ACADEMIA GREEN ENERGY

Review Article
Published: 2024-05-24
https://doi.org/10.20935/AcadEnergy6227

# Biofuel as an alternative for Sub-Saharan Africa's transition to cleaner energy

Stephen Enyinnaya Eluwa[1,*], Oluwaseun Kilanko[2]

Academic Editor: Halil Durak

## Abstract

Energy plays a vital role in the social and economic development of any nation. Compared to other regions of the world, Sub-Saharan Africa lags behind in energy access. About half of the population lacks access to electricity and other cleaner fuels. With vast arable land and good climatic and soil conditions, Sub-Saharan Africa could address its energy supply challenges through bioenergy. This article reviews the biofuel potential of some Sub-Saharan African countries, the reasons why biofuel is suitable for the region, and the barriers hindering its expansion and development. Findings from the review indicate that some progress has been made in bioethanol and biogas production; however, biodiesel production is still in its infancy stage in the region. Most of the feedstocks for biofuel production are from agricultural waste. Among the countries in Sub-Saharan Africa, South Africa and Kenya have shown great prospects in the development and utilization of biomass resources for the production of cleaner fuels. Biofuel adoption in the energy mix of Sub-Saharan African countries will reduce overdependence on the importation of crude oil, thereby saving huge foreign exchange. It will also provide employment to millions of people in the agricultural value chain through the cultivation of bioenergy crops. In terms of climate change mitigation, biofuel holds great potential in reducing carbon emission associated with fossil fuels.

**Keywords:** *biomass, biofuel, Sub-Saharan Africa, feedstock*

**Citation:** Eluwa SE, Kilanko O. Biofuel as an alternative for Sub-Saharan Africa's transition to cleaner energy. *Academia Green Energy* 2024;1. https://doi.org/10.20935/AcadEnergy6227

## 1. Introduction

Biomass encompasses all-natural substances originating from plant or animal wastes, which can serve as a fuel source. This includes agricultural resources and residues, forest resources, household/municipal solid waste, industrial waste, and other wastes, as well as algae [1]. These materials are referred to as feedstock in bio-refining and are categorized into four generations. The first generation refers to the biofuels derived from agricultural products: sugar/starch-based crops and oilseeds (e.g., sugarcane for bioethanol production or palm oil for the production of biodiesel). Through fermentation or transesterification, first-generation biomass feedstock can be processed into bioethanol or biodiesel. The second generation refers to biofuels produced using biomass liquid technology such as bioethanol, biohydrogen, and so on from lignocellulosics. The third generation is biofuel from algae, while the fourth is derived from bioconversion of living organisms (plants and microorganisms) using biotechnology apparatuses [2]. Due to concerns about the adverse effects on global food prices using first-generation biomass feedstock, research is moving toward the use of second-generation biomass feedstock, which is otherwise known as lignocellulosic biomass resources. These are feedstocks from wood and crop residues and dedicated crops primarily cultivated for the purpose of biofuel production [3]. Cherubini [4] noted that increasing interest in second-generation biomass feedstock as a sustainable alternative to fossil fuels globally stems from the fact that they are not food crops and so there is no fear of competition arising from the demand for food crops as feedstock for biofuel and food crop for human consumption.

In today's context, biomass encompasses materials such as fallen trees, branches, tree stumps, yard trimmings, scraps, wood chips, and agricultural residues [5]. Biomass is abundant in nature and broadly dispersed globally with its distribution being dependent on the geographical area [3]. Biomass as a sustainable energy reservoir is plentiful, enduring, and emits notably lower levels of greenhouse gases (GHGs) in contrast to conventional fossil fuels. The application of bioenergy offers an alternative to fossil fuels while also aiding in waste management, fostering rural development, and enhancing agricultural productivity. As the world continues to grapple with the effect of carbon dioxide emissions emanating from fossil fuels, researchers, innovators, and policymakers are seeking innovative ways of reducing the carbon footprint associated with fossil fuels and improving energy efficiency. Biomass, an energy source that can be renewed, is a compound of carbon, hydrogen, and oxygen, with a minor presence of nitrogen and a small quantity of other atoms

[1]Environmental & Engineering Services, Bodley Company Limited, New Bodija, Ibadan, Oyo State, 234, Nigeria.
[2]Department of Mechanical Engineering, Covenant University, Ota, Ogun State, 234, Nigeria.
*email: ellis772000@yahoo.com

including alkaline earth and heavy metals, and is seen as a game changer in the reduction of carbon dioxide emissions.

It is noteworthy that biomass, being stored in solar energy, remains accessible year-round. Power plants relying on biomass could theoretically operate year-round with plant load factors surpassing 70%, making their performance comparable to centralized power stations in terms of investment and operational expenses [6, 7]. According to Dasappa [5], the performance aspect of biomass is rarely matched by other renewable resources such as wind, solar, and hydro in electricity generation. Yet the utilization of biomass-derived fuels such as producer gas and biogas for various purposes is perhaps the lowest among all renewables.

Electricity generation from biomass will help in reducing overreliance on electricity generation from gas and coal-powered turbines, thereby lessening carbon emissions into the atmosphere. Biomass electricity generation has better economic and ecological benefits [8]. It can replace the demand for coal consumption required by traditional coal-fired electricity generation [9] and can equally help in addressing the environmental pollution associated with agricultural and forestry wastes, through recycling and utilization of biomass resources [10].

Adopting biomass energy holds the promise of significantly diminishing GHG emissions. When biomass is burned, it emits approximately the same quantity of carbon dioxide as fossil fuels. Nonetheless, while fossil fuels release carbon dioxide trapped by photosynthesis millions of years ago, constituting essentially "new" GHG emissions, biomass releases carbon dioxide that is primarily offset by the carbon dioxide absorbed during its own growth (contingent upon the amount of energy expended in its cultivation, harvesting, and processing) [11]. According to the International Renewable Energy Agency [12] report, bioenergy accounted for about 70% of global renewable energy use in 2019, out of which 25% was used in the transport sector in the form of liquid biofuel.

The conventional method of combustion of fossil fuels such as crude oil, natural gas, and coal for the production of transportation fuels and generation of electricity has been established over several decades. However, there is a growing global concern for the release of GHG, particularly carbon dioxide into the atmosphere [3]. In the global carbon dioxide emission index, Sub-Saharan Africa emits less compared to China, the United States, and other highly industrialized nations. Nevertheless, there is a need for Sub-Saharan Africa to transition from high dependence on fossil fuels, including coal, to renewable energy sources like biomass to meet its growing energy demand for transportation and electricity generation. Therefore, this article reviews the potential of biofuels in Sub-Saharan Africa. It also highlights the reasons why biofuel is essential for the transition to cleaner fuels in Sub-Saharan Africa, and the challenges militating against the penetration of biofuel in the region are identified.

## 2. Methods

The study adopted a systematic search of published literature to find relevant articles that highlight the bioenergy potential and statistics in Sub-Saharan Africa, the reasons why biofuel is suitable, and the barriers hindering the development of biofuel. Major databases consulted include Science Direct, Springer, Google Scholar, Scopus, and MDPI, among others. Literature related to bioenergy from international agencies portals such as International Renewable Energy Agency (IRENA), American Petroleum Institute, Energy Information Administration (EIA), and United Nations Industrial Development (UNIDO) was also consulted. As much as possible, the authors tried to consult extant literature published in the last four years. However, when necessary for anecdotal evidence, literature older than four years was consulted. The scope of this review is limited to biofuels in Sub-Saharan Africa, but there were instances where Europe, America, Japan, Australia, and Brazil were mentioned for the sake of emphasis.

### 2.1. Renewable energy situation in Sub-Saharan Africa

Energy is the foundation of the modern-day economy and virtually everything done by humans today, which depends upon one form of energy or the other [13]. A stable and affordable energy supply is an indispensable basis for the successful development of countries in Sub-Saharan Africa [14]. The majority of countries in Sub-Saharan Africa currently grapple with epileptic power supply and millions of households do not have access to grid electricity. According to the IEA [15] report, about 598.8 million people in Sub-Saharan Africa do not have access to electricity. What this implies is that about half of the population lack access to electricity. Sub-Saharan Africa is endowed with a large quantity of renewable and non-renewable energy resources. Despite the large potential of renewable and non-renewable energy resources in Sub-Saharan Africa, the region continues to face critical energy challenges [16].

Meeting the energy needs of more than half of the population in Sub-Saharan Africa, who do not have access to electricity and other cleaner fuels, has become a developmental dilemma facing governments. With poor infrastructure and low technological advancement, the process of generation, transmission, and distribution of grid electricity is a major challenge for most countries. In this regard, renewable energy stands as the most viable, efficient, and environmentally friendly way of energy access to millions of people who do not have access to grid electricity in Sub-Saharan Africa. Although renewable energy is more environmentally clean and sustainable than fossil fuels, obtaining financing for it in Sub-Saharan Africa is more difficult than for fossil fuels. This could partly be ascribed to a lack of knowledge of renewable energy technologies and high production costs [17].

### 2.2. Biofuel potential in Sub-Saharan Africa

A large percentage of biofuels produced globally are generated from highly industrialized nations such as Japan, the United States, Australia, and the European Union, in efforts to reduce carbon emissions from fossil fuels. However, in poor developing regions, like Sub-Saharan Africa, biofuels are perceived as a catalyst for reducing dependence on high international oil prices, boosting the continent's energy sector and creating employment opportunities [18]. Biofuels are increasingly penetrating into the energy sector and their demand as alternatives to fossil fuels (petroleum and coal) is increasing [19]. Globally, biofuels are becoming increasingly attractive as an alternative to fossil fuels. The surge in promotion, development, adoption, and utilization of biofuels stems from the concerns over dwindling supplies, increasing demand for clean energy, and negative environmental and health impacts resulting from the use of fossil fuels [3, 20–22]. According to Abila [19], another factor that has brought about a surge of interest in biofuels in both developed and developing countries is the increasing cost of petroleum products and concerns about carbon emissions associated with the high consumption of petroleum products. Harnessing biomass for fuel, biopower, and bioproducts has important effects on international energy policy, the economy, and rural development [3]. It reduces overdependence on crude oil-producing nations and supports rural economies through job creation and provision of additional income sources [23]. Bio-derived materials offer various energy options. Specific crops can be utilized for ethanol production, which can be mixed with gasoline to create vehicle fuel. Ethanol serves as a cleaner substitute for wood or charcoal in cooking stoves. Alternatively, second-generation biomass or its byproducts can be combusted to generate electricity [24].

Sub-Saharan Africa possesses a vast array of bioenergy resources, offering significant potential to satisfy the increasing need for modern energy services across the continent. Enhancing the utilization of biomass-based energy holds promise in advancing energy accessibility. As biomass resources are intricately linked with agricultural practices and land utilization, appropriately crafted investments in bioenergy can enhance agricultural efficiency, localize energy provision, mitigate GHG emissions, diminish deforestation, stimulate economic activities along the supply chain, deliver social benefits, and empower underprivileged communities in Sub-Saharan Africa [25]. Besides the biomass resources, Sub-Saharan Africa is endowed with other renewable energy sources such as hydro, solar, wind, and a host of others. Owing to the vast array of renewable energy resources in Africa, there has been a regional quest for generation and distribution of renewable fuels in the last two decades [5, 26, 27]. The quest for renewable fuels in the energy mix of Sub-Saharan Africa has led to the development of biogas, bioethanol, biodiesel, and other biochemicals produced from agricultural, industrial, and domestic resources [28]. Among the biofuels, bioethanol and biodiesel have been commercialized in some countries in Sub-Saharan Africa and are seen as economically viable renewable fuels that are reliable, clean, and easily accessible [19, 29].

Liquid biofuel policies aiming at addressing climate change, ensuring energy stability, particularly amidst fluctuating oil prices and diminishing petroleum reserves in numerous developed nations, have spurred worldwide attention toward cultivating bioenergy crops. The bio-economy readiness index of some Sub-Saharan African countries for climate action reveals that Kenya ranked second in the world, while Tanzania ranked eleventh [30]. Sub-Saharan Africa has suitable climatic and soil conditions for the production of biomass. However, the economic viability will largely be influenced by farm management practices and government policies. Some countries in Sub-Saharan Africa have made appreciable progress in bioenergy production. In Sudan, about 50% of the country's total ethanol in 2020 was produced from sugarcane, with annual production of about 60 million liters of bioethanol and 50 million liters of biodiesel [31]. In Kenya, bioethanol production in 2016 was about 413 megaliters (ML) [32]. Realizing the environmental and health benefits of replacing biomass (charcoal and fuelwood) with clean cooking fuels such as ethanol, the Kenyan government created an ethanol cooking fuel industry master plan, which encourages businesses that deliver clean cooking solutions. KOKO Networks, a Nairobi-based energy company, was one such company launched in 2019 to deliver clean cooking solutions. The company uses ethanol from Vivo Energy Plc (operating under a license from Shell) and sells ethanol directly to end-users (households). KOKO sells specialized ethanol stoves at subsidized rates and has a vast network of fuel automated teller machines (ATMs) to supply clean and affordable cooking solutions to homes in rural and urban centers [33]. Whitehouse [34] noted that the ethanol market for urban cooking in Kenya alone has a potential value of about $600–800 million, and significant potential exists for the maturation of additional markets on the continent. In Mali, various ongoing biofuel initiatives are currently under way. One such initiative is the Mali-Folkecenter Nyetaa (non-governmental organization (NGO)) project that assists farmers in growing Jatropha oil seeds. The communities around Mali-Folkecenter Nyetaa are provided with electricity generated from power plants powered by Jatropha oil seeds. The project has set up a 15-year electrification plan aimed at generating about 300 KW of electricity for over 10,000 rural households. More than 100 hectares of Jatropha is expected to be established for the feedstock [32]. In Zambia, Shane and Gheewala [35] estimated biogas production from animal dung to be $1.473 \times 10^9$ m³ and $1.819 \times 10^9$ m³ from crop residue. Also, the prospects of biogas use for rural electrification in a hybrid configuration joining biogas with photovoltaic, wind, and pumped hydro in Cameroon showed good results [36].

The provision of clean cooking fuel from high-quality charcoal briquettes produced from local bamboo has gained prominence in Uganda through a company called Divine Bamboo established in 2016. Divine Bamboo is the largest producer of bamboo seedlings in Uganda [37]. The company trains youths and rural women on how to grow sustainable bamboo plantations specifically for energy production purposes. They are supplied with seedlings and have access to biomass technologies that offer them the opportunity to produce bamboo briquettes, which simultaneously provide additional income, meet their in-house fuel needs, and contribute to protecting the environment. The technological component involves the use of efficient and improved conversion technologies to carbonize bamboo. The technologies used include a drum carbonizer, which is a simple and easy-to-fabricate carbonizer with a lid and an inner cone to which a chimney is attached. Generally, the technology is about 40% more efficient than conventional conversion technology; a retort, which is a built carbonizer consisting of a cavity wall, a lid, a grate, a chimney with an air control mechanism and an outlet where the char is collected [37].

In Ethiopia, the Gaia Association (now Gaia Clean Energy) and the Former Women Fuelwood Carriers' Association initiated a project on clean energy. The project aimed to demonstrate the viability of ethanol micro-distilleries in Ethiopia. Gaia worked with the selected contractor, Spectrum Technologies of Unity, Saskatchewan, Canada, to procure and install the distillery and also produce ethanol cooking stoves. Based on conservative estimates, baseline documentation, and ongoing ethanol stove monitoring and evaluation, the project mitigates up to 6,000 tonnes of $CO_2$ per year. This will be sold as carbon credits once the program reaches critical mass and is validated (i.e., once 10,000 stoves are in use in Addis Ababa) [37].

Compared to other countries, South Africa has advanced its bioenergy production and utilization. Biojet fuel has been produced from the energy-rich oilseeds of Solaris, a nicotine-free variety of tobacco. A certified 30% Biojet from Solaris blended with aviation fuel was used to power a Boeing 737-800 passenger flight from Johannesburg to Cape Town in 2016 [38]. No other country in Sub-Saharan Africa has achieved such a significant feat in renewable energy adoption. In Mozambique, various initiatives toward biofuel production have been implemented. For example, the Ndzilo production plant has the capacity to produce two million liters of ethanol, while the production of biodiesel from Jatropha oil seeds has been gaining increasing attention [39]. The Mozambique government has equally initiated a policy of blending between 5% and 10% of ethanol with petrol.

In Nigeria, bioethanol, biogas, and biodiesel are produced. However, biogas is more feasible at an industrial scale compared to biodiesel, which is still in the infancy stage. The feedstock required (animal wastes, crop residues) for biogas is readily available in Nigeria and does not pose the threat of deforestation. Nigeria is the highest producer of cassava in the world [40, 41] and produces about 75% of Africa's output [41]. Cassava is the main feedstock for ethanol production in Nigeria. One of the major biofuel companies, the Nigeria Yeast and Alcohol manufacturing plant, plans to establish a 200 million USD ethanol plant, with a targeted production of 30 million liters annually [42]. It is estimated that Nigeria generates 227,500 tonnes of fresh animal wastes daily and about 6.8 million cubic meters of biogas is produced daily from fresh animal waste [43]. Animal waste accounts for about 61 million tonnes of Nigeria's yearly energy reserve [44]. Nigeria is ranked fourth in total primary energy supply from bioenergy behind the United States, India, and China [45]. According to data from IRENA [46] on the biomass potential of some countries in Sub-Saharan Africa (see **Figure 1**), at 25% collection of harvest residue, the net available residue for biofuel in Ghana would range between 0.24 exajoules (EJ) and 0.40 EJ, between 0.25 EJ and 0.43 EJ in Mozambique, 1.24 EJ and 2.09 EJ in Nigeria, 0.21 EJ and 0.42 EJ in South Africa, and 0.31 EJ and 0.53 EJ in Uganda.

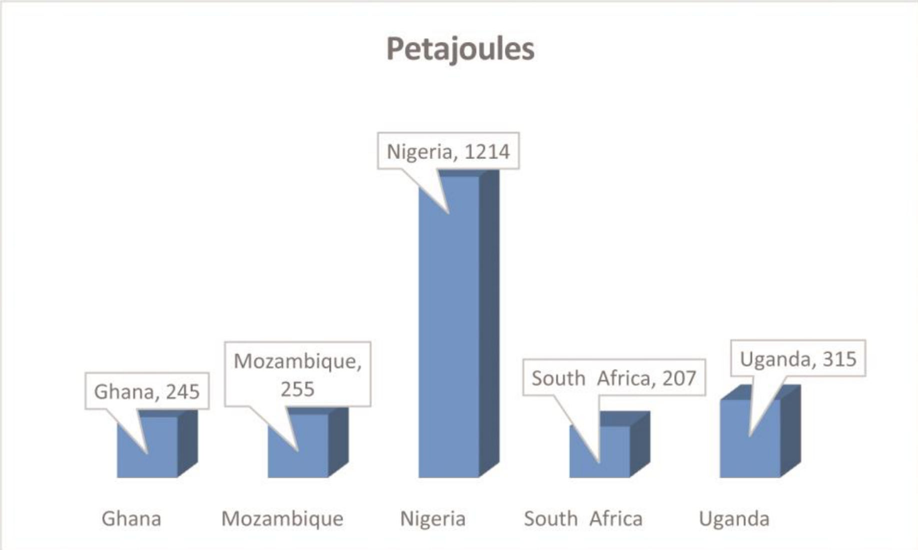


**Figure 1** • Projected biomass residue potential for fuel 2050.
Data Source: IRENA [46].

In terms of bioethanol production from agricultural waste (see **Figure 2**), Swaziland produces about 480 ML followed by Kenya (413 ML), Sudan (408 ML), Tanzania (254 ML), and the least being Guinea (10 ML). It could be seen from the chart that molasses and sugarcane are popular feedstock for bioethanol production in many Sub-Saharan African countries.

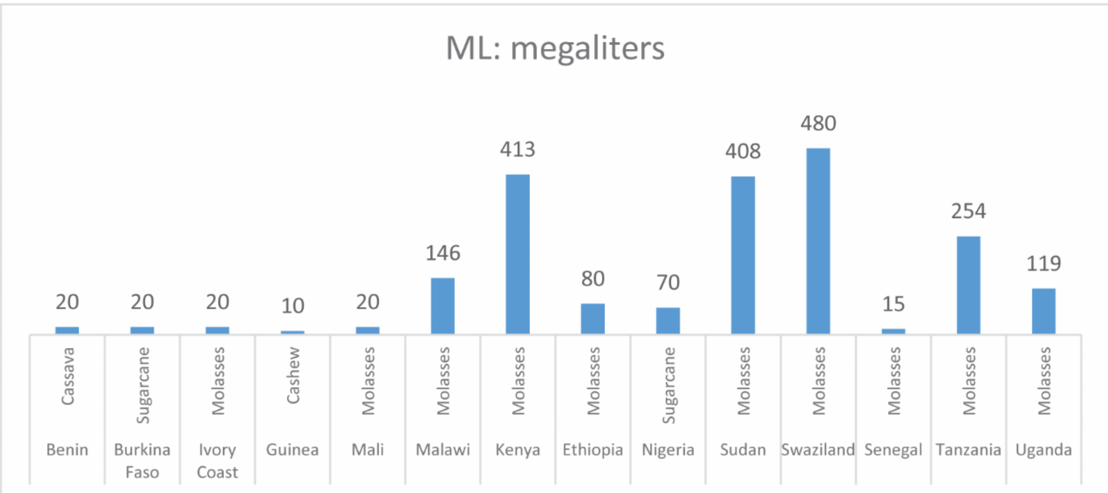


**Figure 2** • Biofuel production from agricultural waste in Sub-Saharan African countries.
Data Source: American Petroleum Institute [32].

The potential growth of biofuel in Africa has started to attract external interest. An Italian Company Eni in 2022 completed the construction of an oilseed collection and processing facility in Kenya that serve as source of raw material for non-food vegetable oil used for biofuel production [47]. The company plans to construct additional processing facilities in several other African countries including Mozambique, Benin, Angola, the Democratic Republic of Congo, Rwanda, and Ivory Coast. Also, the company is working on developing a facility capable of converting agricultural waste into bioethanol for blending with gasoline [48]. All these are attempts to improve the availability of feedstock from non-food biomass for biofuel production in Africa through technology [49].

## 2.3. Why biofuel?

The quest for bioenergy as an alternative to fossil fuels in Sub-Saharan stems from the current economic reality in the region. The majority of countries in the region are grappling with energy crisis. Industries are closing down due to the high cost of powering diesel-generating sets. Over the past four years, the global price of crude oil has been increasing, leading to higher energy costs. For poor developing countries, harnessing renewable energy resources, biomass in particular, presents an opportunity to address their energy challenges. Therefore, biofuel is seen as a pathway for Sub-Saharan African countries in addressing the energy challenge in the region and also reducing carbon dioxide emissions associated with fossil fuels. The following are some of the reasons why biofuel is the preferred alternative for Sub-Saharan African countries.

### 2.3.1. Reduction in the amount spent on importation of crude oil

The non-oil-producing countries in Sub-Saharan Africa such as Sierra Leone, Somalia, Sudan, Togo, Burkina Faso, Cape Verde, Chad, Comoros, Eritrea, Gambia, Benin, Guinea, Liberia, Mauritania, Senegal, and Seychelles spend greater portion of their national income on importation of fossil fuel (crude oil) and gas, which has a huge financial burden on their economy [50]. The price of crude oil is predicted to double in non-oil-producing countries compared to oil-producing countries [18]. In this regard, harnessing the bioenergy potentials in non-oil-producing Sub-Saharan African countries as an alternative fuel source for transportation and electricity generation will help in reducing the amount of foreign exchange used for the importation of crude oil. Barry et al. [51] maintained that switching to alternative fuels by Sub-Saharan African countries will help in reducing the region's dependence on fossil-based fuels, give more people access to electricity, and be cost-effective in terms of generation.

Biofuel has the long-term potential of boosting the energy sector of oil-importing countries. Another major interest of Sub-Saharan African countries in bioenergy is the struggle to liberate their dangling economies from the overdependence on the crude oil business, which has reduced the overarching chances of competition and authority. Thus, renewable energies are being seen as a possible replacement for fossil fuels especially in automobiles and other internal combustion engines when used either in pure form or blended with gasoline [25].

### 2.3.2. Development of agriculture value chain

Sub-Saharan Africa is blessed with favorable climatic conditions, fertile soil, and enormous land mass for the cultivation of crops, which will serve as food for its teeming population and feedstock for biofuel production. Farmers can grow specific crops that are used for biofuel production and then receive incentives from local biofuel industries. Organic residues from food crops that are inexpensive and are considered waste materials can be used in the production of biofuels. The majority of the rural population in Sub-Saharan Africa live in poverty and bioenergy production will help in developing the rural farming systems through the cultivation of some crops such as Jatropha oil, which will enhance their income.

### 2.3.3. Environmental sustainability

Based on the 2015 Paris Climate Change Agreement, slowing down the rise in global temperatures to below "2°C and limit to 1.5°C" by the end of this century cannot be achieved without the incorporation of biofuel into the energy mix of various nations [52]. Biofuels have the potential to reduce GHG emissions compared to fossil fuels. However, the rate of reduction in GHG emissions varies greatly, depending on the feedstock and biofuel [53]. The first-generation biofuels from food crops have faced criticism due to competition with food production and sustainability issues. However, the second- and third-generation biofuels made from non-food raw materials such as agricultural residues and algae offer a more favorable balance and lesser environmental impact [54]. In the transportation sector, biofuels can play an important role in GHG emissions reduction [55]. Biofuels produced in African countries can enable low-carbon transportation on the continent. By 2035, energy demand for road transportation in Africa will increase by almost 40%, and the expected increase in a number of vehicles will come from used (second-hand) light-duty vehicles that are diesel and gasoline powered rather than electric, which are imported from Europe, United States, and Japan [56]. In this regard, promoting biofuels in the transportation sector in Africa will reduce the carbon dioxide emissions associated with the status quo. In addition to providing low-carbon fuel in the transportation sector, biofuel industry development in Africa will help in expanding access to clean cooking. An estimated 940 million people in 2020 (about 85% of the population) across the continent are using coal, charcoal, and fuelwood (biomass) for cooking, which have debilitating effects on the environment [49].

### 2.3.4. Cost of installation

Installation of big hydropower or gas turbines for electricity generation is capital intensive. Some countries in Sub-Saharan do not have the financial resources to embark on such projects. Thus, they depend on partnership or funding from International Monetary organizations such as the World Bank, the African Development Bank, and other donor agencies. Investment in bioenergy may not require huge capital such as big hydro and gas turbine projects. For example, in 2023, Zimbabwe expanded its 920 MW Hwange thermal station by adding 300 MW units at a cost of $1.4 billion, with about 85% of the funding coming from China (www.reuters.com). However, to establish a biopower plant in Nigeria, using 50 tonnes of sugarcane bagasse to generate 130 MWh of electricity will cost about $89 million [57].

## 2.4. Barriers to biofuel development in Sub-Saharan Africa

Bioenergy development has been extremely constrained with a low success rate of commercial deployment in Sub-Saharan Africa. Key barriers to its commercial utilization span various aspects covering biomass resource, technology, economics, finance, and institutional and regulatory frameworks. High dispersal, poor supply infrastructure, and high sourcing costs are some of the biomass resource-related barriers. However, technical barriers include poor understanding among local players of feedstock technology and lack of technologies that are suited for the African context. Financial barriers manifest in the form of high costs of pre-treatment and conversion and poorly tested business models. Institutional barriers include inadequate interfacing between different supply chain stages and actors, alongside unfavorable institutional and regulatory frameworks [58].

The economic factors hindering bioenergy production in the region include the availability of raw materials, plant capacity, and processing technology [59]. There have been concerns about conflicts with food production, as land that could be used for food crop cultivation may be diverted to cultivation of non-edible oleaginous (e.g., Jatropha oil seeds). The skepticism with regard to the usage of land for biofuel production in Sub-Saharan Africa is because a vast majority of the countries are primarily dependent on agriculture as a means of survival [18]. Also, many Sub-Saharan African countries have not attained food sufficiency; thus, using food crops such as cassava, sorghum, sugarcane, and others as feedstock for biofuel production will exacerbate hunger in some countries. In some countries in Africa, concerns surrounding food security have resulted in governments actively cautioning against the development of bioenergy [60]. Local food production can be displaced by the production of biofuel crops if local farmers lose their land, either by selling or being taken, or if they switch to biofuel crop production themselves [61]. Liquid biofuel production is an inter-sectoral industry, and its economic viability depends on the policies of different sectors [30]. Policy relating to land administration in most Sub-Saharan African countries is overlapping, with no clearly defined role on jurisdiction and control. For example, in Ethiopia, Gebreegziabher et al. [62] noted that land allocation for bioenergy production was allocated by the Federal Government, Regional Governments, the Ministry of Agriculture, and the Ministry of Investment, which makes it difficult to know what hectarage of land was planted with biofuel crop or other agricultural crops, how much is the productivity per unit area, and what inputs are required. The use of different institutions according to Gebreegziabher and colleagues resulted in duplicating the same piece of land to different investors and different management plans proposed for the same piece of land. Besides the aforementioned, bioenergy development in Sub-Saharan Africa has been stalled by strong but non-favorable government policy imperatives and vested interests of different stakeholders at all levels (local, state, national, and international), multi-national agencies, organized private sector, and NGOs. The interest of these stakeholders is manifested in the dictatorship in feedstock selection and usage, with Jatropha and sugarcane being the most contentious ones [25]. Another major factor hindering bioenergy expansion in the region is the concern for the environment. Forests and green vegetation serve as carbon sink, and cultivating large hectares of land for bioenergy plants could lead to the depletion of forests and the emission of carbon dioxide into the atmosphere culminating in the incidence of global warming and climate change. All these factors have become issues in biofuel expansion and development in Sub-Saharan Africa.

### 2.5. Way forward

Despite the identified barriers to bioenergy production and expansion in Sub-Saharan Africa, biofuel has been seen as a potential catalyst to stimulate African development [63]. Biofuel feedstock production is a land-intensive and potentially a labor-intensive process: factors that would seem to make it well suited to the Sub-Saharan African situation [60]. Thus, some areas that need attention for bioenergy development in Sub-Saharan Africa include:

i. Formulation of right policy on land administration/tenure for agriculture and bioenergy, taking into consideration the differences in socio-political settings in each country.

ii. Adoption of the latest technologies and technical know-how in the bioenergy sector.

iii. Reduce the competition on food crops with bio-feedstock through a selection of suitable feedstock.

iv. Integration of local finance and microfinance institutions that understand local markets, conditions, clients, and additionally engaging international institutions, such as multilateral and bilateral donors, for sustainability of liquid biofuel production.

v. Long-term planning and targets by governments, low-interest rate loans, preferential taxes, and mandatory blending consumption of biofuels.

vi. Pre-investment assessment of the environmental and social impact of bioenergy development in terms of plant establishment and farms for cultivation of feedstock.

vii. Establishment of large-scale production plants with cutting-edge technologies to ensure that the market is strong with high-energy yield, thus making biofuel economically competitive to fossil fuel.

## 3. Conclusion

The key to address energy access to millions of people in Sub-Saharan Africa without access to clean energy lies in bioenergy. The region is endowed with vast arable land and good climatic and soil conditions that are necessary for the production of biofuel feedstock. Currently, in Sub-Saharan Africa, bioethanol and biodiesel are obtained from a wide variety of sources such as cassava, sugarcane, Jatropha, molasses, and cashew. The rising cost of crude oil in the international market and the quest to reduce carbon dioxide emissions accompanying fossil fuel consumption position biofuel as the best alternative for countries in Sub-Saharan Africa. Both the oil-producing and non-oil-producing countries in Sub-Saharan Africa are battling with the energy crisis. For oil-producing countries such as Nigeria, the government's decision to remove subsidy on petroleum products has exacerbated poverty and economic hardship for millions of people. However, for the non-oil-producing countries, the rising price of crude oil in the international market means that more foreign exchange is required for the importation of petroleum products. Adoption of bioenergy is one of the ways countries in Sub-Saharan Africa could use it to address energy poverty and climate change. Sub-Saharan Africa with similar climatic condition such as Brazil should emulate the experience Brazil has had with biofuel development. Brazil is the world's leader in biofuels. It achieved this feat through right policies on biofuel production such as mechanized agriculture on huge plantations to provide the needed feedstock and the use of advanced biofuel conversion processes.

## Funding

The authors declare no financial support for the research, authorship, or publication of this article.

## Author contributions

Conceptualization, S.E.E.; resources, K.O.; writing – original draft preparation, S.E.E.; writing – review and editing, K.O. All authors have read and agreed to the published version of the manuscript.

## Conflict of interest

The authors declare no conflict of interest.

## Data availability statement

Data supporting these findings are available within the article, at https://doi.org/10.20935/AcadEnergy6227, or upon request.

## Institutional review board statement

Not applicable.

## Informed consent statement

Not applicable.

## Sample availability

The authors declare no physical samples were used in the study.

## Additional information

Received: 2024-04-01

Accepted: 2024-05-04

Published: 2024-05-24

*Academia Green Energy* papers should be cited as *Academia Green Energy 2024*, ISSN pending, https://doi.org/10.20935/AcadEnergy6227. The journal's official abbreviation is *Acad. Energy*.

## Publisher's note



## Copyright



## References

1. Schoene D, Killmann W, vonLüpke H, Loyche Wilkie M. Definitional issues related to reducing emissions from deforestation in developing countries. FAO. 2007;5:1–26.
2. Rutz D, Janseen R. Biofuel technology handbook—draft version, WIP renewable energies, project report: biofuel market place; 2007. p. 152.
3. Ben-Iwo J, Manovic V, Longhurst. Biomass resources and biofuels potential for the production of transportation fuels in Nigeria. Renew Sust Energy Rev. 2016;63:172–92.
4. Cherubini F. The bio-refinery concept: using biomass instead of oil for producing energy and chemicals. Energy Convers Manag. 2010;51:1412–21. doi: 10.1016/j.enconman.2010.01.015
5. Dasappa S. Potential of biomass energy for electricity generation in Sub-Saharan Africa. Energy Sust Dev. 2011; 15(3):203–13.
6. Dasappa S, Subbukrishna DN, Suresh KC, Paul PJ, Prabhu GS. Operational experience on a grid connected 100 kWe biomass gasification power plant in Karnataka, India. Energy Sust Dev. 2011;15:231–9.
7. Ravindranath NH, Somashekar HI, Dasappa S, Jaysheela Reddy CN. Sustainable biomass power for rural India: case study of biomass gasifier for village electrification. Curr Sci. 2004;87(7):932–41.
8. Xin-gang Z, Wei W, Shuran H, Xuan L. Impacts of government policies on the adoption of biomass power: a system dynamic perspective. Sustainability. 2023;15:1723. doi: 10.3390/su15021723
9. Li Y, Lin J, Qian Y, Li D. Feed-in tariff policy for biomass power generation: incorporating the feedstock acquisition process. Eur J Oper Res. 2023;304:1113–32.
10. Energy Information Administration (EIA). Biomass explained. 2021 [cited 2024 Mar 29]. Available from: https://www.eia.gov
11. National Renewable Energy Laboratory (NREL). Biomass energy basics. A national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. 2024 [cited 2024 Apr 12]. Available from: https://www.nrel.gov/research/re-biomass.html
12. International Renewable Energy Agency (IRENA). Global renewables outlook: energy transformation 2050. Abu Dhabi: IRENA; 2020. ISBN 978-92-9260-238-3. Available from: www.irena.org/publications36
13. Eluwa SE, Ali NE, Kilanko O. Renewable energy and green technology adoption: a viable option for efficient energy supply in Nigeria: barriers and government policies. J Sustain Energy Environ. 2021;12:87–95.
14. Präger F, Paczkowski S, Sailer G, Sarfo N, Derkyi A, Pelz S Biomass sources for a sustainable energy supply in Ghana—a case study for Sunyani. Renew Sustain Energy Rev. 2019; 107:413–24.

15. IEA. Access to electricity improves slightly in 2023, but still far from pace needed to meet SDG7. 2023. Available from: https://www.iea.org/publications

16. Eluwa SE, Ho CS, Kilanko O. Renewable energy provision in Africa. ARPN J Earth Sci. 2015;4(1).

17. International Renewable Energy Agency (IRENA). Africa's renewable future. The path to sustainable growth. Abu Dhabi; 2010. Available from: www.irena.org/publications

18. Sekoai PT, Yoro KO. Biofuel development initiatives in Sub-Saharan Africa: opportunities and challenges. Climate. 2016; 4:33. doi: 10.3390/cli4020033. Available from: https://www.mdpi.com/journal/climate

19. Abila N. Biofuels adoption in Nigeria: analysis of sustainability and policy issues. Acta Wasaensia. 2014;311, ISSN 0355-2667.

20. Abila N. Biofuels development and adoption in Nigeria: synthesis of drivers, incentives and enablers. Energy Policy. 2012;43:387–95.

21. Doku A, Falco SD. Biofuels in developing countries: are comparative advantages enough? Energy Policy. 2012;44: 101–17.

22. Mintz-Habib N. Malaysian biofuels industry experience: a socio-political analysis of the commercial environment. Energy Policy. 2013;56:88–100.

23. Demirbas A. Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. Energy Convers Manag. 2008;49:2106–16. doi: 10.1016/j.enconman.2008.02.020

24. Payton B Bioenergy offers Africa a sustainable future. 2022 [cited 2024 Mar 18]. Available from: https://african.business/2022/11/energy-resources/africa-faces-challenges-in-developing-bioenergy

25. Dahunsi SO, Fagbiele OO, Yusuf EO. Bioenergy technologies adoption in Africa: a review of past and current status. J Clean Prod. 2020;264:121683.

26. Rahman MA, Aziz MA, Ruhul AM, Rashid MM. Biodiesel production process optimization from Spirulina maxima microalgae and performance investigation in a diesel engine. J Mech Sci Technol. 2017;31(6):3025–33.

27. Su X, Xu J, Liang B, Duan H, Hou B, Huang Y. Catalytic carbon dioxide hydrogenation to methane: a review of recent studies. J Energy Chem. 2016;25(4):553–65.

28. Mungwe JN, Colombo E, Adani F, Schievano A. The fixed dome digester: an appropriate design for the context of Sub-Sahara Africa? Biomass Bioenergy. 2016;95:35–44.

29. Alfa MI, Adie DB, Igboro SB, Oranusi US, Dahunsi SO, Akali DM. Assessment of biofertilizer quality and health implications of anaerobic digestion. Renew Energy. 2014;63:681–6.

30. Miftah FK, Mutta D. Potential markets and policies for sustainable liquid biofuel production with emphasis to Eastern Africa countries: a review. Energy Sustain Soc. 2024; 14:1. doi: 10.1186/s13705-023-00428-x

31. Khayal OM, Suleiman OI. Prospects of renewable energy in Sudan. Glob J Eng Sci. 2022;10:1–10. doi: 10.33552/GJES.2022.10.000742

32. American Petroleum Institute. Renewable fuel standard. 2016 [cited 2024 Mar 15]. Available from: http://www.epa.gov/otaq/

33. Sguazzin A, Genga B. Koko networks provides Kenyans with cheaper, greener cooking fuel. Financial Mail. 2022 Nov 1, Available from: https://www.businesslive.co.za/bloomberg/news/2022-11-01-koko-networks-provides-kenyans-with-cheaper-greener-cooking-fuel

34. Whitehouse D. Ethanol for cooking can help reduce Africa's energy poverty. Africa Report. 2019, June 25. Available from: https://www.theafricareport.com/14506/ethanol-for-cooking-can-help-reduce-africas-energy-poverty

35. Shane A, Gheewala SH. Missed environmental benefits of biogas production in Zambia. J Clean Prod. 2017;142:1200–9.

36. Yimen N, Hamandjoda O, Meva'a L, Ndzana B, Nganhou J, Yimen N, et al. Analyzing of a photovoltaic/wind/biogas/pumped-hydro off-grid hybrid system for rural electrification in Sub-Saharan Africa—case study of Djoundé in Northern Cameroon. Energies. 2018;11(10):2644. doi: 10.3390/en11102644

37. UNIDO. The role of bioenergy in the clean energy transition and sustainable development. Lessons from developing countries; 2021. Available from: https:// www.unido.org

38. Biofuels Digest. Boeing, South African Airways, Mango mark Africa's first commercial flights with sustainable aviation biofuel. 2016 [cited 2024 Apr 18]. Available from: https://www.biofuelsdigest.com/bdigest/2016/07/17/boeing-south-african-airways-mangomark-africas-first-commercial-flights-with-sustainable-aviation-biofuel/

39. Amigun B, Musango JK, Stafford W. Biofuels and sustainability in Africa. Renew Sustain Energy Rev. 2011;15(2): 1360–72.

40. Abila N. Biofuels adoption in Nigeria: a preliminary review of feedstock and fuel production potentials. Manag Environ Qual Int J. 2010;21:785–95. doi: 10.1108/14777831011077646

41. FAO. A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin. Proceedings of the Valid Forum on the Global Cassava Development Strategy. Rome: International Fund for Agricultural Development/Food and Agriculture Organization of the United Nations; 2005.

42. Duku MH, Gu S, Hagan EB. A comprehensive review of biomass resources and biofuels potential in Ghana. Renew Sustain Energy Rev. 2011;15:404–15. doi: 10.1016/j.rser.2010.09.033

43. Ishola MM, Brandberg T, Sanni SA, Taherzadeh MJ. Biofuels in Nigeria: a critical and strategic evaluation. Renew Energy 2013;55:554–60. doi: 10.1016/j.renene.2012.12.021

44. Mohammed YS, Mustafa MW, Bashir N, Mokhtara S. Renewable energy resources for distributed power generation in Nigeria: a review of the potential. Renew Sustain

Energy Rev. 2013;22:257–68. doi: 10.1016/j.rser.2013.01.020

45. Hänninen R, Hetemäki L, Hurmekoski E. European forest industry and forest bioenergy outlook up to 2050: a synthesis. Cleen/Fibic Research Report No D 1.1. 1, Helsinki, Finland; 2014.
46. IRENA. Biofuel potential in sub-Saharan Africa: raising food yields, reducing food waste and utilising residues. Abu Dhabi: International Renewable Energy Agency; 2017. ISBN 978-92-9260-041-9. Available from:www.irena.org
47. Eni. Eni launches the first production of vegetable oil for bio refining in Kenya, Eni, press release. [cited 2024 Apr 15]. Available from: https://www.eni.com/en-IT/media/press-release/2022/07/eni-launches-first-production-vegetable-oil-biorefining-kenya.html
48. Stafler RE. An energy change in Kenya: Eni is trying to develop biofuels that could transform the Kenyan Energy Industry and serve as a model for other African countries in the future. 2023 [cited 2024 Apr 16]. Available from: https://www.eni.com/en-IT/global-energy-scenarios/kenya-energy-change.html
49. Sparkman M, Tobin W, Zandi M. Policy sprint: building a biofuels industry in Africa. Washington (DC): Atlantic Council Global Energy Center; 2023.
50. Eberhard A, Foster V, Briceño-Garmendia C, Ouedraogo F, Camos D, Shkaratan M. Underpowered: the state of the power sector in Sub-Saharan Africa. Washington (DC): The International Bank for Reconstruction and Development; 2008.
51. Barry ML, Steyn H, Brent A. Selection of renewable energy technologies for Africa: eight case studies in Rwanda, Tanzania and Malawi. Renew Energy. 2011;36:2845–52.
52. Rogelj J, den Elzen M, Höhne N, Fransen T, Fekete H, Winkler H, et al. Paris agreement climate proposals need a boost to keep warming well below 2°C. Nature. 2016;534: 631–9; [cited 2024 Apr 8]. doi: 10.1038/nature18307
53. Mitchell D. Biofuels in Africa: opportunities, prospects, and challenges. Washington (DC): The International Bank for Reconstruction and Development/The World Bank; 2011.
54. Rial RC. Biofuels versus climate change: exploring potentials and challenges in the energy transition. Renew Sustain Energy Rev. 2024;196:114369.
55. IEA. Advanced biofuels – potential for cost reduction. Task 41 of the IEA Bioenergy Technology Cooperation Programme. 2020. Available from: https://www.iea.org/publications
56. African Energy Outlook. Global trade in used vehicles report. United Nations Environment Programme. 2022 [cited 2020 Oct 25]. Available from: https://www.unep.org/resources/report/global-trade-used-vehicles-report
57. Oyegoke T, Jibiril BE Design and feasibility study of a 5 MW bio-power plant in Nigeria. Int J Renew Energy Res. 2016; 6(4):1496–505.
58. NIRAS. Assessing the prospects and requirements for bioenergy development in seven demand sectors in Sub-Saharan Africa. 2021 [cited 2024 Mar 18]. Available from: https://www.niras.com/projects/bioenergy-for-sustainable-local-energy-services-and-energy-access-in-africa-bseaa-2/
59. Cansino JM, Cardenete MA, González-Limón JM, Román R. Economic impacts of biofuels deployment in Andalusia. Renew Sustain Energy Rev. 2013;27:274–82.
60. Von Maltitz G, Stafford W. Assessing opportunities and constraints for biofuel development in sub-Saharan Africa. Working Paper 58. CIFOR, Bogor, Indonesia; 2011.
61. Sielhorst S, Molenaar JW, Offermans D. Biofuels in Africa an assessment of risks and benefits for African wetlands. Wageningen: Wetlands International; 2008.
62. Gebreegziabher Z, Mekonnen A, Ferede T, Köhlin G. Profitability of biofuels production: the case of Ethiopia. Environment for development initiative. 2014 [cited 2024 Mar 7]. Available from: https://www.jstor.org/stable/resrep15006
63. Diaz-Chavez R. The role of biofuels in promoting socio-economic rural development. In: Rosillo-Calle F, Johnson FX, editors. Food versus fuel. London and New York: Zed Books; 2010.