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BIOFUELS AS A SUBSTITUTE SOURCE OF ENERGY IN NIGERIA: CHALLENGES, IMPACT AND PROSPECTS

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Abstract
Achieving an affordable clean energy in accordance to the Sustainable Development Goal (SDG 7) is a challenge in Nigeria and other African countries. Most of the currently used energy strategies are either not sustainable or poorly maintained. Nigeria is a major exporter of fossil fuel but currently faced with serious energy crisis, which necessitates the search for a sustainable renewable form of energy as substitute to fossil fuel in order to meet the SDG 7 target. Biofuel has been recognised as a sustainable form of renewable and alternative energy in Nigeria with sugarcane, cassava, plant seed and waste materials as possible feedstock for the production. The feedstocks are mostly obtainable and available nearly everywhere in Nigeria with the likelihood of maximizing them to drive social and economic growth to people and the nation at large. Using biofuel as renewable and alternative source of energy also has some challenges, impact and prospects. The challenges include social, economic, environmental and technical issues that arise from biofuel production and use. The social and economic issues include the 'food versus fuel' debate and the need to develop responsible policies and economic instruments to ensure sustainable biofuel production. The environmental concerns include deforestation, biodiversity loss and soil erosion. The impact of biofuel production is generally about the fewer emissions of greenhouse gases when burned in an engine and are generally considered carbon-neutral fuels as the carbon they emit has been captured from the atmosphere by the crops used in biofuel production. The prospects of biofuel as substitute source of energy in Nigeria are enormous; it will not only boost the economic development of Nigeria but will also ensure energy security. It was recommended that government should diversify it sources of energy from fossil fuel to biofuel as substitute and at the same time maximized her biomass resources for socio-economic growth.
Keywords: Biofuel, Alternative, Energy.

Introduction

Provision of cheaper and clean energy is one of the seventeen sustainable development goals, which is paramount in most countries of the world particularly Nigeria. Sustainable Development Goals interconnects with other goals since it plays a vital role in socio-economic development of a nation (Ramchandra and Boucar, 2011). Over the years, the need for energy has increased in many African countries due to rapid population growth, increase in small-scale industries and technological inventions. This demand is notably high in Nigeria being the most populous nation in Africa, with a population of about 220 million people growth in industrialization. Unfortunately, this demand is rarely met as access to affordable and clean energy in Nigeria faces several challenges. Consequences of this inaccessibility to energy include poverty, poor health services, decline in economic growth, unimplemented research and poor socio-economic imbalance (Oyedepo, 2012).

In Nigeria, energy consumption goes into household, industries, agriculture, transport and commercial sectors, hence, the need for more energy generation and more alternative sources (Emodi and Ebele, 2016). There is persistent inconsistency in the availability and market price of electricity and petroleum products in Nigerian energy sector reflecting the inefficiency to meet demand and makes the challenge more conspicuous. The country is rich in conventional energy sources, which comes mainly from crude oil, coal, natural gases, wind and solar. However, apart from the inefficiencies the energy sector faces the conventional energy sources have other issues such as being non-renewable and non-biodegradable and may encourage environmental degradation. Due to environmental issues cause by the conventional sources of energy, a suggestion has been made towards finding alternative to the conventional sources of energy in Nigeria. With the low level of scientific and technological development in Nigeria, the country depends on attracting foreign investors to assist in strengthening the energy sector and one key area of interest as an alternative is the renewable energy sources.

Interestingly, Nigeria is endowed with various renewable energy resources which biomass, hydropower, solar, wind and potentials for hydrogen utilization are the most abundant. To achieve the utmost use of these resources, the Nigerian government must shift attention towards biofuel industry with intensified efforts on the agricultural sector (Onuoha, 2010). This in effect will increase the support for renewable resources as alternative to fossil fuel in Nigeria and with the current state of environmental pollution; use of clean energy source which is environmentally friendly will be the ultimate alternative.

The exponential increase in industrialization, population growth and urbanization over recent years has resulted in a global energy crisis and concern regarding the dependence on non-renewable sources of energy. In terms of the environment, the burning of fossil fuels could emit gaseous pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NO_x), sulphur oxide (SO_x), volatile organic compounds (VOCs) and particulate matter (PM), which can change the composition of the atmosphere and thus have harmful effects on climate and public health. In an attempt to mitigate the damaging effects of climate change and public health due to greenhouse gas (GHG) emissions, the Paris Agreement, introduced in 2015, set a target to 'limit global temperature rise to 2oc above pre-industrial levels, while pursuing efforts to limit the increase to 1.5oc' (UNFCCC, 2015). An estimated 58% of fossil fuels are consumed by the transportation sector through roads, rail, air and water. In 2016, the transport sector alone was responsible for 16% of the total global GHG emissions, highlighting the pressing need for green alternatives to petrol and diesel (Ritchie and Roser, 2021).

A potential solution to reduce GHG emissions, stabilise the global climate, and improve energy security is to transit from the use of conventional fossil fuels towards greener, renewable sources of energy. Key renewable energy sources include solar, wind, hydro, geothermal and biofuel, all of these have the ability to provide energy services with reduced emissions of GHGs and air pollutants (Owusu and Asumadu-Sarkodie, 2016). Sustainable Development Goal (SDG), one of the 17 SDGs established by the United Nations General Assembly, aims to highlights the importance of international cooperation with the increased use of renewable energy sources. In addition, as countries strive to reduce poverty, they in turn increase urbanization and are becoming key contributors to the rising GHG emissions. At present, six (6) of the top ten (10) emitting countries are developing countries (Crippa et al., 2019).

Considering the different renewable energies, biofuels are arguably a potential renewable energy source in the transportation sector. Almost all other renewable energies, particularly solar, wind,

hydro and nuclear power sources, generate electricity and hence cannot equally compete with oil (Arutyunov and Lisichkin, 2017). There are multiple difficulties associated with electricity, which make these energy sources less appealing, such as transmission over long distances and conversion to different types of energy sources. In addition, biofuels can be used within current infrastructures and require less technological advances compared with other energy sources, based on this reason, both developed and developing countries focused on expanding their bioenergy market and set up intergovernmental strategies for the use of biofuels. The introduction of such policies, particularly in Europe, the US and some African countries has caused the biofuel industry to grow in the last decade with biofuels now representing around 3% of transport fuels in use globally (Timilsina, 2014).

Concept of Biofuels

Biofuels are combustible fuels produced from organic matter such as plant materials and animal wastes. They can exist in solid, liquid, and gaseous forms. However, many researches focus on liquid biofuels as they have the greatest potential to help decarbonize the transport sector due to easier integration with existing technology (Guo et al., 2015). Ethanol is currently the most widely used biofuel globally, accounting for approximately 80% of all liquid biofuel production. The use of global ethanol as a biofuel 9so-called, 'bioethanol') production has increased significantly in recent years, with the global production predicted to be over 135 billion Lt by 2024 with the largest contributions from the USA (42%) and Brazil (31%) biofuel industries (OECD/FAO, 2015).

Biofuel is an example of resource that can serve as substitute to the conventional fossil fuel in Nigeria and the world at large. Biofuel is a non-fossil fuel derived from biomass, it can be categorized as; bioethanol, biomethanol, biodiesel, biohydrogen and biogas (Amigun et al., 2011). Amid the different categories, bioethanol and biodiesel are the most common in Nigeria. Biofuels are fuels derived directly or indirectly from biomass. Biofuel used for non-energy purposes are excluded from the scope of energy statistics (for example wood used for construction or as furniture, biolubricant for engine lubrication and biobitumen used for road surface).

Biofuel can be split up into three main types: as highlighted by (Letcher, 2020)

1. Solid biofuels e.g. fuel wood, wood residues, wood pellets, animal waste, vegetal material etc.
2. Liquid biofuels e.g. bio gasoline, biodiesel, biojet kerosene, ethanol, bio alcohols, green diesel, straight vegetable oil, bioether, etc.
3. Biogases e.g. from anaerobic fermentation and from thermal processes e.g. biogas and biomethane, syngas, etc.

Solid biofuel covers solid organic, non-fossil material of biological origin (also known as biomass) which may be used as fuel for heat production or electricity generation. In energy statistics, solid biofuels is a product aggregate equal to the sum of charcoal, fuelwood, wood residues and by-products, black liquor, bagasse, animal waste, other vegetal materials and residuals and renewable fraction of industrial waste.

Liquid biofuels includes all liquid fuels of natural origin e.g. (produced from biomass and/or the biodegradable fraction of waste), suitable to be blended with or replace liquid fuels from fossil origin. In energy statistics, liquid biofuels is a product aggregate equal to the sum of biogasoline, biodiesels, biojet kerosene and other liquid biofuels.

Biogas is a gas composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass or by thermal processes from biomass, including biomass in waste. In energy statistics, biogas is a product aggregate equal to the sum of landfill gas, sewage sludge gas, other biogases from anaerobic digestion and biogases from thermal processes (Letcher, 2020).

Classification of Biofuels

Biofuels are categories into four based on the feedstock used in production, limitations as a renewable source, and technological progress. They include:

First generation biofuels: These are produced from edible feedstocks, such as bioethanol from corn and sugar cane, biodiesel from oil seed crops (soybean, oil palm, rapeseed and sunflower) using well understood, economically viable technologies and processes, such as fermentation, distillation and trans esterification (Astolfi et al., 2020). First generation biofuels only provide minimum benefit over fossil fuels in terms of greenhouse gas emissions as they require a large amount of energy from fossil fuels to grow, collect and process.

Second generation biofuels: These are produced from agricultural by-products or cellulosic materials such as wood, leaves and grass and can be grown on marginal land (Li et al., 2012). They are produced by converting cellulose into sugar units, which can be converted to ultimately produce alcohol. Cellulosic sources that grow alongside with food crops could be used for biomass, but this process takes away so many nutrients from the soil and would need to be restored nutrients by applying fertilizer. This process is both costly chemically and economically and time consuming, requiring sophisticated equipment and large-scale facilities.

Third generation biofuels: These are made from aquatic cultivated feedstock, that is, algae (Kumar et al., 2018). Algae have been known to have great potential as biofuel feedstock due ti their capabilities of producing much higher yields with reduced resource inputs (Daroch et al., 2013). The use of algae also has other environmental advantages, as a result of their ability to fix CO_2 which has been proposed as a method for removing CO_2 from flue gases from power plants, thus reducing GHG emissions (Choi et al., 2019).

Fourth-generation biofuels: These are found from the bioengineered microorganisms e.g. Bioengineered algae, yeast, fungi and cyanobacteria (Jiang et al., 2014). Second, third and fourth generation biofuels are commonly referred to as ‘advanced biofuels’ and thought to hold many advantages over first generation fuels, but they are still in the research and development phase and have not reached their full commercial potential.

Notable Impact of Biofuels

In general, biofuels emit fewer greenhouse gas emissions when burn in an engine and widely considered carbon-neutral fuels as the carbon emitted has been captured from the atmosphere by the crops used in biofuel production. However, life-cycle assessments of biofuels have shown large emissions associated with the potential land use change required to produce additional biofuel feedstock. If no land use change is involved, first-generation biofuels can on average have lower emissions than fossil fuels (Jeswani et al., 2020). However, biofuel production can compete with food crop production. Up to 40% of corn production in the United States is used to make ethanol and worldwide 10% of all grains is turned into biofuel. A 50% reduction in grain used for biofuels in the US and Europe would replace all of Ukraine’s grain export. Several studies have shown that reductions in emissions from biofuels are achieved at the expense of other impacts, such as acidification, eutrophication, water footprint and biodiversity loss (Jeswani et al., 2020).

A key benefit associated with the replacement of fossil fuels with biofuels is the reduced air pollution from motor vehicles (Zabbey and Olsson, 2017). Explosions are reported with the extraction of crude oil for fossil fuels and many aquatic reserves can be polluted during extraction, posing a damaging effect to sea-life, thus extraction of biofuels is far less damaging to the environment. Biofuels tend to burn cleaner, the increased use of biodiesel and ethanol blends in vehicle engines, causes a reduction in PM, CO and unburned VOC emissions than traditional fuels (Shekofteh et al., 2020).

The use of second-generation biofuels is believed to increase environmental sustainability, since the non-food part of plants is being used to produce second generation biofuels, instead of being disposed. Thus the use of second-generation biofuels increases the competition for lignocelluloses' biomass, increasing the cost of these biofuels (Dinh et al., 2009). The European Commission has officially approved a measure to phase out palm oil-based biofuels by 2030. Unsustainable palm oil agriculture has caused significant environmental and social problems, including deforestation and pollution.

Adoption of biodiesel as a fractional component of diesel use was investigated using a global three-dimensional chemistry transport model, STOCHEM-CRI and found an overall improvement in air quality with reductions in ozone, PM, aromatic species and peroxy acetyl nitrate (PAN) (Cooke et al., 2010). Additionally, despite the favourable reduction in PM, CO and VOC emissions, the majority of the literatures revealed that there is an unfavourable increase in NO_x emissions when using biofuels as opposed to fossil fuels. The combustion and exhaust emissions of a single cylinder diesel engine, with biodiesel blends, found that nitrogen oxide emissions were significantly higher than diesel alone (Can et al., 2017). The general consensus across the literature is that the increased NO_x emissions result from higher combustion temperatures produced by the slightly advanced injection of biofuels into the engine cycle, due to their different physical properties compared with conventional fossil fuels. An alternative theory is that the higher levels of NOx are caused by a reduction in heat dissipation due to reduced soot production, which would also lead to increased flame temperatures. The increased NO emissions from biofuels could lead to adverse impacts on both the environment and public health as a result of formation of additional ozone, which is a component of photochemical smog and powerful oxidant (Zhang et al., 2019).

In recent decades, many epidemiological studies have investigated the link between O_3 exposure and adverse health effects. Research into the health impacts associated with O_3 exposure has continued into the 1990s and 2000s. Studies have shown significant and sustained links between short-term O_3 exposure and hospital admissions, with many also reporting a strong association with mortality across the world (Goldberg et al., 2001). There are some cases where biofuels blends reduced NO_x and CO emissions, as a result of a greater resistance against knocking (Tan et al., 2017). This inconsistency between literatures is understandable due to the complexity of combustion and the variation between different studies such as: engine type, vehicle age, fuel injection strategy and other conditions, which influence emissions.

Challenges of Biofuels Production in Nigeria

Biofuel production is a possible venture in Nigeria. Most of the states have the potential of being able to produce biofuel with the agricultural endowment. However, technological advancement and governmental policy are not well planned to cater for the biofuel production. A few preliminary tests have been conducted using feedstocks like, sugarcane, cassava, coconut, oil palm and soya. However, having the enormous capacity for oil plantation and cassava cultivation

makes these products stand out as major promising feedstocks for biofuel production in Nigeria (Haruna et al., 2017).

Land plays a key role in the agricultural sector. The traditional land tenure practice in Nigeria used to depend on communal ownership, which is considered as customary land tenure practice. With civilization, the communal ownership emerged to become individual ownership under the auspice of the federal government with the land use decree. Despite the land use decree, the customary land tenure practice continuous to dominance which gives the community control over land use. Communal control over land in Nigeria creates a lot of bottleneck for investors due to tribal and ethnic clashes over land dispute (Aliyu et al., 2017). This has brought huge drawbacks to use of fallow land in some of the rural communities with massive arable land; most especially in the use of these lands to grow feedstock for biofuel production. The current major challenge is the invasion of farmland by grazing herdsmen. The herdsmen have become major threat to farmers in most rural areas in Nigeria, which has let to severe loss of human lives. This has created many communal issues bringing a setback to use of farmland for cultivating feedstock for biofuel production (Rathmann et al., 2010).

High production cost has also been identified as one of the challenges plaguing biofuel production in Nigeria (Haruna et al., 2017). Currently, the estimated cost of production is higher than the present cost of fossil fuel. This makes it challenging to embark on the production of biofuel particularly bioethanol and biodiesel. In some cases, the feedstocks used can serve as food, which has caused a competition between the resources serving as feedstock for biofuel. Since this may likely be a threat to food, the current strategy is to consider the use of feedstocks that are non-food. With this new discoveries in science and technology, it is important that priority should be given to processes that makes biofuel production environmentally friendly and cost effective (Haruna et al., 2017).

Competition between biofuel feedstock and food is a compelling challenge in Nigeria. It is an obvious fact that since the tin price of food in 2007, the competition between the cost of food and biofuel became a major problem (Rathmann et al., 2010) even until date. This is so unfortunate because this should not have been the case in Nigeria. Nigeria has no constraint of arable land; however, the country has 785,000 km^2 of accessible farmland without any limitation hence prospective possibility of improved agricultural output and efficiency (Abila, 2012).

The use of renewable form of energy is not well established in Nigeria apart from the hydrogenation of energy, which has been inconsistent due to poor maintenance culture. The government is making effort to initiate programmes to create awareness and enlightenment on the use of renewable energy resources; this include developing policies, incentives and regulatory environment necessary for biofuel to thrive in Nigeria (Onuoha, 2010). Effort from the Jatropha growers, processors and exporters association of Nigeria has shown that Nigeria requires 2.4 million litres of biodiesel on a daily basis to adequately implement the Paris agreement on climate change (Punch, 2016).

Issues relating to biofuel are social, economic, environmental and technical problems which may arise from biofuel production and use. Social and economic issues include the ‘food versus fuel’ debate and the need to develop responsible policies and economic instruments to ensure sustainable biofuel production. Farming for biofuels feedstock can be detrimental to the environment if poorly executed. Environmental concerns include deforestation, biodiversity loss and soil erosion as a result of land clearing for biofuels agriculture. While biofuels can contribute

to reduction in global carbon emissions, direct land use change for biofuel production can have the inverse effect.

Technical issues include possible modifications necessary to run the engine on biofuel, as well as energy balance and efficiency. The International Resource Panel outlined the wider and interrelated factors that need to be considered when deciding on the relative merits of pursuing one biofuel over another. The IRP concluded that not all biofuels perform equally in terms of the effect on climate, energy security and ecosystems, and thereby suggested that environmental and social effects need to be assessed throughout the entire life cycle (Leweandroski et al., 2019).

Prospect of Biofuel Production in Nigeria

The prospect of biofuel in Nigeria is great because of arable land for growing feedstocks for biofuel production. Biofuel production is a possible venture in Nigeria. Most of the states in Nigeria have the potential of being able to produce biofuel feedstocks with the agricultural endowment. However, technological advancement and government policy are not well planned out to cater for the production. The future of biofuels depends on profitability and new technologies. Technological advances and efficiency gains higher biomass yields per acre and more gallons of biofuel per ton of biomass could steadily reduce the economic cost and environmental impact of biofuel production.

The prospect of biofuel as renewable and alternative sources of energy in Nigeria is enormous; it will not only boost the economic development of Nigeria, but will also ensure energy security. Research works in this area should be encouraged to enable provision of sufficient and reliable energies for most communities in the country. The projected forecast of biofuel globally particularly ethanol production is to increase to 132 billion L by 2030, while global biodiesel production is projected to increase to 50 billion L, driven principally by Indonesia's mandate increase over the initial projection years. Thus feedstocks for biofuel production vary from country to country (EIA, 2023).

Beside the contributions of biofuels in frontally remedying climate related impacts of fossil fuel, they also have direct socioeconomic benefits in terms of creation of job and generation of wealth with consequences on poverty profile of the country.

Advantages of Biofuel as Substitute Source of Energy over Fossil Fuels

The following are some of the advantages of biofuel as substitute source of energy as highlighted by (Huang et al., 2013, Rosegrant et al., 2008):

SAFER THAN PETROLEUM: Biodiesel in its pure, unblended form causes far less damage than petroleum diesel if spilled or released to the environment. It is safer than petroleum diesel because it is less combustible.

BEST ALTERNATIVE ENERGY: A fossil is a natural extracted fuel which arises as a result of the decompression of buried dead animals, while biofuel is any biomass fuel from plant or algae, or animal waste. Since these materials can quickly be replenished, biofuels are considered to be the best alternative or renewable energy source.

Environmental Friendly: Biofuel are generally considered to be more environmentally friendly than fossil fuels because they produce less greenhouse gas emissions when burned.

Energy Efficiency: One of the major benefits of using biodiesel is energy efficiency. While petroleum diesel is currently more efficient for use in a car or truck, biodiesel production is more energy efficient.

Reducing Foreign Oil Dependency: Using renewable energy like biofuel will help to reduce nations dependence on foreign oil in combination with other sustainable measures, for instance,

expert says that using biogas, enacting tax incentives for hybrids and fuel-cell vehicles, and raising fuel economy standards for motor vehicles will help wean many nations off the need for foreign oil.

Health Benefits: It's been reported that about 10,000 people die from pollution-related to gasoline engines every year in the United States. That is because gasoline releases nitrogen oxides and acetaldehyde into the air. These molecules react with sunlight to form smog, which results in air pollution. This air pollution then creates issues like lung disease, cancer, and other respiratory diseases.

Positive Economic Impact: Another benefit of using biofuel is its positive economic impact. Biodiesel production has had a widely positive impact on the economy of many nations over the last two decades. For instance, biodiesel production was at about 500,000 gallons in 1999 and just a decade later, in 2009, it was at about 545 million gallons. This added a whopping $4.28 billion to the GDP of many countries.

Sustainability: Biofuel is more sustainable than its fossil fuel counterpart. Fossil fuels are a finite resource, that one day; the world will run out of it. On the other hand, biofuels are renewable energy made from plants. We can set plants so they may grow over again to continue creating biofuel. There are also many forms of biofuel made from various types of plants. Compared to fossil fuel, the possibilities for biofuels are seemingly endless.

High-Quality Engine Performance: Biofuel offer high-quality engine performance. Biofuel can be used in existing diesel engines with little or no modifications necessary to the system. In most of these vehicles, the performance is the same, if not better. Studies have shown that biofuel also help engines last longer since they do not have a high viscosity rate.

Conclusion

The challenges, impact and prospects of biofuel as a renewable and alternative forms of energy in Nigeria was discussed. The challenges hampering the development of biofuel as an alternative form of energy in Nigeria include; land tenure system, high production cost, poor governmental policies and competition between biofuel feedstocks and food also poor technology. With the current rising demand for safer energy, Nigeria needs to diversify to biofuel as alternative to fossil fuel and at the same time maximizing her biomass resources for socioeconomic growth.

Nigeria need to pay attention to its waste management system, which has the potential to generate sufficient energy to drive the economy and serve as means of employment. It is also high time for Nigeria to develop its own technology to run biofuel production from its currently developed plants feedstock industries. It might be necessary to create more awareness on the importance of biofuel as well as encourage and create suitable and enabling environment for local and international investors on biofuel production with good policies and incentives.

Recommendations

1. It is necessary for the government to create awareness on the importance of biofuel as well as encourage and create suitable and enabling environment for local and international investors on biofuel production
2. Government should focus on waste management system to generate sufficient and efficient energy to drive the economy and serve as means of employment opportunities for its citizens.
3. Government and private organizations needs to diversify their sources of energy from fossil fuel to biofuel as alternative and at the same time maximized their biomass resources for socio-economic growth and development.

4. The challenges affecting biofuel production such as land tenure system, high production cost, poor government policies, competition between biofuel feedstocks and food, and poor technology etc. should be taking care off by the government and private organizations for biofuel production to strive.

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