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Review Article

Strategic Evaluation of Biofuels as a Dependable Solution for Our Energy Crisis in Nigeria

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Abstract: The quest for safe, secure and sustainable energy has posed one of the most critical challenges of this age. Nigeria is blessed with vast biomass resources, yet lacks the wherewithal to harness and develop a sustainable energy framework, this review highlights the complexity of biofuels which is a direct product of biomass and the sheer diversity of options already available, hence advocating biofuel as an option to solve the current energy crisis if it is economically, socially and technologically sustained and the public acceptability is maximized.

Keywords: Biomass, Biofuel, Sustainable Energy, Resources

1. Introduction

Ecological disadvantages have come into prominence as the use of fossil energy sources suffers a number of ill consequences for the environment, including the greenhouse gas emissions, air pollution, acid rain, etc and also perturbs the climate [1]. Serious geopolitical implications arise from the fact that the society is heavily dependent on only a few energy resources such as petroleum, mainly produced in politically unstable oil-producing countries and regions. Indeed, according to the World Energy Council, about 82% of the world's energy needs are currently covered by fossil resources such as petroleum, natural gas and coal. Whereas petroleum will certainly not become exhausted from one day to another, it is clear that its price will tend to increase. This fundamental long-term upward trend may of course be temporarily broken by the effects of market disturbances, politically unstable situations or crises on a world scale [2].

Worldwide, questions arise concerning our future energy supply. There is a continual search for renewable energy sources that will in principle never run out, such as hydraulic energy, solar energy, wind energy, tidal energy, geothermal energy and also energy from renewable raw materials such as biomass. In the long run, more input is expected from solar energy, for which there is still substantial technical progress to be made in the field of photovoltaic cell efficiency and production cost. Biofuel, the renewable energy released from biomass, is expected to contribute significantly in the mid to long term. According to the International Energy Agency (IEA), biofuel offers the possibility to meet 50% of the world energy needs in the 21st century if harnessed accordingly. In contrast to fossil resources, agricultural raw materials such as wheat or corn have until recently been continuously declining in price because of the increasing agricultural yields, a tendency that is changing now, with competition for food use becoming an issue. New developments such as genetic engineering of crops and the production of bio-energy from agricultural waste can relieve these trends [1-3].

Biomass is an organic matter derived from living, or recently living organisms. it can be used as a source of energy and most often refers to plants or plant-based materials that are not used for food or feed, and are specifically called lignocellulosic biomass [3]. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Biofuels refers to a wide range of fuels which are in some way derived from biomass, organic matter. In today's society they are gaining increased public and scientific attention due to rising gas and oil prices. It is considered as one of the key renewable energy resources of the future because of its large potential economic benefit and environmental advantages. As at 1990, biomass is the fourth largest sources of energy in the world, accounting for about 13% of primary energy use [4]. Potential biomass materials to be used for biofuels include wood chips, rotted trees, manure, sewage, mulch, and tree components. Chlorophyll present in plants absorbs carbon dioxide from the atmosphere and water from the ground through the process of photosynthesis. The same energy is passed to animals when they eat them. It is considered to be a renewable source of energy because carbon dioxide and water contained inside plants and animals are released back in to the atmosphere when they are burned and we can grow more plants and crops to create biomass energy.

1.1. Methods of Conversion of Biomass to Biofuel

Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, biochemical and electrochemical methods [5].

1.1.1. Thermal Conversion

Thermal conversion processes use heat as the dominant mechanism to convert biomass into another chemical form. Also known as thermal oil heating, it is a type of indirect heating in which a liquid phase heat transfer medium is heated and circulated to one or more heat energy users within a closed loop system [6]. The basic alternatives of combustion (torrefaction, pyrolysis, and gasification) are separated principally by the extent to which the chemical reactions involved are allowed to proceed (mainly controlled by the availability of oxygen and conversion temperature). Energy created by burning biomass is particularly suited for countries where the fuel wood grows more rapidly, e.g. tropical countries.

1.1.2. Chemical Conversion

A range of chemical processes may be used to convert biomass into other forms, such as to produce a fuel that is more conveniently used, transported or stored, or to exploit some property of the process itself. Many of these processes are based in large part on similar coal-based processes, such as Fischer-Tropsch synthesis, methanol production, olefins (ethylene and propylene), and similar chemical or fuel feedstocks. In most cases, the first step involves gasification, which step generally is the most expensive and involves the greatest technical risk [7]. Biomass is more difficult to feed into a pressure vessel than coal or any liquid. Therefore, biomass gasification is frequently done at atmospheric pressure and causes combustion of biomass to produce a combustible gas consisting of carbon monoxide, hydrogen, and traces of methane. This gas mixture, called a producer gas, can provide fuel for various vital processes, such as internal combustion engines, as well as substitute for furnace oil in direct heat applications [8]. Because any biomass material can undergo gasification, this process is far more attractive than ethanol or biomass production, where only particular biomass materials can be used to produce a fuel. In addition, biomass gasification is a desirable process due to the ease at which it can convert solid waste (such as wastes available on a farm) into producer gas, which is a very usable fuel. Other chemical process such as converting straight and waste vegetable oils into biodiesel is transesterification [9].

1.1.3. Biochemical Conversion

As biomass is a natural material, many highly efficient biochemical processes have developed in nature to break down the molecules of which biomass is composed, and many of these biochemical conversion processes can be harnessed.

Biochemical conversion makes use of the enzymes of bacteria and other microorganisms to break down biomass into gaseous or liquid fuels, such a biogas or bioethanol. [9] In most cases, microorganisms are used to perform the conversion process: anaerobic digestion, fermentation, and composting.

1.1.4. Electrochemical Conversion

In addition to combustion, biomass/biofuels can be directly converted to electrical energy via electrochemical (electrocatalytic) oxidation of the material. This can be performed directly in a direct carbon fuel cell, direct liquid fuel cells such as direct ethanol fuel cell, a direct methanol fuel cell, a direct formic acid fuel cell, a L-ascorbic Acid Fuel Cell (vitamin C fuel cell) and a microbial fuel cell. The fuel can also be consumed indirectly via a fuel cell system containing a reformer which converts the biomass into a mixture of CO and H_2 before it is consumed in the fuel cell. [10]

1.2. Forms of Biofuels

1.2.1. Biogas

Agricultural co-products or waste such as straw, bran, corn cobs, corn stover, etc. are lignocellulosic materials that are now either poorly valorized or left to decay on the land, also crops or organic waste streams can also be efficiently converted into biogas and used for heat, power or electricity generation [11]. Hence these raw materials attract increasing attention as an abundantly available and cheap renewable feedstock. The technology is recommended especially for small scale plants located far from the natural gas grid and especially if the produced heat can be utilized. In countries with tax systems favouring use of biogas for vehicles (i.e. Sweden and Germany) upgrading of biogas should be considered especially for medium and large scale biogas plants for proper harnessing and utilization of the substrates. Anaerobic digestion is a natural process that converts a portion of the organic carbon in manure into methane (CH_4) and carbon dioxide (CO_2). Its benefits include substantial odour reduction, reduction of greenhouse gas (GHG) emissions, and potential pathogen reduction in manure [12-14] hence produces biogas on renewable basis, producing digested slurry which is good manure and its nutrient value is better than ordinary farmyard manure. Biogas contains approximately 50 to 65 percent CH_4. Biogas usage is increasing rapidly on a daily basis, for reasons that fuel costs have been rising steadily for a number of years and the taxation burden increases. Regards to its pollution free source at little or no cost and no offensive smell is produced. Biogas produced from the Anaerobic Digestion of manure can be used for heat production to power generators or micro-turbines to generate electricity, or simply flared also can be used in cooking and lighting. [14]

1.2.2. Biodiesel

Biodiesel is an ecofriendly, alternative diesel fuel prepared from domestic renewable resources, It is a renewable source of energy which seems to be an ideal solution for global energy demands. It has attracted considerable attention during the past decade as a renewable, biodegradable and non-toxic fuel which has served as an alternative to fossil fuels [15-17].

Oilseeds such as soybeans, rapeseed (canola) and palm seeds (and also waste vegetable oils and animal fats), can be equally processed into oils that can be subsequently converted into biodiesel [18]. Recently, researchers are focusing on non edible seed oils, waste oil and oils from agricultural waste for biodiesel production since it is assumed that large-scale production of biodiesel from edible oils may bring global imbalance to the food supply and demand market [19-24].

1.2.3. Bioethanol

Agricultural crops such as corn, wheat, sugar cane and beets, potatoes, tapioca, etc. can be processed in so-called biorefineries into relatively pure carbohydrate feedstocks, the primary raw material for most fermentation processes. These fermentation processes can convert those feedstocks into a wide variety of valuable products, including biofuels such as bio-ethanol. Currently, bioethanol is the most common biofuel. Almost 99% of it is produced from corn grain and other cereals and it is referred to as first generation. In the United States, ethanol production rates are in the range of 14–15 billion gallons per year at corn dry mills; these mills produce not only ethanol but also corn oil and dry distillers' grains (DDG) – a product that is used as animal feed [25-28]. In developing countries, researchers have transcended from first generation bioethanol that utilize energy crops and competes with the global food supply to the second generation bioethanol which uses lignocellulosic waste, hence supports the waste to wealth assertion then to the third generation bioethanol where microorganisms like Algae is now used as the raw material thereby enhancing the use of non economically viable materials but there lies the problem of the production process which is highly costly [2].

2. Sources of Biomass in Nigeria

Forest is a major source of biomass that has the potential of contributing substantially to a nation's biofuel resources when it is utilized for industrial purposes. It provides perennial renewable feedstocks which would not compete with foods and could be more sustainably harvested, hence its availability, outstanding diversity and adaptability makes it a global renewable resource for biofuel generation [29-32]. Global Forest Resources Assessment of Nigeria forest biomass is presented in Table 1. It has the opportunity of maximizing renewable energy resources to stir development, create reliable fibres up- ply, and contribute to domestic economies. Similarly, Wood fuel, including wood for charcoal is a major biomass feedstock used in Nigeria to meet household energy needs. It is the highest produced forest biomass in Nigeria. In 2008, over 62.3 million wood fuels were produced and consumed It is estimated that about 55% of annual global use of wood is utilized as fuel wood in developing countries [33] Animal waste from farms, non edible plant seed oils from plants, lignocellulosic wastes from farms and industries, municipal solid waste, food waste and industrial waste, all these are major sources of biomass in Nigeria but poor management has caused these resources to pollute the environment which is a major problem in the country, hence underutilized as well.

Table 1. *Biomass stock in forest FRA 2010 category Forest Biomass (million metric tones oven-dry weight).*

	1990	2000	2005	2010
Above-ground biomass	3,459	2660	2261	1861
Below-ground biomass	830	638	543	447
Total living biomass	4289	3298	2804	2308
Dead wood	601	462	392	323
Total	4890	3760	3,196	2,631

Source: FAO. Global forest resources assessment: country report, Nigeria. Rome; 2010.

3. Energy Situation in Nigeria and the Challenges

EIA estimates that in 2011 Nigeria's primary energy consumption was about 4.3 Quadrillion Btu (111,000 kilotons of oil equivalent). Of this, traditional biomass and waste accounted for 83% of total energy consumption. This high percent represents the use of biomass to meet off-the-grid cooking heating and cooking needs, mainly in rural areas yet it is not properly harnessed and integrated to meet our basic energy requirements. For many years now, Nigeria has been facing an extreme electricity shortage. This deficiency is multi-faceted, with causes that are financial, structural, and socio-political, none of which are mutually exclusive [34].

At present, the power industry in Nigeria is beset by major difficulties in the core areas of operation: generation, transmission, distribution and marketing [35]. In spite of Nigeria's huge resource endowment in energy and enormous investment in the provision of energy infrastructure, the performance of the power sector has remained poor, in comparison with other developing economies [36]. There is no doubt that expensive and unreliable power remains a major concern to all sectors of the economy in Nigeria: the industrial, commercial, and domestic sectors especially. Multiple and unpredictable power cuts, which have become a daily occurrence in Nigeria, often result in equipment malfunctioning, which make it difficult to produce goods and provide service efficiently. As a result of this fundamental problem, industrial enterprises have been compelled to install their own electricity generation and transmission equipment, thereby adding considerably to their operating and capital costs [37].

Most businesses in Nigeria, large and small, end up relying on the generator for electricity to power their businesses. For instance, MTN – the South African mobile phone company and the largest mobile phone supplier in Nigeria – is estimated to 'have installed 6000 generators to supply its base stations for up to 19 hours a day. The company spends $5.5 million on diesel fuel to run the generators. Enweze [38] has estimated that about 25% of the total investments in machinery and equipment by small firms, and about 10% by large firms, were on power infrastructure. Despite the attempts by some firms to supplement the power supply by PHCN, electricity demand by consumers, particularly domestic users has continues to increase, hence the dependency on biomass energy to resolve the issue.

Ohimain, [39] reviewed several possible challenges that could affect the installation and operation of a 1 MW biomass fired electricity plant in Nigeria. First, Nigeria has no previous experience in the installation and operation of biomass plant. Many countries before embarking on biopower had installed pilot/demonstration plants. Experience gained from these demonstration plants were fine-tuned before the installation of full scale plants. Without, this experience, Nigeria will probably purchase and install a turn-key plant. Hence, the country could be faced with the challenges of maintenance.

Another potential challenges is the availability of waste wood feedstock. Typically, about 980 kg per hour of wood waste will be required as feedstock to produce 3.8 MW of thermal energy and 1 MW of electricity, thus, requiring 8,584.8 tonnes of waste wood per year [40]. This quantity would not have been a challenge, since the quantity of wood waste production nationwide is 5.2 million tonnes per year. But biomass resources in the country is not localized or concentrated in a small area. It is widely distributed around the country. Therefore, considerably energy and efforts will be expended gathering wood waste around the country.

Another barrier is the issue of cost. All over the world, biomass to electricity projects are expensive to install Though, this appears expensive, but the cost of operation might be very low if the plant is located close to saw mill districts where wood wastes are in excess.

Another potential challenge of biomass electricity plant in Nigeria is lack of policy framework for the effective and sustainable operation of the plant.

4. The Way Forward

Nigeria is challenged with the twin problems of solid waste management and insufficient power generation. Because of the lack of better management approaches, Success stories of biomass energy production sited in farms in India, USA and other countries abound

These practices negatively impact humans in addition to the loss of useful energy into the environment. Like Brazil, Nigeria is taking a more top-down, supply-led approach than has perhaps been evident in other countries, many of whose policies are more market-driven. However, the government is not just looking to Brazil for information; it also plans to start up the industry using a Brazilian import partnership. Brazil is to initially supply Nigeria with fuel ethanol in order to develop the market and fuel supply infrastructure, and test out the ground. Both countries signed a memorandum of understanding in 2005. The import reception facilities at Atlas Cove and Mosimi areas are already being modified in preparation for the distribution of the biofuel [41]. The recent surge in oil prices has made biofuels much more cost competitive with gasoline and spurred new investment. biofuel production will continue to expand as long as world petroleum prices remain high.

5. Practical Steps to Develop Nigeria's Potentials in Biofuel

In line with the European Union [42], suggest five key policy axes, pulling together the measures government will take to promote the production and use of biofuel in Nigeria as suggested as follows:

5.1. Stimulating Demand for Biofuel

There is need to encourage policies that will favour biofuel (including second generation products), so as not to compete the global food supply.

5.2. Capturing Environmental Benefits

The need to examine how biofuel can best contribute to emission targets; work to ensure sustainability of biofuel feedstock cultivation; and look again at limits on biofuel content in petrol and diesel.

5.3. Developing Production and Distribution of Biofuel

The need to set up specific groups to consider biofuel opportunities in rural development programmes; and increase monitoring to ensure no discrimination against biofuel.

5.4. Enhancing Trade Opportunities

Assess the possibility of putting forward a proposal for separate customs codes for biofuel; it will pursue a balanced approach in trade talks with ethanol-producing countries;

5.5. Research and Development

Government should specifically support the development of an industrialized 'Biofuel Technology Platform' which will make recommendations for research in this sector.

Through research, production costs could be cut considerably beyond 2010. Research and development issues in biofuel in Nigeria should, therefore, focus on the following:

(1) Assess the potential for scientific developments to contribute to greater and more efficient production of biofuel, primarily liquids for use in the transport sector, review international policy.
(2) Science and industrial experience, for example the USA and China biofuel research roadmaps and the European Technology Platforms
(3) Provide insight into relative priorities for research and development for biomass and each class of biofuel consider the barriers to further development, scientific or otherwise
(4) Identify research and development that should be

funded publicly and that which would be better funded by industry

(5) Highlight the gaps between the current situation and the potential that biofuel could realistically achieve, in terms of cost, yield and environmental performance - particularly greenhouse gas emissions savings

(6) Provide context for biofuel and consider how these issues will be affected by developments in the science and engineering

(7) To identify potential environmental and socio-economic impacts of biofuel development, e.g. the consequences of increases in feedstock production - including the environmental impacts and implications for public policy; local production and use versus transportation and wider distribution; developmental benefits.

Now that the Federal Government is venturing into biopower by the installation of two plants, they have to create the enabling policy framework to allow public participation. There should be established power purchase agreement/frameworks. The rates for these agreements should be more favourable than fossil fuel electricity because biomass electricity is renewable and performs additional function of ridding the environment of wastes, thus precluding the associated impacts. There should also be other policy incentives such as tax holidays, tax exemption and waivers, subsidies, grant etc.

Direct biomass combustion technology is mature but biomass gasification technology though has been commercialized to a limited extent, the technology is still undergoing research, development and demonstration (RD & D) in many countries. We therefore suggest that during procurement phase of the project Nigeria should source for gasifier manufacturers from the list of countries with proven capacity and track records of biomass gasification and biopower generation.

6. Conclusion

Strategic evaluation throws light on the efficiency and effectiveness of comprehensive plans in achieving desired result. Ultimately, biomass conversion processes are attractive because they are in practice today, encourages energy diversity and the advances in scientific understanding necessary to achieve this goal appear realizable, nevertheless, they remain a sure and economically viable approach for sustainability and reduction of fossil fuel consumption. For a growing number of technical applications, the economic picture favours renewable resources over fossil resources as a raw material. Whereas It is obvious that agricultural feedstocks are cheaper than their fossil counterparts today and are readily available in large quantities. What blocks their further use is not economics but the lack of appropriate conversion technology. Whereas the petrochemical technology base for converting fossil feedstocks into a bewildering variety of useful products is by now very efficient and mature, the technology for converting agricultural raw materials into chemicals, materials and energy is still in its infancy.

Recommendation

There is an urgent need to bring coherence across various research areas that are related to biofuels but not yet focused on it, with their expertise, it will address access to the best technological skills and financing available to underpin the sustained growth of the industry. Hence this will radically change the agricultural sector in Nigeria, which is currently dedicated only to food production, and will create thousands of new jobs as Africa gears up for what is probably one of its first biofuel and certainly one of its many desperately needed agrarian revolutions.

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