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Energy Demands and the Place of Biofuel Technology and Forest Management Initiatives

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Abstract

Energy is an indispensable driver of development in our society and depended on to run daily activities and functions. To a great extent, the bulk of the energy supply are from fossil fuel; whose costs are increasing becoming huge and its inherent consequences and impact on the environment glaringly undeniable. This work reviewed the impact of the growing energy consumption trend, major sources, need for an alternative that is friendly to the environment and devoid of financial, political and trade uncertainties. Various forms of bio-fuel were seen as viable options to consider in the quest for improved energy provision. Among the various forms of bio-fuels, forest based bio-fuel was seen as a potential source of the much needed clean energy considering its ubiquitous nature. This however needs to be sustainably utilized and optimized across different spatial scales by adhering to stipulated forest management guidelines and use efficiencies. The study advocates that there should be a gradual reduction on fossil-based fuel use and maximizes bio-fuels which are much readily available in different forms in our environment. Through such concerted efforts, fossil fuel-driven climate change associated impacts and uncertainties will likely become much reduced.

Keywords: biofuel, climate change, energy consumption, forest management, sustainability

Introduction

Energy is a basic requirement for everyday living and used in different forms to propel societal activities and functions. Its provision is mainly dependent on fossil fuel (petroleum, diesel and natural gas) as sources of energy (Metzeger, et al. 2008); especially as it is widely known, much mobile and less technical in use. The US energy information administration 2019 report projects that between 2018 and 2050 world energy consumption will rise by nearly 50% with Africa increasing by 110%. Conversely, the 2019 international energy outlook revealed that between 2010 and 2019, global energy consumption grew from 500 to over 600 quadrillion Btu with countries that do not belong to the Organization of Economic Cooperation and Development (OECD) leading in consumption. As at 2018, with a global population of about 7.59 billion, the global energy consumption was about 620 quadrillion British thermal unit (Btu). The United Nations department of economic and social welfare has projected the world population to be 9.74 billion with sub-Saharan Africa getting almost 99% increase by 2050. This population size will require a projected energy consumption of about 910.7 quadrillion British thermal unit. The above projection means that the world will be in need of additional 290.7 quadrillion (Btu) to achieve energy sufficiency by 2050.

Varying sources of energy have been used over the years, but the struggle to get a dependable and sustainable source of energy is still ongoing; especially as it is becoming glaring that the demand is growing with population increase and globalization. Avtar et.al (2019) reveals that between 2000 and 2012, coal was the main source of energy and saw a larger growth in the usage ratio than other sources of energy such as crude oil and natural gas. Crude oil on the other hand has been used globally as a main source of energy and much demand on its reserves has risen across the globe. Alongside with natural gas, oil has been extracted at increasing scales across oil producing nations using different extraction techniques and processes. Lately, other sources of energy such as Oil shale and tar sands though have resources totalling at least 4 trillion barrels (bbl) but are still expensive in terms of conversion cost and related processes of extracting hydrocarbons being experimented for optimum consumption within local and international spheres. These processes are unconventional and much more expensive sources of oil making and dependence on them will equally lead to vulnerabilities and supply disruptions. Furthermore, they have no doubt led to environmental degradation in an increased magnitude across spatial scales, especially in developing countries where environmental friendliness and protection are not always adhered to. Hydrocarbons, especially oil has been depended on to meet energy needs, however, their volatile price, politics, technological intricacies, costs and environmental considerations have made it unarguably necessary to look for alternatives. Biofuel is considered a viable option in filling this gap and providing a reliable and potential energy store for a vast majority.

According to Krishnamurthy et.al (2016) the term "biofuel" refers to a solid, liquid or gaseous fuel such as bioethanol and biodiesel that is predominantly produced from bio-renewable feedstock. Biofuel and other non-oil based sources were well thought-out as a supplement to fossil fuel which faced a major crisis between 1973 and 1979. Attention towards biofuel resurgence in the early 2000s was due to heavy distress arising from climate change depleting fossil oil reserves. On one end, biofuel is promoted as a solution to climate change issues and setting up of a better energy supply globally because biofuel is considered carbon neutral, as the biomass absorbs roughly the same amount of carbon-dioxide during growth as when burnt. Biofuel can be grouped into specific types depending mostly on the parent material from which it is derived at the production process. Some of them include; bio-alcohol, biodiesel, green diesel, vegetable oil, algae fuel, bio-ethers, biogas, syngas and solid fuel (derived from materials such as wood pellets and dried manure).

Forms of Biofuels

Biofuel in addition to their positive carbon balance when compared to fossil fuel represents a significant potential for sustainability and economic growth of developed and developing countries because they can be generated from locally available renewable materials. Biofuels are usually classified into three generation mostly as a result of their source and efficiency.

Lavoie et.al (2013) opined that First generation biofuel are biofuel generated mostly from edible biomass such as sugarcane and corn, other marginal feedstock that are used and considered to produce first generation bioethanol (which is produced from the fermentation of glucose using genetically modified yeast strains such as *Saccharomyces cerevisiae*) include but not limited to barley, potato wastes, whey and sugar beets. Brazil is one of the leading countries in the feedstock.

Second generation biofuel are biofuel produced from a wide array of feedstock such as non-edible lignocellulose biomass. The second generation biofuel are in three main categories: homogenous such as white wood chips; quasi-homogenous such as agricultural and forest residues and non-homogenous which includes low value feedstock like municipal solid waste. Lavoie et.al (2011) agreed that the price of this biomass is significantly cheaper compared to the price of vegetable oil, corn and sugarcane which is an incentive. On the other hand, many biomasses such as corn which serve dual purpose of fuel and feedstock can now be focused on either fuel or feedstock and put to rest the fuel-or-feedstock debate which will subsequently allow the use of cheaper biomass as raw material to be used in biorefinery.

According to Brennana and Owendea (2010), the third generation biofuel is fuel produced from algal biomass which has a very distinctive yield when compared to the classical lingo-cellulosic biomass. Algae come naturally from stagnant ponds and more recently from algae farms where they are nurtured for the specific purpose of creating biofuel. The algae focude has some major advantages; no CO_2 back into the atmosphere, self-generating biomass, algae can produce up to 300 times more oil per acre than conventional energy crops. Algae have among other uses been used experimentally as a new form of green jet fuel designed for commercial travel.

Historically, forest products such as algae and wood have served fuel (firewood and charcoal) and economic purposes but with the need for renewable energy, their importance is geometrically increasing. The forest is now favoured as a reliable option for the massive supply of renewable biomass materials which will help drastically reduce our reliance on fossil fuel. The conversion process of these forest products (wood in this case) involves the process of extraction of the wood-based biomass from the forest after which it is broken down to sugar using enzymatic or thermochemical processes then converted to ethanol (if biodiesel is the intended product) or other products through fermentation. Algae which is the most popular resource for third generation biofuel has been reported to have photosynthetic efficiency ranging from 3-8% while many terrestrial crops are at 0.5%. Algae is classified into two categories: Seaweeds also called macroalgae and microalgae

Seaweeds are generally more plant-like without true roots, stems, leaves and have simple reproductive structure. They can grow on both fresh and saltwater, they are often fast in growth and can reach up to 60m in length. Most of them grow on rocky substrates while some are attached to sand particles forming stable, multi-layered vegetation while capturing as many available photons of light as possible. Their advantages include shorter life cycles which allow for cost-effective cultivation and do not need fresh water or fertilizer.

Microalgae are smaller (usually less than 0.4mm) and so require a microscope to observe. They are classified into three in terms of abundance: diatoms (Bacillariophyceae), green algae (Chlorophyceae) and golden algae (Chrysophyceae). They are able to grow in salty solutions and in ponds or pools both in arable and non-arable lands without the need for herbicides or pesticides. It is possible to increase the lipid content of microalgae by almost 80% above what it can produce naturally. Microalgae produce a larger amount of lipids which is needed for the production of biodiesel while macroalgae produces a larger amount of sugar which is necessary for the production of biogas using anaerobic digestion. Algae and other GMO products planted solely for the purpose of energy generation are the foundation of the 4th generation.

An interesting forest based biofuel is the wood biomass. The wood biomass consists of the totality of wood residue obtained from wood cultivation, exploitation and processing. Wood is a key raw material for the production of liquid biofuels due to its content of lingo-cellulosic biomass. Branco et.al (2018) opined that Bioethanol is the most produced biofuel corresponding to about 73% of the 135.3 billion liters of biofuel produced in 2016.The United States which is the biggest producer accounts for 59% followed by Brazil which is responsible for 27% of the global production and that bioethanol can be used as a replacement for pure gasoline or in blends with gasoline. The use of bioethanol in spark ignition engines has many advantages when compared with gasoline. Ethanol has a higher oxygen content which promotes better combustion, lower exhaust emission and a higher octane number which allows engines to operate at a higher compression ratio. As a form of advantage over the first generation biofuel, wood biomass can be produced from residual biomass from forests, wood pellets and saw dusts from industrial and municipal wastes. Also along the biofuel conversion pathway, intermediate chemicals are produced which can be sold on their own or undergo further refining to produce biofuels such as bio-jet fuel. This creates the needed product flexibility at any point in time based on market demands. The wood conversion processes involves a pre-treatment which breaks down tough fibers in the wood and exposes the sugar (cellulose and hemicellulose). After this, hydrolysis and fermentation takes place, then esterification and hydrogenation stage and finally to ethanol dehydration and polymerization which is the final stage of the wood based hydro-carbon formation.

Demand for Wood Biofuel and Challenges

Parikka (2003) discovered that about 70-75% of global wood harvest is either used or potentially available as renewable energy source, but the search for the best kind of wood biomass to be used for biofuel production requires the knowledge of the chemical composition and quantity of moisture contained. This is because, the biomass with a lower moisture content will cost less to transport and will reduce the stages of processing and the energy conversion equipment needed for biomass power. The moisture content of freshly harvested forest biomass and crop residue typically varies from 40-60% by weight and can be higher especially if the residue is exposed to precipitation. The chemical composition of woods of different species varies but is mostly composed of cellulose, hemicellulose and lignin. Mill-wood residue (MWR) generated from the conversion of matured stems of teak (*Tectona grandis*) and Gmelina (*Gmelina arborea*) at the saw mill of Forestry Research Institute Nigeria, Ibadan, revealed thus:

Combustion Properties of Extracted Lignin from the Mill-Wood Residue

Combustion properties	Gmelina	Teak	Mixed
% Volatile Matter	27.6	35.31	35.29
% Ash	3.48	11.37	6.80
% Fixed carbon	68.57	53.32	57.91
% Heating value (kj/kg)	32.79	30.13	31.70

The heating value of the extracted lignin from the MWRs was determined as a function of the volatile matter, ash and carbon content. Extracted lignin from Gmelina MWR had the lowest volatile matter and ash content averaged 27.6 and 3.48% respectively. It could be inferred that the lower the volatile matter and ash content of a biomass material the higher would be the fixed carbon and by extension the heating value. High percentage fixed carbon and heating values of lignin extracted from the residues attest to the lignin as a major energy bearing compound in wood and can be used to predict the energy value of wood. Challenges such as proper storage problems to avoid the chips, sawdust and off-cuts degrading while on the ground or become fuel for uncontrolled bush-burning can be resolved through large, systematic and commercial uptake of this wood biomass. Kiln drying is likely to increase the production cost of woody biomass especially the ones exposed to rainfall during storage or transportation but with a robust forestry where the value-chain will recognize all the players in the forest management process, this cost will become insignificant when compared to the value created. Also, the application of a supply-chain using GIS based technique will ensure optimum tracking of transportation, spatial distribution and arrangements at centralized locations with minimum loss at a cheaper cost.

The wood biofuel value-chain

Our growing population, continuous rate of urbanization, deteriorating climate and increasing energy demand are challenges that came with value adding opportunities. The entire vegetative cover is a major source of solution with additional fringe benefits to most of the challenges stated above. Wood fuel (firewood and charcoal) production and sale is a fast growing industry in Africa, this growth is driven by the fact that a good number of the population relies on wood fuel as their primary household energy source and demand from international markets including European Union. According to UNEP Report (2019), Africa is now the second largest exporter of biomass fuel product to Europe after North America with South Africa and Egypt leading. Namibia also exports compressed wood logs made from forest vegetation to UK. A report by FAO shows thus:

Quantity and value of Africa's wood-fuel export 2000-2015

YEAR	WOOD-FUEL (ALL SPECIES)			WOOD CHARCOAL		
	M^3	1000USD$	US$/$M^3$	TONNES	1000 US$	US$/TONNE
2000	1873	63	33.64	182757	34 905	190.99
2005	10038	881	87.77	329063	73 483	223.31
2010	410673	22460	54.69	467622	109 626	234.43
2015	664248	23092	34.76	453451.1	106 102	233,99

Source: http://www.fao.org/faostat/en/#data/fo

The table clearly indicates a steady increase in the value of all wood fuel species and charcoal sold from 2000-2015 and a reason to deepen investment in the sector

The benefits to be derived from a properly managed wood biomass forest will follow the basic steps of a typical value-chain which goes from production to processing, then to transportation, distribution and consumption. The charcoal sector in Rwanda is valued at 77million US$/year while in Kenya, it is valued at 450 million US$/year. In Tanzania, charcoal contributes 650 million US$/year to the economy. The profit earned by a transporter in Kenya is about 4% of the price of a sack of charcoal. (Morrissey, 2017).Likewise, other countries in Africa utilize it as a major source of energy and income, especially in their rural and sub-urban centers even though there is no documented evidence.

The production of this woody biomass will involve a systematic tree planting mechanism which will ensure a regeneration cycle that will help in achieving sustainability and do away with top-bottom management. This entire process will acknowledge and engage local technology, expertise, laws and incentivize at premium prices these locales that are very important part of a sustainable agribusiness. The involvement and payment of the local communities at the standard international market rates gives a sense of ownership and a better understanding of the need to protect this valuable forest resource. The availability of raw materials such as woody biomass wastes (such as off-cuts) will become important inputs in paper, tissue and related products production and definitely increase employment and quality of life. The carbon business which is dependent on biomass will be further strengthened and profitable.

Forest management concerns

Production of biofuel from plants such as oil palm (biodiesel) or even sugar-based ethanol will normally have a direct annual deforestation or land use change in regions where they are extracted from. With the quest to have more fuel available for consumption, larger acres of land will be devoted to the cultivation of plants from which they will be eventually extracted, thus deforesting or converting the original forest areas to farmlands. These no doubt have social and environmental impacts which have formed a basis for debate in recent times. An example could be drawn from the associated concerns on whether changes from agricultural food to fuel production could cause (small scale) farmers to lose access to their farmlands and potentially affect the food-chain and land-based income generation. On the other hand, environmental concerns are mainly related to the emissions (of carbon) and climate change impacts such increased agricultural switch could result to, associated loss of biodiversity and consequently, the ecosystem services losses that go with it. While direct land use changes and the debate on the extent to which biofuel production and extraction could affect biodiversity and food supply-chain persists, the reality of its impacts on ecosystems are quite glaring. This is more clearly exemplified by the indirect land use change (ILUC) concept which is seen in situations when land or crops that is supposed to be used for producing food or animal feed are instead used for growing biofuels, and the existing agric production shifts geographically to new land areas created by converting natural areas (Croezen et al. 2010).

With increased demand across spatial scales, there is need to bring in and advocate for sustainability in the utilization of biofuels (or wood fuel), especially since most of them are from ecosystems (such as forests) and much demand would imply more degradation of such ecosystems. Such efforts targeted at sustainable use would embrace both wood fuel (solid or liquid fuels from biomass) and also fuel wood which are unprocessed sticks, branches and logs (which may be converted to charcoal eventually). This is deemed a necessary step that will reduce the chances of forest degradation- which is seen as a long term reduction in total output, quality and potential of services that ecosystems provide. Achieving such targeted objectives would require: 1) promoting the establishment of tree plantations, especially those that grow fast and have much yield such as Neem (*Azadirachta indica*), gmelina (*Gmelina arborea*) and Eucalyptus (*Eucalyptus spp*). This will help to shift attention and pressure from natural ecosystems whose usage and subsequent degradation would affect ecosystems adversely and introduce trade-offs in their ecosystem provisioning. 2) Ensuring that biomass are extracted from mature trees and that a healthy juvenile population size that will enhance recruitment and replacement of the mature and emergent population is dutifully conserved (Igu, 2017). 3) Maximally utilizing forest residues and timber harvest left-overs. Small logs of wood that is normally left after harvest as well other chippings should be used in a bid to reduce wastage of forest resources. 4) Regulating harvest times and using suitable techniques during harvest such as selective logging. Such initiatives will no doubt preserve the ecosystem, promote resource efficiency and ecosystem stability. 5) Promote the use of crop residues and reduce over dependence and use on forest ecosystems. 6) Adequately taking care of ecosystems and monitoring their health and state regularly. This will require ensuring that diseases and pests do not ravage the ecosystem by engaging in early detection, removal of the affected trees (in the case of infection) and addressing the cause of the harm promptly. Such quick actions may involve the use or spraying of chemicals in the case of diseases and the use of biological methods in the case of pests.

Mitigating climate change through reduced greenhouse gases (GHG) is a major thrust for promoting the use of forest-derived biofuels. The scarcity, exorbitant price and irregularities surrounding fossil fuels are other factors promoting the initiative to engage forests and other biofuel energy sources as credible options. Efforts should be made to preserve these sources of energy across the globe, especially in developing countries which are less proactive in sustainability and conservation of ecosystems.

Conclusion

Energy consumption and demand is increasing across the globe and is characterized by irregularities in pricing, supply and availability. Biofuel was seen as a suitable option and alternative for the rising demand and vagaries of energy resources across the globe. Different forms of biofuel were reviewed and insights on their various features, forms and characteristics deduced. It was deemed important that such resources and the landscapes where they are sourced from be sustainably used and managed appropriately.

References

Alaswad, A., Dassisti, M., Prescott, T., Olabi, A.G (2015) Technologies and developments of third generation biofuel production. Renewable and sustainable energy reviews, Elsevier, pp. 1446-1460

Avtar, R., Tripathi, S., Aggarwl, A.K, Kumar, P (2019) Population-Urbanization-Energy Nexus: A Review.www.mdpi.com/journal/resources. DOI: 10.3390/resources 8030136

Ayadi, M., Sarma, S., Pachapur, V., Brar, S. and Cheikh, R. (2016). History and Global Policy of Biofuels. Doi.10.1007/978-3-319-30205-8_1.

Branco, R.H.R, Serafim, L.S and Xavier, A.M.R.B (2018). Second Generation Bioethanol Production: On the use of pulp and paper industry wastes as feedstock. https://creativecommons.org/licenses/by/4.0/

Brennana, L. and Owendea, P. (2010). Biofuels from microalgae – A review of technologies for production, processing and extractions of biofuel and co-products. Renewable Sustainable Energy. Rev. 14: 557-577

Buford, M. A. and Neary, D. G. (2010) Sustainable biofuels from forests: Meeting the Challenge. Biofuels and sustainability reports. Ecological society of America

Bunger, J. (2011). Oil shale and tar sands. In D. Ginley and D. Cahen (Eds.), Fundamentals of Materials for Energy and Environmental Sustainability (pp. 127-136). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511718786.014

Charis, G., Danha, G., Muzenda, E. A (2019). Review of timber waste utilization: Challenges and opportunities in Zimbabwe. 2nd International Conference on Sustainable Materials Processing and Manufacturing (SMPM, 2019). https://doi.org/10.1016/j.promfig.2019.07.005

Croezen, H. J., Bergsma, G. C., Otten, M. B. J. and van Valkengoed, M. P. J. (2010). Biofuels: indirect land use change and climate impact. CE Delft, Delft, Netherlands.

Dale, B.E and Holtzapple, M. (2015). The need for biofuels. American Institute of Chemical Engineers. www.aiche.org/cep

Giovanni, C. (2014). The first oil shock, stylized facts, reflections and the easterly puzzle in a forty-year retrospective. Munich Personal RePEc Archive. https://mpra.ub.uni-muenchen.de/58130/

Igu, N. I. (2017). Species diversity and structure of an intact freshwater swamp forest in the Niger Delta. Open Journal of Forestry, 7: 242-254.

ITTO (1992). Criteria for the Measurement of Sustainable Tropical Forest Management. International Tropical Timber Organization Policy Development Series No. 3. Yokohama, Japan

Milledge, J. J., Nielsen, B. V., Maneein, S. and Harvey, P. J (2019). A Brief Review of Anaerobic Digestion of Algae for Bioenergy. www.mdpi.com/journal/energies. doi:10.3390/en12061166

Krishnamurthy, R., Patel, S., Patel, P. (2016) Microalgae: Future Biofuel. Indian Journal of Geo-marine Sciences. Vol. 45(7) pp. 823-829

Lavoie, J-M, Beuchet, R., Berberi, V and Chornet, M. (2011). Bio-refining lignocellulosic biomass via the feedstock impregnation rapid and sequential steem treatment. In: Biofuel's engineering process technology. Bernardes, M. ed. Intech publishing, Croatia. Pp. 685-714

Lee, R and Lavoie, J. (2013). From First- to Third-Generation Biofuels: Challenges of Producing a Commodity from a Biomass of Increasing Complexity. Animal Frontiers, 3: 6-11.

Martin-Garcia, J. and Javier-Diez, J. (2012) Sustainable Forest Management: An Introduction and Overview. In Jorge Martin Garcia and Julio DiezCasero (eds) Sustainable Forest Management – Current Research, Intech, pp. 3-6

MCPFE (1993). General Declaration and Resolutions adopted in: Proceedings of the Second Ministerial Conference on the Protection of Forest in Europe. Helsinki 1993 Report, liaison unit. Vienna.

Metzger, J.O. and Hutherman, A. (2008) Sustainable Global Energy Supply based on Lignocellulosic biomass from afforestation of degraded areas. Naturwissenschaft. Springer Verlag 2008

Morrissey, J. (2017). The energy challenge in sub-Saharan Africa: A guide for advocates and policy makers: Addressing energy poverty. Boston

Oluwadare, A.O, Annguruwa, G.T, Sotannde, O.A (2016). Characterization of energy value of lignin extracted from mill-wood residues of *Gmelina arborea* and *Tectona grandis*. Journal of Forest Science and Environment, 1 (1): 14-20

Parikka, M. (2004). Global biomass fuel resources. Biomass and Bioenergy, 27: 613-620. 10.1016/j.biombioe.2003.07.005.

Parker, N., Tittmann, P., Hart, Q., Nelson, R., Skog, K., Schmidt, A., Gray, E., Jenkins, B.M (2010). Development of a biorefinery optimized biofuel supply curve for the western United States. Biomass and Bioenergy, 34 (11): 1597-1607

Perlack, R.D., Wright, L.L., Turhollow, A.F., Graham, R.L., Stokes, B.J and Erbach, D.C. (2005). Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a Billion-Ton Annual Supply. National Technical Information Service, Springfield, VA (http://www.osti.gov/bridge)

Ratnatunga, J and Balachandran, K (2009). Carbon Business Accounting: The impact of global warming on the cost and management accounting profession. Journal of Accounting, Audit and Finance

Shalaby, E.A (2013). Biofuel: Sources, extraction and determination. http://dx.doi.org/10.5772/51943

Spirchez, C., Lunguleasa, A. and Croitoru, C. (2017). The importance of wood biomass in environmental protection. AIP Conference Proceedings. 1918.020007. 10.1063/1.5018502

UNEP (2019). Review of wood fuel biomass production and utilization in Africa: A desk study. Nairobi

United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision. New York: United Nations.

US EIA (2019). International energy outlook 2019 with projections to 2050. Washington DC 20585. Pp.24. https://www.eia.gov/ieo

Wu, N., Moreira, C., Zhang, Y., Doan, N., Yang, S., Phlips, E., Svoronos, S. and Pullammanappallil, P. (2019). Techno-Economic Analysis of Biogas Production from Microalgae through Anaerobic Digestion. Doi:10.5772/intechopen.86090.