Assessment of Biofuel Resource Potential, Prospects, Challenges and Utilization in Ethiopia: Sourcing Strategies for Renewable Energies- A Review

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Abstract

Lately there has been renewed interest in biomass based renewable energies. This is due to energy security concern, growing environmental benign and spiraling price of fossil fuel. In Ethiopia quality of life and energy consumption is tidily conjoined. This is mainly attributed to fast economic growth, expansion of industry and change of lifestyle of its population. This review paper assesses biofuel resource potential, prospects, challenges of Ethiopia and also investigated strategies for its transport utilization, with particular emphasis on sourcing options for cleaner energies from biodiesel. Possessing huge biomass potential and all types of topographies and climatic conditions that can accommodate the growth of various potential biofuel feed stocks; biofuels are believed to be best renewable alternatives to replace transport fuels. Attracted from its potential, the country has started production and utilization of biofuels, mainly biodiesel and ethanol since 2007. Although the biodiesel production is marred by many challenges. Generally, the economic and environmental benefits of biofuel development have been advocated in many literatures; however, the Ethiopian biofuel development policy and action plan lacks systematic study of strategies for efficient use of biofuel resource beyond the saving of hard currency by replacing petroleum-based fuels with biofuels, pastoral agricultural development and lessen the exhaust emissions. In this study it is shown that, updating the policy consolidating genuine biofuel development strategies depending on different evaluation adjustments, encouraging global expertise, involvement in specialized technical coordination, using up-to-date technologies and the introduction of advanced biofuel production may help in resolving the ongoing energy problems in the country.

Keywords: Biodiesel, Biofuel, Biomass, Energy, Ethanol, Transportation
1. Introduction

The world is in the transition from fossil fuels dominated energy systems to low-carbon and sustainable energy systems with significant attention on energy efficiency and renewable/sustainable energy resources that safeguard the environment as per the Kyoto goals [1]. Energy resources play substantial roles in the economic development of every country of which, most of the world energy needs are delivered by the fossil based energy sources [2]. Among these sources, oil plays a vital part in the industrial development, transportation, farming sectors, and to meet numerous other essential human needs [2], [3]. Despite the danger of running out these non-renewable energy resources, global demand has been extensively expanded in the last few decades [4] and currently, it is stretched by $10^5$ times more than its natural formation [5]. Therefore, the world is facing many energy-related problems such as rapid and unstable fuel price, uncontrollable emissions and anxieties of national energy security [6].

The fast population growth, industrialization, and change in human living styles are the fundamental reasons behind the increasing demand and the present energy crisis [4], [7]. These problems have led researchers to seek alternative energy sources to our existing carbon-based energy sources [8]. These alternatives incorporate hydropower, solar energy, wind energy, geothermal energy, nuclear energy, and bioenergy (biofuels) resources. Olatomiwa Bifarin (2015) reported that biofuels are the best alternatives, especially for Africa, due to the continent’s enormous biomass potential of all the enumerated alternative energy resources [9]. Biofuels are usually liquid and gaseous fuels, which can be derived from agricultural yields [10], animal wastes and municipal (domestic and industrial) wastes (both solid and wastewater). Similarly, human geography studies show that robust economic distributional influences can happen due to biofuel utilization [11]. Thus, the enthusiasm for biofuel development has been growing and has established remarkable attention in present-day as the best alternative replacement of fossil fuels, especially in transportation and power generation sectors [12]–[14]. Correspondingly, due to their environmental recognition, and scope of seen benefits, biodiesel and ethanol are considered as viable alternatives to conventional diesel and petrol fuels [15], [16]. Due to the above mentioned and other several supposed advantages, many countries are promoting their sustainable use. Similarly, Ethiopia, as a net oil importer country and having an enormous agricultural base, has started developing biofuels with an aspiring goal.

Ethiopia’s fuel import expense has intensified the strain of the country’s equilibrium of payments significantly. For instance, the Ethiopian Petroleum Supply Enterprise (EPSE) purchased 3.3 million tons of oil at an expense of US$1.37 billion in 2017[17]. The imported volume surpasses the sum from the previous year by 10% and the expense is 248 million USD higher than that of 2016 [18], and it keeps increasing as shown in Figure1. This is affecting the balance of expenses negatively as it is increasing with time. In reaction to the price upswing of oil, and partially in reaction to climate fluctuations, Ethiopia has been looking into its energy strategies to move from imported oil fuels to domestically produced biofuels [19].

![Figure 1: Net energy imports of Ethiopia up to 2016, data adapted from [17].](image)
Furthermore, Kebede et al (2010) reported that 1% growth in GDP requires a 0.55% rise in energy use in developing countries [20]. This indicates that any increment in the current per capita GDP in these countries depends on expanded use of electricity (energy, in general). Hence, to accommodate the exponentially growing energy needs of the country, biofuel development is a priority. Most of the perceived gains from biofuel development include inexhaustibility and biodegradability, increase in the economy by declining imported fuels by exploiting indigenous assets for biofuel production, energy access enhancement, rural society growth, deprivation lessening, and greenhouse gas discharges reductions[16], [21].

Therefore, it is imperative to overview the revealing issues focusing on Ethiopia’s potential and status of biofuel development and forecast the future of its growth, depending on the possibilities for biofuel development, policies implemented, motivational mechanisms in place and utilization schemes. In this review, assessment of type biofuels that are being used today in Ethiopia along with their development progresses and utilization pattern, their economic, environmental, and social impacts (considering their advantages and disadvantages during the course of their generation up to utilization), are presented and discussed. Few possible obstacles to the biofuel development in Ethiopia are discussed in the last section before concluding remarks and recommendations are suggested.

2. Biofuel Resource Potential in Ethiopia

Ethiopia has huge biomass potential and many non-edible and edible oil crops, which can be used for the production of biofuel. Furthermore, it has all types of topographies and climatic conditions that can accommodate the growth of various potential biofuel feed stocks. Africa is viewed as one of the real extension regions for the development of biofuel feedstock, and research has demonstrated that Ethiopia has an appealing potential for the establishment of biofuels in Africa [22]. Ethiopia could deliver up to 60 Peta-joules (PJ) of energy from sugarcane, which is comparable to 1.7 billion liters of bio-jet fuels [22]. It has roughly about 30% of its land distinguished as feasibly accessible for purposes other than food-based plant growth and ecological preventions [22], about $25 \times 10^3$-hectare accessible land and favorable natural conditions for biofuel development [23]. There is about $7 \times 10^3$ hectare recognized suitable land only for sugar cane cultivation [24]. Furthermore, different oil-bearing seeds and potential biomasses including castor bean, jatropha, cassava [25], croton, palm, Pongamia, and moringa [26] grows in Ethiopia readily. Besides, castor and jatropha plants are the most known biodiesel feedstock’s which are considered as native seeds [26]. As shown in Figure-2 about $327,094$-hectare land has been identified as favorable land for biofuel feedstock plantation and was given to investors in 2008 in four regions of the country mainly for farming of castor bean, jatropha, and palm trees [24].

![Figure-2: Land allotted for biofuel development in various districts of Ethiopia][24].

3. Prospects of Biofuel Production

Numerous African nations including Ethiopia are motivated by biofuel energies. For examples, Zimbabwe and Malawi began various biofuel activities during the 1980s [27]. In
Tanzania, biofuel advancements exist on various scales [28]. In Nigeria, there are biofuel production endeavors from 1st generation biomass feedstock inputs [29], sustainable biofuel development in Botswana without sizable increase in food price since 2005 is reported by Kgathi D et al. [30], production of biodiesel from jatropha in West African countries exists [31], however, the majority of these efforts are in their earliest stages. Moreover, the consolidated impacts of environmental change, the unpredictability of fuel costs, the ongoing food crisis and the worldwide financial downturn has positioned a feeling of anxiety among planner’s, ventures and experts to discover economical and reasonable arrangements in biofuel developments.

In such respect, Ethiopia is an important case for examining the advancement and capability of biofuels in Africa. Excited by the different typically depicted open doors lying in front of the development of biofuels, the Ethiopian government boosted a broad bioenergy development program and appointed project announcement in 2007 for castor and jatropha. These two products were particularly promoted for their flexibility and ability to develop on non-arable land and dry climatic conditions [32]. Castor, Jatropha, and Pongamia have been recognized as primary biodiesel feedstock by the government [33]. As indicated by [34], from all African nations, Ethiopia was reported to have the biggest planted jatropha (about 20,000 ha) in the year 2012. Yet, the majority of these plants are not cultivated for fuel production purposes instead either growth was for housing fences or utilized for ecological restoration purposes.

To reduce the amount of imported crude oil, Ethiopia has been producing a considerable amount of bioethanol from sugarcane mainly in a sugar factory, which is being used for petrol blending, merely in a lower proportion. Currently, Fincha and Metehara sugar plants in Ethiopia are delivering around 30 million liters of ethanol from molasses per annum. Even though Ethiopia had planned to produce 1.7 billion liters of bioethanol per year from sugarcane molasses with effect from 2007, [35], however, the production amount reached about 400 barrels per day in 2016 (that is 146 000 liters) (Figure-3)[36]. The plan was very ambitious, and currently, only two facilities from the above-mentioned plants are producing ethanol much below the anticipated amount. However, developments to produce additional ethanol are in progress at large portions in many other new under construction national sugar factories. There is a prospect of additional ethanol generation when sugar industrial facilities under development come to finish. At present there are about 13 sugar factories, 8 of them are operational and 5 of them are under construction, of which one of them is expected to start ethanol production soon [37].

Figure-3: Ethiopia ethanol production, data adapted from[36].

Ethiopia had a plan to achieve the E20 goal by 2015. But, the nation’s plan was hindered because of the absence of ethanol supplies following postponements in redesigning sugar plants and poor executing methods [38]. For example, the highly anticipated Tendaho sugar processing plant (one of the 13 sugar factories) was set to start production in January 2013, with a production capacity of 19,000 metric tons of sugar; 120 MW of power and generation of 63 million liters of
ethanol, still the ethanol production is yet to start[39]. Similarly, the new Kessem plant has been expected to come to function, delivering 12,500 m$^3$ of ethanol every year alongside to 153,000 metric tons of sugar in 2015 and yet not operational [40]. However, additional projects are in the pipeline that can increase the biofuel production amount of the country. For example, Natifa, a construction company from Israel has made secured a $100 million credit to produce 20,827 cubic meters of ethanol from Wolkaity Sugar industrial facility in Tigrai Regional State[41]. Additionally, Ethiopia and Eugen Schmitt (a German distillation technology company mainly involved in the design, manufacturing, and assembly of alcohol production facility) are developing a $51 million ethanol plant having a generation capacity of 60,000 liters of ethanol per day at the Wonji Shoa Sugar Factory since October 2017. Eugen Schmitt will have 83% of the share, while the Ethiopian government and three different investors will take the remaining 14% and 3% shares, respectively[42].

In Ethiopia, ethanol blending with gasoline was started in 2009 [35]. Nile Oil (private company) was the first enterprise to start mixing 5% ethanol mixing with gasoline (E5). Currently, companies called Oil Libya and National Oil are doing the blending process [43]. Subsequently, in five years between 2011 and 2015, the country has a mixed aggregate of 59.6 million liters of ethanol equivalent to 46.9 million US dollars of fuel imports based on the E10 approach [43]. The mixing of ethanol is exclusively done in Addis Ababa and it is meeting 10-15 percent of transport fuel utilization in the capital [44]. The country has a target of increasing the national ethanol mixing facilities in different places of the nation in the near future.

For biodiesel production, the Ethiopian government is spending 2.8 million dollars since July 2014 to deliver 5 X 10$^8$ liters of biodiesel from jatropha annually with the support of the Norwegian government fund. Undertaking in 18 districts in five regions which are expected to help about 14 million agriculturists and rural communities[45]. Whereas, biodiesel production and blending it with conventional diesel fuel for a diesel engine is yet to start.

4. Utilization Schemes of Biofuel in Ethiopia

Cross-sectional time sequence evidence of 25 years for 20 Sub-Sahara African countries reveals that wood fuel represents 70% of energy utilization, trailed by oil [46]. Similarly, Ethiopia is perceived as the poorest country beside it is a net energy importer [47]. Ethiopia population lives below the energy poverty line with minimal access to electricity while its main energy supply is largely from biomass [48]. Waste and biomass are the nation’s essential energy sources accounting 92.4% of Ethiopia’s primary energy supply, trailed by oil (5.7%) and hydropower (1.6%)[49]. The Ethiopian Ministry of Water, Irrigation, and Electricity most recent report demonstrate that the electric access of the nation has achieved 57% while the number of connected households to the grid are just 2.8 million[50]. Ethiopia relies on imported crude oil mainly for the transportation and industrial sectors. Furthermore, these fuels are consumed by backup power generation systems in most industries, business, and residential sectors.

![Figure-4: Share of total primary energy supply in Ethiopia in 2015 (equivalent to 49,990 Ktoe)][49].
The current total energy consumption of Ethiopia is around 40,000 GWh, out of this about 92% is utilized by residential apparatuses, 4% by the transportation segment and 3% by manufacturing. The majority of the energy source is secured from biomass. The country’s electricity production is about 9000 GWh/year fundamentally produced from hydropower (about 92%), and the remaining 4% from wind energy. Out of the total generated electricity about 11% of it is exported to neighboring countries. Conversely, the country imports petroleum for its transportation sector [17]. Though Ethiopia is blessed with enormous alternative energy resources such as hydro, solar, wind, geothermal, and biomass energies, yet the harnessed amount is very little as shown in Figure-5. The Total Primary Energy Supply (TPES) of the country is increasing with time. Besides, it is heavily dominated by biomass, which is usually utilized by low efficient devices.

Figure-5: Ethiopia’s TPES by source in 2018 [17]

Ethiopia’s Total Final Energy Consumption (TFEC) energy is dominated by biomass, followed by oil, electricity, and coal respectively as shown in Figure-6. The biomass energy is consumed mainly in residential energy applications, particularly for cooking and heating. The oil energy is consumed largely in the transportation sector and in some backup generators and industries as the main energy fuel. The electricity is most energy supplied to the urbanized areas and its principal consumption is for lighting, cooking and slightly for heating purposes. A portion of it is used in industries as the main energy input. However, almost all the coal consumption is in manufacturing industries. As can be seen from figure 15 and 16, the petroleum fuel consumption is huge and all of it is imported consuming a greater portion of hard currency collected from export commodities of the country. Beside, most of the petroleum fuels are consumed mainly by the transportation sector, thus the need for biofuel as a substitute in this sector makes it anticipatory.

Figure-6: Ethiopia’s TFEC by source – in 2016, [17]
5. Possible Challenges of Biofuel Production

Even-though the biofuel development in Ethiopia has got a priority by the government as well as the huge interest by developers to participate on the business because of its perceived economic and environmental benefits, however, its realization to the expectation can be hindered by some barriers if not given a due focus. The possible obstacles that could slow down the biofuel development in Ethiopia are: similar to many developing countries the unstable energy policy, cultural constraint, educational establishment, unsteady economy, absence of core technology and poor capacity building programs[46] could be among the most challenges that the biofuel development program is expected to face.

The dispute on food versus fuel is another obstruction to the development of biofuel[25]. Unless a consensus is reached with the public and stockholders by discussions and awareness creations to convince the public about the pros and cons of the biofuel development agendas, it could be one of the difficulties to be encountered. However, it can be overwhelmed by utilizing non-edible biomass sources[51]. Similarly, besides the food versus energy issue, the association of biofuels with various natural and economic effects such as deforestation, biodiversity, water accessibility, energy-security, food-security and loss of land access [28] are additional issues that need in-depth considerations.

Furthermore, consideration and recognition of the participating stakeholder’s values and attitudes are necessary to accomplish sustainable developments[52]. However, the Ethiopian biofuel development policy seems somehow inclined to favor investors than the small scale farmers due to their larger capital and competence. This reason may create susceptibilities in small and large scale developers anticipating interests in feedstock production and processing plants. Moreover, the issues articulated in most public discussions emphasizing land rights and food security are distinctive. Hence, although they miss the technical part of agricultural, economic and market principles, their opinions shall be included in the decision-making considerations. Unless it will be an additional obstacle to the biofuel development endeavors.

6. Conclusion

Despite the huge potential for biofuel development in Ethiopia, the level of production is very small. The Ethiopian biofuel development was very fascinating until it reaches the E10 blending approach in 2011. Afterward, the production amount remained constant and the current production capacity is below the anticipated target (400 barrels per day in 2016). Regardless of government’s huge investments in sugar factories to produce ethanol as a second product, the country’s goal to start E20 ethanol blending approach in 2015 was not achieved due to delays in most of the sugar factory project completions. Furthermore, the expansion of ethanol blending facilities beyond Addis Ababa to other parts of the country and start biodiesel blending with conventional diesel is yet to be achieved. The upcoming biofuel production expectations are only ethanol from about 13 sugar factories under development. Biodiesel production seems not given due attention.

Due to the lack of basic setups and policy gaps in biodiesel production, big scale biodiesel development seems doubtful. Hence focus shall be given to revitalize small scale local business to produce biodiesel from non-edible oil crops that can be utilized directly for cooking and lighting. The governmental motivational and support schemes should be towards prospering these small scale local businesses as they could have noticeable economic and environmental significances.

The biofuel development policy needs to be reviewed and shall include approaches based on a clear understanding of the current scenarios and future development targets considering its tradeoffs, land use design and economic benefits of biofuel compared to petroleum fuels. Biofuel development can only be feasible for Ethiopia if it is financially feasible and all threats related to its development are alleviated. Thus, in order to avoid undesired outcomes consideration of best existing practices in similar fields and incorporating public opinions in decision making is vital.

Finally, while governmental encouragement is essential for the overall feasibility of biofuel development, the motivational schemes shall focus to make biofuel businesses affordable and
cost-effective. As it can be seen from the ongoing many large sugar factory constructions with the intention of increasing ethanol production amount, massive spending on projects intending only to minimize the expenses on petroleum fuel imports is not necessary. Hence, well studied and precisely selected motivational instruments must be implemented.

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