Biofuel Development in Nigeria Production and Policy Challenges

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Authors’ contributions

This work was carried out in collaboration between both authors. Author AO designed the study, performed the statistical analysis, wrote the first draft of the manuscript and managed the analyses of the study. Author PKA managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Exploring renewable energy resources stimulates social and clean economic development. The global renewable share in the total primary energy supply is steadily increasing but some countries are not actively contributing to this growth. The current Nigeria dependence on depleting fossil-based fuels can only be changed through a balanced and long-term renewable energy policy that is built on a step by step accomplishment basis. Biofuel remains the sustainable and promising option for Nigeria due to a large biomass reserve of 144 million tons per year. Although, biofuels have been identified as the real deal in increasing energy access, productivity, income, employment generation and also in combating carbon emissions which would invariably check the worst effects of climate change, the existing policies engineered to drive biofuel development are weak resulting into the failure to meeting the national targets; a 10% ethanol blending policy target between 2007–2016, 100% domestic biofuels production target by 2020 and 2000MW of electricity from renewables by the year 2020. Besides the uneven policies menace, lack of incentive, poor energy infrastructure, low cultivation of biomass and yields and non-attractive biofuel market price have been the major

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INTRODUCTION

The issue of energy access is a global challenge with about 14% of the current population representing 1.1 billion people across the world being affected. The severity of this crunch varies from continents to countries and countries to countries. The sub-Saharan Africa has the largest share with over 95% in the rural areas living without modern energy or fossil-based electricity [1]. An estimate of 73.6 million Nigerians are without electricity access while 128 million depend on wood, charcoal and waste for cooking [2]. The following facts reflect a huge deficit in energy development and also explain the reason for slow socioeconomic development; the estimated population in 2018 is 200 million with a population growth rate of 2.6% per annual, the installed electricity generation capacity in 2017 (12.8GW) out of which in practised 4GW is realized due to infrastructural shortfall, transmission and distribution losses, the energy consumption per year is 24.72 billion kwh, energy consumption per capital (129.50kwh), demand for electricity (94,000MW in 2018), and total primary energy supply of 149.96 million tonne oil equivalent in 2016 [3,4,5].

The challenge of not only delivering constant affordable energy to the populace but also transitioning to clean energy is at the front burner of government discussions. Therefore, triadic strategic measures are daily considered to mitigate the energy crisis. Significantly, the development of renewable energy is motivated towards moving the nation towards a low carbon economy and generate quick access for rural communities with low energy demand. Continued advances in mini and household solar plants installations are seen across the nation, wind turbine installations are springing up minutely while a ray of light is shone on biomass energy. However, these have not translated into a significant renewable share in the energy mix as 84.1% are fossil based, and about 15.5% sourced from hydropower stations [6]. Biomass is the dominant traditional energy source in Nigeria as a result of its massive availability and the huge reliance on the energy source for cooking and heating purposes by majority of the Nigerian people. Nigeria have impressive electrification goals that would require rapid expansion of decentralised renewable energy (DRE) solutions especially off grid biomass, solar and wind energy, it is predicted that a total installed capacity of 8 GW of DRE solutions is required to realize Nigeria’s 30:30:30 Vision [7,8].

Based on the biomass feedstocks potentials, sustainability and regulation of biomass energy production, the country could become one of the world largest biofuel adoption in the nearest decade. This paper, hence, attempts to underscore biomass energy in the context of biofuel production and policy framework.

SCOPE OF BIOFUEL IN NIGERIA

In a 2019 report of International Energy Agency (IEA) [9], advance biofuels are any sustainable fuels sourced from non-food crop feedstocks with enormous potential to deliver substantial lifecycle greenhouse gases (GHG) emissions savings unparalleled with fossil fuel alternatives, and which in no significant measure threaten food security and availability of land for growing food crops. The cultivation and conversion of these non-food crops do not also distort the sustainability of the ecosystem. Agricultural and forest residues are the chief examples of biofuel raw materials. Examples of biofuel include; cellulosic ethanol (sugar- and starch-based), oil-crop biodiesel, hydrotreated vegetable oil (HVO), hydrotreated esters and fatty acids (HEFA) biojet fuel, among others [10].

Subject to the approval of biofuel energy commission, biofuel feedstock in Nigeria include; agricultural raw materials available on a renewable basis (cassava, Jatropha curcas, sugarcane, cellulose-based products, oil-palm), biodegradable component of municipal wastes, industrial wastes, among others. Under the Nigerian BioFuel Policy and Incentives, (2007), Biofuel refers to ethanol, biodiesel (fatty acid methyl ester or mono-alkyl esters derived from vegetable oil or animal fats for use in diesel engines) and any other fuel generated with its quality conforming to Standards Organization of Nigeria (SON), Department of Petroleum Resources (DPR), etc [11]. One pitfall of the latter definition is the inclusion of food crops in...
biofuel feedstocks without restrain, by implication the food security is hampered. Consequent to this kind of understanding and practice, 22% increase in corn prices and 10% rise in total food prices was observed in 2008 in the US [12]. The renewable European Union (EU) 2018/2001 energy direction has restricted the use of food and feed crops to not more than 7% of final consumption of energy as a way of addressing competition between food and fuel [13]. A more suitable understanding should define biofuel as any usable fuel derived predominantly from non-food plant and animal materials. This understanding will precipitate untold interest and focus on nonedible substances for biofuel production, coupled with its cost-effective and environmentally benign substitute to crude oil and other fossil sources.

2.1 Present Status of Biofuel

Bioenergy is increasingly gaining dominance in the renewable energy sector for electricity, heat and transport fuels. In a recent report by Renewable Energy Association (REA), bioenergy is the UK’s major renewable energy leading providing 96.4%, 11% and 7.4%, electricity, non-domestic renewable heat and total energy consumption respectively [14]. Biofuels produced from biomass has been the core drivers of this feat.

In Nigeria, the renewable capacity and generation has grown slowly [15], while the cumulative primary energy consumption is steeply rising [16] as shown in Figs. 1 and 2. The country’s renewable energy growth is not linear with that of the globe as depicted in Fig. 3 [17], since 2008 the share of renewable energies (biopower, solar PV, wind power, among others excluding hydroelectric power has appreciated significantly. The increasing share of biofuel is also phenomenal in the global power generation.

2.2 The Current Available Biofuel Resources in Nigeria Include

2.2.1 Ethanol

Ethanol is an alcohol manufactured from agricultural crops such as cassava, corn, cornstalks, guinea corn, sugar cane, sorghum, potatoes, wheat, and vegetable wastes. The two major types of ethanol are; Denatured ethanol (ethyl alcohol) and Hydrous ethanol. The former which is often called bioethanol is produced by adding small % of denaturing agent to ethanol to render it undrinkable and it has found wide acceptance in blending Premium Motor Spirit (PMS) to E10, E20 etc [18]. It has high-octane rating of 113 and when blended with 2-5 cheap low chain hydrocarbon, it raises the gasoline rating to at least 87 octane number. This delivers multiple benefits, greater horsepower and speed fuel, better efficient engine and low CO₂ emission levels. The Hydrous Ethanol on the other hand is consumable, it is utilized as industrial feedstocks in the manufacturing of alcoholic and non-alcoholic beverages, drugs, cosmetics, perfumes, among others.

Fig. 1. Electricity consumption and renewable energy production in Nigeria from 2000 to 2014) [15]
In 2017 the world ethanol production peaked at 27 billion gallons after a decline in 2011 and 2012 at 22.4 billion and 21.8 billion gallons respectively as shown in Fig. 4. The United States and Brazil remains the world's leading producers, having produced 85% of the world's ethanol with nearly 16 and 7 billion gallons respectively in 2017 alone [19]. While the U.S. sourced its ethanol from corn, the brazil uses sugarcane. However, Nigeria does not have a data on ethanol production. It is worth mentioning that Nigeria consumes nearly 20 million litres of the ethanol products per year which are majorly imported since there is no distinct local industries or manufacturers for it even though the feedstocks for its production are readily available in the country. The locally brewed ethanol (local dry gin called Burukutu) in the Nigeria communities are largely made from Guinea corn. Several industries sprawling across the country have been listed to commence production of ethanol but no information is available on their existence or commencement of their operations. Allied Atlantic Distilleries Limited, AADL did not start producing the planned 30,000 l/day of ethanol from locally sourced cassava feedstock
in 1999 until 2014 when it started daily processing 250 tons of cassava to generate 9 million litres per annum of extra neutral alcohol [20]. No data on their current status is available. The potential for Nigeria to become contending leader in world ethanol production is undoubtful owing leading position in global annual cassava production as shown in Fig. 5.

Fig. 4. Global ethanol production by country/region and year [21]

Fig. 5. Global cassava production [22]
Due to the current economy situation of the country, cassava is better suitable as food security resources than for energy industry. Nonetheless, considering the level of wastes where 30% of total harvest are wasted, the linearity between cassava production, food access and ethanol production can be achieved, right policy is the cardinal issue in the cassava cultivation and use. For example, the Anchor Borrower’s Programme (ABP) initiated in 2015 by the Central Bank of Nigeria incentivize rice farmers above other commodities farmers, this adversely affected cassava cultivation, a succour was later provided through the introduction of Agricultural Credit Scheme (CACS) in 2018 that prioritizes low interest loan for cassava farming [23,24].

Taking a leap to other ethanol sources, Nigeria is the second largest producer of Corn in Africa after South Africa having produced 11 and 13.10 million metric tons respectively between 2017-2018. The potential to be the best is huge in terms of land availability where Nigeria and south Africa have 6.50 and 2.40 million hectares area for corn cultivation, one obvious advantage of Africa leading corn producer is their high yield of 4.58 metric tons per hectare compared to 1.69 metric tons per hectare of Nigeria [25]. It is important that Nigeria focuses on improving corn yield through the use of improved corn varieties and better cultivation practices. Nigeria is also the largest farmer of Sorghum in Africa and second best in the world after US with about 7 and 12 million metric tons produced respectively in 2017/18. Again while 2.04 million hectares of land was used by US, 5.80 million hectares was utilized by Nigeria, this require a decisive step to tackle low production yield of crops in the country. Ethanol being the fastest growing renewable energy technology in the world is worth developing in Africa in order to eradicate the wasting of agricultural resources [25].

2.2.2 Biodiesel

Biodiesel through a chemical transesterification process are produced from any of these feedstocks; used cooking oils, recycled grease, animal fats and raw or refined plant oils. There is a wide range of plant seeds with high oil content suitable for biodiesel production ranging from non-edible to edible. These include; Jatropha, seashore mallow, Chinese tallow tree seed, camelina, Brassica juncea, palm kernel, soybean, canola, peanuts, etc. Algae is still at research level. Meeting ASTM D6751-15ce1 standard is however required before any fuel can be called biodiesel [26]. A production surge by 7% of combined biodiesel and hydrotreated vegetable oil (HVO) was recorded in 2016, representing about 39 billion litres production in 2017, the average growth rate is 3% and predicted to continue 2023, with US and Brazil the major drivers [25]. Despite the rich availabilities of biodiesel feedstocks in Nigeria (palm oil, jatropha, corn oil, water hyacinth, etc) there is no significant production record. Nigeria with about 1million metric tons of palm kernel in 2017 is the largest palm kernel producer in Africa and 4th in the world while Indonesia for decades remain the dominant leader. Several biodiesel projects have been announced in Nigeria but there is no data to proof their operations [27].

2.2.3 Biogas

As a definition, biogas is a biofuel made up of mainly methane and carbon monoxide. It is produced from biological decomposition of organic matters (anaerobic digestion). The organic wastes such as food scraps, animal wastes, sewages, seaweeds, lawn wastes, crop residues, among others. Biogas is simply transformation of wastes to wealth (that is, useful energy). There are numerous pilot biogas projects in Nigeria which generates biogas from cow dung, poultry wastes, wastewater and sewage, these include; Ajima Farms Biogas Digester Off-Grid with capacity of 20kW of biogas per day using post-harvest residues, Usman Danfodiyo University Sokoto biogas project with a capacity of 425L per day, etc [28].

According to a computational study, Nigeria has a sustainable potential for generating about 26 billion M³ of biogas yearly from 542.5 millions tons per year of biomass generated by plant and animal wastes such as (cow, sheep, goat, pig and poultry dung, sewage and crop residues [29].

2.3 Biofuel Potential in Nigeria

Nigeria due to it large land mass of over 900, 000 km², climatic conditions and population have massive potential for producing sustainable biofuel resources. One feedstock that is underdiscussed and unexplored is the marine based feedstocks (algae and water hyacinth) [30].

2.3.1 Aquatic biomass (water hyacinth)

- Water Hyacinth (Eichhornia crassipes) is a free-floating non-native aquatic
macrophyte (plant) that has invaded aquatic areas in Nigeria from the Porto-Novoo creek in Benin Republic through the Badagry creek in Nigeria [30]. It is a very fast-growing plant, with enormous potential to grow up to 3 ft. (1 m) and 15cm in height and leave breadth respectively and strong ability to double its population within 12 days and can remain submerged in water for at least six months unaffected [31].

Among the sixty-five (65) invasive species found in Nigeria by global invasive species database [32], water hyacinth weed is the most abundant. The National Institute for Freshwater Fisheries Research (NIFFR) reported that it has infested lakes, ponds, rivers, marshes, and other types of wetland habitats of over 30 States out of 36 states including the Federal Capital Territory of Nigeria [33]. This marine weed has a broad environmental tolerance, hence, can survive both in dry and wet seasons. Its adverse environmental consequences has been a subject of concern over the decades which are not limited to, obstruction of light availability to native underwater plants and aquatic invertebrates, excessive oxygen depletion and pH changes, water-flow and navigation restrictions leading to flooding and transportation difficulty especially in the Niger-delta regions, stunted growth or death of fish populations, distortion of marine habitat, loss of biodiversity and recreational opportunities, among others [33].

Several measures have been employed to eradicate water hyacinth from Nigeria water courses without any significant impact. Since 1992, as a way of biologically controlling water hyacinth weed, over 3000 Neochetina weevils have been imported into Nigeria, the impact of this was evidenced on the myriads of holes on the *E. crassipes* plants. Floating barriers were also installed to trap the weeds mechanically and a chemical approach was adopted with the use of glyphosate but the resulting toxicity led to it being outlawed. Despite these mitigation methods, the population of water hyacinth has not declined, rather it is on the upward swing because the approaches are either too expensive or not sustainable [33].

Recent studies have also identified numerous beneficial uses of this weed. It has reliable ability to remove 24-80% of heavy metals (~3 mg/L total metals) from serial concentrations in leachate [34,35,36], remove over 90% of total nitrogen and phosphorus from farm effluent [37] precluding fast initial metal adsorption at its roots [38].

More so, very significant to Nigeria is its vast potential for sustainable biofuel production (fuel ethanol, biogas and other chemicals) through anaerobic digestion coupled with the fact that it is easy to harvest [39]. As revealed in Table 1, invasive aquatic plants have great potential for ethanol production via the anaerobic decomposition process. Exploring this advantage will go a long way to tackle energy crunch in Nigeria.

As shown in Fig. 6, comparing Nigeria to other countries, an upwards increase in renewable energy share from 2010 to 2030 is predicted, the tallest blue bar depicts that Nigeria utilizes so much biomass (including solid biomass in industry), the country expects its share of renewables to shrink dramatically as industry switches mainly to natural gas, and as the use of traditional biomass in households for cooking is replaced by the more efficient use of modern biomass, the share of renewables is much greater in 2030 under REmap 2030 than it would be in the Reference Case [41].

The comprehensive potential of other biofuel feedstocks production in Nigeria are shown in Fig. 7.

**Table 1. Energy composition of aquatic biomass feedstocks [40]**

<table>
<thead>
<tr>
<th>Composition</th>
<th>Raw water hyacinth leaves</th>
<th>Pretreated water hyacinth leaves</th>
<th>Raw water lettuce leaves</th>
<th>Pretreated water lettuce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>17.2</td>
<td>25.7</td>
<td>19.5</td>
<td>27.0</td>
</tr>
<tr>
<td>Cellulose</td>
<td>19.7</td>
<td>34.2</td>
<td>16.5</td>
<td>28.4</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>27.1</td>
<td>27.0</td>
<td>17.3</td>
<td>18.7</td>
</tr>
<tr>
<td>Starch</td>
<td>4.1</td>
<td>4.1</td>
<td>6.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Ethanol yield (ggbiomass$^{-1}$) after fermentation</td>
<td>--</td>
<td>0.17</td>
<td>--</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Fig. 6. Current and projected share of renewable energy in total final consumption by country, (2010-2030) [41]

Fig. 7. Nigeria production of biomass feedstocks trend from 1970-2010 [42]
2.4 Biofuel Projects in Nigeria

The Nigerian National Petroleum Corporation (NNPC), state government and other private organizations have listed several projects on biofuel which principally centred on biogas, ethanol and biodiesel. Most of these projects are on still on the planning state while only very few are operational as shown in Fig. 8.

2.5 National Bioenergy Programme and Policy Mix in Nigeria

The strength and future of any energy systems in achieving clean-energy economy is bound in right, smart and comprehensive policy-making.

The Nigeria energy policy from history predominantly focused on the development and regulation of the petroleum and electric power generating industries. Policies that cover biomass energy are young and evolving with regular modifications and are mostly subsets of renewable energy initiatives. The considerations of these policies include; streamlining of feedstocks to promote sustainability and food security, fuel production and standards for transport applications, the investment and incentives strategies, emission and utilization targets, and public institutions involvement. The Table 2 summarises the key national policies that address biofuel matters in Nigeria energy sector.

Fig. 8. Biofuel projects distribution across the Nigeria
(Source: Data extracted from Agbro et al 2001; Odelakun et al 2006) [20]
Table 2. Summary of some of the biofuel related policies, initiatives and programme [43]

<table>
<thead>
<tr>
<th>S/no</th>
<th>Policy</th>
<th>Date of promulgation</th>
<th>Key objectives</th>
<th>Status</th>
</tr>
</thead>
</table>
▪ Provided for how biofuel should be used.                                                                                                       | Active                      |
|      |                                            |                            | ▪ No verifiable quantitative targets and timeline have been set.                                                                                                                                         | No implementation          |
| 2    | Renewable energy master plan (REMP)        | 2005, Revised 2012         | ▪ Increase national electricity access from 42% in 2005 to 60% in 2015 and 75% by 2025.  
▪ Increase electricity share to 10% of the country’s total energy consumption by 2025.  
▪ Increase the supply of renewable electricity from 13% of total electric- ity generation in 2015 to 23% in 2025 and 36% by 2030. | No implementation          |
|      |                                            |                            | ▪ Targets missed                                                                                                                                  | No implementation          |
| 3    | Rural Electrification Strategy and Implementation Plan | 2006                       | ▪ Promotion of off-grid and standalone systems                                                                                                    | No verifiable quantitative targets and timeline have been set. |
| 4    | Renewable Electricity Policy Guidelines (REPG) | 2006                      | ▪ Expand the market for renewable electricity to at least 5% of total electricity generation and a minimum of 5 TWh of electric power production by 2016.  
▪ Construction of off grid independent renewable electricity systems in rural areas where energy access is zero  
▪ Renewables be integrated into the energy mix of the national grid  
▪ Rural electrification trust funds (RETF) responsible for supporting and mobilising for the financing of renewable electricity | Active                      |
| 5    | Renewable Electricity Action Programme (REAP) | 2006                      | ▪ Provided for the application of all forms of renewable energy sources for electricity generation  
▪ Identified potential gaps, technoeconomic implications of renewable installations.                                                                 | Abandoned                   |
| 6    | Nigerian Biofuel Policy Incentive          | 2007                       | ▪ Linking the agricultural sector of the economy with the downstream petroleum sector.  
▪ Developing and promoting of the nation’s fuel ethanol industry using biomass, that is, agricultural products | No implementation          |
<p>|      |                                            |                            | ▪ 2020 target not currently on track                                                                                                           | No implementation          |</p>
<table>
<thead>
<tr>
<th>S/no</th>
<th>Policy</th>
<th>Date of promulgation</th>
<th>Key objectives</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Vision 20:2020</td>
<td>2010</td>
<td>so as to elevate the export properties of automotive fossil-based fuels produced in Nigeria.</td>
<td>No implementation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Replacement of hazardous octane enhancers in PMS.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Compulsory contribution of all biofuel's companies with 0.25% of their revenue towards funding biofuel research (feedstock sourcing, indigenous technology development and improving agricultural practices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ 100% domestic generation of biofuels locally consumed by 2020</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Place Nigeria among the leading 20 economies of the world in 2020</td>
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<td></td>
<td></td>
<td></td>
<td>▪ Increase the national installed capacity to 35,000 MW by 2020 by following an energy intensive growth trajectory, similar to developing countries like China and India</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Alleviate dependence on gas-fired plants by promoting alternative energy technologies which include biomass, hydro, wind, solar, coal and nuclear.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ replacing 50% of firewood biomass consumption for household cooking with biomass energy technologies by 2020</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Annual installation of 1000MW power generation using biomass resource</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Utilising a biofuel blend not exceeding 10% in transport fuels by 2020 produced locally renewable biofuels from secondary biomass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Provides for the development and deployment of renewable energy technologies with efficient utilization of bioresources for sustainable energy development.</td>
<td></td>
</tr>
</tbody>
</table>
3. SUSTAINABLE BIOFUEL FEEDSTOCK SOURCING POLICIES

The 2007 National Biofuel Policy and Incentives restricted biofuel to meaning ethanol, biodiesel and other fuels produced principally from agricultural raw materials for transport, heat and electricity purposes in accordance to quality specifications stipulated by the Standards Organisation of Nigeria (SON), Department of Petroleum Resources (DPR), and any other competent government agency [44]. The wide spectrum of biomass feedstocks covered include; lignocellulosic materials, vegetable oil or animal fats, biodegradable municipal wastes and industrial wastes. The indigenous crops identified for biofuel production are; Cassava, Sugarcane, Palm oil, Jatropha, cellulose-based materials and other crops subject to the approval of Biofuel Energy Commission. It is predicted that 2 billion and 900 million litres of ethanol and diesel respectively by 2020 will be locally produced, the sustainability of this feat is accommodated in the policy. The policy requires that SerCos which is an outgrower scheme be established shouldered with the responsibilities of setting up integrated biomass plantations across the country and using auditable feedstock weighting equipment and technologies that are approved by the Department of Weights and Measures of the Ministry of Commerce and Industry. The policy also proposes the establishment of a Biofuels Research Agency empowered to collaborate with other research institutes such as International Institute of Tropical Agriculture (IITA), National Cereal Research Institute (NCRI), National Root Crops Research Institute (NRCRI), Nigerian Institute For Oil Palm Research Council (NIFOR), Forestry Research Institute Nigeria (FRIN), Nigerian Stored Products Research Institute (NSPRI), Institute for Agricultural Research and Extension Services (IARES), Agricultural Research Council of Nigeria (ARCN), National Biotechnology Development Agency (NABDA), SHEDA Science and Technology Complex (SHESTCO) Federal Soil Conservation School (FSCS), National Centre for Agricultural Mechanisation (NCAM), National Agricultural Seeds Council (NASC), Nigerian Automotive Council, Raw Materials Research and Development Council (RMRDC) and Federal Institute of Industrial Research Oshodi (FIIRO), among others to develop improved species of cellulosic crops using cutting edge bioengineering practices such as genetically modified (GMOs). Research grants are to be provided by the Central Bank of Nigeria being the mandated money collected from Indigenous biofuel companies [45].

However, these policies recognise that biofuel feedstock production would increase because its cultivation presents alternatives income-earning stream for the farmers. However, the current farming practice is largely subsistence and in effect, feedstocks cultivation such as cassava, oil palm, sugarcane, among others would pose a threat to food security and agrarian land availability. Invasive aquatic plants such as water hyacinth used for biofuel though does not compete for food but raises significant issue with respect to its impact on the environment, like obstruction of light availability to native underwater plants and aquatic invertebrates, excessive oxygen depletion and pH changes, water-flow and navigation restrictions leading to flooding and transportation difficulty especially in the Niger-delta regions, stunted growth or death of fish populations, distortion of marine habitat, loss of biodiversity and recreational opportunities.

In reality, the existing policies on biomass feedstocks cannot guarantee their sustainability. This hence requires an amendment or change, the introduction of sustainability certificate to both biomass growers and suppliers. This certificate would be issued to show that the percentage of harvested cash crops are sold as food is higher than the one sold as biofuel, hypothetically 70:30 for food and fuel respectively. Also, the certificate depicts that biomass suppliers manage their forests or water resources according to environmental, social and economic standards.

3.1 Food and Fuel Land Use Implication

As identified above, the existing biofuel related legislations are weak in resolving the competition between food and fuel for agricultural land and products. Nigeria at present has about 70 million hectares of agrarian land, out of which over 50% are unutilized which means that marginal and abandoned lands are more abundant representing about 37 million hectares [45]. This reveals a huge potential for biomass cultivation especially energy crops like *Jatropha curcas*, Miscanthus and Willow. Nevertheless, the legislation of Nigeria Land Use Act of 1990 considers land to be State Land and does not provide for an exclusive access of an individuals to land. The occupancy of lands is principally held under formal land tenure system which implies that the lands are held by villages,
families, or diverse communal groups and are only accessed by their members and social elites [46]. Government officials and powerful bureaucrats can indiscriminately withdraw the tenure rights from the farmers for their own uneconomical advantages [47]. At present, there is no policy that supports the protection of land allocated for biomass cultivation, this should be introduced and also promulgate laws that ensure local communities right to land for cultivation and transparency among all participating stakeholders in land allocations. More so, investors and local land users should be allowed to negotiate on mutually beneficial terms for land usage for biofuel projects.

In 2001 Cassava revolution started with selling point for bread making and possibility for biofuel production, the consequence of this was a steep hike in cassava prices but it was short-lived. Also, within 2009 and 2013, reviving ethanol industry was grossly advocated for with the intention of using cassava and sugarcane feedstocks [48]. This led to increase in these food crop prices. An effective policy to mitigate food-fuel competition would involve robust investments in agric-infrastructure, improved varieties crop research, and selectively reducing the import duties on food products from other countries most especially when local production cascades due to adverse weather conditions or other unforeseen contingencies. The cultivation and sale of non-food biomass like water hyacinth and Jatropha curcas should be prioritized or incentivized, with a ripple effect on job creation.

3.2 Investment and Incentives

Although, all the existing policies recognize the nonnegotiable need for incentivising all the value chain of biofuel development in Nigeria, but some are either deficient in providing the right approach or presents vague strategies. The National Biofuel Policy and Incentives of 2007 is apt in recommending an import duty waiver for biofuels for with a lifespan of 10 years (that is, 2007-2017) and exemption from taxation, withholding tax and capital gains tax imposed in respect of interest on foreign loans, dividends, services rendered from outside Nigeria to biofuel companies by foreigners will be required [43]. However, the pitfalls of this policy are not farfetched, the timeline is too small because as at 2007 biofuel penetration is foreign to Nigerian energy market and biomass cultivation is alien to the domestic farmers. A gradual reduction in the import duty waiver spreading across 20 years as well as steady reduction in capital gain tax waiver for foreign investors across 10 years, this would be appropriate as this will attract foreign investors and keep them in biofuel business after gaining ground.

The 2005 National Power Sector Reform Act (EPSRA), empowers the National Electricity Regulation Commission (NERC) to initiate energy tariffs and corresponding calculation methodologies for energy production and sale. The policy also recommends that Power Consumer Assistance Fund (PCAF) subsidises the tariff for indigent energy consumers. While this is partly attractive, a recommendation for higher tariff for biomass energy and providing a corresponding robust market for the sale will better support bioenergy market. Buyers of biofuel can be incentivized by being awarded carbon certificate. Introducing right incentives will help solve the numerous constraints impeding biofuel industry growth in Nigeria. These problems are:

3.3 Rural-Urban Migration

Over 60% of the country’s population are youth. This teeming population in the last two decades have developed strong disinterest in agriculture and occupationally emigrating to cities in search of white-collar jobs. Enrolment in agricultural related courses in the public tertiary institutions has dipped as well. This stifles the cultivation of biomass feedstocks. Biofuel policies should incorporate strategies that would rebuild interest and reinfuse confidence in them by granting fully funded scholarship or tuition fees waiver to talented young students interested in studying agriculture related, green energy or biomass resource development related courses. The policy should also promote free capacity training or short extension courses for semi-skilled personnel passionate about bioenergy.

3.4 Recalcitrance of Local Farmers in Adopting Newer Technologies

Besides the inability to access fund to boost biomass cultivation, farmers are also reportedly jettisoning the idea of adopting newer technologies for increasing farm productivity. Right policy would require graduates with academic experience in biomass be deployed as extension workers to the local farmers to educate them on the advantages of modern agricultural practices and also to demonstrate pilot farms to
earn their trust. Prolific local farmers who has adopted these technologies or with greatest productivity be annually sent on foreign trips to international farms as incentives for diligence. This would encourage international or multi-stakeholder partnership and higher agricultural productivities.

3.5 Lack of Funding

Many local farmers and investors desire to expand their exploit in biofuel industry but are crippled by inability to secure loans or grants. Though, the Bank of Agriculture (BOA) and Bank of Industry (BOI) were obligated to provide the needed fund to support agribusiness in Nigeria, complex bureaucracy, irrational collateral conditions and mistrust confronts its success. Zero or low interest rate policy should be mandated for biomass feedstock farmers, suppliers and biofuel producers. To circumvent the collateral conditions, the policy should encourage the establishment of cooperative societies through which members can engage with the designated financial institutions to secure needed funds.

3.6 Lack of Market

In 2008 when biofuel development received an early boost, several locals engaged in massive cultivation of cassava and *Jatropha curcas* but were pushed to abandon their farm produce as a result of lack of market. Few that got rid of their harvest sold them at meagre prices that cannot cover production costs. Biofuel policy should mandate the establishment of Commodity Board managed by the government who will buy these products from them at good prices regardless of the market situations.

3.7 Risk Volatility

Many farmers have lost their farms to pest attack, ruminants attack, drought and other adverse weather conditions. The absolute loss is a major setback for cultivation growth of biofuel raw materials. Biofuel policies should synergize with the existing Agricultural Insurance Scheme to protect biomass farmers against loss due to adverse weather. Challenge with the existing insurance schemes is implementation, strategies to ensure its implementation.

Other Incentives for biofuel projects that could be included in biofuel policies are tax holidays and tariff waiver for imported biomass seeds, equipment and supplies. The incentives should be gazetted and communicated to all local farmers in their local dialects both to protect the locals from sabotages, and the nation from politically powerful investors who can hedge out others to gain exceptional benefits and to protect domestic and foreign investors from vague policies that escalates the risk of investments.

3.8 The National Energy Targets

The different policies have produced different national energy targets meant to lubricate the strategies for achieving success especially in the renewable sector. As shown in Table 3, vast majority of these targets are likely going to be missed because largely the input of private stakeholders was not requested by the public institutions when formulating them, they do not reflect the local realities nor consistent with local efforts. Besides the poor energy financing on the part of the government, there is also no working synergy among the public and private institutions in framing targets and the devolvement of tasks have not been effective.

4. PUBLIC INSTITUTIONS AND PRIVATE STAKEHOLDERS’ ENGAGEMENTS

4.1 Nigerian National Petroleum Corporation (NNPC)

NNPC was founded in 1977 after the commercial oil exploration began in Oloibiri, the corporation is primarily responsibility for upstream and downstream developments in the crude oil industry. It also regulates and supervise the oil sector under the auspice of the federal minister for petroleum. Under the presidential directive in 2005, NNPC created a new department; the Renewable Energy Division (RED). Through RED, NNPC is tasked to the launch of a biofuel program for Nigeria which aims at creating a sustainable domestic industry by integrating the energy and agricultural sectors of the country. As obtained from NNPC website, NNPC through the RED has introduced the Automotive Bio-fuel program for the production of fuel-ethanol and bio-diesel to be blended with PMS (Premium Motor Spirit) which is otherwise called as Petrol and AGO (Automotive Gas Oil). The new fuel is termed “Green Gasoline” containing 10% biofuel. RED seeks to embark on commercial production of biofuel, earn carbon credits from Clean Mechanism Development (CDM) projects and coordinate Biofuels business in Nigeria. NNPC
published list of biofuel projects which until now are yet to executed, these include; 20,000 ha Sugarcane Plantation/ fuel ethanol plant Project Agasha-Guma Fuel Ethanol Project, 20,000 ha Sugarcane Plantation/ fuel ethanol complex in Kupto malleri, Gombe State; 15,000 ha Cassava Plantation/ fuel ethanol complexes in Okeluse and Ebenebe in Ondo and Anambra States respectively; 5,000ha & 8,000ha Oil Palm-based Biodiesel plantation/plant on two sites (Calabar and Ikom respectively) in Cross River State and 20,000ha Sugarcane Plantation/Fuel Ethanol Plant in Jahun- Miga in Jigawa State [49].

4.2 Federal Ministry of Power (FMP)

FMP is mandated to formulate and implement the policy of the Federal Government of Nigeria (FGN) with respect to generation, distribution and transmission of power nation-wide both fossil and renewable based energy. Through its Renewable and rural Power Access department partners with the Federal Ministry of Environment to work on the Waste-to-Power (Bioenergy) Projects and other RE projects such as Small and Medium Hydro Power Plant. In addition to this, FMP signed an MoU with the Nordic Countries on cooperation & development of energy sector in Nigeria in particular renewable energy [50].

4.3 Federal Ministry of Science and Technology (FMST)

The ministry engages in several renewable energy, energy efficiency and rural electrification activities. FMST is currently supervising 17 Research and Development Institutions and interfacing with other cognate MDAs to diversify the economy. The renewable energy, biofuel and biomass section of one of its departments coordinates research activities in renewable energy technology (wind, solar, biomass etc.) especially in terms of electricity generation and supply to rural areas where grid connection is unavailable. Through the National Agency for Science and Engineering Infrastructure (NASENI). The ministry is tasked by Biofuel policy to facilitate bio-fuel technology transfer between relevant research institutes and industries.

4.4 Federal Ministry of Environment (FMENV)

The ministry through the Environmental Assessment Department (EAD) issues the Operational Permits, Facilities and Operation Licensing (FOL) and certification of environmental audit to operators in biofuel industry as well as to oil and gas operators. The EAD office ensures implementation of operational phase of Environmental Management Plan (EMP) of environmental impact assessment (EIA) approved projects and also to conduct periodic environmental compliance monitoring / inspection of biofuel or oil and gas facilities in line with approved EMP for the operational phase.

4.5 Federal Ministry of Water Resources (FMWR)

FMWR develops and implements water management policies. The ministry also facilitates and creates enabling environment for integrated conservation, development, management of various sustainable water uses for preservation of freshwater ecosystem. The ministry through one of its agencies, Nigeria Integrated Water Resources Management Commission (NIWRMC) is empowered to regulate and monitor the use of surface water resources for the growth of marine biomass feedstock such as water hyacinth for biofuel production without compromising the environment.

4.6 National Power Training Institute of Nigeria (NAPTIN)

NAPTIN was established in 2009 an agency of the Federal Government of Nigeria, operating under the aegis of the Federal Ministry of Power. The institute seeks to provide training for power sector personnel (especially the fresh graduates) and coordinate training activities that will enhance indigenous skills acquisition. NAPTIN offers short course, trainings and workshops on renewable energy systems. Cost is a core constraint to attracting young graduates to this scheme because they are exorbitant ranging from about $150 to $1500. Most fresh graduates can only access low paying jobs usually below the official $83.6 minimum salary. Consequently, they are dissuaded leading to limited availability of skilled personnel in energy industries.

4.7 Nigerian Electricity Regulatory Commission (NERC)

The commission is responsible for developing and approving Standards, Manuals & Codes for
Table 3. Summary of national energy targets [43]

<table>
<thead>
<tr>
<th>S/no</th>
<th>Sector</th>
<th>Target</th>
<th>Timeline</th>
<th>Performance against target</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Installed capacity base</td>
<td>6GW</td>
<td>2009</td>
<td>Achieved</td>
</tr>
<tr>
<td>2</td>
<td>Share of hydropower to the nation’s electricity generation</td>
<td>15%</td>
<td>2015</td>
<td>Missed</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>20%</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>4</td>
<td>Share of wind power to the national electricity generation mix</td>
<td>1%</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>5</td>
<td>Share of solar energy to the national electricity generation mix</td>
<td>1%</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>6</td>
<td>Replacing firewood consumption for cooking with biomass energy technology</td>
<td>50% firewood</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>7</td>
<td>Biofuel blend in transport fuels</td>
<td>10%</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>8</td>
<td>Total share of renewable to the national electricity generation mix</td>
<td>2000MW</td>
<td>2020</td>
<td>On track</td>
</tr>
<tr>
<td>9</td>
<td>Domestic production of biofuels consumed in the country</td>
<td>100%</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>10</td>
<td>Increase installed capacity</td>
<td>35,000MW</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>11</td>
<td>Biopower</td>
<td>400MW</td>
<td>2025</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>12</td>
<td>Hydropower (small-scale)</td>
<td>2GW</td>
<td>2025</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>13</td>
<td>Solar PV (large-scale &gt;1MW)</td>
<td>500MW</td>
<td>2025</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>14</td>
<td>CSP</td>
<td>5MW</td>
<td>2025</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>15</td>
<td>Wind power</td>
<td>40MW</td>
<td>2025</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>16</td>
<td>Share of the population with energy access</td>
<td>60%</td>
<td>2017</td>
<td>Missed</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>75%</td>
<td>2020</td>
<td>Not currently on track</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>90%</td>
<td>2030</td>
<td>Not currently on track</td>
</tr>
</tbody>
</table>

the Nigerian Electricity Industry which encompasses biofuel industry. NERC sets a target of generating a minimum of 2,000MW of electricity from renewables by the year 2020. Similarly, NERC mandates both Electricity distribution companies (DisCos) and Nigerian Bulk Electricity Trading Company (NBET) to procure minimum of 1000MW (representing 50% of the total projected renewable sourced electricity. The commission in 2015 established the Feed-In – Tariff for biomass, solar, Wind and Small Hydro and to regulate the energy distribution price and access to grid by end users. In order to regulate and monitor grid connection of renewable energy projects, the commission introduced three strategies;

1. Net-metering for very small capacities (typically below 1MW)
2. Feed-in tariff for capacities up to
   a. 5 MW of solar,
   b. 10 MW of wind,
   c. 10 MW of Biomass and
   d. 30MW of small hydro.
3. Competitive tender for capacities above these thresholds to be procured through NBET [51].

4.8 Rural Electrification Agency of Nigeria (REA)

The Nigerian Rural Electrification Agency (REA) is the Implementing Agency of the Federal Government of Nigeria tasked with electrification of rural and unserved communities through small scale RE projects. REA formulates rural electrification policies and strategies part of which includes:
i. 60% rural access to electricity by 2020,
ii. Annual connection of over 1 million rural households to electricity by 2020,
iii. Demand the utilization of cheap and high-quality options in RE projects while applying for grants,
iv. Provide grants towards the initial start-up costs of qualified RE projects,
v. Higher electricity tariffs margins between the rural areas than urban centres to boost RE projects, and
vi. RE schemes with generating capacity at a single-phase site of 1MW or less, or distribution capacity of 100kw or less are exempted from license.

Like other public institutions the 2020 targets are going to fail because of ineptitude budgeting and implementation of the strategies, grants are not provided for the RE indigenous investors, neither do the foreign investors willing to come in due to sprawling bureaucracy involved [52].

4.9 National Biotechnology Development Agency (NABDA)

NABDA is a top research institute established in 2001 under the aegis of the Federal Ministry of Science and Technology to implement the policy that is aimed at promoting, coordinating, and setting research and development priority in biotechnology for Nigeria. The agency under through its department; Bioenergy Research Centre has pilot projects on biogas generation from animal wastes and agricultural residues [48].

4.10 Standards Organisation of Nigeria (SON)

SON is the apex standardization body in Nigeria. The biofuel policy of 2007 tasks organization to develop quality specifications for biofuel products. However, since no substantial biofuel production is achieved yet in Nigeria, the SON's activities in biofuel standardization is not conspicuous [48].

5. NON-GOVERNMENTAL ORGANIZATIONS

In the recent times, increasing number of non-profit organisations are entering into biofuel projects and becoming active in the field. Some engage in public discussions and information exchange among interdisciplinary experts, lobbying and awareness creation. Some of these NGOs are:

5.1 Council for Renewable Energy in Nigeria (CREN)

The association which was established in 2004 comprised of stakeholders with significant presence and engagement in all sectors of renewable energy technologies and businesses. Their prime objective include, advocating for diversification from fossil energy to the use of renewable energy technology in Nigeria as well the cutback the greenhouse gas emissions. CREN creates platforms where professional sector, government and civil servants, academics, associations, industry, financial institutions and services can come together to collectively develop comprehensive sustainable renewable energy strategies for Nigeria [53].

5.2 Manufacturers Association of Nigeria (MAN)

MAN was established in 1971 with over 3000 current members which are active stakeholders in Nigerian manufacturing and construction companies. The association engages with politicians, other sectors of the economy and society at large to advocate for infrastructural development especially in the energy sector, made-In-Nigeria Product, regulatory issues, among others. Additionally, the association also formulates policy recommendation with the aim of securing an efficient and profitable environment for manufacturers which includes industrial wastes management. MAN has achieved over 1500 advocacy success. They also provide uninterruptible power supply to their members with month payment at affordable prices. However, it is not clear if they run on renewable energy technologies currently [54].

5.3 Nigerian Society for Engineers (NSE)

This is a technical and trade union for engineering professionals founded in 1958 in Nigeria. The society's thematic focuses are politics, society and industry. NSE seeks to promote the development and acquisition of technology by conducting visits to places of engineering interest, reading technical papers, holding meetings and conferences, publishing books, journals and periodicals on engineering matters and to facilitate engineering research [48].
5.4 Energy Institute Nigeria (EINIGERIA)

The association is a branch of Energy Institute with its headquarters in London. EINIGERIA was established in 2011 with key aim of providing support to people interested in the nation’s energy sector through the promotion of standards of operations and best practices through technical sessions, provision of cutting-edge support to Universities through learning affiliate membership and accreditations to approved training centres, organising specialized trainings and workshops for energy investors [55].

5.5 Gaps in Public Institutions Engagements

5.5.1 Inconsistencies/conflict in policy/policy somersault

The biofuel related RE policies designed by the different public institutions have strong potentials to drive the industry to global competition level, the main impediment to its actualization is lack of commitment for implementation. Most proposed RE projects remains in the paper while few that were commissioned had been abandoned. An effective implementation would require arrogating penalties for stakeholders that default. Another drawback to biofuel policies implementation is the ambiguous and short-term target setting, it is evidently that the existing RE targets are expected to fail because they do not consider the need for progressive development, starting with thorough awareness at the grassroots.

More so, a practical biofuel approach would require advancing biofuels in phases. This in turns will build an enabling environment that allows step-by-step policy support, institutional capacity building, and monitoring as practised in many advance nations like United Kingdom. National RE sensitization schemes should be the baseline strategy which upon certified completion other phases should evolve from. Ohimain (2012) recommended that the commencement of next phase is premised on the success of the previous phase giving enough opportunities to acquire enough skills and experience from breakdowns and achievements. Beyond ameliorating the risk of gross failure of RE projects [48], phase execution would also attract more investors because of the earned trust. It will also help the nation to identify its strength in all the phases of the project from biomass sourcing, biofuel production, to fuel trading. The risks of such a phased development strategy are less because implementing each phase could depend on the success of the previous phase. The phased approach would also allow countries to consider their comparative advantage of each phase. Some countries may have a comparative advantage in the production of feedstocks, but not in the manufacturing of biofuels, and the phased approach would allow them to evaluate each activity before developing policies.

6. CONCLUSION AND FUTURE DIRECTIONS

The key conclusions of this study are that Nigeria has enormous potentials for biofuel production based on the over 144 million tons per year reported biomass reserve. It is noteworthy that all the renewable targets from 2007 till date has failed and that the existing renewable policies require strong overhauling in order to achieve RE2030 target. Achieving high penetration of biofuel into Nigeria energy market would necessitate the active participation of private investors, government, tertiary institutions, artisans, traditional rulers, among others.

Energy policies are driven by two forces, namely: the background analysis and the political foreground. The latter are supersonic, self-serving and well-known accounting for the inconsistencies in biofuel development in Nigeria. In order to forestall the failure of future renewable targets in Nigeria, the government and all other policymakers involved in developing policies should consider the following:

- Developing achievable but ambitious switch targets and pathways for biofuel production, distribution and market. Targets should be set for every phase; sensitization of the public, setting up national database for indigenous biomass feedstocks, cultivation of feedstocks, production and markets. Individual states can set discrete targets and be incentivized for actualizing it.
- Providing a robust incentive system for indigenous stakeholders in biomass energy, this include, a fully sponsored international trainings and workshops for farmers that achieved high feedstocks production, zero collateral loans to indigenous biofuel investors, bursary for renewable energy students, grants to public institutions engaging in biofuel R&D, fossil subsidies should ameliorate while biofuel should experience high subsidies across its lifecycle. etc.
• Creating a sustainable and transparent market environment. Foreign investors in biomass energy should enjoy easy access to necessary information without being subjected to undue bureaucratic bottlenecks. All guidelines, policies and law should be gazetted and availing a level playing ground for large scale biofuel market investors and their counterparts in fossil-based energy. Biofuel quality should be standardized, meeting international specifications and making it exportable. National certification and license should be issued to investors with required credentials.

• Investing in Energy infrastructure. Local fabricators of biofuel equipment should enjoy low tax and import duties on biomass seeds, equipment and services should be small as well.

• Promoting cutting-edge knowledge and technology alternatives. Tertiary institutions (college of educations, polytechnics and universities) should offer renewable as a major programme with a rich and updated syllabus, this will boost indigenous human capacity building. Biofuel development from indigenous bioresources should also be integrated into the research focus for research students. Energy industries should be developed flexibly to accommodate latest technological innovations and advances. Car manufacturer like Innoson vehicle based in Anambra state, Nigeria should start considering motors that run on biomethane and other clean biofuel products.

• Developing smooth phase biofuel integration into the national grid. The future that the country should look forward to is the integration of biofuel energy into national grid, this however should not be sprint but a long-term scope.

The benefit of developing biomass energy in Nigeria cannot be overemphasized, besides the international pomp that follows it, national clean-energy economy, job creation, emission reduction and increased energy access are the inseparable gains.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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