



Challenges of Liquid Biofuel Policies and Institutions in Eastern Africa Countries of Ethiopia, Kenya and Tanzania

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Abstract

Most African countries made deliberate decisions to invest in liquid biofuel leading to the formulation of the bioenergy strategy in 2007. The study on challenges and policies on liquid biofuels was conducted in eastern Africa countries of Ethiopia, Kenya and Tanzania to understand institutional, marketing, and policy challenges. The study was based on interviews and discussions with stakeholders related to liquid biofuels. In marketing, policies affecting business were not stable as strongly agreed by 36.4% of the respondents, and agreed by 45.5% of the respondents. The liquid biofuels especially biodiesel was relatively new in the countries, and most relevant issues were unknown. The major problems with liquid biofuels were land rights that created conflict as stated by 54.5% of the respondents, lack of updated policies and strategies focusing on .provision of incentives, institutional strengthening, l monitoring, and evaluation systems. The liquid biofuel investment in eastern Africa was affected by crop and forest land because it was not based on pre-assessment of land use planning. The 2010s failure of the eastern Africa Governments ambitious plan to produce liquid biofuels was caused by institutional, market, and technical challenges which can be solved by creating smallholders awareness, and modifying policies.

Key words: institutions, investment, opportunity, policy, smallholders, and trade

Introduction

Liquid biofuels are clean renewable energy sources that have the potential to contribute to climate security enhanced energy access and improved air quality of t rural households. Globally, about 2.7 billion people will have no access to clean cooking energy by 2030 (OECD/ IEA, 2017). According to IEA (2019), 850 million people globally and over 550 million in Africa (48% of the world) have no access to electricity (OECD/IAE, 2017). Bioenergy, as one of the seven “key pillars” of decarbonisation for getting to Net Zero by 2050, is a key driver to attaining energy for all and ensuring world temperatures are “well below 2°C and limited to 1.5°C” as per the Paris Agreement (Brito Cruz *et al.*, 2014; Rogelj *et al.*, 2016). IEA (2021) .

The main commercialized transport liquid biofuels made from biomass materials are bioethanol and biodiesel, commonly produced from sugarcane or corn and soybean or palm oil. The global market shares of bioethanol and biodiesel in 2017 was 64% and 36% respectively (Trent, 2019). Using pure or blended bio-ethanol and bio-diesel as alternative fuel, with conventional fuel is an important option to reduce petroleum fuel consumption and holds potential to reduce GHG emissions.

Biodiesel reduces emissions of carcinogenic compounds by as much as 85% compared with petro-diesel (Yage *et al.*, 2009).

Solid biomass and fossil fuels which are sources of greenhousegases (GHGs), can be substituted by liquid biofuels. In eastern Africa, families are expected to switch to hydroelectricity as a cheaper and cleaner alternative. However, hydroelectricity production is influenced by climate change while biomass based energy sources are less influenced by climate change. Production and utilization of liquid biofuels in Africa can strengthen management and use of forest ecosystems for sustainable development, reduce dependence on solid biomass fuels, address poverty reduction and environmental protection and reduce indoor air pollution (CRGE, 2011).

Africa countries made investments in green energy including liquid biofuel since 2007, which was guided by individual countries policies and regulations. The evolving picture is one of an unclear development of the biofuel industry on the continent; therefore, it is important to understand the status of the biofuel industry and what guidance individual countries can use in developing policies and regulations to guide the industry with higher domestic energy

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demand, which is mostly satisfied by imports of foreign energy.

Accordingly, the present study investigated the existing and likely future opportunities or prospects, in addition to the challenges in production and use of biofuels in eastern Africa; assessing the competitiveness of African biofuels in the international market; identifying policy, regulatory and institutional frameworks and their weaknesses and strengths relevant to liquid biofuel production in the context of

changing climate in order to facilitate planning the growth and development of local, national and sub-regional liquid biofuels sector.

Materials and methods of the study

Pre-tested questionnaires were used to interview respondents while Global Positioning System (GPS) were used to give coordinates of locations. The locations of the field studies are shown in Figure 1.

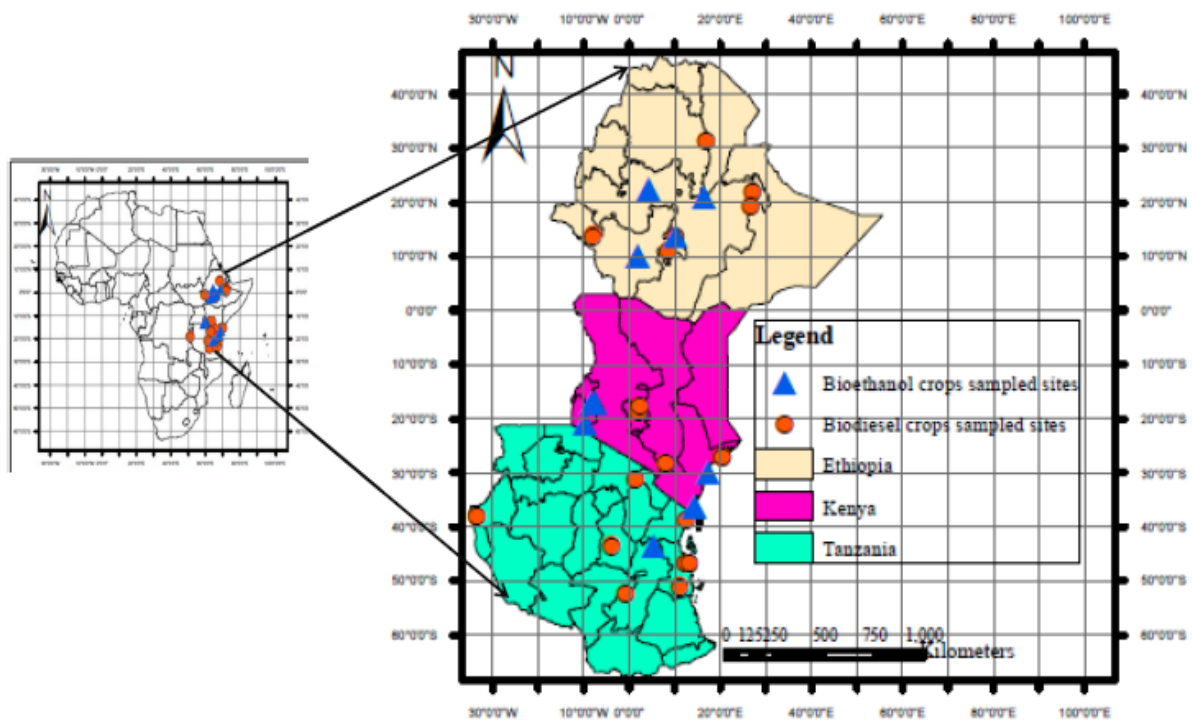


Figure 1: Location of the field study sampled areas

Study areas and data collection procedures

Different regions of Ethiopia, Kenya and Tanzania were assessed, 6 to 10 key

informants and three focused groups were identified and recruited from a constellation of producers and processors of feedstock, research institutions and universities,

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relevant lead agencies, national and international NGOs. In the study primary and secondary data sources were assessed in February to May 2021. The primary field data was collected by purposive sampling technique and interviews on the technical and socio-economic aspects related to the production and use of liquid biofuels. Purposive sampling technique is widely used in qualitative research for the identification and selection of information-rich cases related to the phenomenon of interest (Palinkas et al., 2015).

Key informants and focused groups were interviewed about the past activities and current status of liquid biofuels by using pretested structured and semi-structured questionnaire. The assessment of biofuel condition was carried out based on guidance of experts of energy and environment sectors.

The interview responses obtained from the smallholder farmers and their associations was triangulated with the respective district development agents and official government reports, and private sectors and GHG emissions were compared based on the availability of liquid biofuels from previous literature. Qualitative data was summarized by narration and quantitative data was analysed by descriptive statistics.

Sugar factories were interviewed on types and cost of feedstock, cost of technology and financing, market mandates and targets, and customer demand. The responses were further categorized on levels of agreement as Strongly Agree; Agree; neither Agree nor Disagree; Disagree; and Strongly Disagree.

Results and discussion

Development of liquid biofuel systems creates income opportunities for farmers by diversifying crops for both food and biofuel production, creates investments infrastructure like roads construction, offers prospects of energy security, reduce pressure on forests for wood fuel, and reduce dependency on oil imports (UN, 2007). The other prospects are development of local industries, provision of alternative energy for rural mechanization, foreign exchange earnings from exports, import substitution of fossil fuels, long-term financial, social and environmental sustainability. The availability of suitable land, water, cheap labour, suitable climate for growing many of bio-energy crops in the eastern African region, in addition to global warming due to climate change that requires a shift to bioenergy are the opportunities. Existence of national and international legislations and commitments

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to guide production of feedstocks and use in ways that ensure safety to the environment and consumers are ways of promoting the opportunities.

Table 1 shows socio-economic challenges of production and utilization of liquid biofuels in eastern Africa. For instance, while pastoralist areas prioritized for Jatropha growing for biodiesel, facts on ground have showed that these areas are not

suitable for producing Jatropha due to their aridity with limiting soil moisture of less than 200 mm annually. This is corroborated by findings by a study on, “Jatropha: Reality Check” (GTZ, 2009). . The lack of budget for processing of Jatropha seeds to oil and biodiesel resulted in dumping about 50 tons of seeds in Bati district of Ethiopia (Figure 2).








Figure 2: Jatropha seeds in Bati, Amhara region of Ethiopia

Other challenges were lack of accurate and sufficient data on biofuel crops, general institutional, market, economic, social, technical, legal challenges; lack of incentives in biofuel development and utilization; internal company problems, and lack of monitoring and evaluation of project activities, weak policies and weak institutional capacity (Table 1).

The coping mechanisms of biofuel production and utilization challenges were found to be creating institutional reform,

creating market access, providing credit access and grant, creating awareness of local people about liquid biofuel, capacity building of institutions and factories, limiting the blending levels of biofuel, providing subsidies and incentives to new biofuel sectors, improving productivity, sustainable management, modifying land tenure policy, and dissemination of research information (Table 2).

Table 1. Major socioeconomic challenges in liquid biofuel production in eastern Africa countries of Ethiopia, Kenya and Tanzania

Major challenges	Ethiopia	Kenya	Tanzania
 Institutional	<ul style="list-style-type: none"> • Weak coordination among different agencies concerned with biofuel development. • Frequent structural changes in administration • No clarity of activities at Federal and Regional levels, lack of political support for biofuel activities • Lack of sustainable land use policy 	<ul style="list-style-type: none"> • Lack of policy and regulatory support and no well-structured institutional arrangements • Lack of incentives and Government support 	<ul style="list-style-type: none"> • Absence of proper policy • Absence of institutional memory that the biofuel one stop centre, Tanzania Investment centre (TIC) was not found upon visitation.
 Market	<ul style="list-style-type: none"> • Buyers did not get sufficient amount of first generation biofuel feedstocks to process to liquid biofuel. • Sellers had no market for the small biofuel feedstock and there was no local processing. 	<ul style="list-style-type: none"> • Lack of markets and investments in first generation biofuels • Feedstock are currently not profitable. 	<ul style="list-style-type: none"> • Biofuels access to gas station market was hindered in Tanzania due to lack of blending ratios.
 Economic	<ul style="list-style-type: none"> • High initial investment costs of biofuel production in marginal areas, • At the market level, the petroleum price was by far lower than liquid biofuel price, 	<ul style="list-style-type: none"> • Limited sources of investment capital • High prices of biofuels compared to petro-based fuels 	<ul style="list-style-type: none"> • Lack of initial price guarantee for biofuels investment (e.g. through fixed prices by the Government)
 Social	<ul style="list-style-type: none"> • Lack of smallholders participation • Lack of local community support • Lack of feasibility study • Land use conflict 	<ul style="list-style-type: none"> • Biodiversity loss and conflict with local people. 	<ul style="list-style-type: none"> • Control of land and irrigation water sources by biofuel crops and fear of food security
 Technical	<ul style="list-style-type: none"> • Lack of trained people • Lack of quality planting materials • Lack of techniques on silvicultural/ agronomic management, • Absence of quality standards • Lack of clear definition of marginal land to promote biofuel production • Old ethanol factories, poor maintenance and lack of spare part, 	<ul style="list-style-type: none"> • Lack of quality planting material • Lack of enough trained people • Non-mechanized system of production, • Marginalized lands not clearly defined • Factories that used to process biofuels delapidated, 	<ul style="list-style-type: none"> • Modern technologies were expensive to acquire and use.

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



 Regulations and incentives	<ul style="list-style-type: none"> • There was limited incentive in biofuel production and blending, 	<ul style="list-style-type: none"> • Biofuels strategy lacking on incentivization of biofuels production 	<ul style="list-style-type: none"> • Lack of long term, stable and clear policies, regulations and incentives.
 Productivity	<ul style="list-style-type: none"> • Low yields of jatropha, and infestation by pest and disease • Shortage of ethanol production currently for fuel, 	<ul style="list-style-type: none"> • Poor productivity of biofuel or food crop • Occurrence of pests and diseases 	<ul style="list-style-type: none"> • Poor productivity of degraded and marginal lands
 Experience and monitoring and evaluation	<ul style="list-style-type: none"> • Fresh graduate who have no administrative and technical experience managed the biofuel project at higher level, • Lack of monitoring and evaluation 	<ul style="list-style-type: none"> • No follow up to sustain the liquid biofuel sector. • Lack of implementation of research findings 	<ul style="list-style-type: none"> • Issues around biofuel are unknown, • Lack of knowledge on land rights and biofuel production, • No follow up to sustain the sector.
 Land tenure	<ul style="list-style-type: none"> • Land ownership remains with the state and fear of unclear future tenure change; conflict of local people on land 	<ul style="list-style-type: none"> • Unclear land tenure system 	<ul style="list-style-type: none"> • Unclear land tenure system
 Poor research information	<ul style="list-style-type: none"> • Unstability of research coordination offices of bioenergy activities 	<ul style="list-style-type: none"> • Poor research on breeding of quality planting material. 	<ul style="list-style-type: none"> • Lack of researches to uncover areas where the production of biofuel plant species can be profitable.

Table 21. Coping mechanisms for addressing the challenges in liquid biofuel production in eastern Africa countries of Ethiopia, Kenya and Tanzania

Coping mechanisms of biofuel challenges	Ethiopia	Kenya	Tanzania
<ul style="list-style-type: none"> • Institutional reform 	<ul style="list-style-type: none"> • Key government institutions responsible for biofuel development need to be strengthened at regional, zonal and district levels, • Policy amendments to cope up with the failure of biofuel investment. 	<ul style="list-style-type: none"> • Formulation of regulatory support and well-structured institutional arrangements, and guarantee markets, 	<ul style="list-style-type: none"> • Formulation of framework to support biofuel development at specific ministry level or its departments
<ul style="list-style-type: none"> • Market access 	<ul style="list-style-type: none"> • Creating local markets like sugar factories and biogas agency, • Link farm producers with small and medium enterprises (SMEs) 	<ul style="list-style-type: none"> • Creating local markets of biofuels by the government, 	<ul style="list-style-type: none"> • Determining biofuel blending ratios and creating local enterprises and market,
<ul style="list-style-type: none"> • Credit access and grant 	<ul style="list-style-type: none"> • Provision of credit to the biofuel producers association at lower interest rate of banks with initial grant in interest free period and searching innovative financial mechanisms through bids 	<ul style="list-style-type: none"> • Providing initial investment capital in the same way as Ethiopia 	<ul style="list-style-type: none"> • Provision of initial price guarantee for biofuels (e.g. through fixed prices by the Government)

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• Awareness creation	<ul style="list-style-type: none"> • Creating awareness of local community on importance of liquid biofuel, • Local determination and demarcation of land and plant species for biofuel feedstock production, • Conducting feasibility study and environmental impact assessment on the profitability of biofuel production and utilization, • Promoting smallholders and outgrowers for biofuel crop production, 	<ul style="list-style-type: none"> • Limiting biodiversity hotspots from biofuel crop production, • Local determination and demarcation of land and plant species for biofuel • Feasibility study and environmental impact assessment of liquid biofuel, 	<ul style="list-style-type: none"> • Determining land, plant species and irrigation water sources for surrounding farmers and for biofuel production, • Creating awareness of the local community on importance of biofuel, • The same as Kenya
• Capacity building	<ul style="list-style-type: none"> • Technically capacity building of staffs and laboratories, • Training in growing and management of biofuel crop production, financial incentive for inputs, and long-term credit schemes etc. • Hiring trained people and allowing on job training of local people, • Solve the power shortage and poor maintenance in sugar factories. 	<ul style="list-style-type: none"> • The same as Ethiopia, • The same as Ethiopia, • Creating mechanized system of production 	<ul style="list-style-type: none"> • The same as Ethiopia
• Limiting the blending levels	<ul style="list-style-type: none"> • Fixing the blending ratio of biodiesel and bioethanol depending on the availability of feedstock in the country, 	<ul style="list-style-type: none"> • The same as Ethiopia 	<ul style="list-style-type: none"> • The same as Ethiopia
• Tax weaver, subsidy and incentives	<ul style="list-style-type: none"> • Tax weaver in importing biofuels, tools and equipment required for liquid biofuel production and blending, • Financial incentives to attract private sector in blending; government subsidy such as grant, tax reduction and land allocation 	<ul style="list-style-type: none"> • Address transport tariff of imported fossil fuel so as to increase the demand for locally produced biofuels. 	<ul style="list-style-type: none"> • Establishment of long term, and stable incentives.
• Productivity improvement	<ul style="list-style-type: none"> • Local breeding of quality planting material of the biofuel crop, • Improving productivity of biofuel plant species by selecting, diversifying breeding, and by enhancing soil fertility; pest and disease control; • Awareness creation on the importance of biofuels 	<ul style="list-style-type: none"> • The same as Ethiopia 	<ul style="list-style-type: none"> • The same as Ethiopia
• Sustainable management	<ul style="list-style-type: none"> • Developing monitoring and evaluation strategy for liquid biofuel, • Establishment of institutional clear mandate in liquid biofuel sector, • Promote the manufacture of local technologies to supply spare parts, 	<ul style="list-style-type: none"> • The same as Ethiopia 	<ul style="list-style-type: none"> • The same as Ethiopia
• Land tenure policy	<ul style="list-style-type: none"> • Establishing clear land tenure system and secure land ownership 	<ul style="list-style-type: none"> • Establishing clear land tenure system 	
• Disseminate research information	<ul style="list-style-type: none"> • Searching highly productive and profitable biofuel crops, 	<ul style="list-style-type: none"> • The same as Ethiopia 	<ul style="list-style-type: none"> • The same as Ethiopia

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- Conducting research on breeding of quality planting material, high yield, and water use efficiency, for liquid biofuel production.

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The sustainability of bioethanol production was generally found to be fluctuating because of biomass supply and low technical capacity of factories. In the case of biomass feedstock supply, interviewed bioethanol producing sugar factories provided different responses as summarized in Table 3. Most of the responses were agreeing on the issues, risks and barriers of liquid biofuel production. For example, about the presence of enough incentives to

companies to grow feedstock for biofuel plant, 63.6% Agreed that incentives were lacking, 9.1% of the respondents Strongly Disagreed and the same percent Strongly Disagreed. In marketing, the policies affecting the business were not stable and clear, as 36.4% Strongly Agreed, 45.5% Agreed, 18.2% neither Agreed nor Disagreed and none of the respondents Agreed in their responses (Table 3).

Table 3. Perception of different stakeholders on liquid biofuel production in eastern Africa countries

Issues, Risks and Barriers	Percentage of respondents				
	SD (1)	D (2)	NAD (3)	A (4)	SA (5)
Feedstock:					
Companies do not get enough incentives to grow feedstock for biofuel plants.	9.1	0.0	18.2	63.6	9.1
There is not enough feedstock for advanced biofuels business expansion.	0.0	9.1	36.4	54.5	0.0
Smallholder farmers are willing to sacrifice land for biofuel feedstock production	0.0	18.2	9.1	63.6	9.1
There is inadequate regulation for biomass feedstock quality in the country/region	0.0	9.1	9.1	63.6	18.2
Competing uses for biomass feedstock (such as heat, power and bioproducts) pose a major risk for our biofuel business	0.0	18.2	18.2	54.5	9.1
Biofuel feedstock can outcompete food production and water	0.0	9.1	9.1	63.6	18.2
Biofuel feedstock caused deforestation and reduced stream water levels	0.00	7	11.2	18.2	63.6
Better mechanisms are needed to monitor biofuel feedstock prices	0.0	9.1	18.2	63.6	9.1
Biomass transport and storage logistics are not available at volumes required by full-sized biorefineries	0.0	0.0	0.0	100.0	0.0
Feedstock price uncertainty hampers our business.	0.0	0.0	18.2	63.6	18.2
Feedstock quantity and quality variations disrupt our production and low productivity	0.0	0.0	18.2	63.6	18.2
Cost of Technology and Financing:					
The eastern Africa region is not ready for second level generation biofuel due to technology constraints	0.0	9.1	9.1	63.6	18.2
eastern Africa countries can afford the technology that goes with large scale advanced biofuels deployment	0.0	9.1	18.2	54.5	18.2

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Inadequate transport infrastructure will constrain the marketing of advanced biofuel products.	18.2	36.4	18.2	27.3	0.0
Eastern Africa countries will be producing second generation biofuels at significant levels in the 2040.	0.0	0.0	36.4	63.6	0.0
Lack of funding /financing is a major barrier to investment in advanced biofuels.	0.0	0.0	9.1	9.1	81.8
Markets through mandates and targets:					
Policies affecting our business are stable and clear	36.4	45.5	18.2	0.0	0.0
Mandates and blending obligations for advanced biofuels should be strengthened by price mechanisms like rebates, tax credits, reduced tax rates, and a market value for carbon.	0.0	0.0	18.2	18.2	63.6
Eastern Africa renewable fuel targets are insufficient to encourage investments in advanced biofuel production	0.0	0.0	36.4	36.4	27.3
Eastern Africa biofuel markets are too fragmented, then more coherent central regulation is needed	0.0	0.0	45.5	54.5	0.0
Targets for expansion of advanced biofuels production are not sufficiently ambitious	0.0	0.0	0.0	81.8	18.2
Regulatory uncertainty impedes investments in biofuel production	0.0	0.0	0.0	81.8	18.2
Blending limits discourage investment in advanced biofuel production	0.0	0.0	0.0	81.8	18.2
Eastern African governments should increase blending ratios and introduce flexi-fuel vehicles even if it's at a small scale to create local market for biofuels	0.0	0.0	54.5	27.3	18.2
Import tariffs are needed to protect domestic investments in advanced biofuels	0.0	0.0	0.0	100.0	0.0
Import tariffs have a negative impact on eastern African biofuel operations	0.0	0.0	36.4	36.4	27.3
Consumer demand:					
Introduction of Flex-Fuel Vehicles (FFVs) in eastern Africa could inspire biofuel production in the region	0.0	0.0	0.0	54.5	45.5
The future of eastern Africa biofuels is dependent on the customer	0.0	0.0	36.4	36.4	27.3
Introduction of electric vehicles (EVs) in the developed world pose a serious threat for biofuels business even in eastern Africa	0.0	0.0	54.5	45.5	0.0
International agreements will eventually limit greenhouse gas emissions in transport by forcing them to use biofuels	0.0	0.0	0.0	81.8	18.2
Sales of biofuel by-products and co-products is a necessary part of business to increase profits and encourage more companies to invest	0.0	0.0	0.0	18.2	81.8
Environment and Social	0.0	0.0	0.0	0.0	0.0
Biofuel production will not increase GHG emissions, land use change and indirect land use change	18.2	27.3	54.5	0.0	0.0
Conflicts over land could be more prominent due to expansion of first generation biofuel feedstock	0.0	0.0	18.2	54.5	27.3
Smallholder farmers will not benefit from biofuel expansion due to small land holdings	27.3	72.7	0.0	0.0	0.0
Food-vs-Fuel debate continues to push advanced biofuels business forward.	0.0	0.0	0.0	54.5	45.5

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Environmental advocacy groups have not helped advance the production of biofuel generation biofuels.	0.0	0.0	27.3	27.3	45.5
Biofuels production will result in increased poverty and food insecurity	45.5	27.3	27.3	0.0	0.0
Biofuels production could increase deforestation and increase environmental pollution	45.5	27.3	27.3	0.0	0.0

Note: Feed stocks issues: Key: SD (1) = Strongly Disagree; D (2) = Disagree; NAD (3) = Neither Agree Nor Disagree; A (4) = Agree; SA (5) = Strongly Agree

The use of first generation crops such as Jatropha, Croton, Sugar cane and Sweet sorghum were found to compete with food crop land. Further, those conventional feed stocks such as corn and sugarcane were not sufficient to supply the global demand of bioethanol production because they are also needed for food and animal feed, in the presence of low productivity of crops as Strongly Agreed by 18.2%, and Agreed by 63.6% of the respondents (Table 3).

The other mechanisms for addressing the challenges were; putting up policies that should facilitate/enable sustainable production of biofuel. The policies should address the environmental degradation (biodiversity loss) associated with clearing of vegetation. Furthermore, the policies should guide investments in ways that balance is secured between food security and livelihood of the communities.

The liquid biofuel especially biodiesel was found to be relatively new in the countries, and that most relevant issues around biofuel are unknown. The major problems that can

arise with biofuel and other large-scale agricultural investments are connected with land rights, and create conflict as stated by 54.5% of the respondents.

Effect of liquid biofuel production on cropland, forest margins and food security

The biofuel investment affected cropland in different ways in all areas visited because it was largely not based on pre-assessment of land-use plans. The local people interviewed (Table 3) responded that water levels in streams were reduced after forest clearance for biofuel crop production. However, biofuel crop planting activity in degraded land improved the water resources because those biofuel crops protected the soil and conserved water. For example, jatropha plantation in Bati woreda in northern Ethiopia served as gully rehabilitation and reduced the water erosion.

In eastern Africa countries the biofuel investments were of project nature, with

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occasional project funds that supported farmers for the biofuel feedstock. During the project the local people shifted to paid jobs as their means of income source when they gave their land. However, this support was later stopped when the projects terminated. When the local people got the land back in short period of time they resumed the agricultural practice without impairing food security. Many of biofuel production initiatives had collapsed, and with biofuel crop planting having no long term food security effect.

In Kenya, the productivity of biofuel feedstocks or food crops per unit area was below the expected maximum due to low quality planting materials, and poor management. Biofuel investments were mainly made on grazing land, degraded land and other suitable marginal land. There was many years of land lease to investors. However, the biofuel investments in most cases were abandoned and the land areas replaced by bushes, shrubs or converted to agricultural land.

In Tanzania, farmers, environmentalist and NGO's prompted the Tanzanian government to suspend the allocation of arable land, processing any new

applications for biofuel projects and eviction of farmers over biofuel projects, pending ratification of a law and establishment of a regulatory mechanism to govern the sector and monitor the biofuel industry. In Tanzania, initially farmers faced a trade-off between selling their food to the biofuel producing companies or retaining it as food. This happened when the price of the food crops was higher in biofuel producing area than selling or retaining it as food. This led to the shortage of food to the community. Experience from Action Aid (2010), reported the vulnerability of rising in food prices in rural households as the results food shortages linked to over selling.

The effect of biofuel production on crop and forest land was associated with displacement of land. In all parts of the study areas in eastern Africa farmers complained about the land taken for jatropha and castor bean production. The forests in western Ethiopia, Gambella and Benshangul Gumz were cleared for oil palm and jatropha cultivation. In eastern Ethiopia in Babile elephant sanctuary and surrounding districts about 10,000 ha of primary forest land was cleared for castor biofuel crop production. The forest was meant for unique elephant population that

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exists only in east Africa (BirdLife Africa Partnership, 2012), thus disrupting migration routes. The allocation of forest and agricultural land for liquid biofuel crop production caused conflict with local people. The investment also destroyed wild life habitat (Gebreegziabher *et al.*, 2014).

In Ethiopia, over 80% of biofuel developments were done in arable lands, forest lands and woodlands (MELCA Mahiber, 2008). A land use land cover change in one of the sugar factories of Ethiopia called Finchaa, which made expansion to produce additional sugarcane showed that cultivated land, settlement and sugar cane plantation increased at a rate of about 580 ha/yr, 140 ha/yr and 140 ha/yr, respectively, whereas wetland, forest land and bare land reduced by 600 ha/y, 330 ha/yr and 60 ha/yr, respectively, in 1987–2019 (Tolessa *et al.*, 2021). The wet land and forest lands were the main victims of many of the biofuel investments in Ethiopia.

In Kenya, investments in biofuel production was said to be neither in forest land nor in settlement areas. Biofuel investment was mainly on grazing land, degraded land and other suitable marginal land. However, BirdLife Africa Partnership (2012) stated that in Kenya, over 20,000 ha of forests

were deforested in Tana River Delta and Dakatcha woodlands for sugar cane plantation which are important bird areas, seasonal grazing lands and regulators of the flow of River Tana. Clearance of mountains for biofuel production raised complains and conflict with environmentalists. In Kenya, land covers change transitions between 1988 and 2017 as a proportion of land area was 0.86% \pm 0.47 mainly because of deforestation of dense forest (Bullock *et al.*, 2021).

In Tanzania, clearing of natural vegetation such as miombo woodland and the montane forests resulted in loss of watersheds which are important sources of rivers. The consequences of clearing large areas of natural forest habitats to give way to biofuels resulted in loss of biodiversity and created a “carbon debt” by releasing significant GHG emissions (Markensten and Mouk, 2012) and blocked the route followed by wild animals. Biofuel development created biodiversity loss, land conflict, labor issues, and indigenous right issues in places in Tanzania (Hance, 2015). In Kisarawe District Coastal Forests which were important habitat for endemic and endangered bird species, endangered primate, and transit route for elephants and buffaloes, sources of edible wild plants,

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pottery soils and water were partly deforested for jatropha plantation (BirdLife Africa Partnership, 2012). A land cover change (LCC) study conducted in Tanzania revealed a significant increase in cultivated land, a decrease in forested land and encroachment into forest reserve from 1985 to 2011. The conversion of land used for crop production into jatropha farming caused direct and indirect LCC in the area. In Kisarawe district, bareland area was converted to 8613ha agricultural land because of the introduction of jatropha farming (Mwakapuja et al., 2017).

Eastern African countries have undergone extensive environmental change in the past three decades, largely driven by the expansion of cropland and the conversion of naturally vegetated land covers by factors like biofuel crops. From 1988 to 2017, the area of cropland and settlements increased and largely reduced in woody vegetation (Bullock et al., 2021). Open forest (natural and planted forest tree-covered areas with 15–40% canopy cover) commonly observed in eastern Africa countries when compared to dense forest (natural and planted forests tree-covered areas with over 40% canopy cover, Olson et al., 2001). Deforestation of open forest occurred most frequently in Tanzania. However, the exact

effect of biofuel development on deforestation and land cover change was difficult to determine because the areas of biofuel investment in most cases was abandoned and the land areas was replaced by bushes, shrubs or agricultural crops.

Trade and competitiveness of eastern Africa biofuels in international markets

Increasing the growth of domestic and international biofuel markets depend on increasing availability of feedstocks because a major constraint to the growth of biofuel markets is development of biofuels feedstocks. In Ethiopia, ethanol demand has been growing for transport and household cooking, pharmaceutical and alcohol beverage industries. For example, Gaia Association (2014) estimated bioethanol for substitution of kerosene demand as 85 million liters per year in Ethiopia.

In all countries surveyed, there were considerable potential domestic and foreign markets for liquid biofuel because of large population size and external cooperation. Ethiopia, Kenya and Tanzania are members of the Common Market for Eastern and Southern Africa (COMESA), embracing 20 countries with a population of about 380 million, and have market access at preferential tariffs. East African countries

also have potential accesses to the Middle East markets, European markets and US markets. The internal markets can play great role in the production of liquid biofuel by fueling demand. For example, in Ethiopia the blending for the transport sector from 2009 to 2015 was about

48,000.kiloliters of ethanol that saved the country \$39.6 million to import fossil fuels. The highest earning was in 2011/12 at about \$9.23 million ; however, after 2015 the blending was interrupted by insufficient production of ethanol in the sugar factories (Figure 3).

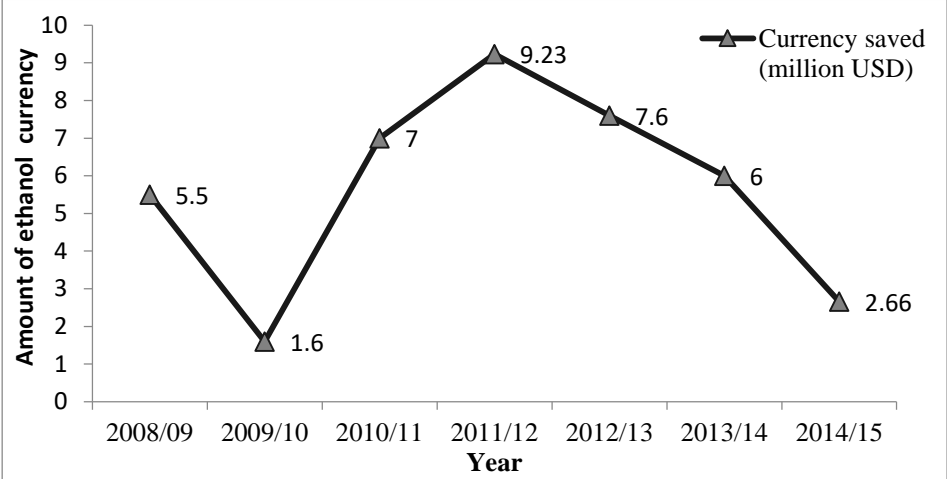


Figure 3: Ethanol blending in Ethiopia, 2009 to 2015

During the initial stage of COVID 19 pandemic in March 2020 to February 2021 the demand of ethanol increased. The excise taxed ethanol was sold at USD 1.74 per litter which reduced demand.

In Kenya, bioethanol production emerged at the end of 2011 through the preferential trade terms on sugar agreed with other producers within the COMESA. Kenya had been using imported ethanol as cooking fuel for low income urban dwellers. The cost of bio-ethanol was inflated by 25% import tariffs and 16% value added tax (VAT) . If government of Kenya made bio-ethanol

zero-rated for VAT and eliminated tariffs, it could displace charcoal and kerosene (Dalberg, 2018). The import could be from the neighbouring countries like Ethiopia. In Kenya, biofuel investment was socially acceptable because of job creation and reduction of unemployment, income increment, increasing energy supply and reducing soil erosion.

In Tanzania in 2007, *Jatropha Curcas* was labeled as one of the most exciting potential energy crops, but this potential was not realized a decade later. The cost of biofuel production was slowly declining as the

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price of petroleum was rising and increased awareness of renewable energy (UN, 2007). Furthermore, due to lack of regulatory framework for quality standards the study deduces, at this point in time that Tanzania biofuels, cannot compete in external markets. Tanzania had five main sugar mills in 2021, all of which had plans for investment and expansion. However, priority was given to sugar production (the country was a net importer) and better efficiency by clustering smallholder farms to improve agricultural practices and logistics management. Tanzania planned to import ethanol from Brazil in 2011 to reduce the cost of fuel by 10% but that was not achieved.

In eastern Africa, although investment in biofuels is currently not profitable, the market is projected to grow nationally and internationally with projected economic development and increased environmental awareness.

The quantity and quality of eastern African biofuels in the international markets

The eastern Africa countries has had bioethanol production and E10 (i.e. ratio of 90 to 10 of petrol and bioethanol respectively) blending program in early

1980's in Kenya, and in 1979 in Ethiopia in their capital cities. The reduction in capacities of sugar factories and the low attention given to ethanol fuel production (because of drop in global fossil oil prices, and an increase in the price of beverage ethanol for alcoholic consumption), the ethanol had been sold for beverage factories within and out side the countries. Kenya was selling beverage ethanol to Uganda and Democratic Republic of Congo in the late 1980s.

After 2007 blending ratios planned to be issued by the Energy Regulator from time to time in Kenya, however, according to the Ministry of Energy the country hasn't had a blending ratio issued. In Ethiopia, blending of ethanol and gasoline was commenced with the cooperation of Ministry of Industry and United Nations Industrial Development Organization (UNIDO) with the feasibility study conducted by the State Alcohol Monopoly of Finland Ltd. Then a French expatriate followed with a feasibility study of the production of yeast and bioethanol from molasses (Sugar Corporation, 2013). One of the sugar factories called Finchaa sugar factory was producing 6 million liters anhydrous ethanol annually since 2005 as a result of contract agreement entered with foreign, Italian company with an ex-factory

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price of \$0.202 per litre until the recent government decision that banned the export and to use for local gasoline blending (Tekle, 2008).

There was also information on the import of ethanol from USA and other countries and no document on the export of ethanol from Kenya. In Tanzania, there is no record of exporting ethanol and as it mostly depends on import activities.

Quality test of bioethanol was done by simple thermometer and alcohols meter. The quality of bioethanol was determined based on ISO certificate. The alcohol level of bioethanol for transport fuel was $\geq 99.9\%$ (0.1% water) depending ISO standards. In Ethiopia, government was controlling oil distributing companies about the safety measures and operation to ensure the quality of the blended gasoline; however, there was no quality control system of the final blended gasoline at fuel stations and no quality standards because the fuel stations were operating in the already installed infrastructure of pure gasoline. Therefore, controlling the quality of gasoline requires modification to new infrastructure. Kenya Bureau of Standards (KEBS) was supposed to ensure quality of biofuels and set blending standards but not available in practice. In Tanzania, due to

lack of regulatory framework for quality standards, there was no quality control.

In 2007 *Jatropha curcas* was labeled as one of the most exciting potential energy crops in Ethiopia, Kenya and Tanzania, but this potential has not been realized a decade later in 2020/21. Liquid biofuels were not available in the local market; therefore, the current study revealed that eastern African biofuels cannot compete in external international markets.

Policy and institutional frameworks for sustainable biofuel production in eastern Africa

In eastern Africa, regulations in biofuel investment forbid clearance of forest lands, while promoting feedstock production from degraded land that does not compete with food production. The focus of biofuel development is rural renewable energy development and climate change adaptation and mitigation. In Ethiopia the liquid biofuel policies include Biofuel Strategy of 2007, and Biomass Strategy of 2013, Biofuel Round Table of 2016 and others. In Kenya, the policies in liquid biofuel include *National Biofuels Policy (2010)*, the *Strategy for Developing the Biodiesel Industry (2008-2012)* and *biomass strategy 2013*. In Tanzania, a task force was formulated for the implementation of liquid

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biofuel investment. Key government bodies controlling investment in liquid biofuel sector are the Ministry of Water, Irrigation and Energy and Ministry of Agriculture in Ethiopia; Ministry of Energy, Ministry of Environment & Forestry, Ministry of Lands & Physical Planning and Ministry of Agriculture in Kenya and Ministry of Energy in Tanzania. However, all of these institutions lack clear mandate, and no follow up to sustain the liquid biofuel sector.

Currently, eastern Africa has no policies developed to aid sustainable production,

transportation and consumption of liquid bio-fuels. The policies of the past failed because of lack of government support, as priority of energy shifted to hydro power in Ethiopian and Tanzania, and to geothermal energy in Kenya. The lack of policies hinders the development of biofuel companies as it limits them to small-scale (local) and bars access to more traditional fuel markets like gas stations and international markets. For example, in Tanzania, biofuels access to gas station market was hindered by lack of blending ratios (Table 4).

Table 4. Strengths and weaknesses of policies in development of liquid biofuel in eastern Africa countries of Ethiopia, Kenya and Tanzania

Country	Objective	Strength	Weakness
Ethiopia	<ul style="list-style-type: none"> • Produce adequate biofuel energy from domestic resources to substitute imported petroleum products and to export excess products, • Promote investment in forestry biomass • Ensure social and environmental sustainability of biofuel. • Planned expansion of ethanol production by constructing more sugar estates with ethanol mills attached • Planned to produce 450.3 million liters of biodiesel. 	<ul style="list-style-type: none"> • Plan to reduce deforestation through and replacing firewood by renewable energies including liquid biofuel, • There was ethanol blending policy, E5 in 2008/2009, E10 in early 2011; and amendments to agricultural development and taxation policies were made to attract large-scale investments in agriculture including biofuels, • Planned to substitute fossil fuels in the transport sector. 	<ul style="list-style-type: none"> • The institutions lack clear mandate on liquid biofuel sector. • Insufficient research information for biofuel policy to guide to grow bioenergy crops and to provide land • The energy policy of 2012 does not explicitly mention development of biofuels. • Lack of local people awareness creation.
Kenya	<ul style="list-style-type: none"> • Forbid clearance of forest lands, while promoting feedstock production from degraded land that does not compete with food production. • Strategies for promotion of collaboration with development partners; Mandates the government to 	<ul style="list-style-type: none"> • Formulation of policies lead to the establishment of research activities on liquid biofuels • Mandates the government to facilitate the production of biofuels. • Promotes strategies for preservation and conservation ecosystems. 	<ul style="list-style-type: none"> • All of the institutions lack clear mandate. • Insufficient research information for biofuel policy to guide to grow

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	<p>facilitate the production of biofuels. It also directs KEBS to ensure quality of biofuels and set blending standards.</p> <ul style="list-style-type: none"> • Provides instruments and tools for assessing proposed development activities on sustainable basis. 	<ul style="list-style-type: none"> • Benefitted from Clean Development Mechanism (CDM) in the sugar industry using co-generation of electricity. 	<p>bioenergy crops and to provide land</p> <ul style="list-style-type: none"> • No monitoring and evaluation
Tanzania	<ul style="list-style-type: none"> • Formulated guidelines for investments in the biofuel sector. • Project document on strengthening the policy, legal, regulatory and institutional framework for bioenergy development in Tanzania was prepared. 	<ul style="list-style-type: none"> • Tanzania Investment Centre was the one stop centre for all biofuel investment in the country • Guideline and sustainability criteria developed by Task force. • liquid biofuels which include biodiesel and bioethanol can be blended with petroleum products at various ratios. 	<ul style="list-style-type: none"> • Tanzania has no policies developed to aid sustainable production, transportation and consumption of liquid bio-fuels. • Both policies, legal and regulatory frameworks are in draft. • Lack of institutional memory on the reasons behind closure biofuel investment • TIC lost coordination efforts and lack proper implementation.

Problems in the biofuel related strategies and policies

The biofuel investment in eastern Africa countries was a kind of complain in 2007. The investment was abandoned without further generation of income on lands meant for local community. In Ethiopia the farmers lost trust on the local development agents and professionals because the promised income from the widely planted jatropha (more than 48 districts) and other biofuel crops was not realized. Similarly, large areas of jatropha, castor and croton planted in Kenya and Tanzania left without

any significant income (Table 5 and Table 6).

The problems in liquid biofuel investment can be summarized as:

- Lack of sustainability and standards on producing, processing and consuming liquid biofuels in the value chain.
- Lack of consensus on definition of marginal land, which were planned to plant biofuel crops.
- Lack of clear mandate of the different ministries engaged, and regional offices to enforce regulations, such as land

allocation, feedstock type selection, and licensing promoting investment.

- Lack of appropriate technologies in the different steps of liquid biofuel production and processing.
- In Ethiopia, and Tanzania there was principle of “one-stop-shopping” investment regulations that guided biofuel development which was abandoned .
- There was no private sector incentives to invest in biofuels. It is believed that incentives are necessary tools to encourage entrepreneurs into biofuel production.

Table 5. The strength and weakness of institutions for liquid biofuel industry in eastern Africa countries of Ethiopia, Kenya and Tanzania

Country	Institutions for biofuel development	Strength	Weakness
Ethiopia	<ul style="list-style-type: none"> • Ministry of Mines and Energy (Ministry of Mines, Petroleum and Natural Gases (MoMPNG), • Ministry of Water, Irrigation and Energy, and Ministry of Agriculture, • Regional energy offices, • Rural energy promotion center, • Ethiopian Institute of Agricultural Research and Ethiopian Environments and Forest Research Institutes 	<ul style="list-style-type: none"> • Establishment of bioenergy directorate, • Introduction of renewable energy sources and technologies such as wind, solar, and biogas, • Initiation of the concept of liquid biofuel such as bioethanol, and biodiesel, • Conducting research on forestry, firewood and agricultural energy crops 	<ul style="list-style-type: none"> • Lack of coordination, lack of monitoring and evaluation, lack of silvicultural and agronomic management lack of market identification for liquid biofuel feedstock production and lack of budget to conduct research, • The activities at federal, regional and investment offices were not clear and sometimes overlapping, in activities like land provision. • Frequent administrative structure changes that disturb attentive work,
Kenya	<ul style="list-style-type: none"> • Ministry of Energy (MoE), • Ministry of Environment & Forestry, • Ministry of Lands & Physical Planning and Ministry of Agriculture 	<ul style="list-style-type: none"> • MoE has coordinated the formulation and development of many relevant policy and regulatory frameworks on liquid biofuels production and processing, • Formulation of policies to produce biofuels in nonresidential, and degraded lands 	<ul style="list-style-type: none"> • All of the institutions related to biofuel lack clear mandate and no follow up to sustain the liquid biofuel sector.
Tanzania	<ul style="list-style-type: none"> • Ministry of Energy (MoE) by then Ministry of Energy and Minerals (MEM) • Ministry of Energy 	<ul style="list-style-type: none"> • Tanzania Investment Centre is the one stop centre for all biofuel investment in the country 	<ul style="list-style-type: none"> • All of the institutions related to biofuel lack clear mandate and no follow up to sustain the liquid biofuel sector because of lack of policies, lack of blending ratios, lack of institutional memory and lack of documentation to recall past events on biofuel, and all in all lack of biofuel coordination,

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Policy directions

The eastern Africa countries faced failure of biofuel policies in the production period of 2007 to 2021. Then it is possible to deduce the need for additional policies that include updating the biofuel strategy, provision of incentives, institutional strengthening, development of directive, standards and guidelines, formulating biofuel development, monitoring and evaluation system. Therefore, policy directions are required depending on the problems and deficits identified. The policies need to have two dimensions namely political and

strategic pillar. The political pillar deals on the institutional strength of the ministry on the authority, coordination, and promotion of different organizational level of biofuel production as well as the directorate through political actions. While the strategic pillar deals on developing strategic actions both in supply and demand side so that the biofuel market could be strengthened by establishing fixing prices, promoting high yielding varieties, and developing land-use planning protocols (Table 6).

Table 6. Political and strategic pillars of biofuel development sector in eastern Africa countries of Ethiopia, Kenya and Tanzania

Policy dimension	Ethiopia	Kenya	Tanzania
Political pillars	<ul style="list-style-type: none"> •Strengthening the authoritative body •Strengthening institutional capacity •Coordinating among ministries •Establishing international market •Carry out regional and international stakeholder analysis •Favourable policies and regulations •Assist small-scale producers •Promote public private partnership •Collaborate with international actors •Linking biofuel with emission reduction funding •Promote local processing capacity by installing processing factories 	<ul style="list-style-type: none"> • The same as Ethiopia • The same as Ethiopia • The same as Ethiopia 	<ul style="list-style-type: none"> •Strengthening the authoritative body •The same as Ethiopia •Coordinating among ministries •The same as Ethiopia •Carry out regional and international stakeholder analysis •Favourable policies and regulations •Assist small-scale producers •Promote public private partnership •Collaborate with international actors •Linking biofuel with emission reduction funding •The same as Ethiopia
Strategic pillars	<ul style="list-style-type: none"> •Establishment of national markets in addition to international market •Value chain analysis and GHG emission determination of the lifecycle of liquid biofuels utilization , •Fixing the prices of feedstock, liquid biofuel and blended fuel. 	<ul style="list-style-type: none"> •The same as Ethiopia •The same as Ethiopia •The same as Ethiopia 	<ul style="list-style-type: none"> •The same as Ethiopia •The same as Ethiopia •The same as Ethiopia

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<ul style="list-style-type: none"> • Managing the environmental impacts • Carrying out capacity building 	<ul style="list-style-type: none"> • The same as Ethiopia 	<ul style="list-style-type: none"> • Managing the environmental impacts • The same as Ethiopia
<ul style="list-style-type: none"> • Developing land use planning • Understanding interactions between biofuel crops and ecosystem dynamics • Mainstreaming research and development of biofuel crop • Promote high yielding varieties 	<ul style="list-style-type: none"> • The same as Ethiopia • The same as Ethiopia • The same as Ethiopia 	<ul style="list-style-type: none"> • Developing land use planning • The same as Ethiopia • The same as Ethiopia • The same as Ethiopia
<ul style="list-style-type: none"> • Intercropping in agricultural farm plots • Avoiding use of basic food crops • Favoure biofuel with biodiversity • Demonstrating for small holder • Research bio-fuel crop productivity 	<ul style="list-style-type: none"> • The same as Ethiopia 	<ul style="list-style-type: none"> • Intercropping in agricultural farm • Avoiding use of basic food crops • Favoure biofuel with biodiversity • The same as Ethiopia • The same as Ethiopia

Conclusion

- Africa is reported to have biofuel development strategies since 2007 that targeted to increase the role of biofuel in reducing the import of petroleum; however, this has not borne much fruit in terms of an actual growth in biofuel industry due to several bottlenecks.
- Challenges in liquid biofuels production and utilisation include lack of enough trained people, non-mechanized system of feedstock production, lack of investment capital, lack of quality feedstock planting material and unclear land tenure systems. Other challenges include lack of multidisciplinary and holistic policies that encompass environment, agriculture and the community, and lack of local knowledge on liquid biofuel production.

- Some of the coping mechanisms to contain these challenges include facilitating access to credit from banks, as well as national governments providing incentives such as tax reduction, and subsidies in the form of enabling policies, friendly regulatory frameworks and active political support.
- The biodiesel development in eastern Africa was not successful because of lack of previous experience, lack of local people participation, lack of well-known biodiesel crops, lack of technology, insufficient research on many aspects of the industry, and insufficient land suitability analysis. Collaboration of smallholders farmers, private sector and government in liquid biofuel production was very low, therefore constraining sustainable production of biofuel.

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- The involvement of foreign investors in eastern Africa for the production of biodiesel was not realistic, taking place without the knowledge of the need of local people, the type of soil and climate and crop type.
 - Bioethanol production from sugar cane molasses in eastern Africa is viable with production of over 100,000 litres per day whereas viability and competitiveness of biodiesel production require highly productive feedstock per unit area and per unit time higher than the currently utilized feedstocks such as jatropha, croton, castor, and oil palm. Bioethanol production relied entirely upon government efforts on sugar cane molasses. The efforts in sweet sorghum in Kenya and cassava in Tanzania were promising.
 - The failure of the liquid biofuel investment resulted in policy direction towards research on biofuel crops, mixed model of small and large scale production of bioenergy crops on degraded lands.
- The foreign large-scale plantations of biofuels might not always be a suitable mode of production, since they will involve taking up considerable land; something, if not done properly, could create considerable pressure on land in the

near future that could lead into social conflicts as the population grows.

Recommendations

- Favorable economic situation in the countries and biofuel trade liberalization to private sectors and regional centers of private public partnership are highly important.
- There is need for policy and regulatory support such as subsidies on acquiring advanced technology for lignocellulosic ethanol and pyrolysis oil production in addition to well-structured institutional arrangements. Feedstock producers and processors need contractual agreements with guaranteed markets.
- Radical changes are required based on the international interest of climate policy that include right human and organizational capacity , right legal system and other frameworks to achieve biofuel sector green goals, and facilitate public, private sector, SMEs and researchers, and civil society organizations to engage in biofuel development.
- Policy incentives are crucial to make commercially driven biofuel successful for the formulation of common policies by neighbouring countries on pricing and blending to prevent cross border smuggling.

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- Co-operation between stakeholders (government ministries, farmers, alcohol producers, oil marketing companies and car manufacturers), is highly needed for the elaboration and the implementation of the liquid biofuels projects.
- Establishment of long-term, stable and clear policies, regulations and incentives are highly needed for liquid biofuel investment.
- Initial price guarantee for biofuels (e.g. through fixed prices by the government) in order to secure return on investment in the biofuels sector; protection of local manufacturers against biofuels imports in order to facilitate the build-up of a strong national biofuels industry; and establishment of revenue sharing

mechanisms to ensure that small-scale farmers benefit from additional revenues generated through the production of biofuels should be practiced.

Conflicts of interest

There is no conflict of interest.

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