ICAO

PROJECT FUNDED BY

European Union

KENYA

FEASIBILITY STUDY ON THE USE OF SUSTAINABLE AVIATION FUELS

ICAO-EUROPEAN UNION ASSISTANCE PROJECT: CAPACITY BUILDING FOR CO_2 MITIGATION FROM INTERNATIONAL AVIATION

Author: David White
Technical Consultant on Sustainable Aviation Fuels

Project funded by the European Union
EuropeAid/Development Cooperation Instrument
DCI-ENV/2013/322-049

EXECUTIVE SUMMARY

The International Civil Aviation Organization is a United Nations agency working together with its 192 Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices and policies in support of a safe, efficient, secure, economically sustainable, and environmentally responsible international civil aviation sector.

In its efforts to help reduce carbon dioxide emissions, ICAO has developed partnerships with international organizations and states to develop assistance projects and promote a basket of measures designed to support Member States as they work to achieve the global aspirational goals. These goals, adopted by the 37th Session of the Assembly in 2010, seek to improve fuel efficiency by 2 per cent per year from 2020 and to keep net carbon dioxide emissions at the same evels (i.e. carbon neutral growth from 2020).

One such partnership is the Capacity Building for CO_2 Mitigation from International Aviation assistance project, a joint initiative of ICAO and the European Union (EU). This project aims to support 14 selected States in Africa and the Caribbean in their efforts to develop and implement their State Action Plans for the reduction of CO_2 emissions from international aviation; improve their aviation environmental systems; and identify, evaluate and implement mitigation measures in selected States. Kenya is among the beneficiary States under the project.

One of the promising mitigation measures identified in Kenya's State Action Plan is the development and deployment of sustainable aviation fuels (SAF) for international aviation, that have the potential to reduce life-cycle CO_2 emissions compared to current aviation fuel. As part of the ICAO-EU assistance project, a study into the feasibility of a commercial SAF supply chain in Kenya was commissioned.

The study examined the feasibility of various potential feedstocks based on conflicting uses, logistics, co-benefits, volumes and socio-economic factors. It identifies paths and required actions that could be pursued by relevant stakeholders to develop a viable SAF industry. It identifies key barriers and presents fact-based outcomes to assist stakeholders to prepare business and policy recommendations.

It is anticipated that this study will help advance the creation of a regionally replicable SAF supply chain in Kenya that may provide significant economic, social and environmental benefits for the country in the coming decades. This report identifies the current state of affairs relating to biofuels in Kenya, the policy environment, the infrastructure that is already in place, existing and potential feedstocks, and risks and opportunities. It provides guidance on a pathway to a domestic SAF industry given the identified constraints and resources, framed within the context of the unique issues that Kenya and many other African States face as they strive to transition from emerging, to a middle-income economies.

The study also examined the potential to supply airport ground handler companies with locally-sourced biodiesel in ground service equipment servicing commercial operations.

The study found that Kenya has a set of conditions suitable for the development of a national SAF industry.

It is recommended that focus be directed to waste-based feedstocks, namely, used cooking oil (UCO) in the short to medium term, and municipal solid waste (MSW), sugarcane field by-products (cane tops) and water hyacinth in the long term. All of these are available in significant quantities and are either already aggregated or localised in specific regions.

It is recommended that priority be given to UCO feedstock for a number of reasons:

- it is a waste available in significant volume and which grows rapidly, annually;
- new legislation encourages aggregation and beneficial reuse;
- there is a proven SAF conversion pathway certified for use in aircraft up to a 50 per cent blend and;
- there are social and environmental co-benefits through avoiding release to the environment and potentially providing an income stream to the community.

Initial analysis indicates that up to 200 million litres of SAF per year could be derived from UCO by 2030. This can be supplemented by emerging feedstocks, including croton nut which is native to East Africa.

The remaining feedstocks (i.e. MSW, cane tops and water hyacinth) provide the potential to deliver large volumes of feedstock in the long term. Each of these materials has significant environmental, social and economic issues associated with them that may be addressed through their use.

This report puts forward a 10-year roadmap and action plan to mobilize stakeholders and resources, to institute favourable policy and legislation, and to systematically assess the technical, economic and sustainability aspects of each pathway in order to ensure that a de-risked, investible business case can be realised to allow a national SAF industry to be established.

ROADMAP FOR A KENYAN SAF SUPPLY CHAIN TO MEET INTERNATIONAL AVIATION REQUIREMENTS

VISION	To identify and establish an indigenous SAF supply chain that supports the nation's Vision 2030 objective of achieving middle income status and helps the Kenyan aviation industry fulfil its emissions reduction targets.

OPPORTUNITIES	Large volumes of wastes (and residues)	Strong govt commitment on renewables	Stable govt and business support framework	Feedstock co-benefits will help reduce costs	Social benefits from engaging and rewarding public via collection strategies
CHALENGES	Feedstock collection systems inefficient or non-existent	Lack of technical expertise and research experience in target area	Inefficient waste collection regimes	No refining infrastructure	Agricultural land use not suited to broadscale cultivation

FIRST STAGE (2018-2019)
Laying the groundwork
Cooperation and capacity building

- Identification of feedstock with best potential for Kenyan conditions.
- Identify relevant stakeholders – their roles and responsibilities.
- Establish framework for oversight and coordination.
- Local cooperation and capacity building:
  - Establish measures for increasing cooperation and information sharing;
  - Capacity building on: feedstock, sustainability, refining, quality testing and market for SAF and biodiesel;
  - Funding and resource support mechanisms identified to advance studies.
- International cooperation – knowledge transfer and partnerships with East African States.
- Undertake biodiesel trial and implement permanent offtake for GSE.

SECOND STAGE (2020-2023)
Demonstrating the potential and proving the viability

- Ensure complementary policy and regulatory framework in place for advanced fuels and sustainability. Including government support and incentives.
- Complete techno-economic (TE) and sustainability analysis on jet fuel pathway utilising Kenyan used cooking oil (UCO).
- Education and awareness raising with potential investors and project developers.
- Extend biodiesel supply to other international airports.
- Undertake TE and sustainability analysis on cane-tops, MSW and water hyacinth feedstock with appropriate conversion technology centering on Kisumu.

THIRD STAGE (2023-2027)
Making it a reality - Implementation

- Ensure new petroleum infrastructure is complementary and supportive of SAF.
- Continue to advance scale up UCO collection systems.
- Complete business case and groundwork for first HEFA plant.
- Complete business case and groundwork for first UCO-based advanced fuels refinery producing renewable diesel and other products.
- Undertake techno-economic analysis into economic production and collection of croton nut oil to supplement UCO feedstock.
- From the results of the TE and sustainability analysis on cane tops, MSW and water hyacinth feedstock determine implementation plan.

CONTENTS

ABBREVIATIONS AND ACRONYMS

AiASAL	Arid or Semi-arid Land
ATJ	Alcohol-to-Jet
AEWG	Aviation Environmental Working Group
CAEP	Committee on Aviation Environmental Protection
CO_2	Carbon Dioxide
GHG	Greenhouse gas
EAC	East African Community
EFK	Eco-Fuels Kenya
EU	European Union
FT	Fischer-Tropsch
GDP	Gross Domestic Product
GSE	Ground Support Equipment
Ha	Hectare
HEFA	Hydroprocessed Esters and Fatty Acids
ICAO	International Civil Aviation Organization
INDC	Intended Nationally Determined Contribution
JKIA	Jomo Kenyatta International Airport
KAA	Kenya Airports Authority
KCAA	Kenya Civil Aviation Authority
KEBS	Kenya Board of Standards
kl	Kilolitre
KSh	Kenyan Shilling
LAQ	Local Air Quality
ML	Megalitre
MoALF	Ministry of Agriculture, Livestock and Fisheries
MoENR	Ministry of Environment and Natural Resources
MoEP	Ministry of Energy and Petroleum
MSW	Municipal Solid Waste
MTP	Medium Term Plan
PM	Particulate Matter
RERAC	Renewable Energy Resources Advisory Committee
SAF	Sustainable Aviation Fuel
SARP	Standards and Recommended Practices
SE4ALL	Sustainable Energy for All
SDG	Sustainable Development Goals
SVO	Straight Vegetable Oil
SWOT	Strengths, Weaknesses, Opportunities and Threats
UCO	Used Cooking Oil
USD	United States Dollar

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The aviation sector requires a substitute for petroleum-based fuel to improve its ability to reduce emissions and also address energy security. This step is more difficult for the aviation sector, whereas relative to ground transportation, aviation fuel is constrained by a stricter set of safety, technological and regulatory requirements.

The only alternative fuel which is likely to meet all of the environmental, economic and technical challenges in the medium term, is sustainable aviation fuel derived from biomass (non-food parts of crops, plants, woody material, waste and other organic matter) . These are "drop-in" biofuels that are functionally identical to petroleum fuels and fully compatible with existing infrastructure. Such fuels can be blended with fossil-based aviation fuel and requires no modification of distribution systems or engines. This is in contrast to biofuels such as bioethanol and biodiesel that are chemically and functionally distinct from fossil-based transportation fuels.

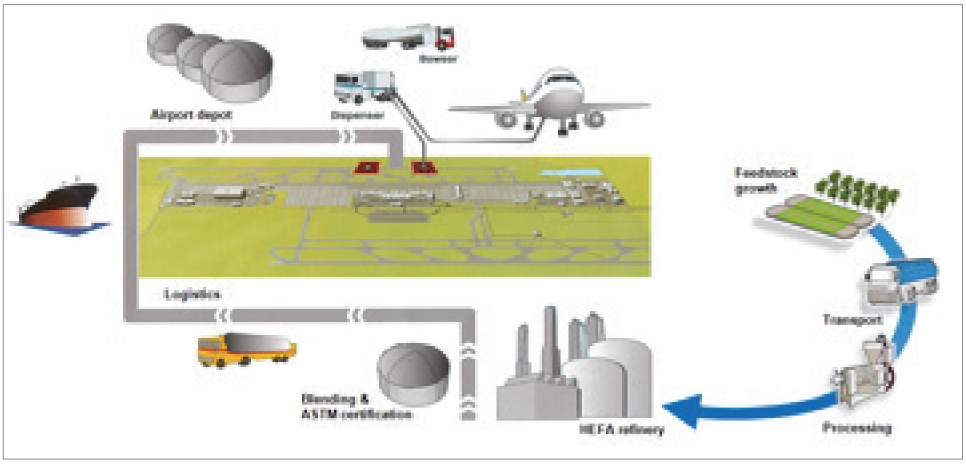
A sustainable aviation fuel supply chain consists of a number of key components:

- sustainable biomass production (feedstock);
- processing and transport of the feedstock;
- conversion of this biomass into aviation fuel (technology); and
- blending and distribution of the aviation fuel to the aircraft (logistics).

This supply chain is shown in Figure 1 using a crop-based feedstock, but is applicable to most feedstock types.

FIGURE 1

A Schematic Representation of a Sustainable Aviation Fuel Supply Chain (crop-based) (Source: IATA)



In developing a feedstock supply chain that will produce commercial quantities to fulfil an airline's medium and long-term goals, sustainability will be a key challenge. The availability of large quantities of cost effective sustainable feedstock from which to produce SAF is one of the main bottlenecks to enable large enough scale and long enough biofuel production runs for a production facility. The type of feedstock will influence processing, transport and conversion.

[1] McIntyre, A., A. El-Ashram, M. Ronci, J. Reynaud, N. Che, K. Wang, and S. Mejia. 2016. "Caribbean energy: macro-related challenges." (2016).

[2] Familiar, J. 2015. "Unlocking the Caribbean's energy potential." World Bank. January 31, 2015. http://www.worldbank.org/en/news/opinion/2015/01/31/unlocking-the-caribbeans-energy-potential

1.1 MANAGING EMISSIONS FROM INTERNATIONAL AVIATION

International aviation emissions currently account for 1.3 per cent of total global anthropogenic CO_2 emissions, and this is projected to increase as a result of the continued growth of air transport. ICAO and its Member States recognize the critical importance of providing continuous leadership in order to limit or reduce aviation emissions that contribute to global climate change. The 39th ICAO Assembly reiterated the global aspirational goals for the international aviation sector of improving fuel efficiency by 2 per cent per annum and keeping the net carbon emissions from 2020 at the same level, as established at the 37th ICAO Assembly in 2010, and recognized the work being undertaken to explore a long-term global aspirational goal for international aviation in light of the 2°C and 1.5°C temperature goals of the Paris Agreement. The ICAO 39th Assembly also recognized that the global aspirational goal of 2 per cent annual fuel efficiency improvement is unlikely to deliver the level of reduction necessary to stabilize and then reduce aviation's emissions contribution to climate change. More ambitious goals are needed to deliver a sustainable path for aviation.

To achieve international aviation's global aspirational goals, a comprehensive approach consisting of a basket of measures, including technology and standards, SAF, operational improvements and market-based measures to reduce emissions is necessary (**Figure 2**).

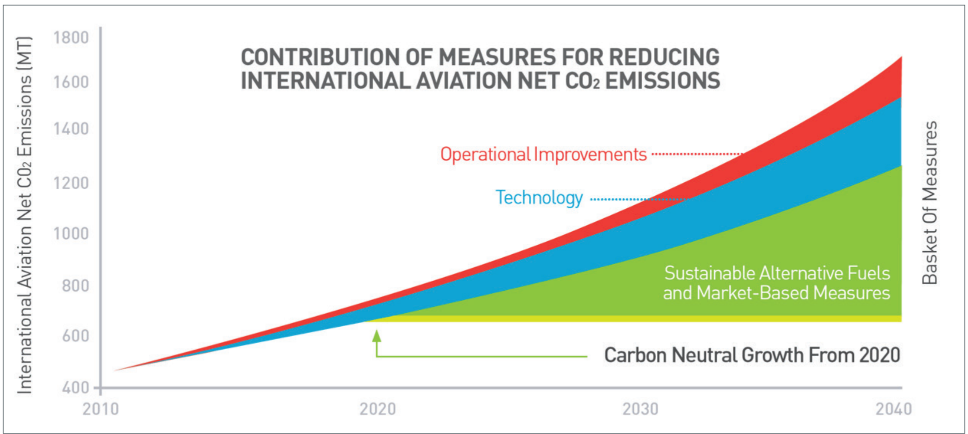


FIGURE 2
Contribution of Measures for Reducing International Aviation Net CO_2 Emissions (Source: ICAO)

A particular focus has been the development of sustainable aviation fuels (SAF) as a highly relevant means to reduce net CO_2 emissions, depending on the feedstock and production process adopted. When biomass, organic material that comes primarily from plants, is used to develop alternative fuels, the plants absorb CO_2 for growth during photosynthesis in relatively short time scales. The carbon that is then emitted back into the atmosphere during combustion will return to the plants in a closed loop. Ideally in this scenario, no additional carbon would be injected into the biosphere as is currently the case with the use of aviation fuel. When waste (e.g. Municipal Solid Waste (MSW) or industrial waste gases) is used to produce alternative fuels, the emissions reductions are derived from the additional use of the fossil carbon generated during the production of the original product.

Beyond CO_2 emissions reductions, there could also be additional benefits, such as promoting new domestic industries and production systems, improving the competitiveness of the aviation and tourism sectors in the State in the long-term, and improving local air quality (LAQ) by decreasing the particulate matter (PM)[3] emitted by aircraft[4].

[3] At the engine exhaust, particulate emissions mainly consist of ultrafine soot or black carbon emissions. Ultrafine particulate matter (PM) emissions are known to adversely impact both health and climate.

[4] https://aviationbenefits.org/environmental-efficiency/local-air-quality/

With the interconnection between energy and sustainable development, bioenergy[5] is a prime example of how energy can link with other areas, including water quality and availability, ecosystems, health, food security, and education and livelihoods, and can harness multiple benefits insofar as the development is properly planned and managed. Through the use of alternative fuels for transportation and bioelectricity, the development of sustainable and modern bioenergy can be promoted both on a small-scale for local use in stand-alone applications or mini-grids, as well as on a large-scale, for production and commoditization of bioenergy. At the same time, modern bioenergy can replace inefficient and less sustainable bioenergy systems.

The Government of Kenya, supported by the ICAO – EU assistance project, updated and submitted an improved State Action Plan to reduce CO_2 emissions from international aviation to ICAO in 2015. This Action Plan provides a comprehensive approach for Kenya to reduce aviation CO_2 emissions, and identifies a range of measures selected from the basket of measures, including exploration of the feasibility to develop and use SAF.

The following feasibility study is a result of the ICAO – EU assistance project, and determination of Kenya to contribute towards the sustainable development of its aviation sector, and specifically to assess the use of SAF in aircraft operations, as well as to power Ground Support Equipment (GSE). This feasibility study aims to support the creation of a SAF supply chain in Kenya that may provide significant economic, social and environmental benefits for the country in the coming decades. This study seeks to identify routes that could be pursued by different stakeholders to develop a viable SAF industry. It will include recommendations and will identify key barriers to developing a SAF industry in order to assist stakeholders to prepare business and policy recommendations.

This document identifies the current state of affairs related to biofuels in Kenya, the policy environment, the infrastructure that is already in place, existing and potential feedstocks, and risks and opportunities. The document will provide guidance on a pathway to a domestic SAF industry given the identified constraints and resources. It is important that the recommendations are framed within the context of the unique issues that Kenya and many other African States face as they strive to transition from emerging, to middle-income economies.

In addition, the study contributes to a number of global development priorities. In particular, ICAO Member States may realize economic, social, and environmental advantages by building a new SAF industry, contributing to the ambitious and transformational vision set out in 13 of the UN Sustainable Development Goals (SDGs). In particular, SAF contributes to the following UN SDGs:
SDG 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture – To increase productivity and production of SAF feedstock, resilient agricultural practices will have to be implemented, while considering the need to maintain ecosystems, strengthen capacity for adaption to climate change, extreme weather, drought, flooding, and other disasters, and progressively improve land and soil quality. Transferring these practices to food production, in particular in developing and least developed States, could help address hunger and malnutrition, whilst ensuring that SAF production avoids competition with food production.

SDG 3 – Ensure healthy lives and promote well-being for all at all ages – Using SAF could result in reduced emissions of PM and sulphur oxides, thereby reducing aviation's impact on LAQ[6]. Further research is ongoing to quantify the impact of SAF on LAQ.

[5] Bioenergy refers to the energetic use out of a material of biological origin, such as biomass or biofuels.

[6] CAAF/09-WP/05. Retrieved from https://www.icao.int/Meetings/caaf2009/Documents/CAAF-09_WP005_en.pdf

SDG 4 – Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all – Access to affordable and quality technical, vocational, and tertiary education, including university, can increase the number of youths and adults who have relevant skills for employment and entrepreneurship as needed to develop a local SAF supply. SAF creates a new industry with needs for new technical skills. ICAO has been convening hands-on training Seminars and Symposia for Member States focused on the exchange of latest knowledge on environmental subjects, as well as assisting States to implement environment-related ICAO policies, Standards and Recommended Practices (SARPs) and guidance, providing inclusive and equitable quality education to all.

SDG 5 - Achieve gender equality and empower all women and girls – A sound policy framework along the SAF supply chain at a national, regional, and global level could help to ensure full and effective participation of women and equal opportunities for leadership at all levels of decision-making in political, economic, and public functions in this new industry.

SDG 7 – Ensure access to affordable, reliable, sustainable and modern energy for all – This is the SDG mostly closely related to SAF, since it is inherently a new source of clean energy for aviation, and its deployment will be a key element for reducing aviation's dependence on fossil fuels, contributing to the diversity of energy sources for aviation and reducing the risks associated with a single energy source.

SDG 8 – Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all – All steps are being taken to make the SAF industry sustainable since its onset, helping to decouple economic growth from environmental degradation. Especially on Small Island Developing States with heavy international tourist aviation traffic, a local supply of SAF could reduce high aviation fuel importation costs. Additionally, the SAF supply chain can present broad positive social and economic effects in a variety of ICAO Member states, contributing to promote the sustained, inclusive and sustainable economic growth expected by SDG 8.

SDG 9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation – Research and development for developing new types of alternative fuel has grown significantly during the last 10 to 20 years as a result of the use of mandates, tax breaks, subsidies, and advantageous funding arrangements between alternative fuel producers and national governments[7]. Thus, investing in more research on SAF diversity, scaling-up of development, and deployment will contribute to SDG 9 by promoting inclusive and sustainable industrialization and fostering innovation.

SDG 10 – Reduce inequality within and among countries – In the spirit of the ICAO "No Country Left Behind" campaign, ICAO will continue to facilitate communication of initiatives and promotion of the development of partnerships between ICAO Member States, including the sharing of information and best practices related to the development of supply chains for SAFs, aiming at spreading the economic and social benefits associated with this new industry development to an increasing number of ICAO Member States. Additionally, it shall be noted that developing countries are taking the lead on several SAF deployment initiatives, which confirms the potential contribution of the SAF development to this SDG.

SDG 11 - Sustainable cities and communities – Improvements in LAQ from SAF use and the sustainable production of SAF also contribute to SDG 11, helping to make cities and human settlements inclusive, safe, resilient and sustainable.

[7] Panoutsou et al., 2013

SDG 12 – Ensure sustainable consumption and production patterns – Sustainability criteria required for SAF production contribute to SDG 12, which focuses on ensuring sustainable consumption and production patterns, such as an environmentally sound management of wastes throughout their life cycle to reduce their release to air, water, and soil. Further, SAF might enable a substantial reduction in waste generation by, for example, using MSW as feedstock. Sustainability certification of SAF might also encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle.

SDG 13 – Take urgent action to combat climate change and its impacts – Production and deployment of SAF is inherently a strategy to reduce global greenhouse gas (GHG) emissions due to their reduced emissions on a life cycle basis when compared with current aviation fuel, as was acknowledged during the First ICAO Conference on Aviation and Alternative Fuels (CAAF/1)[8]. This action is in line with SDG 13, which appeals to States to take urgent action to combat climate change and its impacts.

SDG 15 – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss – Sustainability criteria for SAF will consider land-use change effects that may be associated with SAF production. This will contribute to a sustainable use of terrestrial ecosystems, such as forests. For example, the production of SAF from forestry residues can be an essential component of sustainable forest management.

SDG 17 – Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development – SDG 17 is in line with SDG 10, which calls for a reduction in inequality within and among countries. In the spirit of the ICAO No Country Left Behind initiative, ICAO will continue to facilitate communication and promote the development of partnerships between ICAO Member States, including the sharing of information and best practices related to the development of supply chains for SAF, aiming at spreading the economic and social benefits associated with this new industry development to an increasing number of ICAO Member States. The Global Framework for Aviation Alternative Fuels (GFAAF) is a good example of ICAO action in contributing to this SDG.

1.2 THE WORK OF ICAO TO ADDRESS GREENHOUSE GAS EMISSIONS

ICAO is a UN specialized agency, established by States in 1944 to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention).

ICAO works with the Convention's 192 Member States and industry groups to reach consensus on international civil aviation SARPs and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. These SARPs and policies are used by ICAO Member States to ensure that their local civil aviation operations and regulations conform to global norms, which in turn permits more than 100,000 daily flights in aviation's global network to operate safely and reliably in every region of the world[9].

As mentioned, Member States have agreed to the collective global aspirational goals for the international aviation sector of improving fuel efficiency by two per cent per year from 2020 and keeping net CO_2 emissions at the same levels (i.e. carbon neutral growth from 2020). In order to achieve such goals, ICAO Assembly adopted a "basket of measures" to reduce aviation CO_2 emissions consisting of the following seven categories[10] of mitigating measures:

- Aircraft-related technology and Standards;
- Improved air traffic management and operational improvements;
- Development and deployment of sustainable aviation fuels; and
- Market-based measures.

ICAO launched a voluntary programme inviting States to develop a State Action Plan on CO_2 emissions reduction from international aviation, incorporating the above mitigation measures through its implementation. This programme encourages States to report their CO_2 mitigation activities to ICAO and promotes improved communication on environmental matters within the aviation industry. SAF was identified as an important mitigation measure to help States achieve ICAO's global aspirational goals including carbon neutral growth[11]. ICAO is actively engaged in activities to promote and facilitate the emergence of drop-in SAF by exchanging and disseminating information, fostering dialogue among States and stakeholders, and carrying out dedicated work as requested by ICAO Member States to inform decision making[12]. To that end the ICAO Committee on Aviation Environmental Protection (CAEP), a technical committee of the ICAO Council, established an expert group, the CAEP Alternative Fuels Task Force (AFTF), to provide technical input regarding the replacement of aviation fuel with SAF.

[8] CAAF/09-WP/3. Retrieved from https://www.icao.int/Meetings/caaf2009/Documents/CAAF-09_WP024-Rev_en.pdf

[9] ICAO: About ICAO. Retrieved from http://www.icao.int/about-icao/Pages/default.aspx

[10] ICAO Doc 9988, Guidance on the Development of States' Action Plans on CO_2 Emissions Reduction Activities, paragraph 1.1.2. Order Number: 9988, ISBN 978-92-9249-223-6. March 17th, 2014.

[11] For more information on ICAO's aspirational goals, refer to http://www.icao.int/annual-report-2013/Pages/progress-on-icaos-strategic-objectives-strategic-objective-c1-environmental-protection-global-aspirational-goals.aspx

[12] ICAO Environment: Alternative Fuels: Questions and Answers. Retrieved from http://www.icao.int/environmental-protection/Pages/AltFuel-IcaoAction.aspx

In October 2017, ICAO convened its second Conference on Aviation and Alternative Fuels (CAAF/2) in Mexico City, Mexico. Building on the first such ICAO Conference (CAAF/1) held in 2009, the CAAF/2 agreed to a Declaration, endorsing the 2050 ICAO Vision for Sustainable Aviation Fuels as a living inspirational path and calling on States, industry and other stakeholders, for a significant proportion of aviation fuel to be substituted with SAF by 2050, for international civil aviation to reduce carbon emissions significantly, and whilst pursuing all opportunities in the basket of mitigation measures to reduce emissions as necessary. The Conference further agreed that the Vision would be reviewed periodically through a stocktaking process and elaborated at the next CAAF, to be held no later than 2025.

ICAO Environment, within the ICAO Air Transport Bureau, develops SARPs, and provides guidance and support to Member States in their efforts to improve the environmental performance of aviation. ICAO has developed a range of SARPs, policies and guidance material for the application of integrated measures[13] to achieve the following three main goals adopted by ICAO in 2004:

1. limit or reduce the number of people affected by significant aircraft noise;
2. limit or reduce the impact of aviation emissions on local air quality; and
3. limit or reduce the impact of aviation greenhouse gas emissions on the global climate.

The ICAO Secretariat, together with the ICAO CAEP, undertakes most of this work, assisting the ICAO Council to formulate new policies and adopt new SARPs related to aircraft noise and emissions, and more generally, to address aviation's environmental impact[14].

In addition, ICAO has developed tools and guidance material to assist Member States address emissions from international aviation[15], including:

i. ICAO Doc 9988 - Guidance on the Development of States' Action Plans on CO_2 Emissions Reduction Activities - Includes step-by-step guidance on the baseline scenario calculation, the basket of mitigation measures and the quantification of selected measures.
ii. Environmental Benefits Tool - Provides a framework to automate the calculation of baseline CO_2 emissions from international aviation, and estimate expected results obtained through the implementation of mitigation measures selected from ICAO's basket of measures.
iii. ICAO Carbon Emissions Calculator - Allows States to estimate the CO_2 emissions attributed to air travel, using only a limited amount of input information.
iv. ICAO Fuel Savings Estimation Tool (IFSET) - Can be used to estimate fuel savings obtained through operational measures in a manner consistent with approved models.
v. ICAO Green Meetings Calculator - Can be used to support decision-making in selecting meeting location with minimum CO_2 footprint from air travel.
vi. Action Plan on Emissions Reduction (APER) website - Interactive website reserved to States' action plan focal points to assist them prepare and submit their Action Plans to ICAO.
vii. Aviation Environmental Systems (AES) - An efficient CO_2 emissions monitoring system for international aviation, developed in each beneficiary State of the ICAO-EU assistance project.

1.3 ICAO-EU ASSISTANCE PROJECT: CAPACITY BUILDING FOR CO_2 MITIGATION FROM INTERNATIONAL AVIATION

On 17 December 2013, ICAO and the EU signed an agreement to implement the Capacity Building for CO_2 Mitigation from International Aviation assistance project, to support 14 selected States in Africa and the Caribbean to reduce CO_2 emission from the aviation sector. Kenya is among the beneficiary States of this assistance project.

The ICAO-EU project offers guidance and resources to prepare feasibility studies, and access to financial resources through partnerships with interested parties in support of the implementation of mitigation measures described in their Action Plans. The overarching objective of the project has been to contribute to the mitigation of CO_2 emissions from international aviation by implementing capacity building activities that will support the development of low carbon air transport and environmental sustainability[16]. This project focuses on the following three areas of activity:

a) improve capacity of the national civil aviation authorities to develop their Action Plan on CO_2 emissions reduction from international aviation;
b) develop an efficient CO_2 emissions monitoring system for international aviation in each selected Member State; and
c) identify, evaluate, and partly implement priority mitigation measures, specifically those measures included within the States' Action Plans that can be replicated by other States.

The model can be replicated and adapted to additional countries, creating a global system of cooperation to take action to reduce CO_2 emissions.

[13] ICAO Environment: Environmental Protection. Retrieved from http://www.icao.int/environmental-protection/Pages/default.aspx
[14] ICAO Environment: Committee on Aviation Environmental Protection (CAEP). Retrieved from http://www.icao.int/ENVIRONMENTAL-PROTECTION/Pages/CAEP.aspx
[15] ICAO Environment: Retrieved from http://www.icao.int/environmental-protection/Pages/default.aspx
[16] ICAO Environment: Retrieved from https://www.icao.int/environmental-protection/Pages/ICAO_EU.aspx

1.4 KENYA: STATE SNAPSHOT

Kenya is the economic, financial, and transport hub of East Africa. Kenya's real Gross Domestic Product (GDP) growth has averaged over five per cent for the last eight years. Since 2014, Kenya has been ranked as a lower middle-income country and aims to reach middle-income status by 2030 under its Vision 2030 development programme[17]. After gaining independence in 1963, Kenyans overwhelmingly adopted a new constitution in a national referendum in August 2010 introducing additional checks and balances to executive power and significant devolution of power and resources to 47 newly created counties[18].

The population of Kenya is approximately 46,800,000 with more than 43 per cent living below the poverty line[19].

Agriculture is the mainstay of the Kenyan economy, contributing one-third of GDP. About 75 per cent of Kenya's population work at least part-time in the agricultural sector, including livestock and pastoral activities (arable land 9.8 per cent; permanent crops 0.9 per cent; permanent pasture 37.4 per cent).

Other issues that must be considered in assessing SAF supply chains include:

- Over 75 per cent of agricultural output is from small-scale, rain-fed farming or livestock production;
- 80 per cent of Kenya is classified as arid or semi-arid (ASAL);
- Only 1,000 km2 of the total of 570,000 km^2 is irrigated;
- Adverse effects of climate change, weak environmental governance and overreliance on traditional biomass energy have led to serious exploitation of natural resources. This in turn has led to deforestation, biodiversity loss, encroachment on wildlife habitats and land and water degradation, especially in the ASALs;
- Only 20 per cent of households are connected to the national electricity grid and 70 per cent of the population relies on biomass for primary household needs[20].

Inadequate infrastructure continues to hamper Kenya's efforts to improve its annual growth to the 8 to 10 per cent range so that it can meaningfully address poverty and unemployment. This is exacerbated by the ongoing drought.

Food security has deteriorated since the end of 2016 and conditions remain critical in half of the country's 47 counties[21], with 2.7 million people in need of food aid. The number of people who will need food aid was expected to rise to 3.5 million by August 2017.

[17] Kenya: vision 2030, Government of the Republic of Kenya, Ministry of Planning and National Development and the National Economic and Social Council (NESC), Office of the President, 2007.

[18] https://www.cia.gov/library/publications/the-world-factbook/geos/ke.html

[19] The quantitative approach of measuring poverty defines the poor as those who cannot afford basic food and non-food items (http://eldis.org/vfile/upload/1/document/0708/DOC14829.pdf)

[20] Government of Kenya. National Energy and Petroleum Policy (Draft). Working paper. n.p., 2015. Print.

[21] https://www.theguardian.com/global-development/2017/jun/02/drought-centre-stage-kenya-election-campaign-food-prices-rise

2. AVIATION IN KENYA

Aviation is an important component of the economic and social structure of Kenya. It safely and affordably connects people and businesses to each other and the world. Kenyans rely on air transportation to support key sectors of the economy, particularly international trade and tourism. Aviation is also critical to rural and regional development and prosperity especially as land transport infrastructure is poor.

AVIATION'S ECONOMIC CONTRIBUTION TO GDP

The aviation sector contributes KSh 24.8 billion (1.1 per cent) to Kenyan GDP.
This total comprises:

- KSh 13.0 billion directly contributed through the output of the aviation sector (airlines, airports and ground services);
- KSh 6.1 billion indirectly contributed through the aviation sector's supply chain; and
- KSh 5.7 billion contributed through the spending by the employees of the aviation sector and its supply chain.

In addition, there are KSh 59.2 billion in "catalytic" benefits through tourism that raise the overall contribution to KSh 84.0 billion or 3.7 per cent of GDP.

The aviation sector directly supports 46,000 jobs in Kenya. This total comprises:

- 13,000 jobs directly supported by the aviation sector;
- 17,000 jobs indirectly supported through the aviation sector's supply chain; and
- 16,000 jobs supported through the spending by the employees of the aviation sector and its supply chain.

In addition, there are a further 142,000 people employed through the catalytic (tourism) effects of aviation

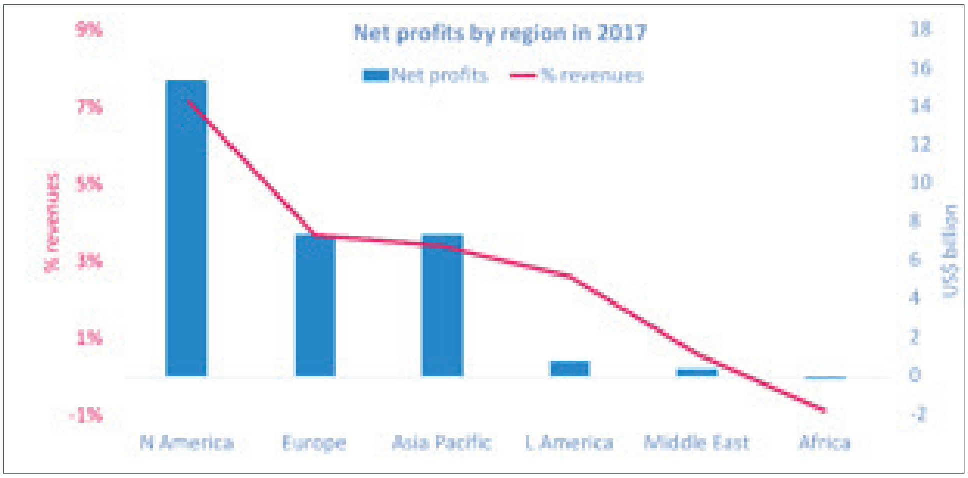
From: Oxford Economics. Economic Benefits from Air Transport in Kenya. Rep. N.p., 2011. Print.

The aviation industry in Kenya has continued to expand with 8.89 million passengers and 264,314.5 tonnes of cargo being handled at Kenya's major airports as at June 2015. The frequency of services and the number of international and domestic destinations served by Kenyan air carriers have increased tremendously over the last year.

The number of passenger arrivals and departures were 4.47 million and 3.072 million respectively, while those in transit stood at 1.35 million in June 2015[22].

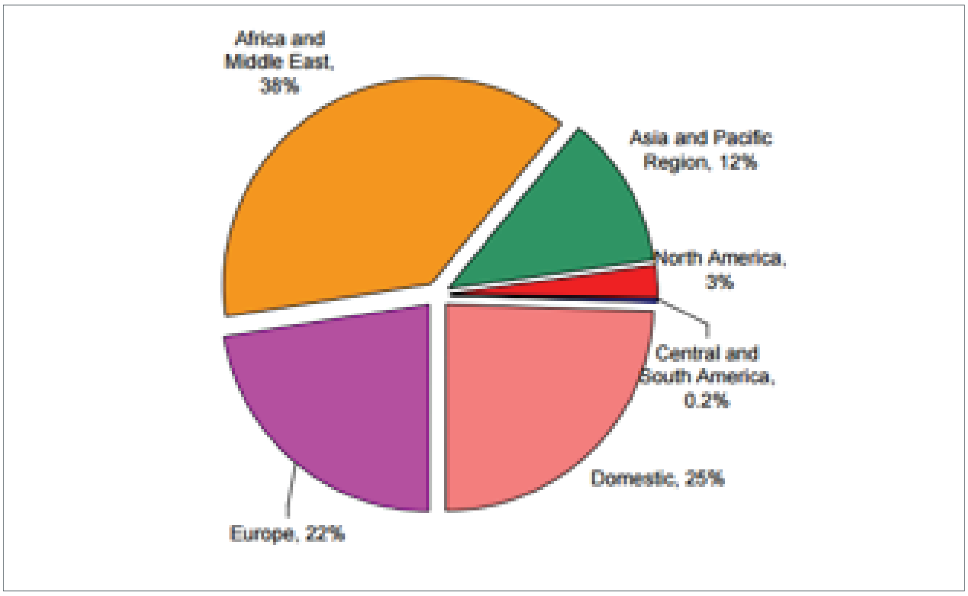
[22] Kenya Civil Aviation Authority 2015, Kenya's Action Plan For The Reduction of CO_2 Gas Emissions in Aviation Sector

FIGURE 3
Net Profits by Region 2017
(Source: IATA Mid-Year Report 2017[23])



However, while the international airline industry on the whole is profitable with a $4.2bn net profit margin in 2016, African carriers have suffered economic difficulties (**Figure 3**).

FIGURE 4
Regional distribution of scheduled passenger trips originating in Kenya[24]
(Source: IATA)



The three largest airports in Kenya handle over 6 million passengers a year: Jomo Kenyatta International Airport (80 per cent of passenger traffic); Moi International Airport (18 per cent); and Eldoret Airport (2 per cent). In total, over 7 million passengers arrive or depart from Kenyan airports each year. Over 283,000 tonnes of freight is handled annually[25].

[23] http://www.iata.org/publications/economics/Pages/industry-performance.aspx
[24] https://www.iata.org/policy/Documents/Benefits-of-Aviation-Kenya-2011.pdf
[25] Kenya Civil Aviation Authority 2015, Kenya's Action Plan For The Reduction of CO_2 Gas Emissions in Aviation Sector

3. NATIONAL APPROACHES FOR ADDRESSING GHG EMISSIONS

While Kenya contributes a relatively small amount to global total CO_2 emissions, there is a strong desire by the government to take action due to the severe effects of climate change on the country, especially as manifested through the prolonged drought. The Government estimates it will need \$40 billion over the next 15 years, some of it in the form of foreign aid, to fully implement its climate mitigation and adaptation plans[26]. There are a number of international and domestic policy mechanisms in place relating directly or indirectly to addressing GHG emissions that will have a bearing on SAF development.

3.1 THE PARIS AGREEMENT

Kenya's Intended Nationally Determined Contribution (INDC) under the Paris Agreement covers a range of sectors across the economy including the implementation of low carbon and efficient transportation systems. Under the Agreement it commits to reducing its GHG emissions by 30 per cent (143 $MtCO_{2e}$) relative to business as usual levels by 2030, contingent on receiving international finance, investment, technology development and transfer, and capacity-building support.

In response to the challenges posed by climate change and to assist in meeting their INDC commitments Kenya has developed a National Climate Change Response Strategy (NCCRS), National Climate Change Action Plan (NCCAP 2013), and a National Adaptation Plan (NAP) which provides a vision for low carbon and climate resilient development pathways, while a National Climate Change Framework Policy and legislation have been enacted to facilitate effective response to climate change. Kenya is operationalizing these policies and plans through the implementation of climate change actions in various areas such as afforestation and reforestation, geothermal and other clean energy development, energy efficiency, climate smart agriculture, and drought management. The results of this feasibility study aim to complement these programmes.

Bioenergy is an important element of the NCCRS both for electricity production and bio-derived fuels, which also contribute to local economies. Kenya currently relies entirely on crude oil imports with local prospecting showing some potential (see section **Fuel Infrastructure in Kenya**). Utilizing locally produced SAF and biodiesel in GSE will reduce this dependence on oil imports that are expected to continue to rise in cost and will ease the pressure on the country's aging petroleum infrastructure.

While Kenya's INDC covers emissions from domestic activities and excludes international aviation, there would be great value in aligning actions relating to SAF development and utilisation between the two.

RECOMMENDATION

The Ministry of Transport should provide submission for review of the National Adaptation Plan on the inclusion of SAF development for both international and domestic operations.

[26] https://www.theguardian.com/environment/2015/jul/24/kenya-pledges-to-cut-carbon-emissions-30-by-2030

3.2 VISION 2030

Kenya Vision 2030 (Swahili: Ruwaza ya Kenya 2030) is the country's flagship development programme covering the period 2008 to 2030. Launched on 10 June 2008 its objective is to help transform Kenya into a "newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030 in a clean and secure environment." Developed through "an all-inclusive and participatory stakeholder consultative process, involving Kenyans from all parts of the country," the Vision is based on three pillars: economic, social, and political[27].

The economic, social and political pillars of Kenya Vision 2030 are anchored on macroeconomic stability; continuity in governance reforms, enhanced equity; and wealth creation opportunities for the poor. The Vision 2030 strategy is to undertake reforms in 8 key sectors that form the foundation of society for socio-political and economic growth including energy, infrastructure, and science, technology and innovation (STI), all of which are areas that are complementary to the development of a SAF sector.

- The economic pillar aims to improve the prosperity of all Kenyans through an economic development programme, covering all the regions of Kenya, and aiming to achieve an average GDP growth rate of 10 per cent per annum beginning in 2012.
- The social pillar seeks to build a just and cohesive society with social equity in a clean and secure environment.
- The political pillar aims to realise a democratic political system founded on issue-based politics that respects the rule of law and protects the rights and freedoms of every individual in Kenyan society. In addition, there are KES 59.2 billion in "catalytic" benefits through tourism that raise the overall contribution to KES 84.0 billion or 3.7 per cent of GDP.

Vision 2030 is implemented through a series of five-year medium term plans (MTP) at the national level with county governments implementing County Integrated Development Plans (CIDP), which are aligned to the national Medium Term Plan (MTP). The Vision 2030 First Medium Term Plan 2008-2012 (MTP1) succeeded the Economic Recovery Strategy for Wealth and Employment Creation, 2003-2007, as the National Medium Term Plan. Kenya has just concluded the second Medium Term Plan 2013-2017 (MTP2).

Kenya Vision 2030 and the Second Medium Term Plan 2013–2017 identify energy as one of the infrastructure enablers for Kenya's transformation into "a newly-industrializing middle-income country providing a high quality of life to all its citizens in a clean and secure environment". Access to competitively priced, reliable, quality, safe and sustainable energy is essential for achievement of the Vision. According to Vision 2030, Kenya aims to increase the reliance on national energy resources over imports. Biofuel production can contribute to this goal.

Further, the MTP2 has guidance relating to renewable energy and first-generation biofuel. The government will promote development of renewable energy as an alternative source of energy, including generation of energy from solar, wind, biogas ("Biogas for Better Life") and development of bio-energy, such as bioethanol and biodiesel value chains. It also mentions the development of a "National Renewable Energy Master Plan" and updated renewable energy database will be developed.

RECOMMENDATION

The Ministry of Energy and Petroleum (MoEP) to consider inclusion of advanced fuels development, including SAF, in the National Renewable Energy Master Plan in the third Medium Term Plan.

[27] Retrieved from http://www.vision2030.go.ke/about-vision-2030/

3.3 CLIMATE CHANGE ACT 2016[28]

Kenya has established a legal framework to address climate change issues in the country. This follows the signing into law of the climate change bill on 6 May 2016 by President Uhuru Kenyatta. The new law aims to develop, manage, implement and regulate mechanisms to enhance climate change resilience and low carbon development in the country.

In Section 3 Objectives and Purposes of the Climate Change Act 2016 it states - "….this Act shall be applied in all sectors of the economy by the national and county governments to:

- provide incentives and obligations for private sector contribution in achieving low carbon climate resilient development;
- promote low carbon technologies, improve efficiency and reduce emissions intensity by facilitating approaches and uptake of technologies that support low carbon, and climate resilient development;
- facilitate capacity development for public participation in climate change responses through awareness creation, consultation, representation and access to information;
- mobilize and transparently manage public and other financial resources for climate change response;
- provide mechanisms for, and facilitate climate change research and development, training and capacity building".

The Act calls for the establishment of a Climate Change Council that will oversee the execution of these objectives and ensure the mainstreaming of the climate change function by the national and county governments. The Council will also administer the Climate Change Fund established under the Act as the financing mechanism for priority climate change actions and interventions approved by the Council.

RECOMMENDATION

Investigate incentives and support under the Climate Change Act 2016 to encourage the development of SAF.

3.4 NATIONAL ENERGY AND PETROLEUM POLICY 2015

The energy and petroleum sector has been guided by the policies set out in Sessional Paper No. 4 (2004) and governed by a number of statutes, principally the Energy Act, No. 12 (2006), the Geothermal Resources Act No. 12 (1982) and the Petroleum (Exploration and Production) Act, Cap 308. Also included is the Environmental Management and Co-ordination Act (1999) which regulates the environmental aspect of the energy and petroleum sector. Adoption of the Kenya Vision 2030 and the promulgation of the Constitution of Kenya (2010), made it necessary to review both the policy and all these statutes so as to align them with the Vision and the Constitution. The policy also builds on the Strategy for developing the Bio-Diesel Industry in Kenya (2008-2012)[29].

The vision set down in the updated Energy Policy (released in June 2015) is "Affordable Quality Energy for All Kenyans" and the mission is to "Facilitate Provision of Clean, Sustainable, Affordable, Competitive, Reliable and Secure Energy Services At Least Cost while Protecting the Environment". The Policy has significant components relating to renewable energy directing the establishment of an inter-ministerial Renewable Energy Resources Advisory Committee (RERAC) to, among other things, advises the Cabinet Secretary on a range of issues to help advance its contribution to the overall energy mix. A particular function of the RERAC is guidance on management and development of other energy resources such as agricultural and municipal waste, forests, and areas with good wind regimes, tidal and wave energy. This will presumably cover advanced fuels made from such wastes.

[28] Retrieved from http://kenyalaw.org/lex/actview.xql?actid=No.%2011%20of%202016

[29] Retrieved from http://kerea.org/wp-content/uploads/2012/12/National-Biodiesel-Strategy-2008-2012.pdf

Particular aspects of the policy that will prove beneficial in the development of SAF in Kenya includes:

- The Government shall: (a) Explore and adopt all viable financing options from local and international sources for cost effective utilization of all its energy resources, and in so doing shall endeavour to maintain a competitive fiscal investment climate in the country. (b) Support Public Private Partnerships in the development, operation and maintenance of energy and petroleum infrastructure and delivery systems. (s.31)
- The Government shall: set up a Consolidated Energy Fund to fund infrastructure development; acquisition of strategic petroleum reserves; energy and petroleum sector environmental disaster mitigation, response and recovery; hydro risk mitigation; water towers conservation programmes; energy efficiency and conservation programmes as well as promotion of renewable energy initiatives. (s.32)
- It is anticipated that the Policy will be promulgated after the new energy legislation (Energy Bill 2015) is ratified by the new parliament in 2018.

The National Energy and Petroleum Policy outlines a number of challenges relating to biofuel development in the country. These include:

- insufficient feedstocks to produce biofuels for blending;
- limited research data/information for the use and sustainable production of biofuel;
- insufficient legal and institutional framework to support sustainable generation, utilisation, production, distribution, supply and use of liquid biofuels;
- threat of competition over land use that could lead to food insecurity;
- reliance on rain fed, slow maturing feedstock for biofuels;
- inadequate RD&D on alternative biofuel feedstocks and technologies;
- lack of knowledge among the stakeholders on the importance of biofuels for complementing energy needs in the country; and
- competing uses of the ethanol.

These also apply to the development of SAF and provide a guidepost on the fundamental issues that must be overcome.

FIGURE 5
Section 3.5.3 Policies and Strategies (Source: National Energy and Petroleum Policy, 2015)

Biofuels	Short Term 2015-2019	Medium Term 2015-2024	Long Term 2015-2030
1. Undertake RD&D on biofuel feed-stock.	✓	✓	✓
2. Review the existing legal, fiscal, regulatory and institutional framework.	✓	✓	✓
3. Provide incentives for biofuel production projects and consumption.	✓	✓	✓
4. Collaborate with other stakeholders to ensure efficient use of land resource for biofuel feed-stock, food production and other human needs.	✓	✓	✓
5. Create stakeholder awareness and sensitization on the importance and viability of biofuel production and consumption.	✓	✓	✓
6. Implement the bioethanol pilot program.	✓	✓	✓
7. Initiate and implement biodiesel blend pilot program.	✓	✓	✓

One of the objectives of the Draft Strategy and Action Plan for Bioenergy and LPG Development in Kenya (2015-2020) is to promote alternative and cleaner forms of energy such as biogas, liquefied petroleum gas (LPG), briquettes and liquid biofuels.

As mentioned, the Energy Bill 2017 is proposed to be gazetted in 2018 after being delayed by the 2017 elections. The bill is designed to implement the recommendations contained in the 2015 draft policy. The bill includes sections on promoting biodiesel and gasohol (bio-ethanol), it also talks of "promoting the use of fast maturing trees for energy production including biofuels" and "promoting the use of municipal waste for energy production"[30].

RECOMMENDATION

That the Ministry of Transport coordinate with the RERAC promoting the importance and development of SAF.

Investigation to be undertaken into scope and conditions of the Consolidated Energy Fund and the potential to support in-depth SAF studies.

That consideration be given for advanced biofuels, specifically SAF, to be acknowledged and discussed in the final version of the National Energy and Petroleum Policy and Bioenergy Strategy as well as the Energy Bill 2017.

Though there are some initiatives being undertaken by the government to develop a policy framework for biofuel development, much remains to be done to develop regulations and standards that will promote and regulate the biofuel industry in Kenya. The biofuel industry cuts across several sectors that are governed by different policies, all of which need to be harmonized to speed up the industry in the light of increasing fossil fuel prices. The key will be the efficient and judicious execution of the policy, an area which to date has been lacking.

3.5 THE KENYA SE4ALL INITIATIVE

Sustainable Energy for All (SE4ALL) is a United Nations initiative whose objectives are to mobilize all stakeholders to take concrete action toward ensuring universal access to modern energy services; double the global rate of improvement in energy efficiency and; double the share of renewable energy in the global energy mix, within the UN timeframe of 2030. With support from the African Development Bank, Kenya has formulated an action agenda under the programme, which presents an energy sector-wide long-term vision spanning the period 2015 to 2030. It outlines how Kenya will achieve the SE4ALL goals of 100 per cent universal access to modern energy services, increase the rate of energy efficiency and increase to 80 per cent the share of renewable energy in its energy mix, by 2030. This definition of energy mix relates primarily to electricity and energy for cooking. However, with the SE4ALL project having a high profile in the MoEP and an active cross-Ministry steering committee, it would be logical for it to have a prominent role in advancing the recommendations in this report.

[30] http://www.erc.go.ke/images/docs/Energy_Bill_Final_3rd_August_2015.pdf

4. FUEL DEMAND AND UTILISATION

As Kenya aviation activities grow, so does its demand for fuel. Data supplied by Kenya Airways for the four year-period up to 2014 showed that they achieved a 9.7 per cent improvement in fuel use efficiency (based on litres per revenue tonne kilometre) while total fuel consumption grew at approximately 17 per cent[31] in the same period. As the country continues its journey from an emerging to middle-income economy, liquid transport fuel will continue to play an important role in this transformation.

4.1 FUEL INFRASTRUCTURE IN KENYA

Kenya currently imports all of its petroleum products and distributes them from the receiving port near Mombasa via an 896 km pipeline to off-take points at Nairobi, Kisumu and Eldoret for further distribution by vehicle (see Figure 6). This is done via a "batch" process managed by the Kenya Pipeline Company Ltd. (KPC). Products transported by the pipeline system are super petrol, regular petrol, diesel, illuminating kerosene, and aviation fuel (Jet A-1). The process of tracking the customer's batch or product through the pipeline is done through scheduling. A number of issues exist with this system, including inadequate and aged petroleum infrastructure providing maximum 10 days of operational stocks cover, lack of strategic petroleum stocks and the petroleum infrastructure concentrated only on the southern part of the country leading to massive trucking of products adding greatly to costs. This has resulted in airlines choosing not to refuel aircraft at regional ports such as Kisumu and Eldoret due to the high unit cost of fuel unless operational issues dictate otherwise. Instead, enough extra fuel is loaded before departing for these ports covering both outward and return journeys. This is termed "tankering" and results in higher fuel burn and emissions due to the extra weight of fuel that would otherwise normally not have to be carried.

Economically exploitable oil deposits were discovered in north-western Kenya in 2012; Africa Oil and its partner Tullow Oil, who made the discovery, have indicated that they may be able to start small-scale production of crude oil, transported by road and rail to the Kenyan port of Mombasa, in the medium term. However, low oil prices and Uganda's recent decision to withdraw support from Kenya and partner with Tanzania instead in the construction of a port and transport corridor known as the Lamu Port and South Sudan Ethiopia Transport (LAPSSET) may impede Kenya's establishment as a major oil exporter[32].

Following on from the discovery of oil, Kenya is looking at developing facilities and infrastructure to support the oil industry. Currently, the only such facilities in the country are the mothballed 70,000-barrels-per-day oil refinery in Mombasa, and the pipeline transporting petroleum products from Mombasa to the south-western part of the country. Plans have been developed under the Vision 2030 implementation program to build an oil refinery at Lamu on the Kenyan north coast with a capacity of 120,000 barrels per day to refine oil products for Kenya and Ethiopia. This has been proposed as part of the LAPSSET corridor project. Such a facility may help support the establishment of a SAF supply chain. For example, it will include hydrogen production which is required for SAF manufacture.

[31] Kenya Civil Aviation Authority 2015, Kenya's Action Plan for The Reduction of CO_2 Gas Emissions in Aviation Sector

[32] http://www.erc.go.ke/images/docs/National_Energy_Petroleum_Policy_August_2015.pdf

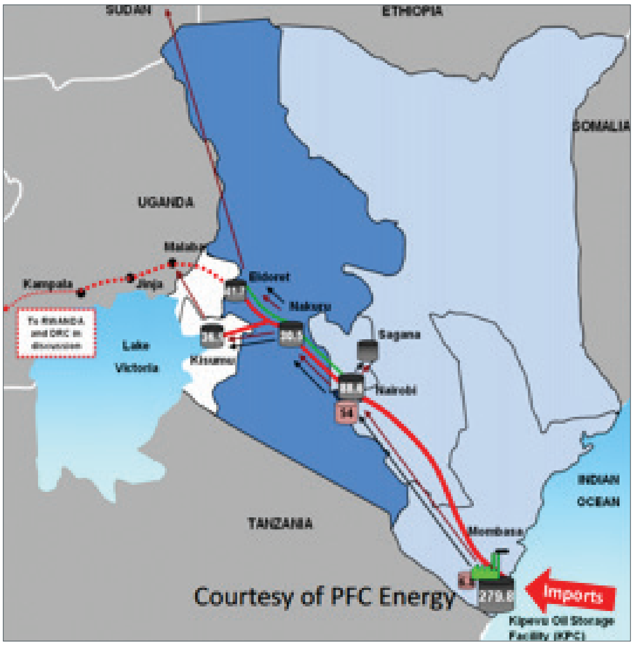


FIGURE 6
Schematic of the Kenya petroleum products pipeline[33]

4.2 AVIATION FUEL

A crucial component in understanding the feasibility of a SAF supply chain for the country is understanding the current and future demand for aviation fuel, particularly for international operations, and what component could be comprised of SAF. Any modelling of demand and potential targets must be realistic and fit into the commercial imperatives of the carriers.

The projected fuel usage for international operations of national carriers was calculated to 2030 for the State Action Plan submitted to ICAO, based on historical fuel usage between 2010 and 2014, and taking into account proposed fuel saving measures[34] (**Figure 7**).

Historical data on fuel burn for the years 2010 to 2014 (five years) were obtained from the main national airline, Kenya Airways (identifier: KQ). While other national air carriers undertake international operations in Kenya as well, KQ represents more than 80 per cent of the international traffic. Due to the challenges faced by other national airlines to provide similar historical data, the baseline was calculated based on KQ data, with allowance made for the other carriers. It has been indicated that future updates of the Action Plan will include more accurate data on the other national airlines as well.

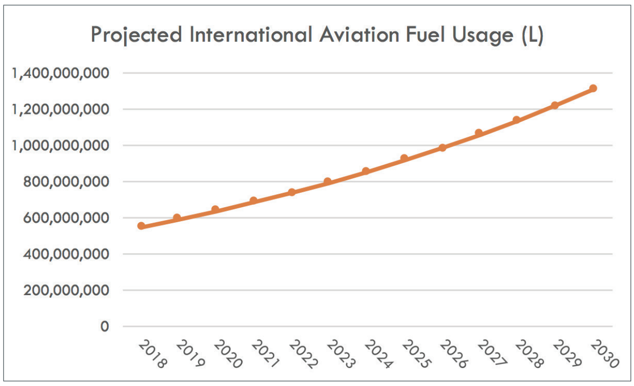


FIGURE 7
Projected fuel requirements for national carriers for international operations (Source: Kenya State Action Plan)

4.3 FUEL REQUIREMENTS BASED ON AIRPORT

Kenya has more than 55 airports, of which four are classified as international airports. Ten airports have refuelling infrastructure as outlined in **Table 1**. This table describes the distribution system to convey Jet A-1 fuel from the storage facility ("tank farm") to the aircrafts wing.

In the case of tanker fuelling, a tank vehicle parks alongside the plane and pumps fuel from the vehicle's tank into the fuel tanks of the aircraft.

For hydrant systems, pipes from storage tanks located on the perimeter of the airport carry fuel to various locations on the runway apron. At each of these locations, a manhole contains underground connection points or hydrants located just beneath the surface. When an aircraft arrives at the position for refuelling, a hydrant refueller parks alongside the aircraft and connects a pipe from hydrant to wing allowing fuel flow.

Fuel Distribution	Airport	
Hydrant System	• Jomo Kenyatta International Airport (Nairobi) • Kisumu International Airport	• Moi International Airport (Mombasa) • Eldoret International Airport
Tanker	• Wilson Airport (Nairobi) • Malindi Airprot • Ukunda Airport	• Lokichogio Airport • Wajir Airport • Nanyuki Airport

TABLE 1
Kenyan Airports with refuelling facilities

[33] http://www.rich.co.ke/rcfrbs/docs/Sumayya%20Presentation%20on%20the%20Petroleum%20Sector%20and%20Opportunities.pdf
[34] Kenya Civil Aviation Authority 2015, Kenya's Action Plan for The Reduction of CO_2 Gas Emissions in Aviation Sector

As no breakdown is available of fuel loaded for specific flight types (i.e. domestic, regional and international), specific carriers or even totals for individual airports, approximate figures were obtained using the following methodology:

- Data was made available by the Kenyan Civil Aviation Authority (KCAA) on all departures from Kenyan airports in 2016 including flight type (eg scheduled, general aviation, military), sector flown, and flight identification (operator).
- Sector information was entered into the ICAO Carbon Emissions Calculator[35] to obtain the approximate aircraft fuel burn per leg. As stated on the website, the methodology applies the best publicly available industry data to account for various factors such as aircraft type, route specific data, passenger load factors and cargo carried.
- The fuel burn data is then matched to the flight movements to provide fuel requirements broken down by airport. Due to the resource intensity of the exercise the four international airports which handle the most movements, were analysed. These are: Nairobi (Jomo Kenyatta International Airport), Mombasa (Moi International Airport), Kisumu (Kisumu International Airport) and Eldoret (Eldoret International Airport).

Aggregating the data from the four airports shows that 88 per cent of the total aviation fuel requirement is for international operations, 7 per cent for domestic operations and 5 per cent for regional operations (**Figure 8**).

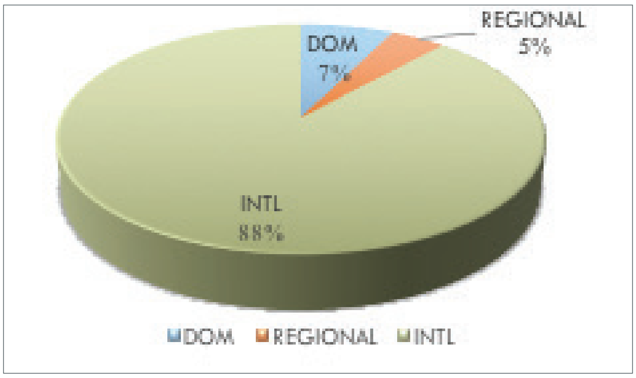


FIGURE 8
Breakdown of Aviation Fuel Requirements for Each Flight Type Across the Four International Airports

[35] https://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

Further investigation of fuel requirements at airport level (Table 2) shows that departing aircraft from Jomo Kenyatta International Airport (JKIA) have the greatest fuel demand with by far the biggest requirement for international flights. Mombasa has the second highest demand, while there are no scheduled international or regional flights (non-scheduled only) from Kisumu or Eldoret, resulting in little to no demand for fuel for international operations (Figure 9). However, this is expected to change in the future as the East African Community grows at an anticipated growth rate of approximately 5 per cent per annum.

While the State Action Plan lists Kenya Airways as making up more than 80 per cent of the international traffic, the calculations based on the 2016 movement data from KCAA show that the airline accounted for 40 per cent of the fuel uplifted in JKIA for international flights.

	Domestic	***Regional***	***International***	***Total***
JKIA	28,310,543	31,331,293	653,156,978	712,798,813
Mombasa	18,347,529	2,937,885	38,264,738	59,550,151
Kisumu	6,599,446	16,924	13,375	6,629,745
Eldoret	4,292,626	6,085	271,306	3,656,014
TOTAL	**57,550,144**	**34,286,101**	**691,435,090**	**783,548,726**

TABLE 2
Approximate 2016 Fuel Requirements for Flights Departing the Four International Airports in Kenya (in litres)

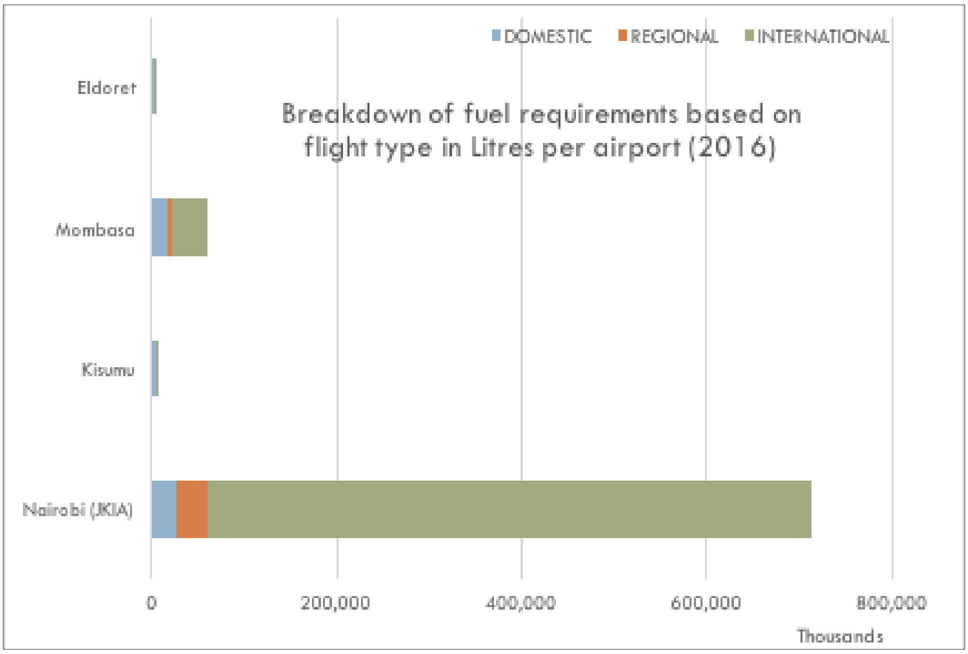


FIGURE 9
Breakdown of Fuel Requirements Based on Flight Type (in litres) per Airport
(Source: Kenya State Action Plan)

5. SUSTAINABLE AVIATION FUEL PATHWAYS

Kenya supports the international aviation industry's climate change targets, including carbon neutral growth from 2020 and an aspirational goal of halving of CO_2 emissions from the sector by 2050. While technological and operational advances will play a role in this, SAF has a crucial role to play in helping to de-couple emissions from industry growth. As both the technology and the economics of SAF improve, the scale of use will increase considerably in future years. However, there are still obstacles to overcome in the process of deploying SAF at a commercial scale, such as establishing regulatory support, accessing financing, and ensuring sustainability. To promote such development in Kenya, SAF supply chains must be developed in a cost-effective way, using proven conversion technologies.

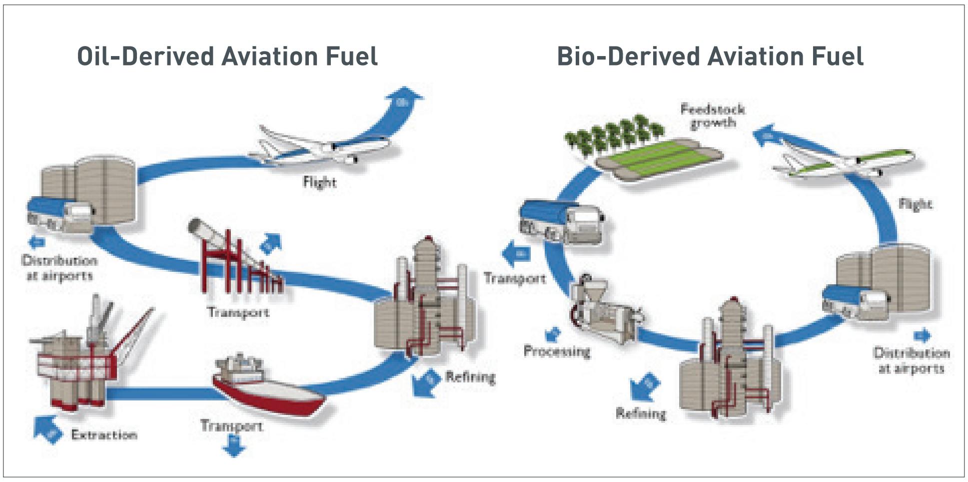
Although SAF is not yet cost-competitive with current aviation fuel, as technology improves, costs are expected to decrease.

To be acceptable for commercial use by airlines and support by the Kenyan Government, sustainable aviation fuel must:

- Be competitively priced compared to fossil based Jet-A.
- Be a 'drop-in' replacement that meets the same technical standards as conventional fossil-derived aviation fuel to avoid redesign of engines, airframes or fuel delivery systems.
- Fulfil internationally recognised sustainability criteria that ensures land, water resources and biodiversity are not adversely affected during the fuel's production and has reduced overall carbon emissions over the fuel's lifecycle.
- Not compete with or interrupt food supply chains.
- Have the potential to deliver significant quantities of fuel reliably in a realistic timeframe.
- Utilise innovation and support the Government's devolution programme by assisting regional economies.

Figure 10 below demonstrates how bio-derived SAF can reduce CO_2 emissions due to carbon recycling using plant-based feedstock.

FIGURE 10
Reducing CO_2 Emissions by Utilizing Bio-derived Aviation Fuel (Source: Flightpath to sustainable Aviation - Sustainable Aviation Fuel Roadmap. Rep. N.p.: CSIRO, 2010. Print)



Low life cycle CO_2 emissions may be achieved by using biomass or waste feedstocks. The first allows for plants to absorb CO_2 for growth during photosynthesis in relatively short time scales. This carbon is emitted back into the atmosphere during combustion and will return to the plants in a closed loop. Therefore, ideally, no additional carbon would be injected into the biosphere as is currently the case for aviation fuel. Another option would be the use of waste feedstock such as Municipal Solid Waste or industrial waste gases. In this case, the mechanism for emissions savings is not the carbon capture through photosynthesis, but the multiple uses of fossil carbon[36].

A biofuel is any hydrocarbon fuel that is produced from organic matter (living or once living) in a short period of time (days, weeks, or months)[37]. This contrasts with fossil fuels, which take millions of years to form. The most common biofuels are bio-ethanol, made from the fermentation of sugar, and biodiesel, made from the trans-esterification of vegetable oils and animal fats.

Global production of biofuel grew rapidly from about the mid-1990s, driven by government subsidies and mandated biofuel blends. This was in response to concerns over fossil fuels' security of supply and environmental damage. That biofuels are an important part of the strategy to mitigate global emissions and address climate change was also a factor.

However, most of the feedstock for biofuel production was food crops, corn converted to ethanol and soybean converted to biodiesel. Also, concerns were raised that these 'first generation' biofuels had potential negative environmental impacts.

Second generation biofuels are generally acknowledged to be from non-food sources. Second generation non-food feedstocks include woody crops and agricultural residues or wastes, which are more difficult to extract and produce fuel. For this reason, advanced conversion technologies are needed in the process, thus the term "advanced biofuels." It is important to note however that the definition of "food" is not clear cut; geography and other socio-economic factor dictate whether a material is a food in one place and non-food in another. This is clear in the case of Kenya. In light of the high rate of malnutrition in the country, any edible plant must be considered food.

Just because advanced fuels are made from non-food feedstocks does not mean they are necessarily sustainable. Sustainable fuels, including aviation fuels, must be produced and utilized in an environmentally, socially and economically responsible way. Stakeholders require assurance on claims of sustainability, which can be provided by reputable certification bodies. What is required are globally harmonized sustainability criteria to determine if an aviation fuel is sustainable. ICAO is currently considering this issue and will release guidance to Member States on potential policies, and a set of sustainability criteria that alternative fuels must meet in order to be considered sustainable.

[36] From the GFAAF: https://www.icao.int/environmental-protection/GFAAF/Pages/FAQs.aspx

[37] http://biofuel.org.uk

5.1 CONVERSION PROCESSES TO DEVELOP ALTERNATIVE FUEL

As of November 2017, five alternate fuels production conversion processes were certified under the standard ASTM D7566, together with specific blending limits with current aviation fuel (as shown in **Table 3**).

Over 100,000 commercial flights have already used "drop-in" alternative fuels and, as of November 2017, four airports currently distribute alternative fuels on a regular basis. Many additional conversion processes are being developed and are at various stages within the ASTM approval process.

ASTM D7566 defines the requirements for the neat product (i.e., alternative fuel) and the blend (of aviation fuel and alternative fuel). Once the blend has been certified against ASTM D7566, it is a drop-in, and can be considered conventional Jet A1 as per the standards ASTM D1655 and DEF STAN 91-91. **Figure 11** illustrates the blending and use process for synthetic SAF and the different quality standards SAF must meet at different steps.

The blend ratio refers to the final product (that is considered 'drop-in') to be introduced to the market. The ASTM standards mark a maximum; however, lower blends can also be certified. Every alternative fuel batch needs to be analysed and certified at the point of origin (where it is blended). Only after being certified can the fuel be considered and treated in the same way as any aviation fuel (i.e., being mixed in the airport fuel farm tanks). Therefore, an appropriate storage facility is required, where the blended batch can be stored separately from other batches until the certification has been completed[38].

This study will not go into conversion pathways in detail and instead will focus primarily on preferred feedstocks that will dictate conversion options. However, it is important to note the technical development issues associated with different processes and the associated cost and complexity in the establishment and operation, especially in an emerging economy as exists in Kenya.

Annex	ConversionProcess	Abbreviation	Possible Feedstocks	Blending ration by volume	Commercialization Proposals
1	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene	FT-SPK	Coal natural gas biomass	50%	Fulcrum Bioenergy, Red Rock Biofuels, SG Preston, Kaidi, Sasol, Shell, Syntroleum
2	Synthesized paraffinic kerosene produced from hydroprocessed esters and fatty acids	HEFA-SPK	Bio-oils animal fat recycled oils	50%	AltAir Fuels, Honeywell UOP, Neste Oil, Dynamic Fuels, EERC
3	Synthesized iso-paraffins produced from hydroprocessed fermented sugars	SIP-HFS	Biomass used for sugar production	10%	Amyris, Total
4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	SPK/A	Coal natural gas biomass	50%	Sasol
5	Alcohol-to-jet synthetic paraffinic kerosene	ATJ-SPK	Biomass used for starch and sugar production and cellulosic biomass for isobutanol production	30%	Gevo, Cobalt, Honeywell UOP, Lanzatech, Swedish Biofuels, Byogy

TABLE 3
Conversion processes approved as annexes to ASTM D7566

[36] Continuous blending systems, where blending is done at the pipeline directly, and not in a tank, cannot be used for alternate fuel blending as the blended batch needs to be certified at the point of origin before coming into contact with any other batch. These systems are sometimes used for other biofuels like bioethanol because the only key parameter to ensure is the blend ratio; such systems cannot be applied to alternate fuels.

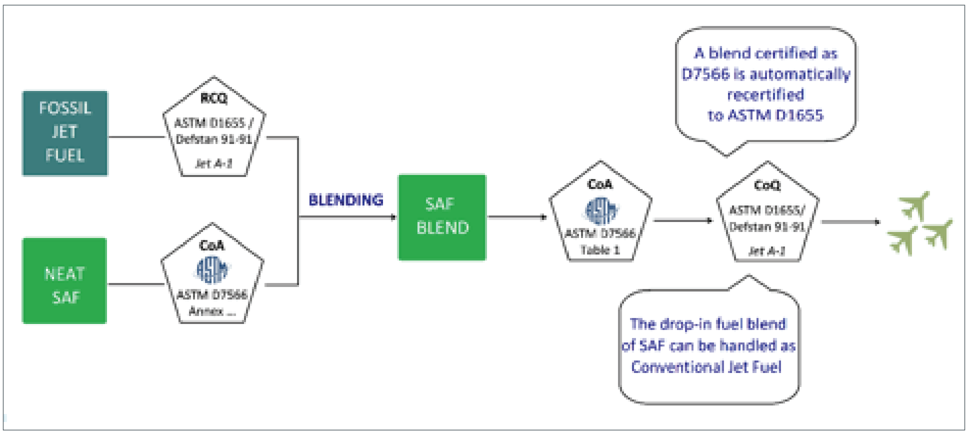


FIGURE 11

Diagram showing the blending and use process for alternate fuels and the different quality standards at different steps

(Source: ICAO)

5.2 SAF FEEDSTOCKS

A feedstock is defined as any renewable material that can be used directly as a fuel or converted to another form of fuel or energy product. Feedstock costs contribute a large portion to the overall fuel production cost and proponents face competing demands for supply that may include other energy uses as well as feed or food. Appropriate plantation, cultivation, and harvesting are required before the feedstock can be processed into fuel.

There are three main families of bio-feedstock that can be used to produce SAF: oils and fats (triglycerides); sugars; and lignocellulosic feedstock.

- **Fuels made from oils and fats:** Oil crops (including novel types relevant to East Africa such as jatropha, croton nut and castor), animal fats and UCO can be processed into triglycerides. Production from micro-algae is an additional promising pathway that is currently in the research and development stage. Triglycerides contain oxygen that needs to be removed in order to produce aviation fuel components, as those are pure hydrocarbons. Different processes are proposed for this, but the currently approved method is the Hydroprocessed Esters and Fatty Acids (HEFA) process.
- **Fuels made from sugars and starch:** Sugars come from sugar crops and cereal starch. They are mainly associated with fermentation routes that generally produce alcohols, which are further upgraded into hydrocarbons. This is the “alcohol-to-jet” (ATJ) pathway. Advanced fermentation has also been developed that directly produces hydrocarbons that can be upgraded into aviation fuel components. It should be noted that fermentation has also been developed from industrial waste gas in the form of carbon monoxide. Cultivation of algae is another way to use waste gas to produce feedstocks: CO_2 is indeed needed to grow algae. Currently approved methods that follow these processes are Synthetic Iso-paraffin (SIP) (formerly referred to as Direct-sugar-to-Hydrocarbon (DSHC) and Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK).
- **Fuels made from lignocellulose:** Lignocellulose is found in plants (including weeds) and in wood, and can come from various energy crops, as well as from agriculture or forest residues and from macro-algae. Lignocellulose can be directly converted into hydrocarbons using thermochemical processes such as Fischer-Trospch (FT), pyrolysis or catalytic cracking. The FT processes (Synthetic Paraffinic Kerosene (FT-SPK) and Synthetic Kerosene with Aromatics (SPK/A)) can also be used to convert MSW, coal or natural gas. Lignocellulose can also be transformed into sugar and can thus be used for the aforementioned fermentation routes. In a similar way, sugars can be transformed into oil by yeast or micro-algae and thus further processed into aviation fuel through deoxygenation.

- **Additional advanced routes**: Additional routes are also being studied to produce alternative fuels directly from CO_2, including CO_2, captured from the atmosphere, without using biomass. Conversion then uses renewable energy to break down CO_2, into CO and O_2, and water into H_2, and O_2, and then recombines CO and H_2 in liquid hydrocarbon using the Fischer-Tropsch synthesis. These processes (e.g. solar fuels) are currently in the research stage[39].

Thus, there are a significant number of processes under development that allow for processing of almost all kinds of feedstock into aviation fuel components, which offers flexibility for regional adaptation and optimization.

Most of the various pathways do not directly produce a drop-in alternative fuel for aviation. They produce components that need to be blended with aviation fuel to obtain the final drop-in fuel. It is important to consider the competing uses of the feedstock, either actual or potential. This includes ground-based biofuels, electricity or steam generation, building materials or even food **(Figure 12**). This is especially true for Kenya, where alternative uses already exist for possible feedstocks such as sugarcane molasses and bagasse.

As stated in the National Climate Change Action Plan while the use of biofuels would lower GHG emissions and the need for fossil fuel imports, large-scale production of biofuels could compete for land with food production if poorly planned; any move towards commercial growing of biofuel crops should be pursued in a well-regulated manner[40]. This is fully supported by the aviation industry and will be addressed in sustainability guidance provided by ICAO.

5.3 BIOFUEL DEVELOPMENTS IN KENYA

No study undertaken to date has considered the potential of advanced or second generation biofuels in Kenya under which SAF falls. A number of studies have been carried out examining the feasibility of bio-ethanol and biodiesel supply chains. The focus of these studies has been on lipid producing feedstocks that are oil-rich including castor, coconut, rapeseed, sunflower, jatropha and croton nut, as well as sugar/starch feedstocks containing mainly glucose which can be fermented and converted into ethanol. These studies are still valid in the context of advanced SAF.

Current markets for ethanol include alcoholic beverages, pharmaceutical and industrial applications, and fuel. The vast majority of current ethanol production in Kenya is exported to Uganda and the Democratic Republic of Congo for beverage use[41]. Another potentially large local market is the use of ethanol in cook stoves and lamps.

FIGURE 12

Potential/actual competing uses for feedstock

Biodiesel could complement, or completely displace, the use of petroleum diesel for many stationary applications. Straight vegetable oil (SVO) that has not been processed into biodiesel could potentially be used in some applications, such as for transport with specially modified vehicles or for farm equipment. SVO and/or biodiesel could potentially be used as a replacement for kerosene as the main source of light and cooking fuel in many parts of Kenya.

5.4 SOCIETAL AND FOOD SECURITY ISSUES AFFECTING FEEDSTOCKS

Land in Kenya is considered a basic commodity that supports life and is treasured. As much as 85 per cent of the country landmass is classified as marginal land and about 15 per cent of land has medium to high potential. Population pressure has led to encroachment of ASALs which have a fragile ecosystem, and can lead to further degradation[42].

The ongoing drought has caused the price of food staples to rise significantly over the course of 2016 and into 2017: the price of maize flour has risen by 31 per cent, milk by 12 and sugar by 21 per cent. Conditions are challenging in half of Kenya's 47 counties. Livestock and milk production has declined, adversely affecting food consumption levels for communities, particularly women and children. In 2017, the "long rains" period over March, April and May only recorded 75.5 mm in the Mandera region, a 40 per cent deviation against the projected 139.3 mm total resulting in failed rejuvenation of pasture for livestock[43]. This is indicative of many areas in the country.

[39] Retrieved from GFAAF: https://www.icao.int/environmental-protection/GFAAF/Pages/FAQs.aspx
[40] Retrieved from http://www.kccap.info/index.php?option=com_content&view=article&id=31
[41] Retrieved from https://asokoinsight.com/news/new-blow-for-mumias-as-it-halts-ethanol-production-kenya
[42] Retrieved from http://www.ke.undp.org/content/kenya/en/home/countryinfo/
[43] Retrieved from http://kenyanewsagency.go.ke/en/weatherman-warns-of-harsh-conditions/

Agriculture dominates Kenya's economy. About 80 per cent of Kenya's work force engages in farming or food processing. Farming is typically carried out by small producers who usually cultivate no more than five acres using rudimentary practices and equipment. These small farms, operated by about three million families, account for 75 per cent of total production. Although there are still important large-scale coffee, tea, and sisal plantations, an increasing number of small farmers grow cash crops[44]. Modelling undertaken by the International Food Policy Research institute shows that overall Kenya will experience countrywide losses in the production of key staples due to climate change[45] a key consideration when assessing SAF feedstocks.

The Government of Kenya has instituted a number of reforms to improve the agriculture sector's efficiency and production. These include legal reforms in which some 130 laws were consolidated to help encourage investment. In addition, the current government has pledged to put 1 million acres under irrigation by 2017. Note currently only about 0.002 per cent of the country is under irrigation. Galana/Kulalu ranch, which is located in the counties of Kilifi and Tana River, was identified as having that potential. The ranch, which covers an area of 1.78 million acres, is strategically located between the Galana and Tana Rivers which have adequate flow to supply the irrigation water. There are conflicting details available on the project, but it is understood that 10,000 acres have put under irrigation and is producing maize. The project can only reach 30,000 acres with current infrastructure beyond which a two-trillion-litre dam would be required[46].

These are important issues to consider when analyzing various potential SAF feedstocks which typically require industrial-scale systems requiring large amounts of land and sufficient water.
Particular consideration needs to be given to identification of suitable wastes and weed species that may be converted to fuel. This includes municipal wastes and weeds such as water hyacinth and prosopis juliflora, known by its common name of "mathenge" plant.

5.5 FEEDSTOCK OPTIONS FOR KENYA

This section provides an overview of existing or potential feedstocks that may be utilized for the production of sustainable aviation fuel in Kenya. The factors which contribute towards a region's suitability for bio-derived aviation fuel production include suitable climate zones and considerable land base to produce biomass feedstocks or significant aggregated volumes of waste. In addition, there must be no conflict with the production of food and other societal and environmental impacts must be minimized. Notwithstanding these issues, the feedstock must integrate into an efficient supply chain that will meet the overarching objectives of supplying the required volumes of SAF reliably at a competitive cost. Ultimately it must contribute towards a business case that will attract investment.

Each relevant feedstock is described in detail below and summarized by listing strengths and weaknesses, as well as a commentary on viability.

The amount of feedstock required to substitute 50 ML of Kenya's international aviation's fuel requirements with SAF in 2026 and 100 ML in 2030 is used to provide a broad indication of the amounts of feedstock required.

5.5.1 SUGARCANE

Sugarcane farming supports over 300,000 small-scale farmers in Kenya. In addition, an estimated six million Kenyans derive their livelihood directly or indirectly from the sugar industry. Domestic production of sugar saves the country about KSh 45 billion in foreign exchange[47]. Though in the current drought, the

SHOULD EDIBLE CROPS BE USED FOR BIOFUELS?

For the development of SAF, the aviation industry has a requirement to not compete with food production. As energy and food prices continue to climb, this question is of the utmost importance, especially in countries like Kenya where approximately half of the population live in poverty and many lack access to adequate food.

It is within this context that SAF supply chains must be considered. Large scale planting of energy crops for fuel production generally may not be considered a sustainable option. This is exacerbated by the lack of irrigation in the country, where the vast majority of agriculture is reliant on rainfall. The drought has also had a major impact on water resources where 30 per cent of rural water points are non-functional resulting in a five-fold increase in water prices.

There may be potential for co-planting of some energy crops (e.g studies have shown that intercropping cassava with tree crops can greatly reduce erosion and increase soil cover), although this could come at the expense of soil fertility. There is also potential for crops such as sweet sorghum, which produces both grain for food as well as sugar, and lignocellulosic material in its stems and leaves.

44 Retrieved from https://softkenya.com/kenya/farming-in-kenya/
45 International Food Policy Research Institute. Climate Variability and Climate Change and their Impacts on Kenya's Agricultural Sector. Rep. n.p., 2010. Print.
46 https://www.standardmedia.co.ke/business/article/2001228507/third-galana-kulalu-project-harvest-nets-103-000-bags-of-maize
47 Retrieved from https://softkenya.com/kenya/farming-in-kenya/

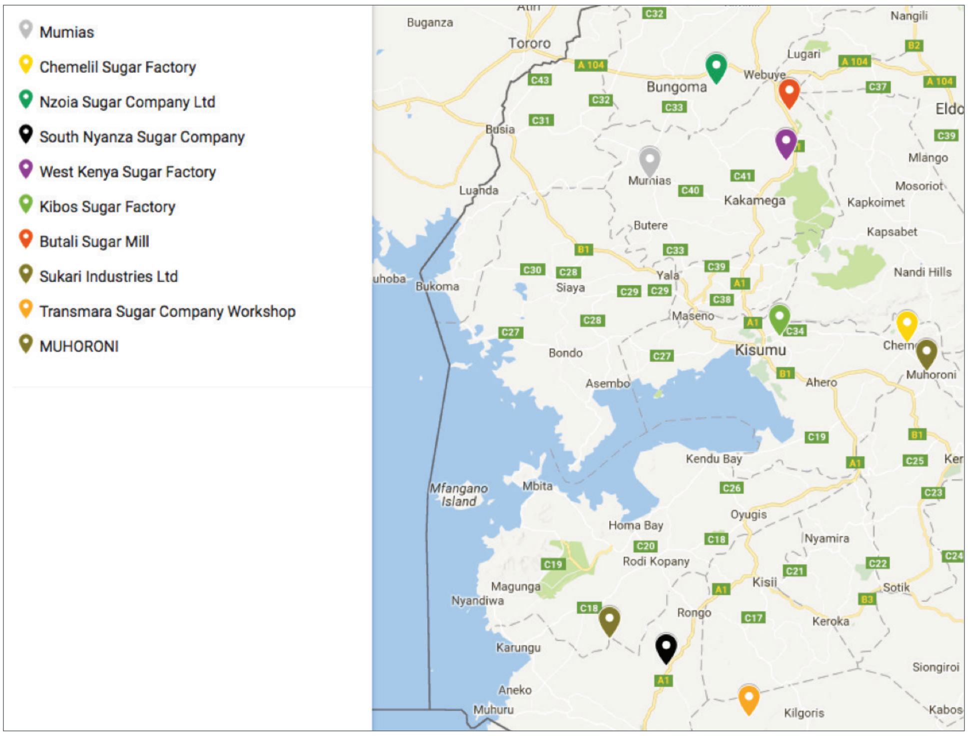
Government has had to import sugar to meet demand. Most farming is in western Kenya, while some sugarcane is grown in parts of the coastal area. Eighty-eight per cent of sugarcane cultivation in Kenya is undertaken by out-growers, the majority of which are small-scale growers; the remaining is under sugar factories in the form of nucleus estates. The total area under cane in the country is presently 203,730 Ha, comprising 189,390 Ha belonging to out-growers and 14,340 Ha nucleus estates (land owned/leased by mills to grow cane)[48]. The geographical spread of plantings would suit a potential supply of fuel to Kisumu International Airport, which is within 100 km of most plantings and mills.

Products include sugar manufacture (from cane juice); power and steam generation (from bagasse); potable alcohol (ethanol) from cane sugar or molasses; power and industrial/fuel alcohol; and methane/biogas (from molasses).

The total sugarcane crush in 2015 was 7,266,023 tonnes from 11 mills[49], ten of which are located in western Kenya (**Figure 13**). This is represents an increase of 10 per cent from the previous year, but is still not enough to avoid imports. The latest entrant into the sugar industry is Kwale International Sugar Company Limited at Ramisi. Situated on the east coast this is a private enterprise that started milling cane in 2015. The largest producers by cane crushed is Mumias followed by West Kenya, Kibos and Nzoia.

In spite of a record crush in 2015, sugar imports grew by 29 per cent in the same period as high demand for industrial sweeteners pushed up the volumes of the product. According to statistics from the Agriculture Fisheries and Food Authority, industrial sugar imports grew by 14 per cent to 147,000 tonnes in 2015 from 129,000 the previous year[50].

FIGURE 13
Locations of sugar mills in West Kenya undertaking crushing activities in 2015 and their proximity to Kisumu
(Source: Google Maps)



The three sugar cane plant components normally identified for biofuel production are: cane sugar; molasses; and bagasse (which is the leftover lignocellulosic material from the crush). A further component, the cane tops, are left in the field after harvesting.

48 Departmental Committee on Agriculture, Livestock and Co-operatives. The Crisis Facing The Sugar Industry In Kenya. Rep. N.p.: n.p., 2015. Print.
49 Information supplied by Kenya Agriculture, Food and Fisheries Authority
50 Meeting with Agriculture, Fisheries and Food Authority May 2017

5.5.1.1 Cane Sugar

Kenya is struggling to improve output due to relatively high production costs and loss-making sugar factories[51], despite favourable growth conditions. Low productivity levels in crushing and refining have led to low sugar yields, capacity under-utilization and, as a consequence, low income to farmers. This in turn negatively affects cane husbandry practices, which has led to low yields at farm level in quantities per hectare and in sucrose content. Sugar production dropped 45 per cent in the 11 months leading to November 2017 due mainly to reduced yields[52].

The current drought has exacerbated the sugar deficit. The government has had to import an additional 150,000 tonnes, of sugar on top of the 200,000 it already imports annually[53].

Due to institutional issues, that the industry is struggling to meet demand, and that it is an essential food, sugarcane should be ruled out as a potential SAF feedstock.

5.5.1.2 Molasses

The beverage ethanol market in Kenya is estimated at 48 million litres per year.
Only three companies are producing ethanol fermented from molasses domestically[54]:

- Spectre International, based in Muhoroni, produces hydrous ethanol from molasses sourced from sugar companies in the western region of Kenya;
- Agro Chemicals & Food Corporation (ACFC) in Kisumu produces ethanol from sugar companies' molasses (mainly from Muhoroni Sugar Company);
- Mumias Sugar Company co-produces ethanol from its sugar production process.

Reportedly, only half of the capacity of Spectre International and ACFC is being used, as both companies are facing structural molasses supply problems. Fulfilling the capacity of both plants would require the entire Kenyan production of molasses (at full sugar plant capacity), which is not feasible given that about half of the molasses produced in Kenya is being sold to small-scale brewers in Uganda and Tanzania.

With cane sugar and molasses being ruled out as feedstock for SAF, only bagasse and cane tops remain as possible feedstock options.

5.5.1.3 Bagasse

Bagasse is the fibrous material that remains after sugarcane is crushed. Typically, for every 10 tonnes of cane that is crushed, 3 to 4 tonnes of bagasse remains. It has high moisture content (typically 40 to 50 per cent) and is usually stored prior to further processing. Bagasse is increasingly used as a fuel for steam and electricity generation at the mills, but it is also a source of organic matter when returned to the soil[55].

As shown in Table 4 below, bagasse production from all mills was 2,288,172 tonnes from 6,596,994 tonnes of sugarcane crushed in 2014[56].

Item	2010	2010	2010	2010	2010
Sugarcane Crushed (TC)	5,591,678	5,385,224	5,830,058	6,810,338	6,596,994
Sugar Made (TS)	522,499	501,473	502,563	602,151	590,150
Molasses Produced (T)	185,074	199,811	222,836	241,561	227,135
Molasses % Cane	3.31	3.71	3.82	3.55	3.44
Bagasse Production (T)	2,137,172	2,015,681	2,185,212	2,468,338	2,288,172
Bagasse % Cane	38.22	37.43	37.48	36.24	34.69

TABLE 4
Aggregated Factory Performance of All Sugar Companies (2010 – 2014)[57]

51 Retrieved from http://www.reuters.com/article/kenya-sugar-idUSL1N0V012T20150121
52 Retrieved from http://allafrica.com/stories/201712270232.html
53 Retrieved https://www.theguardian.com/global-development/2017/jun/02/drought-centre-stage-kenya-election-campaign-food-prices-rise
54 Retrieved from http://afrinol.com/ethanol-market-in-kenya/
55 Retrieved from http://www.yara.co.ke/crop-nutrition/crops/sugarcane/key-facts/agronomic-principles/
56 The most recent figures provided by the Kenyan government.
57 Information supplied by Kenya Agriculture, Food and Fisheries Authority

As part of this study, a number of sugar mills were surveyed regarding their management practices surrounding bagasse. All seven mills surveyed utilize most of their bagasse for steam generation with five (Butali, Transmara, Nzoia, South Nyanza and Chemelil) indicating they have some surplus that could be sold. This surplus is calculated to be approximately 300,000 tonnes of bagasse.

Ethanol may be produced by breaking down the bagasse through hydrolysis into sugars and then fermentation. 300,000 tonnes of bagasse would convert to approximately 50 ML of ethanol (340 L ethanol per dry tonne[58]). There are a number of pathways to produce hydrocarbons from ethanol, the resultant volume would be about 50 per cent of the input[59], resulting in approximately 20 to 25 ML hydrocarbon fuel, including aviation fuel. However, this amount of bagasse is not guaranteed, as determined efforts by the Government are underway to increase the amount of co-generation utilizing bagasse to power mills and potentially supply the grid.

5.5.1.4 Cane Tops

Cane tops, along with miscellaneous trash, are left in the field after manually harvesting the sugarcane. The tops represent 15 to 25 per cent of the aerial part of the plant. They generally consist of green leaves, bundle sheath and variable amounts of immature cane[60]. Harvesting is undertaken manually in Kenya. Cane cutters retrieve the plant stems and leave the tops of the plant in the field.

Discussions with an agricultural specialist[61] and farmers reveal that the bulk of the discarded cane tops play no beneficial role, i.e. soil conditioning, and are in fact often burned in-situ releasing GHG. As opposed to bagasse, cane tops are owned by the farmers and could provide them with an additional revenue stream if collected as a SAF feedstock. Initial investigations indicate it could easily be collected during the cane harvest in a separate hopper allowing one-pass and reducing collection costs.

Based on the current production of sugar, it is estimated that there may be upwards of a million dry tonnes of sugarcane discarded each year.

5.5.2 JATROPHA

Jatropha produces an oil-bearing seed that can be converted into fuel. It is used to control soil erosion, especially in semi-arid areas. Its seedcake, which is high in nitrogen, can be used to improve soil. On the downside, the tree takes five to seven years to reach maturity and full production, seeds contain a highly toxic substance called curcasin, and plantations cannot easily be mechanized. Jatropha is also considered invasive in many parts of the world[62].

About a decade ago, a number of parties promoted the cultivation of jatropha in Kenya to produce oil for biodiesel production. It is believed that one of jatropha's most attractive characteristics is its ability to withstand drought and to grow in semi-arid areas with poor soil fertility. However, a survey of jatropha farmers in Kenya indicates that these purported strengths may have been highly exaggerated. Jatropha is actually very sensitive to fertilizer and water, so that yields may be significantly reduced if grown on marginal, arid lands without significant additional inputs[63]. Jatropha is not a wasteland crop: it needs fertilizer, water, and good management, and even then, results can be unpredictable. A study undertaken by Endelevu Energy on behalf of the then German Technical Cooperation (GTZ) recommended that "all stakeholders carefully re-evaluate their current activities promoting Jatropha as a promising bioenergy feedstock"[64]. Even if the agronomics of Jatropha improved significantly, it would continue to be best utilized at smallholder scale rather than large scale monocultures that would be required for a SAF supply chain.

5.5.3 SWEET SORGHUM

Similar to the sugar cane plant, sweet sorghum contains sugar in its stalk. It can be used for human food (cereal, snack food, baking and brewing), ethanol production, animal fodder and the manufacture of building and biodegradable packaging material. Sweet sorghum produces edible grains, which can help mitigate the potential conflict with food that occurs with other feedstocks while the sweet stalk can be used for ethanol or other fuel production. Sweet sorghum juice contains sucrose, fructose, and glucose. Extraction requires a roller mill or diffuser equipment and potentially may be co-processed in existing sugar mills. Sorghum biomass (bagasse) can be processed by fast pyrolysis to produce syngas, bio-oil, and charcoal or undergo hydrothermal liquefaction. In this scenario, the synthetic gas and bio-oil are used for transportation fuel and the charcoal is applied to fields to improve soil structure.

The type of sorghum currently grown in Kenya does not contain a sweet stalk and is primarily grown for food. The sweet sorghum varieties that can be used for fuel can produce much higher yields. It is useful to note that over 163,000 Ha of land were used to grow sorghum in 2006, which could be replaced with sweet sorghum varieties that would yield at least as much edible grain per hectare, as well as a significant cash crop of sweet stalks for ethanol production[65]. Even though the technologies to process sugar products from sweet-sorghum exists, the constraints for its large-scale cultivation are the limited availability of genotypes suited to different agro-climatic conditions in sub-Sahara Africa[66]. Also, response of sweet sorghum cultivars towards region-specific climatic conditions or changing climatic

58 O'Hara, Ian. "The Potential for Ethanol Production from Sugarcane in Australia." Proc Aust Soc Sugar Cane Technol32 (2010): n. pag. Web.
59 Retrieved from http://www.biofuelsdigest.com/bdigest/2016/06/14/why-is-atj-renewable-jet-fuel-rockin-it/
60 Retrieved from http://www.feedipedia.org/node/558
61 Discussion with Prof. Joash Barack Okeyo-Owuor, Rongo University, jbokeyo@gmail.com
62 A Roadmap for Biofuels in Kenya: Opportunities and Obstacles. Rep. N.p.: German Technical Cooperation (GTZ), 2008. Print.
63 Jatropha reality check a field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya; study. Eschborn: GTZ, 2009. Print.
64 Jatropha reality check a field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya; study. Eschborn: GTZ, 2009. Print.
65 A Roadmap for Biofuels in Kenya: Opportunities and Obstacles. Rep. N.p.: German Technical Cooperation (GTZ), 2008. Print.
66 Olweny, C. Unravelling the potential of sweet sorghum for sugar production in Kenya. Rep. N.p., n.d. Web. Research Application Summary

conditions is a critical aspect for large-scale cultivation. Usually, grain yield in sweet sorghum is very low and grains are not suitable for use as human food. Unexpected yield losses due to environmental stresses and disease outbreaks is another major concern with large-scale planting on marginal lands.

As Kenya has a significant sugar deficit, cultivation of sweet sorghum should be explored primarily for edible sugar production. It would need to be planted on a large scale for SAF production that is not conducive to the current agronomic model in Kenya.

5.5.4 CASTOR SEED

Castor seeds and the oil extracted from them comprise substantial global markets for use in myriad industrial and pharmaceutical applications. Although indigenous to Eastern Africa and highly suitable for growing in many parts of Kenya, castor oil seed has not been grown at a large-scale commercially in Kenya since the 1970s. Nevertheless, Kenya is the 11th largest producer of castor oil seed in the world, producing 3,000 tonnes in 2014[67].

Castor seed is an invasive plant that has medium tolerance to drought, and is suitable for mechanization on a large scale. Also, it is easy to cultivate, needs little attention, has a high oil content and relatively low cost of production. As castor seed does best on fertile, well-drained soils, and therefore, may conflict with food crop cultivation on arable lands. Castor seed is known to exhaust the soil very quickly, requiring the addition of fertilizers. Intercropping with crops that help to replenish soil nutrients may help to maintain soil nutrients.

Castor is increasingly being promoted for biodiesel as well, due to its high oil yield and relatively low water requirements. Cellulose from the stems is used for making cardboard and paper products.

5.5.5 COCONUT

From the leaves to the fruit to the trunk, coconut trees have many uses. The nut is used for food and beverages, like palm wine. The coconut oil extracted from the copra is used in the manufacture of soaps, cosmetics and pharmaceutical products. The oil from the copra is not only edible, but can also be used to manufacture paints and varnishes.

The coconut sector is perceived as a "sleeping giant" with Government estimating that it could inject over KSh 25 billion into the economy annually[68]. Over the years, coconut farming has faced myriad challenges, including serious pests and diseases, poor crop husbandry practices as a result of inadequate extension services to growers leading to a drop in the tree's productivity. The collapse of the sub-sector's cooperative societies in the early 1980s denied farmers bargaining power and opportunity to exploit potential markets as well as neighbouring countries of Tanzania, Uganda, Rwanda and Burundi where coconut products are either lacking, or still under restrictive government policies[69].

While potential 'fuel vs. food' issues would arise from utilising coconut oil as a feedstock, plantings would have to be greatly expanded as yield is about 50 ml/coconut[70].

5.5.6 CROTON NUT

Croton nut is an abundant, indigenous species found all across central and western Kenya, as well as in other East African countries. It is traditionally planted on boundaries and marginal lands to provide firewood and shade. Until recently, its nut had no commercial value (since it is not edible) and largely remains a wasted natural resource. Croton's potential for multiple uses has long been researched by the World Agroforestry Centre[71], and its value for energy production has been recognized for several years by the Government of Kenya. Nonetheless, the species has only recently started to attract international interest, private capital and professional management to the development of its value chain.

Efforts to increase agroforestry through encouraging retaining existing Croton trees and planting of new stock will help meet Kenya's goal of increasing tree cover on farmland to 10 per cent as a means to preserving and maintaining the environment and combating climate change, a goal stated in the 2010 Constitution.

5.5.7 CASSAVA

Cassava is non-invasive and highly tolerant to drought, but susceptible to water logging and salinity. It is also suitable for mechanization on a large scale. Cassava's requirements are few and as a consequence it is frequently cultivated where few other crops could survive. It has no definite maturation point so the roots can be stored in the ground for up to 24 months should the grower intend to use the fresh roots at a later time.

Cassava is a highly nutritious[72] staple food crop for many, and thus could pose a conflict if diverted for biofuel production.

The plant does not produce enough vegetation to cover the soil well. Thus, the production of cassava can result in considerable soil erosion during the entire life of the plant. As little else grows on such soils, the erosion often continues well after the cassava is harvested. Production can also lead to loss of biodiversity. Processing, especially industrial processing, can lead to the deposit of cyanide and organic matter on the soil and in water sources, and dust and foul odours in the air[73].

[67] Retrieved from http://www.factfish.com/statistic-country/kenya/castor+oil+seed,+production+quantity
[68] Retrieved from https://www.standardmedia.co.ke/business/article/2000164745/why-coconut-farming-is-a-sleeping-giant
[69] Retrieved from https://www.standardmedia.co.ke/business/article/2000164745/why-coconut-farming-is-a-sleeping-giant
[70] Retrieved from https://www.ewb.org.au/resources/52/950
[71] Programme for the development of alternative biofuel crops. Rep. N.p.: n.p., 2017. Print. World Agroforestry Centre
[72] Retrieved from https://www.standardmedia.co.ke/business/article/2000176886/cassava-takes-root-in-arid-counties
[73] Shelty, 665; World Wildlife Fund, "Agriculture and Environment: Cassava, Environmental Impacts of Cassava," http://www.panda.org/about_wwf/what_we_do/policy/agriculture_environment/commodities/cassava/environmental_impacts/index.cfm (10 January 2008)

5.5.8 RAPESEED (CANOLA)

Rapeseed is mainly grown for edible oil and animal feed. Rapeseed oil has many valuable industrial uses, including: as lubricating oil, polymer in paints and varnishes, and in the manufacture of emulsions to coat photographic paper and film. Most of the biodiesel produced in Europe is derived from rapeseed. Canola is a particular cultivar of rapeseed. Rapeseed is also beneficial as a cover crop that protects soils, suppresses weeds and can break up the soil with its extensive root system. Wheat farmers in Laikipia and Timau grow rapeseed for these purposes[74].

Though at a relatively small scale in Kenya, rapeseed has huge potential as a source of income in the country as an edible oil crop and livestock feed. The demand for vegetable oils low in saturated fats is high, providing an available market for canola with the seedcake sold as a livestock feed[75].

5.5.9 SUNFLOWER

Sunflower is used mainly for edible oil and animal feed. It can be used as a double crop after early harvested small grains or vegetables, an emergency crop, or in areas with a season too short to produce mature corn for silage. Sunflower can be intercropped with trees because of its ability to restore nitrogen used up by other crops. A recent study showed that when trees are intercropped with sunflower and other crops, soil erosion and nitrogen leaching were significantly reduced, while landscape biodiversity and carbon sequestration increased. It does well in semi-arid areas but is susceptible to disease and pests and is very sensitive to soil pH.

5.5.10 ENVIRONMENTAL WEEDS

As in many parts of the world, Kenya has a number of indigenous and introduced weeds, some of which may be considered for SAF production. As with other types of feedstocks, its suitability depends on a number of factors including composition, available volumes and delivered cost. The weed needs to be concentrated in a contained area close to the processing facilities in order for it to be economically viable. The use of weeds as a feedstock may provide valuable environmental and social co-benefits which can be difficult to monetize.

5.5.10.1 Water Hyacinth

The water hyacinth demonstrates some potential as a feedstock, having become a major invasive plant species in Lake Victoria. The economic impacts of this weed in seven African countries have been estimated at between USD 20 to 50 million every year. Across Africa, costs may be as much as USD 100 million annually[76].

It is believed that water hyacinth entered Lake Victoria from Rwanda via the river Kagera, probably in the 1980s. The hyacinth has since spread prolifically, due to a lack of natural predators, an abundance of space, good temperature conditions, and abundant nutrients, including increasing pollution in the lake[77]. The weed does not have a constant presence but rather has growth and ebb phases. Its current re-emergence is understood to be the biggest invasion since its first attack on the lake in the nineties covering the beaches of Kisumu, Migori, Siaya, Homa Bay and Busia counties, paralysing fishing, lake transport and tourism activities. The affected areas are estimated to cover 60,000 hectares along the Winam Gulf, a significant extension of north-eastern Lake Victoria into western Kenya.

Development and expansion of urban centres and industries with growth of population have overwhelmed existing sewage treatment plants and waste disposal sites[78]. The pollution of major rivers flowing into Lake Victoria has increased due to the discharge of raw or incompletely treated effluents particularly from urban settlements like Kisumu city. As Kisumu city expands in size and population, there has been no corresponding investment in the necessary infrastructure to support the increasing population. Thus, waste management and sewerage disposal facilities have remained inadequate (only 20 per cent of waste generated is disposed of in waste management facilities) and incidences of direct domestic sewage disposal into the lake are becoming more frequent. This has led to Winam Gulf being subjected to heavy pollution from domestic and industrial wastes from Kisumu providing nutrients to the water hyacinth. This is further exacerbated by the nutrient runoff from lakeside agricultural activities.

An accepted reduction strategy, in addition to biological and mechanical controls, is biomass utilisation. This may be as a feedstock for power generation, biofuel production, fertiliser or soil conditioner. In situ, the water hyacinth can improve water quality by removing nutrients and metals from waters, but this is predicated on the hyacinth being removed, as if it is left in the water, it eventually breaks down and releases pollutants, as well as depletes oxygen levels.

From the literature, it appears that utilization does not provide a sustained solution to the spread and impact of water hyacinth, and rather, could provide a perverse incentive to maintain the invasive plant to the detriment of the environment and production systems at high economic and social costs. However, some Government agencies take the view that water hyacinth should be exploited for economic gain. An online review of newspaper articles relating to water hyacinth in Lake Victoria indicates a tension between the government and local population, with the prevailing sentiment being that the Government is not doing enough to address the issue.

Two projects that propose utilizing significant quantities of water hyacinth biomass from Lake Victoria in the short term have been identified from newspaper reports:

- A local Kenyan company has signed a contract with the United Arab Emirates to supply them with 9.8 million tonnes of water

74 A Roadmap for Biofuels in Kenya: Opportunities and Obstacles. Rep. N.p.: German Technical Cooperation (GTZ), 2008. Print.
75 Retrieved from http://www.farmerstrend.co.ke/complete-guide-canola-farming-kenya/
76 Retrieved from https://na.unep.net/geas/getUNEPPageWithArticleIDScript.php?article_id=98
77 Retrieved from https://en.wikipedia.org/wiki/Water_hyacinth_in_Lake_Victoria
78 Juma, Dauglas Wafula, Hongtao Wang, and Fengting Li. Impacts of population growth and economic development on water quality of a lake: Case study of Lake Victoria Kenya water. N.p.: n.p., n.d. Print.

hyacinth and other aquatic weeds from Lake Victoria to be used as a fertilizer with water retention qualities[79]

- The UK firm Equinox Energy Capital and Thika Way Investments are reported to be constructing a 35-megawatt hyacinth-to-energy plant at Homa Bay (within Winam Gulf). The Biogas enterprise comprises the staged development and implementation of several biogas power plants with a total feed-in generation capacity of 35 MW in the area. The proponents have leased 100 acres of land at Chwowe beach in Karachuonyo sub-county from the Homa Bay County government for the project, whose lifespan is estimated to be 30 years. 650,000 tonnes of water hyacinth feedstock is required to feed the plant (400 wet tonnes biomass/Ha from 1,630 Ha)[80]. It is understood a fermentation process is proposed to produce the biogas.

Timeframes were not listed for either of these planned initiatives in the associated media releases.

Water hyacinth fulfils many of the criteria deemed necessary for bioenergy production. It is a perennial, abundantly available, non-crop plant, biodegradable with high cellulose content; however, its strong disadvantage is that it has over 90 per cent water content, complicating harvesting and processing, and limiting the biofuel conversion technologies that can be deployed. Hydrothermal conversion (HTC) is a thermo-chemical conversion technique that may prove suitable that uses liquid sub-critical water (already present in the biomass) as a reaction medium for conversion of wet biomass and other waste streams to a low oxygen bio-oil.

Assuming a 50 per cent conversion rate of the dry biomass to bio-oil, approximately 20,000 litres bio-oil would be produced per hectare of hyacinth, yielding about 12,500 litres of aviation fuel (utilizing the figures for the Equinox Energy Capital plant). This would require approximately 2,600 Ha of water hyacinth to substitute 50 ML of Kenya's international aviation fuel requirements with SAF in 2025 (5,200 Ha to substitute 100 ML in 2030).

5.5.10.2 Other Environmental Weeds

Invasive weeds that are fast growing with large quantities of biomass and low water requirements may be suitable as SAF feedstocks. One of the most pervasive land-based weeds is the mathenge plant, which is invasive in parts of Kenya, Tanzania and in northern Uganda. In Kenya, this species was originally introduced in the ASAL areas of Kenya. It has recently dramatically expanded its range and is now widespread in Kenya, occupying an area of over 600 km^2 in more than six counties[81]. While this plant can potentially provide large amounts of biomass feedstock it exists in relatively low densities over very large areas remote from commercial facilities. It is anticipated that the delivered feedstock price would be unfeasibly high and would not be considered for SAF production, but rather for local use as a source of charcoal and timber.

5.5.11 WASTES

To achieve a viable SAF supply chain economics will always be the primary consideration (after technical compliance). As mentioned the unit cost of SAF currently lies well above the unit cost of fossil-based Jet-A1 fuel. Any co-products or benefits with a positive economic value related to a feedstock that will reduce the unit cost should be investigated. Waste is "Unwanted or unusable material, substances, or by-products"[82]. Such materials may usually be procured at no cost and have benefits such as disposal cost avoidance and even health benefits.

5.5.11.1 Municipal Waste

The non-recyclable fraction of MSW is increasingly being targeted as a feedstock for fuel production. MSW is a type of non-hazardous solid waste (with the exception of household hazardous waste) generated by households, businesses, institutions, and light industry (administrative, cafeteria, packaging, etc.).

Utilizing MSW as a feedstock is a compelling proposition as waste poses a huge challenge to society creating social, environmental and economic challenges. As Kenya develops and tracks towards its vision of being a middle-income nation by 2030, a by-product of this accelerated growth is ever-increasing quantities of waste with volumes of solid waste generated across Kenyan urban centres increasing from 4,950 tonnes per day in 2011 to 5,600 tonnes per day in 2014, outstripping its rate of urbanization. A major issue is a lack of a robust collection framework and absence of properly engineered disposal facilities. This has resulted in significant amounts of waste not being delivered to disposal facilities, with only 20 per cent of solid waste generated in Kisumu being dumped at designated dumpsites, 80 per cent in Nairobi and Mombasa at 65 per cent[83] (Table 5). Unfortunately, the management of MSW has not always been a high priority for local and national policy makers and planners, as other issues with more social and political urgency tend to take precedence and leave little budget for waste issues.

As part of Kenya's Nationally Determined Contribution under the Paris Agreement the government is targeting a 5 per cent reduction in 2030 baseline waste emissions, acknowledging the high cost of mitigation in the waste sector relative to other sectors. To advance this objective, steps are underway to establish an integrated waste management framework that includes source reduction, source separation, recycling and reuse, as well as materials and energy recovery.

[79] Retrieved from http://www.the-star.co.ke/news/2017/03/23/kenyan-firm-to-export-hyacinth-to-the-uae_c1529570
[80] Interview with NEMA May 2017
[81] Retrieved from http://mobile.nation.co.ke/news/Mathenge-Cummins-Factory-Baringo-County/1950946-2474782-format-xhtml-114h5my/index.html
[82] Retrieved from https://en.oxforddictionaries.com/definition/waste
[83] Ministry of Environment and Natural Resources Republic of Kenya. Kenya's Nationally Determined Contribution (NDC): Sector Assessment Chapter 8: Waste Sector Analysis. Rep. N.p.: n.p., 2017. Print. Draft

Name of Town	Estimated Waste generated (tonnes/day)	% Waste Collected	% Waste Recovery	Uncollected Waste
Nairobi	2400	80%	45%	20%
Kisumu	500	20%	Unknown	80%
Mombasa	2200	65%	40%	35%
Waste recovery is undertaken by pickers who retrieve materials such as **paper, polythene, plastics, glass, scrap metals, e-waste and waste tyres** for recycling.				

TABLE 5

Waste generation in cities with international airports

All of the disposal facilities in Kenya are open dumpsites. These types of facilities are unplanned, particularly with respect to siting considerations, are haphazardly operated, there are no controls over waste inputs, either in quantity or composition (or both) and there are no controls over emissions of pollutants released due to waste decomposition[84]. An example of an open dumpsite is the Dandora landfill site in Nairobi city. The dumpsite is surrounded by residential dwelling units and is situated next to a river.

Organic waste can be thermo-chemically treated to produce hydrocarbon products. Critical steps include: pre-treatment to remove non-organics and recyclables and to homogenise the feed; gasification, whereby the MSW feedstock rapidly heats up upon entry into the steam-reforming reactor and almost immediately converts to syngas; cleaning, to safely remove any contaminants; and FT processing, through which the clean syngas is processed through a fixed-bed tubular reactor where it reacts with a proprietary catalyst to form FT synthetic crude oil (syncrude). The FT syncrude can then be upgraded to aviation fuel and diesel that can be sold directly into the existing transportation market without requiring any engine modifications. This pathway (FT-SPK) is certified by ASTM for use in commercial operations up to a 50 per cent blend with current aviation fuel.

While MSW may provide large streams of potential alternative fuel feedstocks there are a number of technical challenges dealing with a feed that is low-density and heterogeneous relating primarily to separation and pre-treatment[85]. A number of companies are working to address these challenges.

The Kenya National Solid Waste Management Strategy recommends thermal treatment of waste as it “leads to the generation of useful products besides waste treatment”[86]. Incentivizing the collection and conversion of the organic component of MSW for fuel production will assist in advancing the strategy and promote positive outcomes for the other waste streams.

Name of Town	Estimated Waste generated (tonnes/day)	Max potential fuel yield (kl/day)
Nairobi	2400	360
Kisumu	500	75
Mombasa	2200	330

TABLE 6

Approximate Fuel Yield (150 litres/tonne)[87] Assuming All Waste Collected

[84] NEMA. The National Solid Waste Strategy. Rep. N.p.: n.p., 2015. Print.
[85] Epstein, Alexander K. Developing efficient and cost-Effective use of wastes as feedstocks, caafi.org.
[86] NEMA. The National Solid Waste Strategy. Rep. N.p.: n.p., 2015. Print.
[87] Retrieved from http://www.velocys.com/press/ppt/ppt160223_Energy_from_Waste_Feb2016.pdf

Feedstock	Strengths	Weaknesses	Yield[88]	Alternate Fuel Yield L/Ha/year	Land Requirement[89]	Notes on Viability
Cassava	*Non-Invasive *Hardy crop	*Potential food/fuel conflict *Can cause soil erosion *Would require large areas of broad-scale planting to ensure required feedstock quantity *Logistics framework non-existent	9.6 tonnes/ha/year 160-180 litres ethanol/tonne	1,000	50,000 Ha/ 100,000 Ha	Low – food competition issue. Commercialization hurdles to address before ethanol to aviation fuel becomes viable.
Sugarcane	*Industrial scale planting in place with required logistics *Non-Invasive *Hardy crop	*Food/fuel conflict relating to cane sugar and molasses *Bagasse availability uncertain due to alternative uses *Constrained by lack of irrigation	Cane: 71 v Sugar yield: 70 L/tonne Molasses : 10 L/tonne Bagasse yield: 32 tonnes/ha Sugarcane tops 15 tonnes/ha	- 440 2,400 (ATJ) 3,75 (ATJ)	- 1 10,000 Ha/ 220,000 Ha 21,000 Ha/42,000 Ha 130,000/ 260,000 Ha	Considered low viability for sugar/molasses due to competing uses. Financial hurdles before ethanol to aviation fuel becomes viable. Bagasse shows promise if supply can be secured. Cane,tops show good promise as a feedstock.
Sweet Sorghum	*Can produce both food and fuel	*Specialised harvesting equipment required *No current planting in the country *Would require broad-scale planting	30-40 tonnes/ha/ year (stalk sugar) 40 L/tonne ethanol yield	875 (stalk)	55,000 Ha/ 110,000 Ha	Low – food competition issue. Financial hurdles before ethanol to aviation fuel becomes viable.
Castor oil seed	*Suited to growing in agroforestry systems involving food crops and trees *Easy to cultivate *A high oil content and relatively low cost of production	*Invasive plant that has medium tolerance to drought *Castor does best on fertile, well- drained soils, therefore it may conflict with food uses on arable lands	0.23 (rainfed) tonnes/ha/year 448 litres oil/tonne	64	780,000 Ha/ 1,560,000 Ha	Low potential due to decentralized production and lack of mechanical harvesting. Would require significant area under cultivation.
Coconut	-Coconut is non-invasive, has medium tolerance to drought	-Very susceptible to pests	1.64 (kenya) tonnes/ ha/year 364 litres oil/tonne	300	170,000/ 340,000 Ha	Low – food competition issue. Low due to requirement of large monoculture and harvesting and logistic inefficiencies. Competition with food.
Croton	*Native to the region, widespread *Croton's deep tap-root can withstand drought *The tree produces well for many years and has many other uses and benefits on the farm	*Manual harvesting *Complicated logistics	2.5 tonnes/ha/year 336 litres oil/tonne	420	120,000/ 240,000 Ha	May prove viable in long term with development of harvester and large-scale monoculture.
Jatropha	*Jatropha is used to control soil erosion, especially in semi-arid areas, and its seedcake, which is high in nitrogen, can be used to improve soils	*Takes five to seven years to reach maturity and full production *Seeds contain a highly toxic substance called curcasin *Plantations cannot easily be mechanized *Jatropha is also considered invasive in many parts of the world *Susceptible to many pests and diseases	2.5 (rainfed) tonnes/ ha/year 336 litres oil/tonne	420	120,000/240,000 Ha	Considered unviable option for Kenya – see text.

TABLE 7 Comparison Table of Potential SAF Feedstocks in Kenya

[88] A Roadmap for Biofuels in Kenya: Opportunities and Obstacles. Rep. N.p.: German Technical Cooperation (GTZ), 2008. Print.
[89] Requirements to produce 50ML SAF in 2026 (100ML in 2030)
[90] Retrieved from http://www.fao.org/docrep/003/s8850e/S8850E10.htm
[91] Interview with NEMA staff May 2017
[92] Pereira, Lucas G., Heather L. Maclean, and Brad A. Saville. "Financial analyses of potential biojet fuel production technologies." Biofuels, Bioproducts and Biorefining(2017): n. pag. Web.

Feedstock	Strengths	Weaknesses	Yield[88]	Alternate Fuel Yield L/Ha/year	Land Requirement[89]	Notes on Viability
Rapeseed (Canola)	*Good cover crop and a good source of oil, which can be used for human and animal consumption, as well as in biodiesel production	*Generally grown on a mechanized scale, which often relies on energy-intensive and chemical-intensive methods of farming, which can lead to various detrimental environmental impacts	2 (rainfed) tonnes/ha/year 392 litres oil/tonne	390	130,000/260,000 Ha	Low – food competition issue.
Sunflower	*High yielding	*Requires a lot of water *High-risk crop in Kenya, under threat from four main agents, namely: insect pests, disease, birds and weeds	0.92 (current) tonnes/ha/year 414 litres fuel/tonne	190	260,000/520,000 Ha	Low – food competition issue.
Water Hyacinth (Lake Victoria)	*Localised concentration *Low cost feedstock *Addresses other sustainability issues *Significant amounts	*Variable supply *Harvesting and logistic issues to be addressed *Conversion technology still to be commercialised	400 wet tonnes biomass/Ha	12,500	4,000/8,000 Ha	Viable if supply chain logistics and cost is addressed.
Used Cooking Oil	*Proven conversion technology *Feedstock 'end-of-life' waste product *ASTM certified pathway Collection framework established *Positive regulatory framework for waste collection *Can use existing refinery tech	*Possible competing uses for oil *Volumes limited in long term	-	Yield 0.5L jet/Litre Oil	100ML/200ML	Viable if required volumes can be sourced.

TABLE 7 Comparison Table of Potential SAF Feedstocks in Kenya (continued)

5.5.11.2 Used Cooking Oil

UCO is an end-of-life product that is one of the most abundant usable sources of renewable carbon. The vast majority of flights undertaken to date utilizing alternative fuels has been based on UCO feedstocks. It requires the least amount of inputs and processing than any of the other feedstocks mentioned and can utilize processes within existing refineries.

In many countries, UCO is a valuable resource commanding prices higher than the unit cost of aviation fuel. In Kenya UCO is usually either disposed of down the drain or on-sold to other food outlets and then subsequently dumped down the drain. However, since late 2016 disposing of UCO in the environment is an offense under the Environmental Management and Coordination Act (EMCA) Cap 387 and the associated water quality regulations (2006). To be compliant, generators, such as hotels, are expected to procure the services of a suitably licenced waste handler to dispose their waste cooking oil. It is an offence under the legislation for a generator not to be in possession of waste tracking documents to prove that responsible disposal has occurred. However, this has not been actively policed, resulting in only a small fraction being collected to date.

UCO is processed through the HEFA pathway that combines hydro-treatment and isomerization to convert triglycerides to iso-parafinic hydrocarbons in the jet range. It was ASTM certified in 2011 for use in blends of up to 50 per cent with current aviation fuel (Bio-SPK).

6. USE OF BIODIESEL IN GROUND SERVICE EQUIPMENT

6.1 GROUND SERVICE EQUIPMENT

Ground handling companies utilize a variety of motorized equipment both on the “airside” and “landside” of an airport. This equipment is largely used to service the aircraft between flights and to support the operations of aircraft whilst on the ground. The role this equipment plays generally involves ground power operations, aircraft mobility, aircraft refuelling, and cargo/passenger loading operations. On the landside, fuel is utilized for transporting passengers and staff, moving cargo and running generators and other fixed equipment.

Many airlines subcontract ground handling to an airport or a handling agent, or even to another airline. Ground handling addresses the many service requirements of a passenger aircraft between the time it arrives at a terminal gate and the time it departs for its next flight.

The primary GSE operators in Kenya include Kenya Airways, Kenya Aerotech Ltd, Swissport Kenya, NAS Servair, Tradewinds, Eurocraft and African Flight Services.

GSE types can be categorized by the use of the equipment as follows:

- providing ground power and air conditioning to an aircraft;
- moving an aircraft (e.g., out of a gate, to/from maintenance);
- servicing an aircraft between flights (e.g., replenishing supplies, de-icing, etc.);
- loading/unloading passengers;
- loading and unloading baggage and cargo; and
- servicing the airport’s ramps, runways, and other areas (e.g., sweepers and lawn maintenance equipment)[93].

The majority of the equipment used to service these functions is powered by diesel engines. Diesel is favoured over gasoline especially airside as it has a higher flash point. Biodiesel is used successfully in airports around the world to power GSE resulting in reduced carbon and particulate emissions and improving LAQ. There are other clean options to power GSE such as compressed natural gas and electricity, however these power sources require modification to equipment or new equipment, while biodiesel can be utilized on existing equipment with few or no changes.

A number of factors need to be considered when considering utilizing a biodiesel blend in GSE including: availability; quality; volumes; supply logistics; blending requirements, storage and loading onto equipment. The overarching consideration is ensuring operations are not disrupted.

Biodiesel

Biodiesel is made through a chemical process called trans-esterification whereby vegetable oil is combined with alcohol (methanol or ethanol) and a catalyst, such as caustic soda (sodium hydroxide), to produce biodiesel (methyl or ethyl esters) and glycerol (a valuable by-product usually sold to be used in soaps and other products). International fuel quality and blending standards for biodiesel ensure that the fuel maintains required quality. Approximately one litre of biodiesel is produced for every litre of vegetable oil fed into the process. Biodiesel contains about 93 per cent of the energy content of petroleum diesel, so the B5 blend will achieve about 0.5 per cent less fuel economy or power output than ordinary diesel.

Blends of 20 per cent biodiesel and lower can be used in diesel equipment with no, or only minor modifications, although certain manufacturers do not extend warranty coverage if equipment is damaged by these blends. The B6 to B20 blends are covered by the ASTM D7467 specification. Biodiesel can also be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems. Blending pure biodiesel with petroleum diesel may be accomplished by:

- mixing in tanks at manufacturing point prior to delivery to tanker truck;
- splash mixing in the tanker truck (adding specific percentages of biodiesel and petroleum diesel);
- in-line mixing, whereby two components arrive at tanker truck simultaneously;
- metered pump mixing, petroleum diesel and biodiesel meters are set to X total volume, transfer pump pulls from two points and mix is complete on leaving pump[94].

Two of the largest GSE operators were interviewed for this study: Kenya Airways and Kenya Aerotech.

Kenya Aerotech has been operating since the 1970s servicing a number of airlines, including Emirates, Air France and local secondary airlines, with their primary work coming from cargo handling including Cargolux and Qatar Freight. They operate at JKIA as well as Eldoret and Mombasa International airports. They use primarily diesel in their equipment supplied by the National Oil Company into a single underground tank used exclusively for their own equipment. They run a wide variety of equipment (approximately 52 units) of varying complexity and age. Diesel fuel utilization is approximately 15,000 litres per month of diesel.

[93] Airport Ground Support Equipment (GSE): Emission Reduction Strategies, Inventory, and Tutorial. ACRP REPORT 78.
[94] Retrieved from https://en.wikipedia.org/wiki/Biodiesel

Equipment Type	Number of units
Tractors	16
Baggage Tugs	3
Pallet Transporters	4
Ramp Vehicles	6
Conveyor Belts	5
Super steps	3
Air start Units	1
Water Carts	2
Toilet Units	3
Ground Power Units	3
High loaders	6
TOTAL	**52**

TABLE 8
Type and Number of GSE Operated by Kenya Aerotech (as of July 2017)

Kenya Airways is the national carrier for Kenya operating the majority of flights from JKIA, Eldoret, Kisumu and Mombasa. It operates a large fleet of GSE, servicing primarily its own aircraft, both for passengers and cargo. At JKIA, it fuels vehicles from two underground storage tanks supplied by Total. Table 9 shows diesel usage (in litres) for Kenya Airways, broken down by cargo and passenger operations.

The combined monthly fuel consumption from both companies is nearly 100,000 litres which is expected to increase by about five per cent per year[95]. Both airlines and airports are increasingly investigating strategies to reduce the emissions from their activities. Addressing GSE fuel use not only results in reductions in GHG emissions, but can also have a positive effect on air quality and may improve operational efficiency. The primary fuel type used in ground service vehicles is diesel. Limited volumes of unleaded fuel (ULP) is utilized in small motors (e.g. on baggage conveyors) and Jet A-1 is used in turbine-powered ground power units (GPU).

The primary alternative fuel options for GSE at Kenyan airports are biofuel or electricity. It is understood that electric-powered GSE is being considered within the development plans for the expansion of JKIA. As mentioned, while electric-powered GSE is a proven option in many airports around the world, it does not provide the potential co-benefits relating to socio-economic contribution that biodiesel does. As the airport is a significant

	Bowser 1	Bowser 2	
Cargo	32,249	4,560	
Pax	42,512	4,404	
TOTAL	**74,761**	**8,964**	**83,725**

TABLE 9
GSE Fuel Usage for Kenya Airways at JKIA in January 2017 (in litres)

point user of fuel, it may actively assist in stimulating demand and accelerating the development of sustainable supply chains especially those relating to new generation feedstocks, such as croton nut, that can assist rural communities through supplementary income, as well as biodiversity benefits.

Meeting strict technical fuel quality and engine performance specifications, biodiesel can be used in existing engines without modification and is usually covered by all major engine manufacturers' warranties, most often in blends of 5 per cent up to 20 per cent biodiesel[96].

There are a number of direct benefits to the operator from using biodiesel as a replacement for regular petro-diesel from an operational perspective. These include:

- reduced GHG emissions;
- improved fuel economy;
- reduced particulate and soot emissions;
- a higher flash point, making it safer to store and handle; and
- being a solvent, biodiesel has good engine cleaning properties.

Current Status of Biodiesel in Kenya

Currently, no active regulatory framework has been implemented for the supply of biodiesel in Kenya. There have been Government plans for biodiesel mandates which have not yet come to fruition, notably a strategy for introduction of biofuel blends into the market was developed by the Government in 2010. Facilities for ethanol-gasoline blending have been completed in Kisumu, to be followed by Eldoret and Nakuru[97]. However, these have not been utilised due to insufficient quantities of bio-ethanol feedstocks or diversion of available stocks for higher value uses.

While not successful at the time, biofuels, including biodiesel, remain a focus area for the Government. The National Energy and Petroleum Policy 2015 identifies a number of challenges to be addressed in the evolution of a biofuel industry, including an insufficient legal and institutional framework to support sustainable generation, utilisation, production, distribution, supply and use of liquid biofuels. One of its recommendations is to undertake a biodiesel trial and to encourage RD&D.

[95] Based on passenger growth figures supplied by KCAA.
[96] Virgin Australia Biodiesel Trial 2012 https://www.virginaustralia.com/au/en/about-us/media/2012/VAH-BIODIESEL-TRIAL-BNE-DOM-AP/
[97] Retrieved from http://www.erc.go.ke/images/docs/National_Energy_Petroleum_Policy_August_2015.pdf

Notwithstanding the impediments, some companies have been working on providing a commercial biodiesel supply. It should be noted that biofuel does not attract the fuel excise that diesel and gasoline do.

The Renewable Energy Department of the MoEP is actively involved with supporting the development of the industry with technical advice and capacity building. It has identified that biodiesel producers are having issues with extraction and processing of seed oil and are encouraging local manufacturing of equipment that is normally imported at high cost.

Biodiesel Suppliers

There are currently two known biodiesel/oil producers in Kenya, as indicated in **Table 10**. There were previously three producers, with Zijani taking over Nairobi Biodiesel in 2016.

Name	Location	Feedstock
EFK (Eco-Fuels Kenya)	Nanyuki	Croton Nut
Zijani (formerly Biogen)	Nairobi	Used Cooking Oil

TABLE 10
Biodiesel Producers in Kenya

Zijani produces biodiesel from UCO. Located in Nairobi, its production has grown from 120 to 500 litres per day over the last two years. The company manages UCO disposal for the national coffee shop chain, Java House, which has 45 outlets around the country. Current biodiesel production goes to two customers, one of which is the Human Needs Project in the Kibera Slum of Nairobi. It currently has an excess of 8 to10,000 litres per month available.

As changes to the Environmental Management and Co-ordination (Water Quality) Regulation (2006) are slowly implemented, UCO collection volumes are increasing and current production capacity cannot cope, resulting in Zijani exporting excess oil to India and China for processing into biodiesel. Their ultimate objective is to raise sufficient finance to build processing facilities that can process all of the oil domestically. The company has indicated that the industry is being held back by a lack of willing customers[98].

Zijani has plans to increase production to 23 kl in the short term. In the longer term, they forecast that they will be able to source 300,000 litres per month from over 500 restaurants.

Founded in 2012, Eco-Fuels Kenya (EFK) sources the nut from the croton tree from rural communities, who harvest them mostly from farmlands in several counties in central Kenya. The nuts are processed at the company's factory in Nanyuki, Laikipia County. The extracted oil is sold to local agro-industries, who use it for a number of purposes, including both biofuel applications (as SVO) to run off-grid generators, water pumps and other agricultural machinery), as well as other uses, such as painting, leather tanning and cosmetics. EFK is currently undertaking a trial with Standard Charter Bank supplying SVO to run generators.

The co-products from oil extraction are also valuable. The husks are processed into certified organic fertilizers and biochar, while the seedcake is sold to commercial producers to be used as a rich source of raw protein for animal feed[99]. EFK currently have a network of 5,000 small suppliers collecting from about 100,000 trees twice a year. Harvesting can commence before the tree is two years old and each tree can produce about 100 kg per year (300 kg when older).

The median additional income derived from croton collection and sale was approximately KSh 5,600 (USD 56) in 2016, with one third of the collectors being able to earn between KSh 6,000 and KSh 25,000 per year[100]. This is significant in a country where half of the rural population lives below the poverty line, surviving on less than USD 200 annually per adult. For the poorest farmers surveyed, this additional income contributed up to 33 to 50 per cent of their annual income.

EFK's ability to supply biodiesel to ground service equipment operator is currently limited due to the small volumes generated, its distance from airports and its focus on high-value products and animal feed. As it expands in the future geographically and in size, there may be considerable potential to supply airports.

98 Meeting with Brian Piti Zijani July 2017.
99 Retrieved from http://www.worldagroforestry.org/
100 Programme for the development of alternative biofuel crops. Rep. N.p.: n.p., 2017. Print. World Agroforestry Centre

7. DISCUSSION AND RECOMMENDATIONS

Kenya has an emerging economy with ambitious plans to become a middle-income country by 2030. With two major constitutional reforms since independence in 1963, it is fast tracking its plans to transform Kenya into a newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030 in a "clean and secure environment"[101]. While such an environment will assist in advancing the development of a SAF supply chain, there are significant issues that will influence this journey.

In addition to the socio-economic issues already discussed there is currently no ground-based biofuel framework in place that can be leveraged as a foundation or from which experience and lessons learned can be obtained. Before thoughts can be directed towards the construction of a biorefinery, action needs to be directed towards strong governance and policy related to advanced fuels, adequate resourcing and commitment, definition of potential pathways and initial studies examining the techno-economic viability and sustainability of these pathways. The ultimate aim is to provide the elements that will contribute towards a viable business case clearly articulating risks and rewards that will attract project developers.

Figure 14 outlines issues relating to the establishment of a successful SAF industry in the form of a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis.

FIGURE 14
SWOT Analysis - Establishing a Successful Sustainable Aviation Fuel Industry in Kenya

OBJECTIVE: TO ESTABLISH A SUCCESSFUL SAF INDUSTRY IN KENYA

STRENGTHS:
Advantageous characteristics of the project

- SAF may help alleviate fuel insecurity issues in the medium to long term and improve the balance of trade.
- In the medium to long term, SAF may deliver significant net emissions reductions for Kenya's international and domestic aviation sectors.
- Demand from large "point-source" users is attractive to investors.
- Will provide other significant social benefits e.g. income for feedstock, utilization of wastes.

WEAKNESSES
Disadvantageous characteristics of the project

- Developing a SAF supply chain contains a high level of financial and technical risk.
- It is dependent on a very large amount of feedstock that can be supplied reliably at a competitive price.
- Some conversion pathways still to be commercialized.

OPPORTUNITIES
Elements in Kenya's environment that the project could capitalize from

- Kenya has made a high-level commitment to encourage biofuels and other renewables in its Vision 2030 development plan.
- A very high percentage of electricity generated in Kenya is from renewable sources that will help reduce SAF lifecycle emissions.
- Kenya has large volumes of waste that may be utilized as feedstock.
- Kenya has large amounts of weeds that may be utilized as feedstock.
- Current country fuel distribution system increases cost of fossil fuel making locally sourced fuels more attractive.

[101] http://www.vision2030.go.ke/about-vision-2030/

THREATS

Elements in Kenya's environment that could inhibit progress

- Climate change poses a significant threat to the economic, social and environmental well-being of the country.
- Lack of knowledge relating to renewable fuel production in Kenya.
- Energy policy only contains reference to first generation fuels (biodiesel, bio-ethanol).
- No practical experience exists in Kenya regarding advanced sustainable fuel technologies or manufacture. Expertise in production would need to be transferred along with the technology needed for manufacture.
- Kenya lacks the institutional framework to enact many of its policies.
- Kenya has placed a low priority on enacting biofuel policy with no economic incentives in place.
- Little broad-scale agriculture exists in Kenya that could support the required volumes of feedstocks.
- Poor public infrastructure (i.e. roads, utilities) hinders supply chain logistics and economics.
- Kenya suffers chronic water shortages (less than 0.002 per cent of Kenya is irrigated).
- Kenyan air carriers have limited ability to financially support SAF development.
- Potential competing demand for feedstocks for ground-based biofuels.
- Production costs have high sensitivity to fossil fuel prices.
- Fluctuating aviation fuel cost discourages support for SAF and makes the business case more difficult.

The following sections discuss the key issues to be considered in the development of a successful SAF supply chain in Kenya, as well as recommendations covering both SAF and GSE biodiesel implementation.

7.1 THE AIRLINE PERSPECTIVE

Airlines have been at the vanguard of efforts to promote and accelerate the development of an industry that can produce fuel that meets cost and sustainability requirements reliably at the required volumes. As with any new industry, it is important to establish demand. The incentives for airlines include:

- Diversification of fuel sources. This is particularly important for fuel security, ie if fuel imports are cut off, and as peak oil is reached;
- Addressing national and international obligations. This mainly relates to obligations to address GHG emissions under mechanisms such as the Paris Agreement, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), EU Emissions Trading Scheme (EU-ETS), etc.;
- Corporate sustainability objectives. This relates to addressing stakeholders (i.e. passengers, corporate clients, shareholders) material issues and being a good corporate citizen; and
- Positive Public Relations. By aligning with corporate and public sentiment, the airline may increase sales and therefore revenue.

While the aviation industry contributed nearly KSh 330 billion (USD 3.2 billion) to Kenya's economy, or 5.1 per cent of the country's GDP, according to a report commissioned by the International Air Transport Association[102], the national carrier Kenya Airways has experienced four consecutive years of losses but has been working to turn its results around. Although it posted an operational profit of KSh 897 million (USD 8.6 million) in March 2017, it still closed the year with a loss after tax of KSh10.207 billion (USD 98.8 million).

A key consideration is that airlines generally have difficulty justifying paying more for SAF; the net cost must be no more than what is paid for fossil-based aviation fuel over a contract cycle. This is the net purchase price (production cost minus government incentives and interventions) minus quantifiable co-contributions or benefits (**Figure 15**).

While it is acknowledged that in the long term, SAF must achieve price parity with conventional fuels, in the immediate term support mechanisms are required to stimulate market demand. This support is essential to enable scale–up and optimization, and reduce production costs. This applies to both before and after purchase by the fuel user.

FIGURE 15
The Components Affecting the Final Cost of SAF to an Airline

There are a number of ways the airline may wish to address this SAF premium: absorb the cost; pass on the premium to each passenger; or utilize a corporate programme whereby companies pay for or "sponsor" the premium. Such mechanisms to offset this premium will generally not be sustainable for large volumes of SAF, thus the importance of reducing its unit cost.

7.2 THE PRODUCER PERSPECTIVE

Developing a SAF industry is akin to developing any new, large business endeavour. Once a need and an opportunity to benefit financially is identified, investors will be attracted based on risk and return.

While airlines are willing off-takers of SAF that meets quality[103], sustainability, price and volumetric parameters, this needs to be matched with a suitable supply chain that provides a compelling business proposition for the producer. Like any investment, it must provide a promise of good commercial returns at the lowest risk possible.

There must also be a catalyst to attract the business and technical resources to develop a viable business case.

7.3 FEEDSTOCK PRODUCTION

The primary criteria for suitable feedstock for SAF production are cost, volume, sustainability, and reliability. Another factor affecting feedstock suitability is preferred conversion technology.

As listed in **Table 7**, there are a number of potential feedstock options in Kenya. Many of these feedstocks have the potential to be available in the quantities required to support a SAF industry. A major limiting factor is sustainability considerations, particularly that food production should in no way be impacted. Any potential supply chain should include an assessment against ICAO's sustainability criteria.

102 Oxford Economics. Economic Benefits from Air Transport in Kenya. Rep. N.p., 2011. Print.
103 Internationally recognized fuel specifications.

Review of relevant energy and environmental policies and regulations in Kenya highlights the current lack of consideration of sustainability principles or requirements. The Government should be encouraged to include sustainability frameworks across all policy areas relating to biofuels. Moreover, the Government may wish to review existing and proposed regional and international frameworks as well as the sustainability criteria to be established by ICAO which will enable operators to claim emissions reductions under CORSIA.

There is a high level of food insecurity in Kenya and this is expected to continue into the future as the impacts of climate change worsen. Cassava, cane sugar, molasses, sweet sorghum, coconut, rapeseed and sunflower must be ruled out as potential feedstocks as they are best directed for human, or livestock consumption. In addition to being food, the above feedstocks would require significant amounts of land to satisfy the required volumes of SAF to contribute to international aviation reaching its aspirational goals. This is hindered by the lack of broad-scale farming experience and opportunities in the country, and the current constraints of the land zoning regime.

Additionally, cultivation and harvesting practices are labour intensive in Kenya, with mechanised technology being the exception rather than common-place. Transport in Kenya is a logistical hurdle that can also drive up the cost of production. Poorly maintained roads and vehicles, and the lack of viable rail alternatives means that production should be centred as close to where the feedstock is produced as possible. The scale of production should also be based in part on how much feedstock can be sourced locally. Security is another concern that may require extra costs to protect equipment and supply routes.

Other inputs, such as electricity, labour, transport and processing chemicals used to convert the feedstock into either ethanol or biodiesel, are also an issue. The cost of manual labour for agricultural production and processing is relatively low, however other inputs such as fertilizer and chemicals are expensive.

Based on analysis undertaken in the previous section, it is recommended to focus on waste-based feedstocks, namely UCO, MSW, sugarcane field by-products (i.e. cane tops) and water hyacinth. While UCO has some constraints on potential yields, new legislation makes it a potentially attractive feedstock option for SAF.

Such feedstocks have advantages over other types in that:

- they are often available in large quantities;
- they often have an efficient logistics framework in place (ie municipal solid waste is collected and aggregated);
- these are often unwanted wastes that may provide social and environmental co-benefits when utilized; and
- as waste, they often provide a positive economic proposition.

7.4 USED COOKING OIL

The vast majority of the drop-in biofuels utilized in flights to date have used aviation fuel manufactured from UCO (HEFA) primarily because the technology is mature and it is certified to be used in aircraft undertaking commercial passenger operations by ASTM (Bio-SPK).

It is seen as a "bridging" feedstock; while the conversion technology requires the least amount of inputs and processing utilizing modules from existing refineries, the volumes in most cases ultimately will not be enough to produce the large volumes of SAF demanded by airlines. The rationale is that it will "fill the gap" until other conversion processes based on ligno-cellulosic feedstocks reach commercialization. It is an end of life product that is one of the most abundant usable sources of renewable carbon.

It is recommended that UCO be investigated for use in SAF production in Kenya as it has a number of strengths over other a number of other options, as outlined in Table 8.

Approximately 450 million litres of cooking oil are currently utilised yearly in Kenya, which is projected to rise to about 780 million litres by 2030[104].

There is little data available on the amount of spent oil that may be practically retrieved. Initial studies undertaken by Zijani suggest that 300,000 litres a month could be collected from restaurants in Nairobi. But the potential is much greater. Yet, even if 5 per cent were to be retrieved, it would amount to 22 ML per year, which would produce approximately 10 ML of aviation fuel. In 2030 that would amount to about 20 ML of aviation fuel.

This source may be supplemented by other potentially sustainable oil pathways, in particular croton nut.

Further study is required to determine the true potential of UCO as a SAF feedstock, which should include:

- techno-economic assessment of the HEFA pathway utilizing UCO;
- volumes and trends in cooking oil consumption and UCO generation;
- review of current policy and legislation relating to collection of UCO and recommendations to clarify and enhance;
- mechanisms to extend the requirement for suitable disposal to non-commercial premises; abd
- strategies to improve the retrieval rate of UCO, which would include working with Kenyan counties in order to recommend appropriate awareness and education mechanisms.

[104] Retrieved from http://www.mpoc.org.my/upload/rwmeap1_vijayraghavan_po2012.pdf

Currently the Energy and Petroleum Policy and Climate Change Act broadly encourages biofuel production. Specific mention of individual feedstocks needs to be included, specifically UCO.

While the process is underway to clarify and advance a UCO SAF supply chain, biodiesel production should be encouraged with the existing producer to allow processes to be refined and scaled up. This should include advancing a biodiesel blend for the airport GSE.

RECOMMENDATION

Undertake techno-economic analysis of the UCO as a renewable fuel feedstock with a focus on SAF.

Collection strategies

- Work with County Councils to engage resident groups on community collection
- Recommend that the government acknowledge and support the sustainable development and scale of croton nut oil that may supplement UCO as an aviation fuel feedstock.
- Continue to encourage the development of a biodiesel supply to GSE providing a demand in the short term.

7.4.1 RESIDUES FROM SUGARCANE FARMING

Sugar and molasses from the sugarcane plant have been ruled out as potential feedstocks for SAF production primarily because of conflict with food crop cultivation, but also because of supply variability and shortfalls in supply. Bagasse is of interest in many parts of the world as a renewable feedstock but sugar processors and the Government intend to utilize as much of the bagasse generated as possible for on-site co-generation and supplying surplus into the grid where feasible. The Kenya Agricultural and Livestock Research organization identified cane tops as a potential source of biomass. At harvest time, the sugarcane biomass includes stalks that can be milled, tops, dead and dying leaves, stubble and roots. Sugarcane tops represent 15 to 25 per cent of the aerial part of the plant. They generally consist of green leaves, bundle sheath and variable amounts of immature cane[105]. During manual harvest of the cane the tops are left in the field to rot or are burnt. Initial discussions with agricultural experts indicate that there is no beneficial use of the tops and that they could be collected during the harvesting process (Table 8 provides the SWOT analysis of this pathway).

An advantage over utilising cane tops rather than bagasse is that the farmers own the tops, while the mill owns the bagasse. Any benefit paid would go directly to the farmer.

The sugar cane growing areas around Kisumu County are well placed within the catchment of Kisumu International Airport for the supply of SAF.

To fully understand the potential of this material as a feedstock, investigations need to be undertaken into the following:

- quantification of available volumes;
- issues limiting availability and maximising yields;
- collection and aggregation strategies and issues;
- assessment of viable conversion technologies. This should enable consideration of the potential to accept other types of feedstocks;
- sustainability assessment including risks and opportunities to farmers;
- a techno-economic assessment including an estimation of income potential for producers; and
- assessment of required policy and support mechanisms required at county and national level.

RECOMMENDATION

Undertake sustainability and techno-economic analyses of cane tops as a renewable fuel feedstock, with a focus on SAF.

7.4.2 MUNICIPAL SOLID WASTE

MSW is defined as household waste, commercial solid waste, non-hazardous sludge, small quantity hazardous waste, and industrial solid waste. MSW includes food waste, rubbish from residential areas, commercial and industrial wastes, and construction and demolition debris.

Retrieving the calorific value from municipal solid waste is commonplace throughout the world. While waste-to-energy via combustion, or even gasification, is a common practice, the process of converting waste to liquid fuels is a relatively new process. MSW has potential as a gasifier feedstock because it has a gross calorific value on a dry basis that is nearly as high as most conventional biomass feedstocks.

It is appealing as a potential feedstock as it is readily available in the near-term having a pre-existing collection/transportation infrastructure that does not exist for most conventional biomass resources.

A significant issue exists in Kenya with poor waste management practices. The new Kenyan National Waste Management Strategy[106] responds to this issue by basing actions on the waste hierarchy and promotes waste to energy as one of its focus

[105] http://www.feedipedia.org/node/558
[106] NEMA. The National Solid Waste Strategy. Rep. N.p.: n.p., 2015. Print.

areas. The sources of funding for its implementation plan will be from the Government of Kenya, public-private partnerships, waste generators and development partners.

The headline objectives of the strategy sympathetic to SAF production are as follows:

- achieve approximately 80 per cent waste recovery (recycling, composting and waste to energy) and 20 per cent landfilling in a Sanitary landfill (inert material) by 2030;
- achieve 50 per cent waste recovery (recycling, composting and waste to energy) and 50 per cent semi-landfilling by 2025; and
- achieve 30 per cent waste recovery (recycling, composting) and 70 per cent controlled dumping (tipping, compacting and covering) in key urban areas by 2020.

Waste-to-energy is a pathway that has gained a lot of attention in the aviation sector. The process typically entails gasification of the organic material in the MSW feedstock to a synthesis gas (syngas) that consists primarily of carbon monoxide, hydrogen and carbon dioxide. This syngas is purified and processed through the FT process to produce a "syncrude" product that is then upgraded to aviation fuel or diesel fuel. This pathway has the advantage that it is already approved by ASTM (the first in fact) to be utilised in commercial flight operations. In the past, the FT process was plagued with scale (i.e. it could only operate at large scale) and cost issues. This appears to have been largely overcome and smaller scale plants are currently under development[107].

Waste management in Kenya is devolved to county councils and there are moves by individual counties to formulate their own response strategies that complement the national document. For example, Kisumu County has gazetted the Kisumu County Solid Waste Management Act 2015 that intends to strengthen collection strategies and introduce recycling. Discussions with Kisumu County Council officials reveal that they are in preliminary discussions with a proponent who wished to introduce a waste-to-energy plant based on gasification.

RECOMMENDATION

It is recommended that the viability of utilizing MSW as a SAF feedstock be explored in Nairobi, Mombasa and Kisumu.

Undertake high-level sustainability and techno-economic analysis of MSW as a renewable fuel feedstock with a focus on SAF.

7.4.3 WATER HYACINTH

Water hyacinth was introduced in Lake Victoria from Rwanda via the Kagera River as a result of human activity. After originally infesting Lake Victoria (Uganda), it eventually spread into the Winam gulf, where it has proliferated widely. The East African Community (EAC) Lake Victoria Basin Authority has estimated that the amount of water hyacinth in the Kenya section of Lake Victoria alone is more than 20,000 Ha[108].

Water Hyacinth provides a ready amount of biomass feedstock that could be converted to fuel products through pathways such as hydrothermal liquefaction.

Utilising the biomass beneficially will contribute towards solving a range of associated social and economic problems and would have the potential to garner considerable support and resources from especially the EAC[109] and its Member States. However there are a number of issues to be overcome. The most significant is the "unreliability" of this feedstock, as it is not anchored the hyacinth is mobile. Harvesting strategies must be carefully considered as this has the potential to add significantly to the cost.

The EAC Lake Victoria Basin Authority has dedicated significant resources to studying and investigating management strategies to address this issue. However rather than relying solely on hyacinth as a bioenergy feedstock it is recommended that it be considered in conjunction with other complementary sources of biomass.

RECOMMENDATION

It is recommended that the viability of utilizing water hyacinth in Lake Victoria be investigated as a SAF feedstock.

This would include:

- confirming volumes and mobility patterns;
- undertaking an assessment of harvesting technologies;
- assessing suitable conversion technologies; and
- assessing social, environmental and economic benefits to the region.

[107] http://www.gasification-syngas.org/uploads/downloads/2015-8-1-Velocys.pdf

[108] Meeting with Lake Victoria Basin Authority July 2017.

[109] The East African Community (EAC) is a regional intergovernmental organisation of 6 Partner States: the Republics of Burundi, Kenya, Rwanda, South Sudan, the United Republic of Tanzania, and the Republic of Uganda, with its headquarters in Arusha, Tanzania.

Feedstock	Strengths	Weaknesses	Alternate Fuel Yield L/Ha/year	Notes on Viability
Used Cooking Oil	Feedstock in a form that is relatively straightforward to refine. It is a proven pathway for SAF with hundreds of flights undertaken. UCO is an end-of-life waste that is currently dumped. In Kenya, it is a low-to-zero cost waste. Will pose no sustainability issues including not a food.	Potentially large volumes but limited over other feedstocks being considered. Requires extra hydrogen to refine over biodiesel making biodiesel production a more attractive financial option.	New laws require commercial generators to dispose of UCO to licensed carriers, and is a ready-made aggregation model. More oil could be collected by engaging residents via county councils.	Legislation to dispose of oil to carriers must be policed or potential volumes won't be realized. Supply may change if laws change i.e. for collection.
Sugar Cane Field Residues (Cane Tops)	Large volumes available. Currently is of no known value. Additional income stream for farmer. No known sustainability issues including not a food. Can be collected during cane harvesting.	Low energy density, will require large volumes affecting logistics and cost. Potentially extra work in the harvesting process adding to cost. Conversion technologies still being commercialized. Not available all year round.	Increases in planned irrigation in sugar growing region will increase volumes. Could be combined with bagasse where available.	Resettlement/rezoning programmes reduce number of producers.
Municipal Solid Waste	Large volumes of feedstock at low price to zero cost. Feedstock has no known value. No known sustainability issues including not a food. Waste stream aggregated. Has other positive sustainability outcomes i.e. improved health and environmental outcomes. Large amount of feedstock all year round.	Requires sorting and preparing of the waste stream. Conversion technologies still to be commercialized.	Encouraged under the government's waste management strategy increasing funding potential. Municipal waste streams are increasing.	Waste management infrastructure degraded and outdated. Special interests may interfere with proposed pathway.
Water Hyacinth	Has little to no use or value that will reduce costs. Many co-benefits of removing from lake - reduce multiple impacts on the environment and society. Large volumes available.	Is highly mobile and therefore amount of biomass variable over time. Difficult to harvest.	May qualify for support from international agencies and surrounding States Climate change will probably result in more feedstock. Could use local population for harvesting.	Would require specialized harvesting equipment. Issues with commodifying a significant weed.

FIGURE 11
SWOT Analysis for proposed Feedstocks

7.5 A BIOREFINERY CENTRED ON KISUMU

Three potentially significant sources of feedstock lie within 100 km of Kisumu: municipal solid waste, cane tops and water hyacinth (**Figure 16**). While MSW can provide a stable volume of feedstock throughout the year, sugar cane tops are seasonal aligning with the cane growing season and hyacinth supply varies due to weather, lake conditions, etc. **Table 12** lists possible gross feedstock yields. It does not account for losses or optimisation of feedstock streams.

Fuel (in litres) uplifted by flights departing Kisumu international airport in 2016 were as follows:

	Domestic	Regional	International	Total
Kisumu	6,599,446	16,924	13,375	6,627,745

When the growth rate of aviation is extrapolated from 2012 and 2016 across the whole country to calculate future consumption for Kisumu the result is 14 ML in 2026 and 18.6 ML in 2030. With a corresponding growth in feedstocks over this period it is expected that these feedstocks have the potential to satisfy all fuel demand requirements at a 50 per cent blend rate.

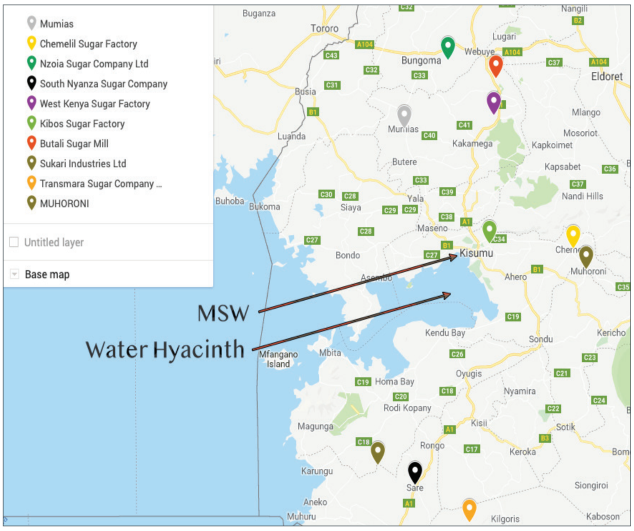


FIGURE 16
Proximity of Three Feedstock Types to Kisumu

While recommendations have been made on individual feedstocks in previous sections, logistics and conversion technology options require investigation to assess whether a particular conversion technology can process the three feedstocks either simultaneously or concurrently. This is complicated by the moisture content of the water hyacinth that makes it generally unsuitable for conversion by gasification and processing through the FT process to produce

Feedstock	Potential Feedstock Yield t/yr	Comments
Sugarcane Tops	3,000,000	15 tonnes/Ha@200,000 Ha[110]
Municipal Solid Waste	182,500	500 tonnes/day[111] generated in Kisumu
Water Hyacinth	8,000,000 wet 400,000 dry	400 tonnes/Ha[112] (wet) 95% water

TABLE 12
Approximate Availability of Feedstock (in tonnes)

a "syncrude" product that is then upgraded to aviation fuel or diesel. Other pathways are available that are amenable to feedstocks with a high-water content. For example, hydrothermal liquefaction uses a thermal depolymerization process to convert wet biomass into crude-like oil that can subsequently be upgraded to petroleum products.

RECOMMENDATION

Demand analysis - Undertake detailed modelling on fuel requirements for Kisumu International Airport.

Supply analysis - Undertake initial feasibility study into a SAF supply chain centred on Kisumu that could process a combination of MSW, cane tops and water hyacinth, including:

- analysis of potential conversion technologies;
- pre-processing and other preparation required; and
- recommendations on feedstock combinations and next steps.

Note: Other recommendations cover detailed assessments of each feedstock.

7.6 BIODIESEL

There are a number of ground service providers or companies that operate GSE in Kenya. Discussions were held with Kenya Airways and Kenya Aerotech on their GSE fuel usage, the potential to utilize a biodiesel blend and issues they feel might arise from utilizing a blend. Both of these companies are members of the Aviation Environment Working Group (AEWG) which is overseen by the KCAA. While both companies are generally supportive of utilizing biodiesel in their GSE, a number of concerns were raised. **Table 13** lists these concerns with responses.

The Kenya Bureau of Standards (KEBS), the government agency responsible for governing and maintaining the standards and practices of metrology in Kenya, have issued a standard relating to biodiesel (KS2227:2010) listing the minimum requirements for a range of properties.

One of the operators has requested that testimonials and case studies on the use of biodiesel blends be supplied by other GSE operators.

It is important that the biodiesel producer works with the Ministry of Energy and Petroleum, the Energy Regulatory Commission and the KEBS to ensure fuel is complies with ASTM6751. This includes the establishment of an ongoing quality assurance programme.

There is considerable interest from the biodiesel manufacturer to supply product to airport operators. There have been few buyers for product to date and having additional clients will assist in seeking finance to scale up operations.

Under the draft National Energy and Petroleum Policy 2015 there is a commitment by the government to "Initiate and implement a biodiesel blend pilot program". Consideration should be given by the biofuel team at the MoEP to facilitating the GSE biodiesel supply as part of this programme.

[110] Kenya Sugar Board. Cane Census 2013/14 – 14/15 Report. Rep. n.p., 2014. Print.
[111] Discussion with Kisumu County Council July 2017
[112] Discussion with NEMA May 2017

TABLE 13
Issues Raised in Relation to Utilising Biodiesel and Responses

Issue Raised	Response
Both operators fully utilize their equipment with little to no backups in case of failures. There are concerns that any mechanical issues due to utilizing biodiesel would have a severe impact.	Biodiesel blends manufactured to government-approved standard will provide perform comparable performance to conventional diesel.
That much of the equipment is very old and concern that it cannot cope with biodiesel.	Biodiesel blends manufactured to government-approved standard can be utilized in diesel engines especially at lower percentage blends.
Will reduced energy density compromise performance of GSE?	Drop in performance will be imperceptible at a B20 blend.
Who blends the fuel and is it undertaken properly?	The biodiesel producer would work with the contracted diesel supplier to undertake blending to best industry practice before delivery.
That there may be blockages of electronic fuel injection equipment on machines manufactured after 2013.	Again, having fuel manufactured to government-approved standard will mean that this will be avoided.
Impact of the production of biodiesel on the environment.	Production of biodiesel by transesterification is not industrially intensive and has few wastes. The only by-product is glycerin, which is sold for soapmaking.
Is the flash point different to conventional diesel?	It is in fact higher than conventional diesel making it safer.

RECOMMENDATION

The AEWG should facilitate awareness and education on biodiesel with members and other GSE operators.

The MoEP should facilitate the supply of biodiesel to GSE operators as part of the biodiesel blend pilot program listed as an action in the Energy and Petroleum Policy 2015.

Kenya Airways and Kenya Aerotech should meet with biodiesel supplier, Biogen, to familiarize themselves with the production process and address concerns on use of product.

With oversight from the AEWG, a 3-month trial should be undertaken utilizing biodiesel blend in GSE.

7.7 GOVERNMENT POLICY AND SUPPORT MECHANISMS

Biofuels have been a component of Kenyan energy policy for a number of years. Since the 1970s, encouragement has been provided for the production of bio-ethanol. Similarly, biodiesel has also been promoted over the last decade. Though biofuel policy is present (directly, or indirectly through renewable energy policy) to guide regulations and standards that will promote and regulate the biofuel industry in Kenya, little of it has been translated into demonstrable action by the government in the last five years. A number of stakeholders have indicated that they were frustrated with the lack of policy execution in this area. This is by no means unique to Kenya. The use of biofuels is not widespread anywhere in sub-Saharan Africa.

The biofuel industry cuts across several sectors that are governed by different policies, all of which need to be harmonized to speed up the industry in light of increasing fossil fuel prices and the imperative to address climate change. The first and second MTPs supporting the execution of the Vision 2030 objectives do not directly refer to biofuel. They do however state that "Kenya aims to increase the reliance on national energy resources over imports", which could refer to the development and use of locally produced biofuel.

Kenya's energy policy instruments, particularly the National Energy and Petroleum Policy (2015), highlight the development of bioethanol and biodiesel for use primarily in road transport. It recommends that land be set aside for the farming of energy crops, giving examples of both food and non-food crops. Seven policy/strategy items are listed with a timeframe listed as the period up to 2030 (Table 14). These items refer to "first generation" biofuels (biodiesel and bioethanol); there is no recognition of "second generation" or advanced fuels such as SAF. Additionally, it does not recognize the requirement for the fuels to have any level of sustainability assessment. While a full assessment against the Roundtable on Sustainable Biomaterials standards would not necessarily be warranted due to the cost and resource requirements, an abridged framework designed and overseen by, for example, the National Environmental Management Authority (NEMA), may be justified.

TABLE 14
Policies and Strategies for Biofuels (section 3.5.3) as Documented in the Draft National Energy and Petroleum Policy 2015 and Suggested Modifications

Policy / Strategy	Suggested Amendment / Addition
Undertake Research Development & Demonstration (RD&D) on biofuel feedstock.	Undertake Research Development & Demonstration (RD&D) on biofuel feedstock that complies with agreed sustainability criteria.
Review the existing legal, fiscal, regulatory and institutional framework. Provide incentives for biofuel production projects and consumption.	Review the existing legal, fiscal, regulatory and institutional framework to identify gaps and ensure targeted actions are in place to support the advancement of sustainable biofuels and advanced fuels.
Collaborate with other stakeholders to ensure efficient use of land resources for biofuel feedstock, food production and other human needs.	Provide incentives for biofuel production projects and consumption. Incentivize projects for sustainable biofuel production for ground purposes and use in aircraft.
Create stakeholder awareness and sensitization on the importance and viability of biofuel production and consumption.	Collaborate with other stakeholders to ensure efficient and sustainable use of land resources for biofuel feedstock, food production and other human needs.
Implement the bioethanol pilot programme.	Create stakeholder awareness and sensitization on the importance and viability of biofuel production and consumption.
Initiate and implement biodiesel blend pilot programme.	Implement the bioethanol pilot programme. Initiate and implement biodiesel blend pilot programme.
	Undertake feasibility assessment of advanced fuels (including SAF).

RECOMMENDATION

That the strategies and policies listed in section 3.5.3 of the National Energy and Petroleum Policy 2015 be revised to address sustainability requirements and advanced fuels including sustainable aviation fuel.

It is recommended that the Biofuel Department of the Ministry of Energy and Petroleum take the lead in advancing the recommendations in this report.

Recommendations must be framed within the context of the devolved Government systems comprising the National and County Governments, in line with the Constitution of Kenya (2010). The extent to which the decentralized processing strategies and feedstocks based on waste products can drive down costs remains to be seen, but the economics of SAF production are likely to remain challenging especially in the East African region. An additional deterrent is the higher market value of alternative products such as gasoline and diesel – with which SAF must compete for production capacity. These issues are exacerbated by the uneven renewable energy policy landscape and its application, with none of the current policy including advanced or second-generation fuels. Other renewable energy options including wind and solar has not flourished in Kenya to date, even though there is a compelling need and a complementary policy framework in place.

RECOMMENDATION

The Government should consider inclusion of advanced fuels development, including SAF, in the National Renewable Energy Master Plan in third MTP.

No practical experience exists in Kenya regarding advanced sustainable fuel manufacture. Expertise in production would need to be transferred along with the technology needed for manufacture. It is recommended that the relevant sections of the Ministry of Energy and Petroleum undertake capacity building in the area of advanced fuels.

7.8 GOVERNANCE AND OVERSIGHT

To encourage continued focus on advancing an indigenous SAF industry, consideration should be given to formulating an agreement and a committee formed by the KCAA, the MoEP and the Ministry of Environment and Natural Resources (MoENR) to collaborate and oversee the advancement of the recommendations in this report and beyond to encourage the development of a SAF industry in Kenya which aligns with the country's development vision and assists the Kenyan aviation industry fulfil its obligations both internationally and domestically.
Focus areas of the committee may include:

- encouraging policy certainty and overcoming regulatory barriers;
- seeking collaboration opportunities and investigating funding options;
- exploring what domestic policy framework(s) is required to provide certainty to developers and investors;
- investigating what kind of explicit carbon price signal is needed to create the demand and economic viability to drive the investment in SAF;
- investigating strategies for overcoming barriers to participation from feedstock providers;
- identifying research requirements to address gaps and barriers;
- identifying mechanisms and pathways to build on the work being done around the globe that will advance the local industry;
- facilitate the interface between state and county governments on policy and actions required at a local level; and
- building capacity with proponents throughout the supply chain.

RECOMMENDATION

Draft and sign declaration between the State Department of Transport (KCAA, Kenya Airports Authority), MoEP, Ministry of Agriculture, Livestock and Fisheries (MoALF), and MoENR (and other entities as required) agreeing to consider the conclusions and recommendations from this study.

Form steering committee to oversee the implementation of the report actions and roadmap.

7.9 POTENTIAL FUNDING AND RESEARCH SUPPORT

To advance a SAF industry in Kenya the pathways identified in this report will require further study and investigation. The identified priority feedstocks will require analysis to better understand potential yields, sustainability issues and techno-economic potential. The Kenyan Government's Energy and Petroleum Strategy identifies the requirement to undertake research and prescribes a specific action – "Undertake Research Development & Demonstration (RD&D) on biofuel feed-stock". While support from the Ministry of Energy and Petroleum is welcome, it would be prudent to investigate other supporting programs and funding mechanisms. Table 12 lists potential funding sources that may be investigated to advance the actions in this study.

Policy / Strategy	Description
Green Climate Fund	Global fund created to support the efforts of developing countries to respond to the challenge of climate change. GCF helps developing countries limit or reduce their greenhouse gas (GHG) emissions and adapt to climate change. The National Environment Management Authority (NEMA) is the Adaptation Fund's (AF) accredited National Implementing Entity (NIE) for Kenya. NEMA commenced implementing AF funded programme titled, 'The integrated programme to build resilience to climate change & adaptive capacity of vulnerable communities in Kenya' in 2016.
Green Adaptation Fund	The Adaptation Fund finances projects and programmes that help vulnerable communities in developing countries adapt to climate change. Initiatives are based on country needs, views and priorities. The UNEP has oversight of a GAF project – "Adapting to Climate Change in Lake Victoria Basin (Burundi, Kenya, Rwanda, Tanzania, Uganda)". One of the project outcomes is "Regional resilience to climate change promoted through innovative, community-based projects". The proposed SAF studies in the Kisumu region may qualify under this outcome.
East African Community (EAC)	EAC oversees the Lake Victoria Basin Commission, a joint programme developed for the overall management and rational utilization of the shared resources of the Lake. The LVBC manages a number of projects that positive outcomes for the lake and member states with funding from a wide range of sources. LVBC staff have already show an interest in supporting the developing of pathways identified in this report.
African Development Bank Group	**Africa Climate Change Fund** Funding for a wide range of climate-resilience and low-carbon activities. **Sustainable Energy Fund for Africa.** Support for small and medium scale Renewable Energy (RE) and Energy Efficiency (EE) projects in Africa. SEFA is also aligned with the Sustainable Energy for All Initiative (SE4ALL) to support preparatory, sector planning and capacity-building activities arising out the AfDB-hosted SE4All Africa Hub. **Scaling Up Renewable Energy Program in Low Income Countries (SREP)** The Scaling Up Renewable Energy Program in Low Income Countries (SREP) is funded by the Strategic Climate Fund (SCF), one of the two Climate Investment Funds (CIF). SREP aims to scale up the deployment of renewable energy solutions and expand renewable markets in the world's poorest countries. It pilots and demonstrates the economic, social, and environmental viability of development pathways that do not exacerbate global warming.
Kenyan Government	**Climate Change Fund** The Climate Change Act 2016 establishes a Climate Change Fund as the financing mechanism for priority climate change actions and interventions approved by the Climate Council. **National Environment Trust Fund** NETFUND is a state corporation under the Ministry of Environment, Natural Resources and Regional Development Authorities. NETFUND was established within the provisions of the Environmental Management and Coordination Act (EMCA) 1999 to facilitate research intended to further the requirements of environmental management, capacity building, environmental awards, environmental publications, scholarships and grants. **Consolidated Energy Fund** Under the Energy Act 2015 the Government is establishing a Consolidated Energy Fund to cater for funding of the proposed National Energy Institute, infrastructure development; energy efficiency and conservation programmes as well as promotion of renewable energy initiatives.

TABLE 15 Potential Funding Mechanisms

8. ACTION PLAN AND ROADMAP

The roadmap aligns with the Kenyan Government's Medium-Term Plans (MTP): the first and second stages cover the third Plan (MTP3) over the period 2018 – 2022 and the third stage covers the fourth plan (MTP4) running from 2023 – 2027 (Figure 17). Table 13 collates the recommended actions documented in the body of the report. These actions mainly lie in the first and second stages which will determine further actions required to establish supply chains on-the-ground extending into MTP4. While four feedstock pathways are recommended for further investigation, the roadmap has a particular focus on UCO as the most proven and accessible pathway for the medium term, while the other three feedstocks are anticipated to have a delayed evolution. This will occur in parallel to the development of a GSE biodiesel supply chain based on UCO which may be enabled in the short term, thus proving elements of the supply chain in common with SAF.

VISION

To identify and establish an indigenous SAF supply chain that supports the nation's Vision 2030 objective of achieving middle income status and helps the Kenyan aviation industry fulfil its emissions reduction targets.

OPPORTUNITIES

- Large volumes of wastes (and residues)
- Strong govt commitment on renewables
- Stable govt and business support framework
- Feedstock co-benefits will help reduce costs
- Social benefits from engaging and rewarding public via collection strategies

CHALENGES

- Feedstock collection systems inefficient or non-existent
- Lack of technical expertise and research experience in target area
- Inefficient waste collection regimes
- No refining infrastructure
- Agricultural land use not suited to broadscale cultivation

FIRST STAGE (2018-2019) Laying the groundwork Cooperation and capacity building	SECOND STAGE (2020-2023) Demonstrating the potential and proving the viability	THIRD STAGE (2023-2027) Making it a reality - Implementation
• Identification of feedstock with best potential for Kenyan conditions. • Identify relevant stakeholders – their roles and responsibilities. • Establish framework for oversight and coordination. • Local cooperation and capacity building: - Establish measures for increasing cooperation and information sharing; - Capacity building on: feedstock, sustainability, refining, quality testing and market for SAF and biodiesel; - Funding and resource support mechanisms identified to advance studies. • International cooperation – knowledge transfer and partnerships with East African States. • Undertake biodiesel trial and implement permanent offtake for GSE.	• Ensure complementary policy and regulatory framework in place for advanced fuels and sustainability. Including government support and incentives. • Complete techno-economic (TE) and sustainability analysis on jet fuel pathway utilising Kenyan used cooking oil (UCO). • Education and awareness raising with potential investors and project developers. • Extend biodiesel supply to other international airports. • Undertake TE and sustainability analysis on cane-tops, MSW and water hyacinth feedstock with appropriate conversion technology centering on Kisumu.	• Ensure new petroleum infrastructure is complementary and supportive of SAF. • Continue to advance scale up UCO collection systems. • Complete business case and groundwork for first HEFA plant. • Complete business case and groundwork for first UCO-based advanced fuels refinery producing renewable diesel and other products. • Undertake techno-economic analysis into economic production and collection of croton nut oil to supplement UCO feedstock. • From the results of the TE and sustainability analysis on cane tops, MSW and water hyacinth feedstock determine implementation plan.

FIGURE 17 Roadmap for SAF supply chain primary focussed on used cooking oil

Recommended Actions	Timeline	Recommended Responsible entity
Aim: Provide the optimal policy and administrative environment to allow advanced fuels and SAF to develop and promote capacity building.		
Draft and sign statement of intent between the State Department of Transport (Kenya Civil Aviation Authority, Kenya Airports Authority), Ministry of Energy and Petroleum, Ministry of Agriculture, Livestock and Fisheries, and Ministry of Environment and Natural Resources (and other entities as required) agreeing to consider the conclusions and recommendations from this study.	Q3/4 2018	State Department of Transport Min Energy and Petroleum, Min Environment and Natural Resources,Min Agriculture, Livestock and Fisheries
Form steering committee to oversee the implementation of the report actions and roadmap.	Q3/4 2018	As above and other relevant entities
Biofuel Department of the Ministry of Energy and Petroleum take secretariat role in advancing the recommendations in this report under the guidance of the steering committee.	2019 onwards	Min Energy and Petroleum
Include submission on action status of this roadmap in the aviation section of the Ministry of Transport and Ministry of Energy and Petroleum submission to the MTP3.	Q4 2018	State Department of Transport Min Energy and Petroleum
Kenyan carriers to investigate appropriate mechanisms to advance SAF development in their organisations as well as participate in national and international relating to SAF development.	2019 onwards	National Carriers
Investigate the potential for cooperation with other nations in the East African Community (EAC), as well as other adjoining countries, on advancing the preferred SAF supply chains with shared benefits.	2019	Steering Committee
The Principal Secretary of the State Department of Transport to provide representation to the Renewable Energy Resources Advisory Committee (RERAC) promoting the importance and development of SAF.	Q3/4 2018	State Department of Transport
Investigation to be undertaken into scope and conditions of the Consolidated Energy Fund and the potential to support in-depth sustainable aviation fuel studies.	Q3/4 2018	State Department of Transport
Investigate incentives and support under the Climate Change Act 2016 to encourage the development of SAF.	2019	Min Energy and Petroleum Min Environment and Natural Resources
Consideration to be given for advanced biofuels, specifically SAF, to be acknowledged and discussed in the final version of the National Energy and Petroleum Policy 2015 and Bioenergy Strategy.	2018/19	Min Energy and Petroleum
That the strategies and policies listed in section 3.5.3 of the National Energy and Petroleum Policy 2015 be revised to address sustainability requirements.	2018/19	Min Energy and Petroleum
Include targeted actions relating to advanced fuels development, including sustainable aviation fuel, in the National Renewable Energy Master Plan in third Medium Term Plan (MTP3) that runs from 2018 to 2023. Include reference to this roadmap.	2019	Min Energy and Petroleum
Amend the National Climate Change Action Plan (NCCAP) 2018-2013 under the INDC policy suite to include advanced fuels including SAF in addition to first generation biofuels. While covering domestic aviation it will have relevance to international aviation. Input into the review of the National Adaptation Plan to include consideration of SAF.	Q3/4 2018	Min of Transport
No practical experience exists in Kenya regarding advanced sustainable fuel manufacture including SAF. The relevant sections of the Ministry of Energy and Petroleum and other nominated agencies to undertake capacity building in the area of advanced fuels.	2018/19	Min Energy and Petroleum
Identify and procure funding to advance actions listed in the plan.	2019	Steering Committee

TABLE 16 Kenyan Sustainable Aviation Fuel Action Plan

Recommended Actions	Timeline	Recommended Responsible entity
Aim: Establish a SAF supply chain based on Used Cooking Oil (UCO) and other non-petroleum oil-based feedstocks.		
Continue to encourage the development of a UCO biodiesel supply to GSE providing a demand in the short term (see biodiesel actions).	2019 onwards	Min Energy and Petroleum
Undertake techno-economic (TE) analysis of used cooking oil as a renewable fuel feedstock for sustainable aviation fuel production.	2019-2020	Min Energy and Petroleum/ Kenyan University
Work with County Councils and relevant ministries to engage commercial and industrial entities on collection strategies. Work with Universities and NGOs on community collection strategies.	2019-22	County Governments in particular Kisumu and Nairobi
Acknowledge and support the development and scale up of other potential sustainable oil feedstocks such as croton nut oil that may supplement UCO.	Ongoing	Min Energy and Petroleum
Investigate the potential of leveraging off planned Lamu oil refinery infrastructure for processing (or co-processing) UCO into aviation fuel or green diesel (for blending into aviation fuel) as per appropriate ASTM specifications.	2020-23	Min Energy and Petroleum
Based on the results of the TE analysis recommend further work to assist in building business case for implementation. This will inform the government's strategy in the MTP4 to encourage construction and utilisation during 2023-2027.	2022/23	Min Energy and Petroleum
Undertake techno-economic analysis into economic production and collection of croton nut oil to supplement UCO feedstock.	2024	Min Energy and Petroleum
Aim: Determine the viability of a SAF supply chain based on Cane Tops		
Undertake sustainability and techno-economic analysis of cane tops as a renewable fuel feedstock with a focus on sustainable aviation fuel.	2020/21	Min Energy and Petroleum/ Kenyan University
Aim: Determine the viability of a SAF supply chain based on Municipal Solid Waste		
Determine viability of utilizing MSW as a sustainable aviation fuel feedstock in Nairobi, Mombasa and Kisumu. Undertake sustainability and techno-economic analysis of municipal solid waste as a renewable fuel feedstock with a focus on sustainable aviation fuel.	2020/21	Min Energy and Petroleum/ Kenyan University
Aim: Determine the viability of a SAF supply chain based on Water Hyacinth		
Determine the viability of utilizing water hyacinth in Lake Victoria as a sustainable aviation fuel feedstock through a sustainability and techno-economic analysis. This would include: • Confirmation of volumes and mobility patterns • Undertake assessment of harvesting technologies • Assessment of suitable conversion technologies • Social, environmental and economic benefits to the region	2020/21	Min Energy and Petroleum/ Kenyan University with input from LVBC

Recommended Actions	Timeline	Recommended Responsible entity
Aim: Investigate an aggregated Feedstock Model for Kisumu for SAF production		
Following on from the recommended studies on cane tops, MSW and hyacinth investigate the viability of aggregating these diverse feedstocks and identifying suitable conversion technologies. **Demand analysis** - Undertake detailed modelling on fuel requirements for Kisumu International Airport. **Supply analysis** - Undertake initial feasibility study into a SAF supply chain centered on Kisumu that could process a combination of municipal solid waste, cane tops and water hyacinth. Including: • Analysis of potential conversion technologies; • Pre-processing and other preparation required; • Provide recommendations on feedstock combinations and next steps.	2022/23	Min Energy and Petroleum/ Kenyan University with input from LVBC
Aim: Encourage the scale up and use of biodiesel as a strategic component of UCO-based SAF development		
Kenya Airways and Kenya Aerotech to meet with biodiesel and diesel supplier to familiarize themselves with the production process and address concerns on use of biodiesel.	Q3/4 2018	Min Energy and Petroleum
The Aviation Environment Working Group to facilitate awareness and education on biodiesel with members and other GSE operators.	Q3/4 2018	AEWG
The Ministry of Energy and Petroleum (MoEP) to facilitate in the supply of biodiesel to GSE operators as part of the biodiesel blend pilot program listed as an action in the Energy and Petroleum Policy 2015.	Q3/4 2018	Min Energy and Petroleum
With oversight from the MoEP and the AEWG, a 3-month trial to be undertaken utilizing biodiesel blend in GSE.	2019	Min Energy and Petroleum, Ground service equipment operators, petroleum retailer, biodiesel manufacturer, KAA, KCAA
On successful completion of the GSE biodiesel trial establish permanent supply of biodiesel blend to GSE operators and other airport diesel users.	2019/20	Min Energy and Petroleum, Ground service equipment operators, petroleum retailer, biodiesel manufacturer, KAA, KCAA

TABLE 16 Kenyan Sustainable Aviation Fuel Action Plan (cont.)

9. BIBLIOGRAPHY

- A Roadmap for Biofuels in Kenya: Opportunities and Obstacles. Rep. N.p.: German Technical Cooperation (GTZ), 2008. Print.
- Airport Ground Support Equipment (GSE): Emission Reduction Strategies, Inventory, and Tutorial. ACRP REPORT 78. (2012) doi:10.17226/22681.
- Allison Kasozi and Harro von Blottnitz. Solid Waste Management in Nairobi: A Situation Analysis. Rep. N.p.: n.p., 2010. Print. Draft.
- Alves, C. M., Valk, M., de Jong, S., Bonomi, A., van der Wielen, L. A.M. and Mussatto, S. I. (2017), Techno-economic assessment of biorefinery technologies for aviation biofuels supply chains in Brazil. Biofuels, Bioprod. Bioref., 11: 67–91. doi:10.1002/bbb.1711.
- Bauer, F., Coenen, L., Hansen, T., McCormick, K. and Palgan, Y. V. (2017), Technological innovation systems for biorefineries: a review of the literature. Biofuels, Bioprod. Bioref., 11: 534–548. doi:10.1002/bbb.1767.
- Bouthillier, Yves Le. The law and policy of biofuels. Cheltenham: Elgar, 2016. Print.
- Dale, B. (2017), A sober view of the difficulties in scaling cellulosic biofuels. Biofuels, Bioprod. Bioref., 11: 5–7.
- Departmental Committee on Agriculture, Livestock and Co-operatives. The Crisis Facing The Sugar Industry In Kenya. Rep. N.p.: n.p., 2015. Print.
- Epstein, Alexander K. Developing efficient and cost-Effective use of wastes as feedstocks, caafi.org.
- Government of Kenya. National Energy and Petroleum Policy (Draft). Working paper, 2015. Print.
- IATA. IATA Sustainable Aviation Fuel Roadmap. Rep. 1st ed. N.p.: n.p., 2015. Print. ISBN 978-92-9252-704-4.
- ICAO DOC 9988 - Guidance on the Development of States' Action Plans on CO_2 Emissions Reduction Activities, paragraph 1.1.2. Order Number: 9988, ISBN 978-92-9249-223-6. March 17th, 2014.
- ICCT. Alternative jet fuel development and deployment in North America. Rep., 2017. Print.
- International Food Policy Research Institute. Climate variability and climate change and their impacts on Kenya's agricultural sector. Rep. n.p., 2010. Print.
- Jatropha reality check a field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya; study. Eschborn: GTZ, 2009. Print.
- Karatzos S, McMillan J, Saddler J, Donohoo PE, Weiss MA et al., The potential and challenges of drop-in biofuels. [Online]. IEA Bioenergy Task 39(2014). Available at: http:// task39.org [November 16, 2016].
- Karatzos, S., van Dyk, J. S., McMillan, J. D. and Saddler, J. (2017), Drop-in biofuel production via conventional (lipid/fatty acid) and advanced (biomass) routes. Part I. Biofuels, Bioprod. Bioref., 11: 344–362. doi:10.1002/bbb.1746.
- Kenya: Vision 2030, Government of the Republic of Kenya, Ministry of Planning and National Development and the National Economic and Social Council (NESC), Office of the President, 2007.
- Kossoy, A., Peszko, G., Oppermann, K., Prytz, N., Klein, N., Blok, K., Lam, L., Wong, L., & Borkent, B. (2015). State and trends of carbon pricing. Washington, DC: The World Bank. doi:10.1596/978-1-4648-0725-1.
- Mabee, W. E. (2017), Refocusing the bioeconomy in an uncertain policy environment. Biofuels, Bioprod. Bioref., 11: 401–402. doi:10.1002/bbb.1774.
- Mawhood, R., Gazis, E., de Jong, S., Hoefnagels, R. and Slade, R. (2016), Production pathways for renewable jet fuel: a review of commercialization status and future prospects. Biofuels, Bioprod. Bioref., 10: 462–484. doi:10.1002/bbb.1644.
- Menandro, L. M. S., Cantarella, H., Franco, H. C. J., Kölln, O. T., Pimenta, M. T. B., Sanches, G. M., Rabelo, S. C. and Carvalho, J. L. N. (2017), Comprehensive assessment of sugarcane straw: implications for biomass and bioenergy production. Biofuels, Bioprod. Bioref., 11: 488–504. doi:10.1002/bbb.1760.

- Michalena, Evanthie, and Jeremy Maxwell. Hills. Renewable Energy Governance: Complexities and Challenges. London: Springer, 2013. Print.
- Ministry of Environment and Natural Resources Republic of Kenya. Kenya's Nationally Determined Contribution (NDC): Sector Assessment Chapter 8: Waste Sector Analysis. Rep. N.p.: n.p., 2017. Print. Draft.
- Molony, T. (2011), Bioenergy policies in Africa: mainstreaming gender amid an increasing focus on biofuels. Biofuels, Bioprod. Bioref., 5: 330–341. doi:10.1002/bbb.293
- NEMA. The National Solid Waste Strategy. Rep. N.p.: n.p., 2015. Print.
- O'Hara, Ian. "The Potential for Ethanol Production from Sugarcane in Australia." Proc Aust Soc Sugar Cane Technol32 (2010): n. pag. Web.
- Okeke, I. J. and Mani, S. (2017), Techno-economic assessment of biogas to liquid fuels conversion technology via Fischer-Tropsch synthesis. Biofuels, Bioprod. Bioref., 11: 472–487. doi:10.1002/bbb.1758.
- Olweny, C. Unravelling the potential of sweet sorghum for sugar production in Kenya. Rep. N.p., n.d. Web. Research Application Summary.
- Opande, George Ogueno, John Charles Onyango, and Samuel Otieno Wagai. "Lake Victoria: The water hyacinth (Eichhornia crassipes [Mart.] Solms), its socio-economic effects, control measures and resurgence in the Winam gulf." Limnologica - Ecology and Management of Inland Waters34.1-2 (2004): 105-09. Web.
- Oxford Economics. Economic Benefits from Air Transport in Kenya. Rep. N.p., 2011. Print.
- Panoutsou C, Bauen A, Boettcher H, Alexopoulou E, Fritsche U, Uslu A, van Stralen JNP, Elbersen B, Kretschmer B, Capros P, Maniatis Ket al., 2013, Biomass Futures: an integrated approach for estimating the future contribution of biomass value chains to the European energy system and inform future policy formation, Biofuels Bioproducts & Bio-refining BIOFPR, Vol: 7, Pages: 106-114, ISSN: 1932-104X
- Pereira, Lucas G., Heather L. Maclean, and Brad A. Saville. "Financial analyses of potential biojet fuel production technologies." Biofuels, Bioproducts and Biorefining(2017): n. pag. Web.
- Programme for the development of alternative biofuel crops. Rep. N.p.: n.p., 2017. Print. World Agroforestry Centre.
- Sapp, M. (2010), Creating value in African biofuels. Biofuels, Bioprod. Bioref., 4: 366–368. doi:10.1002/bbb.234.
- Sapp, M. (2013), Can biofuels really be blamed for food insecurity in Africa? Biofuels, Bioprod. Bioref., 7: 482–484. doi:10.1002/bbb.1444.
- Valdivia, Miguel, et al. "Biofuels 2020: Biorefineries based on lignocellulosic materials." Microbial Biotechnology, vol. 9, no. 5, 2016, pp. 585–594., doi:10.1111/1751-7915.12387.

ICAO

ICAO-EU-PROJECT@ICAO.INT

WWW.ICAO.INT/ENVIRONMENTAL-PROTECTION/PAGES/ICAO_EU.ASPX

PROJECT FUNDED BY

European Union