon Capture and Storage (CCS) or Carbon Sequestration Model. In this business model approach, biomass feedstock is not utilized fully for bioenergy however; pyrolysis process is applied instead of the complete combustion. This will then lead to bio-char (charcoal), bio-oil and gaseous products generation. Since most of the CO_2 is embedded in the charcoal, it is then seized from further uptake in the bioenergy operations but buried beneath the ground. The bio-oil is what is usually used further as fuel for bio-power generations and so on. This approach ensures that not all the CO_2 captured by the plants during photosynthesis is released back in cycle due to charcoal burial and hence, termed carbon negative strategy.

ii) **Value Chain Extension:** Value Chain Extension for Bio-Power Projects is another critical opportunity area which basically entails feedstock value addition by various pre-treatment operations coupled with the conversion or transformation chains. According to [12], value chain analysis stands to address many project related issues constructively such as:

- ''Cutting net costs
- Improving systems efficiency thereby increasing yield and product quality
- Eliminating waste i.e. ensuring zero waste for sustainability

- Reducing products development time''.

The feedstock of interest will majorly be Agro and forest residues for all the technical flow of operations due to the huge economic benefits and waste management opportunities associated. Possible Agro Residues that could be utilized for energy are Cobs, husks, straws, stalks, bagasse, shells, sticks etc.; while possible forest residues are bark, chips, shavings, sawdust etc.

The technique involved here is called **Densification** (i.e. compaction by lowering volume and increasing density) in producing **Briquettes** and **Pellets** Feedstocks. Densification of Residues offers the following advantages:

- It ensures sustainable waste management thereby resolving the issue of waste disposal
- Increases the Net Calorific Value (i.e. Low Heating Value) per unit volume of the residues thereby improving the overall efficiency of their conversion to bioenergy.
- Densified Feedstock are easy to transport and less costly

4.0: Conclusions

The research approach has given detailed assessments of the specialised sets of biomass categories (i.e. Agro-residues and Forestry Production) dedicated to Biopower generation on a wider view of electricity mix scale-up with the GhG Emissions benefits evaluations, the societal and economic impacts of adoption while also highlighting possible surmountable challenges and opportunities for improved benefits. This could be seen as a supporting measure to sustainable development and the Nationally Determined Contributions (NDC) put forward in the 2015 Paris Agreement for global countries. The research outputs on the quantitative analyses clearly reveal that for a 2014 baseline year, lowering fossil energy uptake in the power mix by 50% and augmenting with 90% of the explored total biomass resources (Agro Residues and Forestry Productions) gives rise to electricity increase by 79.9% with a massive GhG reductions of around 171MT and seen to be equivalent to 31325162 automobiles out of operation for the baseline year. Similar approach to the 2030 forecasting showed that fossil-based energy reduction in the power mix by 25% coupled with increment with 90% of the obtained aggregate biomass resources on the projections led to 43.46% power increment with the associated GhG Emissions savings benefits of 194MT, and seen to be equivalent to 35611305 automobiles off-operational in the projected year. To commend lastly, the sole idea of the research paper is on proofs to the decision makers the various opened possibilities in ensuring the energy transformation as basis for their undisputable decisions in these regards in favor of the continent's future.

5.0: Recommendations

As a follow-up to the conclusion drawn, the following points are strongly recommended in adopting biopower systems and ensuring its sustainability in the African Continent:

- Proper policies and regulatory framework in favor of biopower related projects need to be set up at all levels and in all the 54-member states of the continent, stating clearly its relevance and the copious opportunities associated coupled with proper monitoring of the success stories.
- Committees need to be set up for sensitizing the 54-member states of the continent about the needs for sustainable energy supply to the continent while also providing them with the adequate expertise in pursuing the process.
- Bioenergy researchers need to be supported adequately in terms of finance and the enabling environments for conducting bioenergy research particularly the biopower-based research thereby improving their technical knowhow in coming up with multiple innovations.
- Energy Efficiency practice is of paramount importance in the implementation of biopower projects both at the production level and at the demand site level in order to avoid resource over extraction and utilization hence improving their sustainability.
- Need also arises for the continent's collaboration with external bodies for supports through finances, technological transfer for building capacities in the field of renewable energy with stronger focus on bioenergy (biopower).

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