Development of Sustainable Aviation Fuel in Ethiopia: A Roadmap

October 2021

Published under the *Fuelling the Sustainable Bioeconomy* Project supported through a grant from The Boeing Company.

RSB

Roundtable on Sustainable Biomaterials

www.rsb.org

Executive Summary

To explore and advance Ethiopia's capacity to produce biofuels for use as Sustainable Aviation Fuel (SAF), the Roundtable on Sustainable Biomaterials (RSB) initiated the development of a 10-year SAF Roadmap for the country.

The main purpose of the roadmap is to identify the ideal feedstock and technology mix — one that adheres to the robust RSB Standards while informing policymakers on the necessary policy actions needed to incentivise SAF and supporting the development of more proposals and plans aimed at unlocking further funding and investment into SAF research, development, and pilot production.

This report was compiled through work with a SAF Steering Committee that represented the local government, experts, and national airline in examining research and documentation reflecting the country's internal and external environment. SWOT and GAP analyses were also performed. At the same time, feedstock availability was reviewed and the details of the SAF conversion pathways were reported. SAF developments from a global perspective have also been included.

The **main findings** of the roadmap process are as follows:

- The Ethiopian economy relies heavily on agriculture, identified as an 'enabling sector' in the country's 10-year development plan (2021–2030): *The Pathway to Prosperity*.
- Ethiopia's fuel demand is entirely met through imports, with the import of aviation fuel and diesel fuel having increased by 49.4 % and 111 % respectively from 2010 to 2018.
- The development of biodiesel in Ethiopia has been limited to three pilot plants, with no existing biorefinery within the country.
- Only three blending facilities in Ethiopia presently — used for 5% blending of ethanol with gasoline — could be used for SAF blending, and there are only two ethanol distilleries.
- Ethiopia has no blending mandate for biodiesel.
- In its 15-year growth strategy, the Ethiopian Ministry of Transport prescribes a 10% mix of SAF, which would amount to almost 530,000 litres of SAF by 2028/2029.
- The Ethiopian oil industry regulatory framework in its current form cannot address the present and future growth challenges it faces.
- The sole commercially available SAF conversion pathway is hydroprocessed esters and fatty acids (HEFA) technology, an oil-to-fuel pathway.
- Agricultural residues, castor (*Ricinus sp.*), Ethiopian mustard/*Brassica carinata*, *Jatropha curcas*, sugarcane, and water hyacinth were examined as potential feedstocks for delivering locally produced SAF. Castor (foreseen in the Biofuels Development and Utilisation Strategy) and Ethiopian mustard (native to the central highlands of Ethiopia) stand out as the most prominent candidates for SAF production via HEFA technology, although more research is needed.

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- Smallholder farmers scattered over large areas in the country, scarce inputs, inefficient handling chains, and high post-harvest losses contribute to moderate oil feedstock production in the country, with potential for improvement.

Taking these findings into consideration, the **key prerequisites** for the development of a national SAF industry are to:

- Ensure sustainable and non-erratic production of high oil feedstock volumes in compliance with the requirements of the RSB sustainability framework.
- Proceed with the required legal and regulatory amendments to clearly link the aviation transport mode with biofuel deployment.
- Realise the Ethiopian government's clear intention to support the development of the national biofuel industry — specifically focusing on SAF production — by fostering the participation of the private sector via the establishment of appropriate joint-venture and public-private partnership schemes, so long as fair competition is not compromised.
- Initiate focused feasibility studies on the utilisation of selected feedstocks for SAF production to validate yields, taking into consideration environmental and social impacts.
- Invest in improving the poor public infrastructure (i.e., roads and utilities) that are hindering supply chain logistics and economics.
- Elevate currently low research and investment levels, when compared to similar African countries.
- Invest in development of human resources, preparing workers for the highly skilled roles required — particularly for feedstock processing..

The **roadmap for development of a national SAF industry ideally** consists of three consecutive phases:

- Phase 1 (2021–2023): establish an enabling policy environment.
- Phase 2 (2024–2028): demonstrate the potential and ensure an open economy.
- Phase 3 (2029–2030): forward-looking plan (as illustrated in Figure 1).

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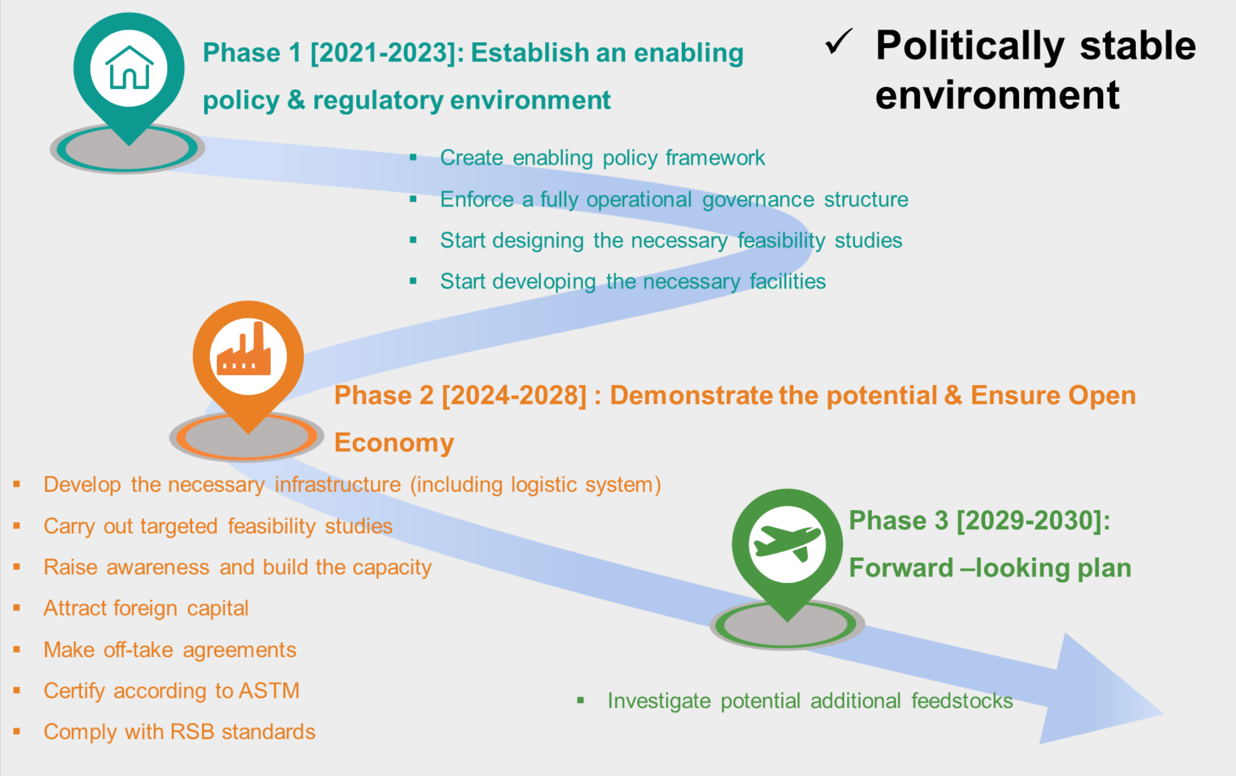

Figure 1: Roadmap Overview

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Acknowledgment

RSB would like to acknowledge the efforts and invaluable contributions of the Ethiopian Sustainable Aviation Fuel (SAF) Roadmap Steering Committee members during the 18-month stakeholder engagement process culminating in the publication of this report. It is thanks to their dedication and insights that the delivery of such a comprehensive roadmap charting the pathway for SAF in Ethiopia is possible.

The Ethiopian SAF Roadmap Steering Committee consists of representatives from government, private sector, and research institutes, and includes: Ministry of Mines, Ministry of Trade and Industry, Environment Forest, and Climate Change Commission (EFCCC), Ethiopian Civil Aviation Authority, Ethiopian Rural Energy Development and Promotion Center, Ethiopian Airlines Group, Ethiopian Biotechnology Institute, Ethiopian Oil companies Association, Ethiopian Agricultural Research Council Secretariat, Ethiopian Petroleum Supplies Enterprise, Addis Ababa University and Ethiopian Mineral Petroleum and Biofuel Corporation.

This report is part of the “Fuelling the Sustainable Bioeconomy” project supported by The Boeing Company. The project aims to help the aviation industry play a leading role in tackling the threat of climate change through the use of SAF, while creating jobs, stimulating economic growth, developing rural livelihoods and protecting the environment. The RSB is grateful to The Boeing Company for its support in unlocking the potential of SAF to be a force for positive social and environmental impact in economies around the world.

We would also like to thank the consultancy Exergia S.A. for their expert services and support in developing this report.

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Glossary of Acronyms

API	Africa Power Initiative
ARDPS	Agricultural and Rural Development Policies and Strategies
ASTM	American Society for Testing and Materials
ATJ	Alcohol-to-jet
CHJ	Catalytic hydrothermolysis jet fuel
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CSR	Corporate social responsibility
DLUC	Direct land use change
EIA	Environmental impact assessment
EIC	Ethiopian Investment Commission
EPSE	Ethiopian Petroleum Supply Enterprise
ETB	Ethiopian birr
FID	Foreign investment development
FRL	Fuel readiness level
GDP	Gross domestic product
GHG	Greenhouse gas
GMO	Genetically modified organism
HA	Hectare
HEFA	Hydroprocessed esters and fatty acids
HFS	Hydroprocessing of fermented sugars
HVO	Hydrogenated vegetable oil
ICAO	International Civil Aviation Organisation
ILUC	Indirect land use change
IPCC	Intergovernmental Panel on Climate Change
Mt CO2e	Million ton of Carbon dioxide equivalent
MT	Metric Tons
MSW	Municipal Solid Waste
PPP	Public-Private Partnership
RED	Renewable Energy Directive

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RES	Renewable Energy Source
RSB	Roundtable on Sustainable Biomaterials
SAF	Sustainable aviation fuel
SAP	State Action Plans
SIP	Synthetic isoparaffins
SNNPR	Southern Nations, Nationalities and Peoples' Region
SPK	Synthetic paraffinic kerosene
SWOT	Strengths, weaknesses, opportunities, and threats
TIN	Taxpayer's identification number
TRL	Technical readiness level
UNDP	United Nations Development Programme

1. Background

1.1 Scope and Objective of the Roadmap

The development of a Sustainable Aviation Fuel (SAF) roadmap in Ethiopia is part of the ‘Fuelling the Sustainable Bioeconomy’ partnership between the *Roundtable on Sustainable Biomaterials* (RSB) and the *World Wildlife Fund* (WWF), which is supported by The Boeing Company. To this end, RSB already signed an MOU in 2019 with the Government of Ethiopia to collaborate on SAF development.

The Ethiopian SAF Roadmap is expected to guide the country through the necessary steps for developing SAF production while fostering local socioeconomic development and taking advantage of the country’s existing agricultural resources — without jeopardising food security and environmental protection. It builds on the recommendations formulated during the multi-stakeholder Scenario Development workshop that RSB led in early 2020, aiming to promote the development of sustainable biofuels in Ethiopia in the next 15 years.

The scenario development process generated four possible plausible scenarios, using political stability and price volatility for the uncertainty matrix: the worst-case scenario (unstable government and high price volatility), two moderate scenarios, and the best-case scenario (stable government and low price volatility).The four scenarios were depicted using storylines with titles representing their respective cases, with the best-case (preferred) scenario being titled ‘TIMECHIGNALESH’ (a song that translates to “I am comfortable with you”).

According to the preferred scenario (TIMECHIGNALESH), the following steps should be taken:

- Raise awareness with all stakeholders, by focusing on the benefits of well-designed biofuel chains — such as energy access, land rehabilitation, climate change mitigation, and the substitution of petroleum products for transport (including aviation).
- Create partnerships across sectors and stakeholders, and with international actors in the sector.
- Support research and development regarding feedstock, technology, and agriculture that will be imperative for the development of the sector.
- Expand from conventional into second-generation production.
- Ensure product diversification and co-product valorisation.
- Support the development and implementation of a biofuels mandate and policies.
- Create an open invitation for partnerships and investment, based on sustainable criteria.
- Develop a carbon finance programme to incentivise community stakeholders.
- Ensure community and social benefits by providing access to products for cooking, lighting, etc.
- Push for the setting and approval of standards in Ethiopia.
- Reach an offtake agreement with Ethiopian Airlines’ governance.

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- Tap into existing Corporate Social Responsibility (CSR) programmes.
- Develop legal and policy framework development and enforcement, including standardisation and certification schemes.
- Support revision of Ethiopia's land use policy.
- Create local job opportunities within sustainable biofuel production.

The roadmap serves the country's long-term ambition of identifying suitable feedstock technologies for SAF production to become the leading SAF producer and supplier in Africa, supporting the decarbonisation of the national airline while driving local sustainable economic development.

1.2 Policy Landscape and Decarbonisation Targets

Emissions from domestic aviation can be addressed by undertaking mitigation policies at the national level, while emissions from international aviation are regulated by the UN's International Civil Aviation Organisation (ICAO).

To this end, ICAO's goals for the international aviation sector are the following:

- An annual fuel efficiency improvement of 2% each year up to 2050.
- Carbon neutral growth from 2020 onwards.

ICAO is promoting the following basket of measures to reduce CO2 emissions:

- Aircraft-related technology and standards.
- Improvement in operations and air traffic management.
- Development and deployment of SAF.
- Market-based measures (CORSIA).

Out of the above measures, the development and deployment of SAF is the most efficient — as a decrease in the CO2 emissions of up to 80% compared to traditional jet fuel can be achieved.

The 37th session of the ICAO Assembly also encouraged its member states (note: Ethiopia is included) to voluntarily submit their state action plans (SAPs) for reducing CO2 emissions from international aviation. The SAPs are long-term plans that should provide an overview of a state's strategy until 2050 and are to be updated every three years. Most of the SAPs provide information about the actions that countries have undertaken to reduce GHG emissions from the aviation sector. These include a list of actions undertaken by airlines and airports, as well as improvements in operations and air traffic management. Measures related to the development of SAF are also enumerated but are generally not supported by an overarching policy framework yet.

CORSIA, on the other hand, is aimed at addressing any annual increase above 2020 levels in total CO2 emissions arising from international civil aviation. SAF operators will be entitled to claim emissions reductions when using alternative fuels, provided the fuels in question meet defined sustainability criteria and are certified by an approved certification scheme.

In that regard, a set of sustainability criteria was approved by the ICAO Council, in the context of consideration of SAF during the pilot phase of CORSIA (until December 31st, 2023). These criteria are registered in the ICAO document 'CORSIA Sustainability Criteria for CORSIA Eligible Fuels' and presented in Table 1.

Table 1: CORSIA Sustainability Criteria for Eligible Fuels

Theme	Principle	Criteria
Greenhouse Gases (GHG)	CORSIA-eligible fuel should generate lower GHG emissions on a life cycle basis.	CORSIA-eligible fuel shall achieve net GHG emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis.
Carbon Stock	CORSIA-eligible fuel should not be made from biomass obtained from land with high carbon stock.	CORSIA-eligible fuel shall not be made from biomass obtained from land converted after 1 January 2008 that was primary forest, wetland, or peatland and/or contributes to degradation of the carbon stock in primary forests, wetlands, or peatlands — as these lands all have high carbon stocks.
		In the event of land use conversion after 1 January 2008, as defined based on IPCC land categories, direct land use change (DLUC) emissions shall be calculated. If DLUC GHG emissions exceed the default induced land use change (ILUC) value, the DLUC value shall replace the default ILUC value.

CORSIA was adopted in 2016 by ICAO, with the aim of stabilising net CO2 emissions from international civil aviation at 2020 levels. ICAO, and by extension CORSIA, covers most of the international air traffic in the world.

There are three discrete phases of CORSIA: the pilot phase (2021–2023), the first phase (2024–2026), and the second phase (2027–2035). Participation of the countries in the first two phases is on a voluntary basis. The second phase will apply to all states that have an individual share of international aviation activities above 0.5%. Excluded are flights to and from Least Developed Countries (LDCs), Small Island Developing States (SIDs), Landlocked Developing Countries (LLDCs), and states that represent less than 0.5% of international RTK — unless they participate voluntarily. Nevertheless, all operators will have to report emissions for all international flights since 1 January 2019, including flights to and from exempted states.

Airlines can comply with CORSIA through the following measures:

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- Adopting more efficient aircraft and operations, to reduce fuel consumption.
- Running on SAF, thereby lowering GHG emissions.
- Utilising a market-based offsetting mechanism.

With the third CORSIA option listed above, operators may address their emissions commitments by offsetting emissions through the reduction of emissions either in the aviation sector or elsewhere, making use of the concept of 'emissions units'. There are two main types of emissions units: 'offset credits' from crediting mechanisms and 'allowances' from emissions trading schemes. Therefore, offsetting could be through the purchase and cancellation of emission units arising from different sources of emission reductions that are achieved through mechanisms, programmes, or mitigation projects.

The pilot phase of CORSIA has been initiated and, although Ethiopia is not among the countries volunteered to participate in this phase, the emissions generated by international flights from and to the country will have to be reported by the aircraft operator. In other words, Ethiopia's national operator (Ethiopian Airlines) will submit its emissions every year (after having them verified by an independent party) to the national authorities and the latter will submit them to ICAO through the CORSIA Central Registry.

For as long as Ethiopia does not participate in the CORSIA scheme[1], Ethiopian Airlines is not required to offset their emissions for routes connecting Ethiopia with other states. If Ethiopia voluntarily becomes a participatory state, Ethiopian Airlines will be required to offset part of their emissions (based on a formula) for flights connecting Ethiopia with other participatory states. At that time, one way of offsetting the named emissions will be via the deployment of the 'CORSIA Eligible Fuels' (refer to Table 1). Even if Ethiopia does not volunteer to be included as a participatory state, it is likely that it will eventually become part of the CORSIA global scheme, provided that the mechanism spreads and develops as planned.

At the EU level, **the revised Renewable Energy Directive RED II** (2018/2001/EU)[2] provides a framework for gaseous biomass fuels produced and/or sold within the EU and introduces sustainability for forestry feedstocks as well as GHG criteria for solid and gaseous biomass fuels. The specifics for the sustainability criteria under RED II are summarised in

Table 2.

Table 2: EU RED II Sustainability Criteria for Eligible Fuels

Plant Operation Start Date	Transport Biofuels	Transport Renewable Fuels of Non-Biological Origin
Before October 2015	50%	-

1 Ethiopia is expected to also be exempt in the second phase, which covers up until 2035 [https://aviationbenefits.org/environmental-efficiency/climate-action/offsetting-emissions-corsia/corsia/who-volunteers-for-corsia/], unless the country decides otherwise.

2 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG

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Plant Operation Start Date	Transport Biofuels	Transport Renewable Fuels of Non-Biological Origin
After October 2015	60%	-
After January 2021	65%	70%
After January 2026	65%	70%

Additionally, RED II stipulates that:

- areas of high carbon stock (wetland, forest, and peatland) should not be used for fuel production; and that
- land with high biodiversity should not be used for biofuels production.

The Directive also foresees a 1.2x multiplier that may be applied to biofuels supplied to the marine and aviation sector. The rationale of the implementation of a multiplier emanates from the fact that aviation fuels currently receive the same policy incentives as those given to road fuels. Nevertheless, road fuels are of a lower quality — meaning that they require less processing to produce than aviation fuels. Unless the latter are prioritised in policy frameworks, producers are highly likely to focus on road transport. Applying a multiplier of 1.2x would urge fuel producers to invest in aviation fuel production instead of using the same feedstock to produce road fuels.

RED II is in the process of being updated[3] to fall in line with the aspirations of the European Green Deal and the 2030 Climate Target Plan. Although the details of the RED II revision are not known yet, the contributions to the consultations on the Inception Impact Assessment for the revision of RED II suggest that the overall RES ambitions will be raised[4].

Under the European Green Deal, the **ReFuel EU Aviation** initiative was established to ramp up the production, deployment, and supply of affordable, high quality SAF in Europe. Although the outcome of this initiative is not yet known, its adoption by the European Commission is expected to take place during 2021, and it looks like the establishment of a SAF blending mandate is chosen as the most prominent measure. More specifically, a SAF blend obligation of 5% will be set for 2030 and will ramp up to a staggering 63% SAF blend mandate in 2050. Moreover, there will be sub-targets for SAF technology pathways with lower technology readiness levels (TRLs) — such as ATJ, FT combination, and PtL. Only renewable fuels of non-biological origin (RFNBO) and fuels made from the feedstocks listed in Annex IX are currently proposed for inclusion in the mandate.

Under RED II, the EU countries are obliged to meet the 14% transport sub-target — meaning at least 14% of the total energy consumed in transport should come from renewable energy — and renewable energy from the aviation sector could count towards the European transport obligation. That said, if the SAF to be produced in Ethiopia and sold to the international market complies with

3 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12723-Sustainable-biofuels-bioliquids-and-biomass-fuels-voluntary-schemes-implementing-rules-_en

4 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12553-Revision-of-the-Renewable-Energy-Directive-EU-2018-2001

the sustainability criteria of EU RED II, **EU countries will be able to include these volumes when calculating the extent to which they have fulfilled their renewable targets.**

1.3 Technology Pathways to Sustainable Aviation Fuel

Despite the relative infancy of the SAF sector, it has achieved noteworthy progress. To date, nine SAF production pathways (including two pathways for co-processing SAF, as seen in Figure 2) are certified by the *American Society for Testing and Materials* (ASTM) for use in commercial aviation — out of which only the HEFA technology (i.e., oil-to-fuel pathways) has reached full commercial scale. Another family of conversion technologies with a high degree of readiness for commercialisation is fuel production via Fischer-Tropsch (FT) synthesis (biomass-to-fuel pathways). A third family of feedstocks capable of producing SAF is sugars and starch (ATJ pathway). It is noted that a fast track for fuel approval has also been introduced, which is a considerable step forward for the SAF industry.

These aviation biofuels are drop-in fuels, which means that they can be directly blended with fossil fuels, but with differing blend limits — depending on the production pathway. The SAF production pathways differ from each other in terms of the technology readiness level (TRL), fuel readiness level (FRL)[5], and GHG emissions.

HEFA-SPK (Hydroprocessed Esters and Fatty Acids to Synthetic Paraffinic Kerosene)

HEFA is produced by the conversion of vegetable oils or waste oils — such as used cooking oils (UCO) and fats. It can be used as a 'drop-in' blending component to produce diesel and aviation fuels. The hydrotreatment process in question consists of thermal decomposition, hydrogenation, and isomerisation reactions to produce diesel, and an additional selective cracking process to produce aviation fuel (i.e., synthetic paraffinic kerosene). The GHG emissions savings involved can be 53–89% compared to fossil fuel as per RED II's comparator, depending on whether virgin vegetable oils or waste fats and oils are used[6].

(*Maximum blending ratio of 50 %. TRL: 9. FRL: 9.*)

5 https://www.caafi.org/information/pdf/frl_caafi_jan_2010_v16.pdf

6 Targeted Aviation Advanced Biofuels Demonstration Competition - Feasibility Study Ref: ED 13924 | Draft final report | Issue number 1 | June 2020

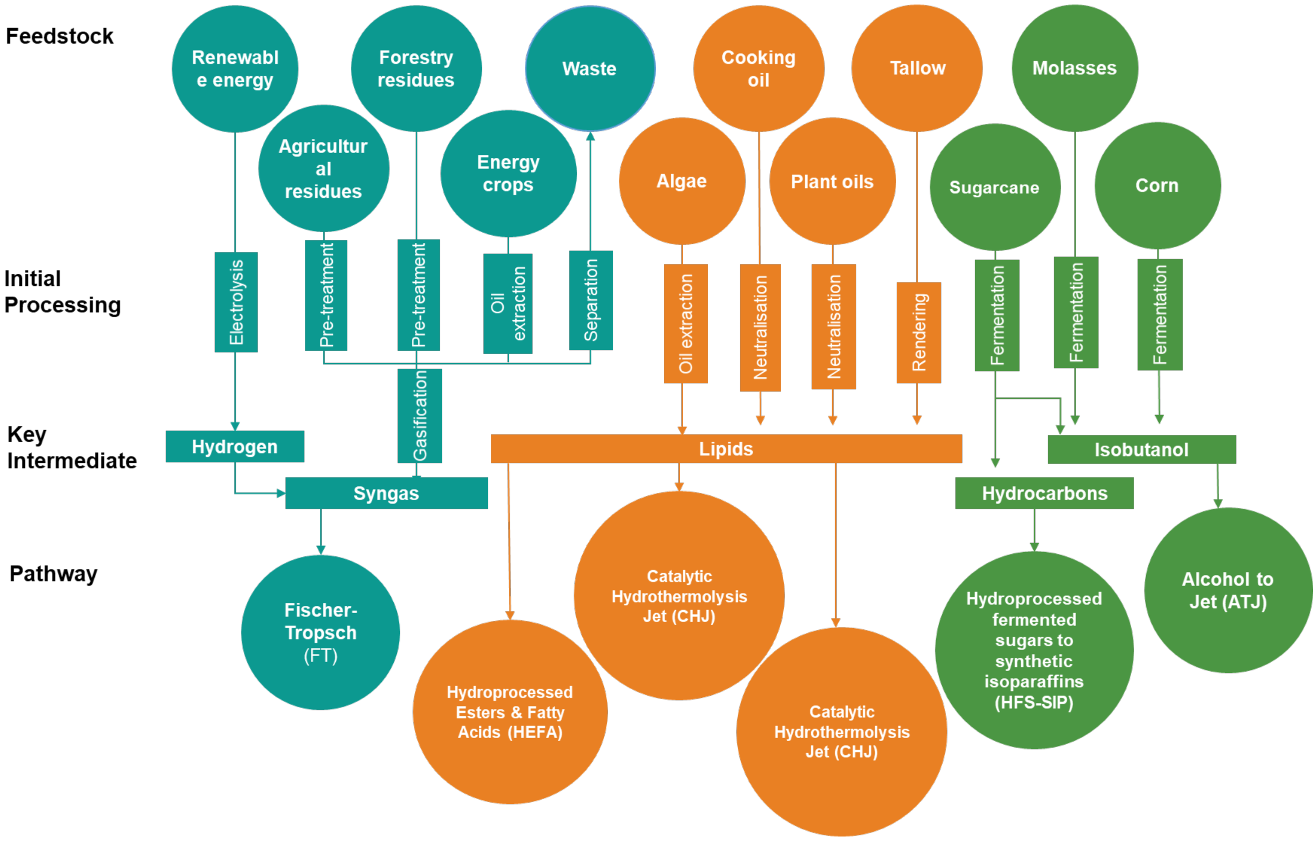

Figure 2: Feedstocks and SAF Pathways (Excluding Co-Processing)

FT-SPK (Fischer-Tropsch to Synthetic Paraffinic Kerosene)

Fischer-Tropsch (FT) fuels are produced via a set of chemical reactions that convert syngas — a gaseous mixture of carbon monoxide (CO) and hydrogen (H2) — into liquid hydrocarbons, including synthetic paraffinic kerosene (SPK). Solid feedstocks, such as biomass, are first gasified to produce syngas, followed by the catalytic FT conversion of the syngas to liquids. FT fuels may be produced from a range of feedstocks, such as coal, natural gas, biomass and/or waste. The GHG emissions savings amount to 56–96%, depending on the GHG intensity of the electricity source used and the energy used in CO2 capture[7].

(*Maximum blending ratio of 50%. TRL: 6-8. FRL: 7.*)

FT-SPK/A (Fischer-Tropsch to Synthetic Paraffinic Kerosene with Aromatics)

This is a variation of FT-SPK, where the alkylation of light aromatics creates a hydrocarbon blend that includes aromatic compounds.

(*Maximum blending ratio of 50%. TRL: 6-7. FRL: 7.)*

7 Targeted Aviation Advanced Biofuels Demonstration Competition - Feasibility Study Ref: ED 13924 | Draft final report | Issue number 1 | June 2020

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HFS-SIP (Hydroprocessing of Fermented Sugars to Synthetic ISO-Paraffinic Kerosene)

The direct conversion of sugars to hydrocarbons may be achieved via biological or thermochemical processes. This process modifies yeast cells to ferment sugars to hydrocarbons that can be used directly as a fuel component. Sugars are converted to hydrocarbons, with GHG emissions savings dependent on the source of the sugars — with 60% being possible if sugar cane is used as the feedstock[8].

(*Maximum blending ratio of 10%. TRL: 7-8. FRL: 5-7.)*

ATJ-SPK (Alcohol-to-jet to Synthetic Paraffinic Kerosene)

The alcohol-to-jet (ATJ) route involves the catalytic conversion of methanol, ethanol, or butanol into kerosene. The typical conversion route is first dehydration of the alcohol/s to alkenes (olefins), followed by oligomerisation into longer-chain hydrocarbons and hydrogenation, with the final step being rectification/distillation into gasoline, aviation fuel, and diesel fractions. Catalytic processes are being developed that yield high fractions of aviation fuel (50%) as opposed to gasoline (15%) and diesel (35%). GHG emissions savings are 65–87%, depending on the production of the alcohol[9].

(*Maximum blending ratio of 50%. TRL: 6-7. FRL: 7.*)

CHJ (Catalytic Hydrothermolysis Jet Fuel)

Waste oils or energy oils (i.e., soybean oil, *Jatropha curcas* oil, camelina oil, carinata oil, tung oil) are catalytically converted to paraffin, isoparaffin, cycloparaffin, and aromatic compounds, which are then fractionated — and the naphtha, jet fuel, and diesel fuel are separated. GHG emissions savings are 80–82%[10].

(*Maximum blending ratio of 50%. TRL: 6. FRL: 7.*)

HC-HEFA-SPK (Hydrocarbon-Hydroprocessed Esters and Fatty Acids to Synthetic Paraffinic Kerosene)

Oils found in a specific alga (*Botryococcus braunii*) yield bioderived hydrocarbons that are hydroprocessed. GHG emissions savings are 53–89%, depending on whether virgin vegetable oils or waste fats and oils are used.

(*Maximum blending ratio: 10%. TRL: 5. FRL: 7.*)

Co-Processing

Up to 5%, by volume, of vegetable oils, waste oils, and fats are processed along with conventional crude oil feedstocks in existing refining complexes. It is not a SAF-focused production pathway per se, but more a result of the approval of co-feeding a small percentage of vegetable oil into a

8 Targeted Aviation Advanced Biofuels Demonstration Competition - Feasibility Study Ref: ED 13924 | Draft final report | Issue number 1 | June 2020

9 Targeted Aviation Advanced Biofuels Demonstration Competition - Feasibility Study Ref: ED 13924 | Draft final report | Issue number 1 | June 2020

10 Targeted Aviation Advanced Biofuels Demonstration Competition - Feasibility Study Ref: ED 13924 | Draft final report | Issue number 1 | June 2020

refining complex. As of today, and for the foreseeable future, HEFA (also known as lipids hydrogenation) is the only certified pathway with commercial scale. However, its main challenge lies in resources, as there is a limited volume of 'advanced' feedstocks' (RED II Annex IX).

(*TRL: 7-8. FRL: 6-7.*)

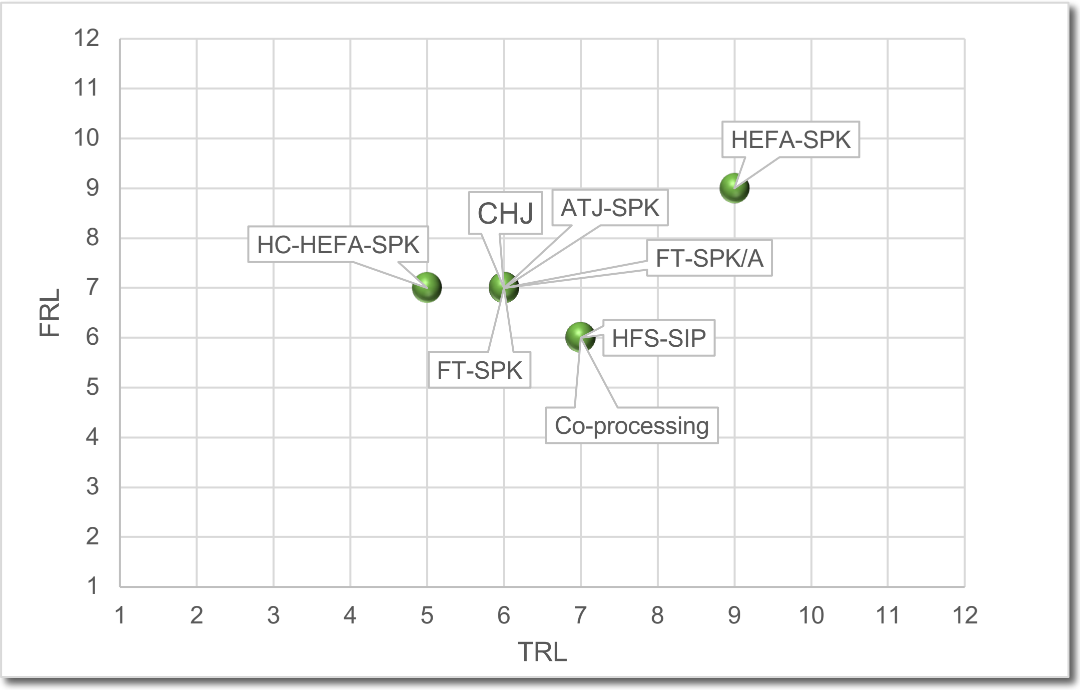

Figure 3: Positioning of the SAF Technology Pathways According to Their TRL and FRL

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1.4 Best Practices for Sustainable Aviation Fuel Development

Despite the numerous challenges holding back the full deployment and commercialisation of SAF, numerous SAF production facilities have been announced worldwide — as shown in

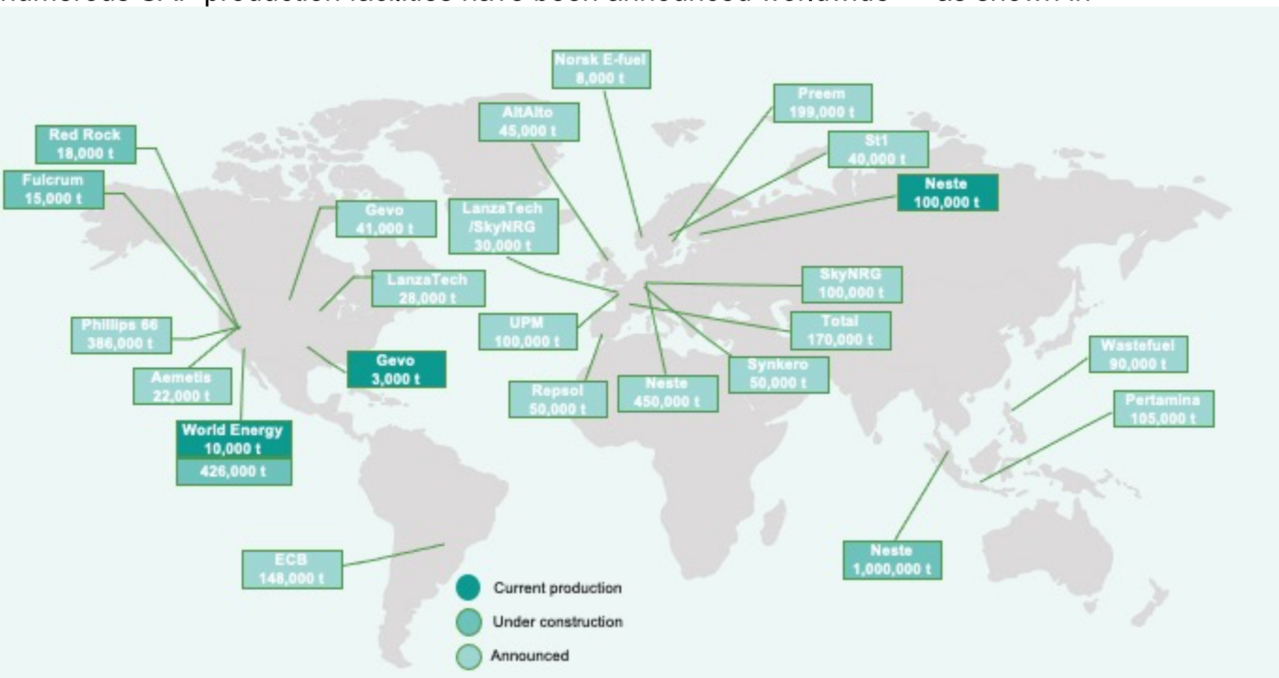

Figure 4.

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Figure 4: Sustainable Aviation Fuel Production facilities and Their Capacities on a Yearly Basis (Tons Per Year)[11]

1.4.1 Global SAF Producers

Neste (EU and Asia)

Neste has moved away from traditional oil refining and refocused its business on producing renewable diesel, SAF, and feedstock for polymers and chemicals. The company uses HEFA technology to convert vegetable oils or waste oils and fats.

It has already emerged as one of the largest SAF producers, with a current capacity of 137.8 million litres/year at its Porvoo refinery in Finland. It is aiming to produce some 1.4 billion litres/year, starting from 2022 at its under-construction Singapore refinery. It is also targeting a further 620 million litres/year of production from 2023 at a Rotterdam plant, where it is undertaking a feasibility study.

On the policy front of the countries with Neste operations, the Netherlands do not currently have a SAF mandate for aviation, although there will be one in force by 2023, which would regulate fuel suppliers. The Dutch civil aviation sector has presented the Dutch government with its ‘Smart and Sustainable’ plan to reduce its gross carbon emissions originating in the Netherlands by 35% by 2030. It identified seven action areas, including greater utilisation of SAF in the relatively short

11 https://skynrg.com/wp-content/uploads/2021/03/WDB-Action-programme_EN_Final-version3.pdf

term. By 2030, the plan envisages that 14% of all fuel produced will be sustainable — reaching 100% by 2050. This will be done through the scaling up of sustainable fuel from new sustainable raw materials and technologies[12].

World Energy Paramount (formerly AltAir)

World Energy acquired AltAir's world-first commercial scale renewable jet fuel refinery, which produces in the region of 132.5 million litres of SAF per year at its refinery in Paramount, California, from a feedstock of agricultural waste fats and oils. Based on RSB's database (2020) of certified operators, it is an RSB-certified fuel — therefore meeting strict sustainability standards — and is blended with conventional jet fuel at a ratio of up to 30%, resulting in a fuel that has significantly lower life cycle carbon emissions. In general, life cycle carbon emissions from SAF can be at least 80% lower than conventional jet fuel. SAF is supplied to airports through existing airport infrastructure and can be used by airlines without requiring technical modification to their current fleets[13].

Repsol

In February 2021, Repsol successfully produced the first 12.5 million litres of biofuel for aviation at its industrial complex in Tarragona, Spain. Its use as a SAF will avoid the emission of approximately 571 metric tons (MT) of CO2 into the atmosphere. In Spain, the Integrated National Plan for Energy and Climate recognises that biofuels currently represent the most widely available and used renewable technology in transportation. In line with its commitment to energy transition and its ambition to achieve zero net emissions by 2050, Repsol will build the first low-emissions advanced biofuels plant in Spain at its refinery in Cartagena, with an annual production capacity of approximately 312.5 million litres of hydrobiodiesel, biojet fuel, bionaphtha, and biopropane[14].

On the policy front, Spain is proposing to establish a national supply of SAF under EU RED II. The initial objective is for 2% of the total supply of aviation fuel (amounting to approximately 187.5 million litres) to be met through SAF in 2025 (referred to as "the balanced compromise")[15].

Total

Total also began producing SAF at its La Mède biorefinery in southern France and its Oudalle facility near Le Havre in northwestern France. The biojet fuel, made from UCO, will be delivered to French airports — starting in April 2021. Starting in 2024, Total will also be able to produce SAF at its zero-crude Grandpuits platform, southeast of Paris. All these SAFs will be made from animal fat, UCO, and other waste and residue sourced from the circular economy.

Total will not use vegetable oils as feedstock. In this way, it will be able to respond, through its production sites in France, to new French legislation (roadmap to develop a SAF industry) that

12 https://dtnac4dfluyw8.cloudfront.net/downloads/200228_w2w_wp4_saf_policy_brief_final.pdf

13 https://www.shell.com/business-customers/aviation/news-and-media-releases/news-and-media-2020/shell-aviation-and-world-energy-collaborate-to-increase-supply-of-sustainable-aviation-fuel.html

14 https://biofuels-news.com/news/repsol-successfully-produces-first-batch-of-saf-in-spain/

15 https://www.icao.int/Meetings/SAFStocktaking/Documents/ICAO%20SAF%20Stocktaking%202019%20-%20AI2-2%20Cesar%20Velarde.pdf

calls for aircraft to use at least 1% biojet fuel by 2022, 2% by 2025, and 5% by 2030[16]. The French government also plans to introduce a levy of €1.50–€18 on passenger flights from 2020 onwards, depending on the flying class and the destination. It is reported that the government expects to raise €182 million through that levy, to fund green transport infrastructure. The levy would apply to all departing flights. The long-term target is in the context of the National Low Carbon Strategy to reach carbon neutrality by 2050.

The initiative sets out the following recommendations for realising energy transition in aviation:

- Mobilise the necessary volume of raw materials for the aviation sector.
- Ensure that sustainable resources — especially those sourced from the circular economy — are used to produce advanced SAF.
- Ensure the industry is economically viable for all players in the value chain through appropriate incentive schemes.
- Use existing airport logistics distribution networks.
- Support and promote production diversification (Biofuels International, 2020)[6].

Eni

Eni's new plant has commenced production of biodiesel, bionaphtha, bioLPG, and biojet fuel. The Eni biorefinery in Gela, Italy (a transformation of the former petrochemical plant) uses up to 100% of the biomass from UCO — as well as fats from fish and meat processing produced in Sicily — to create a zero-kilometre circular economy model for production.

Castor oil will also be used to feed the Gela biorefinery, thanks to an experimental project to grow castor plants on semi-desert land in Tunisia, thereby completely replacing palm oil. The plant's construction began in early 2020 and the launch of the Biomass Treatment Unit (BTU) completes the second phase of the transformation of the industrial site, which is solely dedicated to sustainable production processes[17].

1.4.2 African SAF Producers

Sunchem SA's operations in South Africa have led to the production of 21,500 litres of oil from the Solaris tobacco plant, converted to biokerosene for test flights in 2016 with Boeing and South African Airways (blend of 30% SAF). The fuel was refined by World Energy Fuels in the US and supplied by SkyNRG, with the initiative being supported by Boeing. In South Africa (similarly to Malawi, Brazil, and Italy), Sunchem — being the licensed owner of Solaris — has established collaboration with local partners (i.e., out-grower farms) and is therefore engaged in cultivating areas significantly smaller than 10,000 hectares.

16 https://www.total.com/media/news/press-releases/total-begins-producing-sustainable-aviation-fuel-in-france

17 https://biofuels-news.com/news/enis-new-treatment-plant-begins-operations/

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The Solaris project in South Africa demonstrated the ability to use locally-produced feedstock to develop biojet fuel that meets the RSB standard [18]— the highest sustainability standard for commercial aviation. It also marked the launch of Project Reya Fofa, which will introduce Solaris-based biodiesel into ground-handling operations at O.R. Tambo International Airport in Johannesburg. The project will encourage an increase in feedstock production and infrastructure to achieve a fully localised value chain for a hydrotreated vegetable oil (HVO) biorefinery in the coming years that will produce biojet fuel and green diesel.

South Africa also hosts the Waste to Wing project, which studies the feasibility of using waste biomass to produce SAF that complies with the RSB standards.

1.5 RSB Certification

The RSB is an international, multi-stakeholder standard organisation that has developed a feedstock- and technology-neutral global standard for sustainability. RSB certification covers fuel, biomass, and material products from bio-based and recycled carbon, including fossil waste. RSB's main "Global" certification scheme has been adapted into various schemes to support various regulatory requirements. These regulatory adaptations (RSB CORSIA, RSB EU RED, and RSB Japan FIT) enable operators in these contexts to use RSB certification to demonstrate compliance with both RSB's stringent sustainability requirements and regulatory requirements for specific markets.

RSB's CORSIA Certification is for use by feedstock producers, refineries, and traders globally to certify CORSIA-eligible SAF. The Standard was recognised by ICAO in December 2020 and specifies requirements for operators along the supply chain to produce SAF that is eligible under CORSIA and complies with RSB's sustainability requirements — thus allowing aviation leaders to make powerful claims on GHG reductions and other important sustainability aspects, such as food security, environmental protection, and human rights. Operators can also opt to certify for CORSIA eligibility only (non-RSB), meaning that they will be required to prove compliance against the two CORSIA sustainability criteria only (GHG and carbon stock). SAF certified this way will only carry the CORSIA claim and will not benefit from the additional sustainability impact or claims provided by achieving full RSB CORSIA certification.

The RSB CORSIA Certification enables the certification of SAF made from the following:

- Primary biomass, such as oil or sugar crops and energy grasses.
- Biomass from end-of-life products and production residues, such UCO, agricultural and forestry residues, and animal fats.
- Municipal solid waste (MSW).

The RSB ICAO CORSIA certification scheme incorporates the five ICAO CORSIA Implementation Elements:

18 The Solaris Project was RSB certified until 2019

- CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes.
- CORSIA-Approved Sustainability Certification Schemes.
- CORSIA Sustainability Criteria for CORSIA Eligible Fuels.
- CORSIA Default Life Cycle Emissions Values for CORSIA-Eligible Fuels.
- CORSIA Methodology for Calculating Actual Life Cycle Emissions Values.

The RSB CORSIA certification process includes these four steps[19]:

- Application.
- Selection of certification body.[20]
- Preparation for audit.
- Completion of audit.

RSB also provides RSB EU RED Fuel Certification, which has been designed for fuel producers, traders, processors, and transporters working within, or trading with, the European Union. It is recognised by the European Commission to prove compliance with the requirements of the EU Renewable Energy Directive (RED), as well as demonstrate adherence to RSB's own stringent sustainability principles. RSB is expected to achieve recognition under the recast requirements of RED II by the end of 2021[21], having fulfilled all required assessments at the date of publishing. The scheme describes how to produce biofuels in a way that enhances long-term environmental and social outcomes, as well as guarantee compliance with the EU sustainability criteria and traceability requirements for biofuels and bioliquids.

The RSB EU RED Fuel Certification enables certification all types of feedstocks and covers the following environmental and socio-economic criteria:

- GHG emissions saving.
- Carbon stock preservation.
- High-biodiversity protection.
- Protection of water resources, air, and soil.
- Worker rights.
- Land rights
- Rural development and local food security.

19 https://rsb.org/rsb-corsia-certification/

20 RSB has two accredited certification bodies: Control Union Certifications B.V. and SCS Global Services

21 https://rsb.org/2021/08/03/rsb-and-eu-red-ii-important-updates/

RSB has also developed a Low ILUC Risk Biomass Module to be used jointly with other RSB certification types, which enables operators to make the additional claim that an RSB-certified feedstock or product poses minimal risk of causing indirect land use change.

RSB defines the following three indicators to be assessed for low ILUC feedstocks:

- Additional biomass is produced through a yield increase.
- Biomass is produced from land that was not previously cultivated or was not considered arable land.
- Biomass is derived from existing supply chains and does not require dedicated cultivation of arable land.

The RSB EU RED Fuel Certification process includes the following four phases[22]:

- Application.
- Preparation for audit.
- During the audit.
- Completion of audit.

22 RSB Procedure for Operators Taking Part in the RSB Certification System (RSB-PRO-30-001), Version 3.2., Publication Date: 1 May 2020

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2. Situational Analysis

2.1 Energy Profile of Ethiopia

Ethiopia's energy sector relies heavily on traditional biomass energy sources. Solid biomass is the primary source of energy in Ethiopia, with an 89% share of Ethiopia's total energy supply in 2018. Biomass distribution across the country is uneven, with the northern highlands and eastern lowlands having low biomass cover. Petroleum supplies about 8% of total primary energy, with electricity and coal supplying only 2% and about 1%, respectively. Nearly 90% of Ethiopia's total energy utilisation is accounted for by household use[23] .

Ethiopia's total electricity production reached 4,478 MW in 2021. This figure comprises 4,069 MW from hydropower, 384 MW from wind power, and 25 MW from municipal waste power[24] (

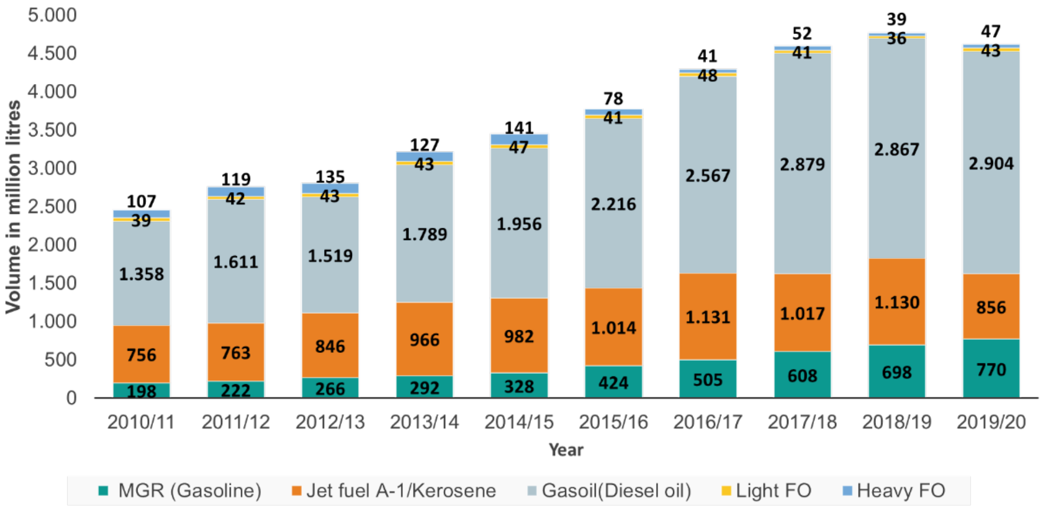

Figure 6).

Ethiopia's economic expansion has led to a rapid increase in the consumption of fossil resources. It is not yet an oil-producing country, but the government has indicated plans to explore oil fields. The country' s fuel demand is met entirely through imports. Ethiopian Petroleum Supply Enterprise (EPSE) is a government monopoly that supplies petroleum products to domestic distributors after purchasing them from international suppliers.

As shown in Figure 6, the country's annual fuel import volume has been growing steadily at an average annual growth rate of 8–13% in the last 10 years. The annual total petroleum products import in the 2019/20 fiscal year reached around 4.6 million litres, which is worth 2.2 billion US dollars (USD)/85.6 billion Ethiopian birr (ETB). Imported petroleum products account for most of the total import expenditure for the country and absorb around 60% of the total export earnings. More specifically, the import of aviation fuel has increased by 49.4% and of diesel fuel by 111% within 2010–2018.

23 MOWIE (2016) National Energy Balance

24 Ethiopia Development Plan (Road to Prosperity), 2021–2031, Ethiopia Plan and Development Commission, 2021.

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Figure 5: Electricity Production Potential

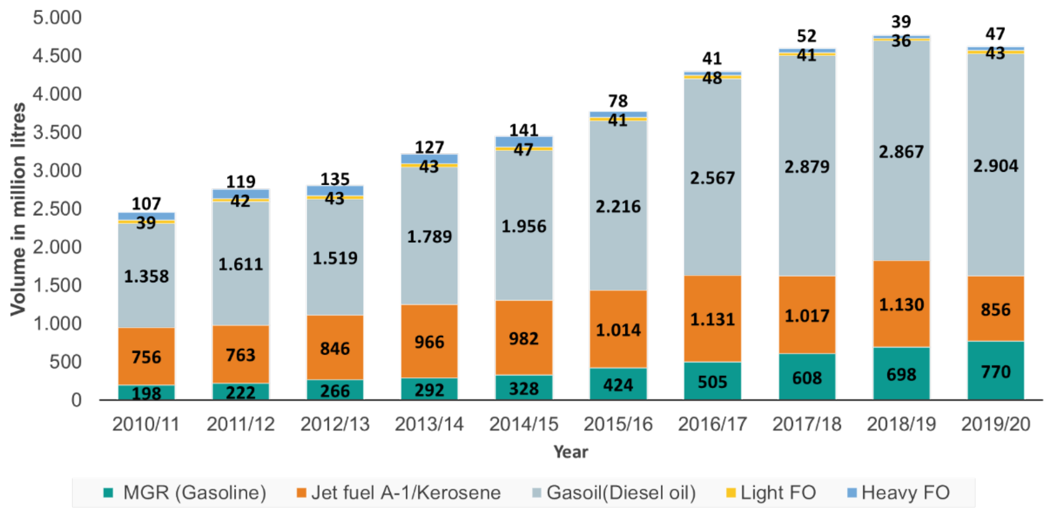

Figure 6: Ethiopia's Annual Fuel Import Volume

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The country's fossil fuel demand is expected to increase considerably in the next 10 years, with the aviation fuel demand forecast for Ethiopian Airlines (shown in Figure 7) expected to double over that time frame.

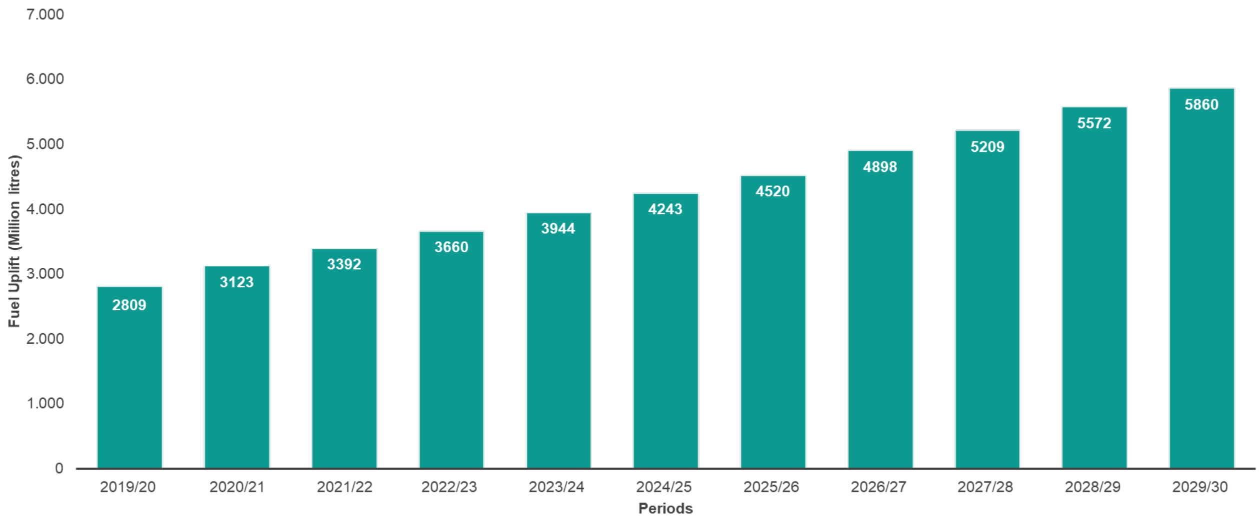

Figure 7: Ethiopia's Aviation Fuel Projection for the Next 10 Years

2.2 Ethiopia's Biofuel Sector Status

Ethiopia is one of the countries in Africa with the highest biofuel potential, and the government has proposed that about 23.2 million hectares of 'marginal' land be converted for biofuel feedstock production — mainly *Jatropha curcas*. The government also issued a biofuel strategy in 2007 to encourage domestic biofuels production, with the objective of reducing the dependence on high-cost fossil oil[25] .The strategy was developed during a period of elevated international interest in biofuels due to record high petroleum prices and was formulated by the then Ministry of Mines and Energy.

Many of the concerns that are important for the sustainable development of biofuels were addressed by the 2007 strategy. However, there are still some important elements that the strategy failed to address. The strategy did not include the Environmental Impact Assessment as a mandatory process for new and expanding biofuel projects. It also stated that less fertile and marginal or degraded lands should be used for cultivation of energy crops that are used for production of biodiesel but failed to define what 'marginal land' means, leaving the method for the estimation of available land unclear. The strategy also did not include any targets in terms of

25 Ministry of Mines and Energy, Biofuel Development and Utilization Strategy; Addis Ababa, Ethiopia, 2007.

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achieving a certain market penetration level or time frame, leaving no benchmark for monitoring the progress of the strategy against specific cross-sectoral activities and timelines.

Following the development of the national biofuel strategy, some biofuel investment activities in different regions of Ethiopia — with a focus on bioethanol and biodiesel — have been undertaken[26].

Bioethanol

Bioethanol production in Ethiopia is integrated with sugar production, as the common feedstock for both is sugarcane. Ethiopia has been producing bioethanol from molasses — the sugar by-product — for more than 30 years. As of today, the production of ethanol is significantly lower than the projected target (about 300 million litres) because of the construction delay of the new sugar factories.

Ethiopia developed its ethanol-gasoline blending standards after the release of its biofuel strategy. In 2009, the country embarked on a 5% blend of bioethanol (technically known as E5) with 95% gasoline, which was doubled to 10% two years later — although the ratio sometimes drops back to 5% when ethanol production is low. Since the launch of blended fuel, 64 million litres of ethanol have been blended with gasoline, saving around USD 50 million[27]. A very ambitious target of utilising 412 million litres of ethanol for cooking has been set, with only a small portion of it attained so far[28]. If Ethiopia vigorously works on fuel switching, gradual substitution of kerosene for cooking with ethanol could save USD 1.135 million in foreign exchange over the next 15 years. The demand for ethanol as cooking fuel by 2020 and 2030 is estimated at about 461 and 679 million litres per year respectively[29].

Biodiesel

Ethiopia also has a strong plan to reduce imported diesel through blending with biodiesel for vehicle fuel consumption. Its biofuel strategy has stipulated that biodiesel development should take place exclusively through the private sector, unlike its bioethanol investments. Despite the ambitious government strategy and the potential economic, environmental, and social benefits of biodiesel, the development of biodiesel in Ethiopia remains limited. The major reasons for the failure of the private sector to invest in biodiesel are the low feasibility of large-scale biodiesel projects, excessively high initial investment costs in marginal areas, low yields, lack of support from the local community, and a significant reduction of the incentives provided to motivate investment in biodiesel.

26 Contextual Analysis of the Biofuel Sector in Ethiopia, RSB, Dec 2019.

27 Contextual Analysis of the Biofuel Sector in Ethiopia, RSB, Dec 2019.

28 Ethiopia Growth and Transformation Plan II (GTPII); Addis Ababa, Ethiopia; 2016

29 Gaia, Association. Ethanol for Cooking Programme in Ethiopia. Addis Ababa, Ethiopia, 2014.

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2.3 Feedstock and Land Availability

Ethiopia has substantial variation in altitude, ranging from 125 m below sea level up to 4500 m above sea level. These topographical differences result in different climatic zones, making Ethiopia an attractive location for producing a large variety of crops.

The country's total land area coverage is about 111.5 million hectares, of which 74.3 million hectares is suitable for annual and perennial crop production. Of the total land area of the country, about 45% (50.2 million hectares) is highland, with the rest being lowland. More specifically, a study conducted by the Ministry of Water, Irrigation and Energy — in collaboration with Wondo Genet Agricultural Research Center — identified 17.6 million hectares of land as highly suitable for *Jatropha curcas* production.

From the total arable land, around 18 million hectares is currently cultivated under rain-fed crops. The irrigation potential of the country is estimated to be around 4.3 million hectares, but currently only a small part is being utilised[30].

Ethiopia's suitable land, favourable climate, and abundant water availability have endowed the country with immense biomass resources. These resources remain sustainable in the country due to extensive non-commercial usage. Because of this, Ethiopia has a great potential to become a major world player in biofuel feedstock development.

The selected feedstocks fall into one of the following categories:

- Known to be used to produce SAF (e.g., agricultural residues, municipal solid waste, and Solaris tobacco).
- Abundant in Ethiopia (e.g., Ethiopian mustard, *Prosopis juliflora*, and water hyacinth).
- Included in the strategy for the short-term biofuel development plan (e.g., sugarcane, *Jatropha curcas*, and castor).

Sugarcane

The potential of untouched fertile as well as irrigable land for sugar cane development in Ethiopia is estimated as **1.4 million hectares**. The country's favourable climatic environment and soil type are proven to cultivate up to 162 MT of sugarcane per hectare[31]. This gives the country a comparative advantage for sugar and bioethanol production from sugarcane.

In 2017/18, about 29,536.49 hectares of land was utilised for sugarcane production by its smallholders, yielding an estimated total of 1,347,035.01 MT. It is mainly used in household consumption — not for industrial purposes[32]. On the other hand, government-owned sugar industries in the country have developed sugarcane on about 100,000 hectares of land.

30 https://www.investethiopia.gov.et/index.php/investment-opportunities/strategic-sectors/agriculture.html

31 Ethiopian Sugar Corporation, Ethiopian Sugar Industry Profile, Addis Ababa, Ethiopia, 2019.

32 Gashaw, E.T., Mekbib, F., Ayana, A. Sugarcane Landraces of Ethiopia: Germplasm Collection and Analysis of Regional Diversity and Distribution. Hindawi-Advances in Agriculture, 2018.

To date, molasses has been the one and only commercially successful bioethanol production feedstock in Ethiopia. As a result, sugarcane cultivation has a direct and significant impact on ethanol production potential. Bagasse, the residue obtained after the pressing of sugarcane stalks to extract juice at sugar factories, has a carbohydrate content that can be used to produce second-generation biofuels.

Although molasses is the sole bioethanol production feedstock, a significant amount of it is used for cattle fattening and road maintenance, and a small part of it is exported. Apart from this, the sugar industry generates sugarcane bagasse, one of the low-cost agricultural residues found in abundance — with high quality — in Ethiopia. About 80% of the bagasse produced is used for cogeneration to produce steam and generate electricity for the mills. The remaining quantity is discarded since it is not utilised in a rate proportional to its generation.

Upon expansion of the current operational factories and completion of the envisaged ones, Ethiopia is expected to produce approximately 680,000 million litres of molasses and generate 7,154,316 MT of bagasse per annum[33].

Agricultural Crop Residue

Wheat, maize, sorghum, and barley are the four major cereals in Ethiopia (see Table 3), contributing a huge residue generation.

These residues are currently utilised mostly for livestock feed, with some also being ploughed back into the soil to enhance soil fertility or utilised in the production of charcoal and briquettes. The surplus amount of the residues is typically burnt on-farm (slash-and-burn method), leading to GHG emissions.

Crop residues are mostly handled as a liability in Ethiopia because the means to transform them into an asset is lacking. Ethiopia has a potential to recover 250 PJ of bioenergy from the immense crop residues available in the country. Among the residues, maize stalk has the highest potential with 170 PJ $y^{-1,}$ followed by coffee husk, sorghum straw, and wheat straw with potentials of 110.75 and 35 PJ y^{-1}, respectively. Moreover, husk and straw of millet, rice, barley, and soybean and sugarcane bagasse also have a significant potential for bioenergy recovery[16].

Table 3: Agricultural Crop Residue Generation in Ethiopia

Crop Residues	Production (10^3 t) in 2015	Projected Production (10^3 t) in 2020
Maize stalk	12,983	20,909.25
Sorghum stalk	7,657.6	12,332.64
Wheat straw	6,868.9	11,062.43

33 Ethiopian Sugar Corporation, Ethiopian Sugar Industry Profile, Addis Ababa, Ethiopia, 2019.

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Crop Residues	Production (10^3 t) in 2015	Projected Production (10^3 t) in 2020
Sugarcane leaf	421.0	678.02
Rice straw	156.9	252.69
Pulse residue	5,431.7	8,747.81
Barley straw	3,339.35	5,378.06
Vegetable residue	289.12	465.63
Coffee husk	823.2	1,325.77

Jatropha Curcas

Jatropha curcas is grown in many parts of Ethiopia due to the favourable air conditions and suitability of the soil. Traditionally, it is used as a hedge, medicinal plant, or structural means to conserve soil and water. The plant has been promoted globally as a biodiesel feedstock, in addition to its ability to rehabilitate degraded land. Likewise, its utilisation for biodiesel development is being promoted in Ethiopia. Considering that, the Federal Investment Commission and the regional investment offices issued licences for several local and international private and non-private *Jatropha curcas* developers.

The productivity of *Jatropha curcas* varies from one agro-ecology to another, depending on the soil type and climatic conditions. According to different studies, the productivity of the plant is estimated at between 0.5 and 12 MT of seed per hectare. A recent study[34] based on the rainfall, temperature, soil type, and altitude required to grow *Jatropha curcas*, showed that Ethiopia has an estimated area of 17.66 million hectares of highly suitable land for its cultivation — which accounts for 15.65% of the country's total land. The country's moderately suitable and marginally suitable land account for 45.4% and 38.03% respectively. Only <1% of the country's total land is not suitable for *Jatropha curcas* cultivation.

In terms of regional contribution, the Oromia region, Benishangul-Gumuz region, Amhara region, SNNP region, and Tigray region contribute to 44.05%, 15.22%, 13.48%, 10.43%, and 9.01% of highly suitable land for *Jatropha curcas* cultivation, respectively. The contributions made by the Afar region and Somali region are 4.05% and 2.67%, respectively. However, there is no significant suitable land for its cultivation in the Gambela region and the Harari region (including the two city administrations, Addis Ababa and Dire Dawa). The oil content of Ethiopian *Jatropha curcas* ranged

34 Ministry of Mines, Petroleum and Natural Gas (MoMPN), Biofuel Development Coordination Directorate. Baseline, Suitability Map, and Value Chain Study on Biofuel Development of Ethiopia, Ethiopia, 2018.

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from 29.88% to 34.34%, in which the highest and lowest oil content was obtained from the SNNP and Oromia regions, respectively. Therefore, *Jatropha curcas* populations growing in different regions of Ethiopia do have a remarkable potential for oil production, as their oil content lies within the optimum range of 30–35%.

Castor

Castor (*Ricinus communis*) is a widely distributed plant among the different regions of Ethiopia. It is a non-edible plant, which can potentially be cultivated on marginal lands, meaning that it does not threaten local food production and as such does not create any conflict in the food-fuel nexus. Suitable conditions for its cultivation are a warm and dry climate with 600 to 700 mm of rainfall and an altitude between 1600 and 2600 metres above sea level. Furthermore, castor requires moist, deep, and drained soils for optimal yield. The average maturity period of castor for providing oil-bearing seeds is between four and five months. It has a high oil yield, which is estimated to be between 260 and 1250 kg of oil per hectare[35]. The production quantity, harvested area, and yield of castor oil seed in Ethiopia have shown an erratic fluctuation in the period 2012–2018. The maximum amount of yearly production registered was 15 million litres in 2013. In 2018, the harvested area and the production quantity were 6,627 hectares and 10,930 MT/year[1], respectively[36].

Ethiopia has an estimated area of 33.1 million hectares (29.32% of the total land of the country) that is highly suitable land for castor development. This estimation is conducted based on assessment of the country's rainfall, temperature, soil type, and altitude, and comparison with the optimum castor cultivation requirements. The moderately suitable, marginally suitable, and non-suitable land account for 48.51%, 21.33%, and 0.84% of the total land of the country, respectively. Oromia region takes the highest castor cultivation suitable land share of 42.5%, followed by Benishangul-Gumuz region, SNNP region, and Amhara Region with their 15.93%, 14.72%, and 11.96% contributions, respectively. The contributions made by the other regions are less significant[23].

Ethiopian Mustard

Ethiopian mustard (*Brassica carinata*), locally known as 'gomenzer' is among the oldest oil crops widely cultivated in Ethiopia as an oilseed and vegetable crop. The crop is best grown in the mid to high altitude (2000–2800 m) areas, with temperatures ranging from 14^{o}C to 18^{o}C, and with rainfall ranging from 600 mm to 900 mm during the growing season, as well as in more fertile, well-drained soil that is close to the homestead.

The major Ethiopian mustard growing areas are in Arsi, Bale, Gonder, Gojjam, Wello, Shewa, Sidamo and Wellega with an estimated production capacity of 50–68 MT produced in areas that range between 30,000 and 45,000 hectares of land in Ethiopia over the last five years. According

35 Jung, S.J, Kim, S.H, Chung, I.M. Comparison of lignin, cellulose, and hemicellulose contents for biofuels utilization among 4 types of lignocellulosic crops. Biomass and Bioenergy 2015 83 322–327.

36 FAO, FAOSTAT, (2018) [accessed 23.03.20]

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to the latest Central Statistics Agency report, the average national yield of Ethiopian mustard in the country is less than 1 MT/ha[37].

Its oil content reaches up to 42% with yellow-seeded lines having more oil and protein and less fibre in their seed than non-yellow seeded isogenic lines.

Mesquite

Mesquite (*Prosopis juliflora)* is a non-native plant species commonly found in most of the Afar landscape, which occupies around 1.2 million hectares. Open areas which were used as venues for playing Afar traditional sports are now invaded by *Prosopis juliflora*. The Afar region's total amount of *Prosopis juliflora* biomass and its yield are estimated at 21 million MT/year and 17.8 MT/ha, respectively. The plant is currently used for firewood, charcoal, and construction purposes.

Water Hyacinth

Water hyacinth (*Eichhornia crassipes)* is a well-known invasive weed in lakes across the world and is harmful to the aquatic environment. It is widely regarded as the world's worst aquatic weed, due to its ability to form dense and impenetrable floating mats on the water surface. It is a free-floating, annual, or perennial aquatic plant that can be used as feedstock for short term periods. Since 2011, the weed has invaded Ethiopia's largest lake — Lake Tana. The area covered in Lake Tana is about 3000–5000 hectares.

Solaris Tobacco

Solaris is a high yield GMO-free tobacco (*Nicotiana tabacum*) plant not yet grown in Ethiopia. It is a promising non-food crop for bioenergy, with over 70 different varieties, out of which the one developed by the Sunchem Holding Company can produce 33% of oil and 67% of protein cake. It requires an intensive annual cropping system, with several implications that should be taken carefully into consideration when planning a production model in a country like Ethiopia — where inputs, commercial agriculture, and high-tech agronomy are scarce.

Biological Portion of Municipal Solid Waste (MSW)

MSW is a type of non-hazardous solid waste (except for household hazardous waste) generated by households, businesses, institutions, and light industry (administrative, cafeteria, packaging etc.). The generation of MSW has been growing steadily in Ethiopia — particularly in Addis Ababa. However, estimating quantities of available waste is challenging, due to the absence of reliable statistics and sub-optimal collection rates, especially outside major cities and in rural areas. Based on an average estimated generation of 0.30 kg per capita per day and a projected population size of up to 110 million, the total amount of generated MSW is expected to be approximately 12 million MT/year.

37 https://www.arcjournals.org/pdfs/ijrsas/v5-i3/1.pdf

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MSW availability is affected by the management of waste streams, from collection to disposal. In Ethiopia, waste collection systems do not exist in many areas. On the contrary, waste is dumped along roads, drainage systems, or any other available space. Major issues include the lack of a robust collection framework and the absence of proper disposal facilities — resulting in large quantities of waste not being disposed of properly.

2.4 Investment Framework

The government's economic strategy has been premised on sound macroeconomic policies, diversification by promoting agriculture and industrial development, and creating a business environment that is conducive to investment and supported by infrastructure development.

According to the World Bank's Ease of Doing Business Report, Ethiopia ranked 146th out of 189 countries in the 2015–2016 edition. One of the greatest hindrances to the operating environment remains the strength and pervasiveness of state-owned and party-affiliated firms. Government has furthermore been hesitant to ease restrictions on non-state participation in the energy, telecoms, and financial services sectors.

The five most problematic factors for doing business in the country, as per the Global Competitiveness Report, include the following:

- Poor access to financing.
- Inefficient government bureaucracy.
- Problematic foreign currency regulations.
- Corruption.
- Unsuitable tax rates.

2.5 Infrastructure Availability

2.5.1 Current Production of Biofuels

Biodiesel Plants

Currently, only three biodiesel pilot plants exist in the country. These are owned by Africa Power Initiative (API), Bati Woreda Biofuel Development, and ATRIF Alternative Energy Plc.

Africa Power Initiative (API) is a public-private partnership (PPP) company formed by the Relief Society of Tigray (REST) and smallholder farmers in Tigray Regional State. API started its operations with an area of 3,000 ha in 2009. API distributed *Jatropha curcas* feedstock to local farmers and assisted in plantations. It is also involved in biodiesel production. The company has recently erected a biodiesel pilot plant, which can produce 2,000 litres of biodiesel per day.

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Bati Woreda[38] Biofuel Development was a public-private partnership biodiesel production project, utilising *Jatropha curcas* seed, located in the Oromia Zone of Amhara Regional State. In the initial phase, about 400 farmers from four farmers' associations were organised to form a cooperative for *Jatropha curcas* seed production. A biodiesel plant with a production capacity of 300 litres of biodiesel per day was then constructed by the Environmental Protection Authority (EPA) with a grant obtained from UNDP.

ATRIF Alternative Energy Plc is a private company engaged in *Jatropha curcas* production and processing. It is in the Cheha Woreda of the Guraghe Zone, in the Southern Nations, Nationalities and Peoples' Region (SNNPR). The company has acquired 108 hectares of land for *Jatropha curcas* production and has so far developed 65 of those hectares. The company has erected a biodiesel plant which has a production capacity of 3,000 litres of biodiesel per day.

Ethanol Distilleries

At present, only two ethanol distilleries are operational in the country — located at the Metehara and Finchaa sugar factories, with a combined nominal capacity of 32.5 million litres per annum (35.2% from Metehara and 61.5% from Finchaa). The distilleries produce two types of ethanol: absolute alcohol (99.9 % Ethanol), used for blending with gasoline, and technical alcohol (95% Ethanol), used for stoves, as well as the chemical and liquor industries.

Ethanol production in both distilleries is erratic and far below full capacity (see Figure 8). The main reasons for decreased ethanol production in the two distilleries are the limited supply of sugar cane, the social unrest in the last two years, and the utilisation of outdated technology — particularly in the cogeneration plant of Metehara — which uses a low pressure (about 20 bar) boiler.

38 A 'woreda' is an Ethiopian administrative district.

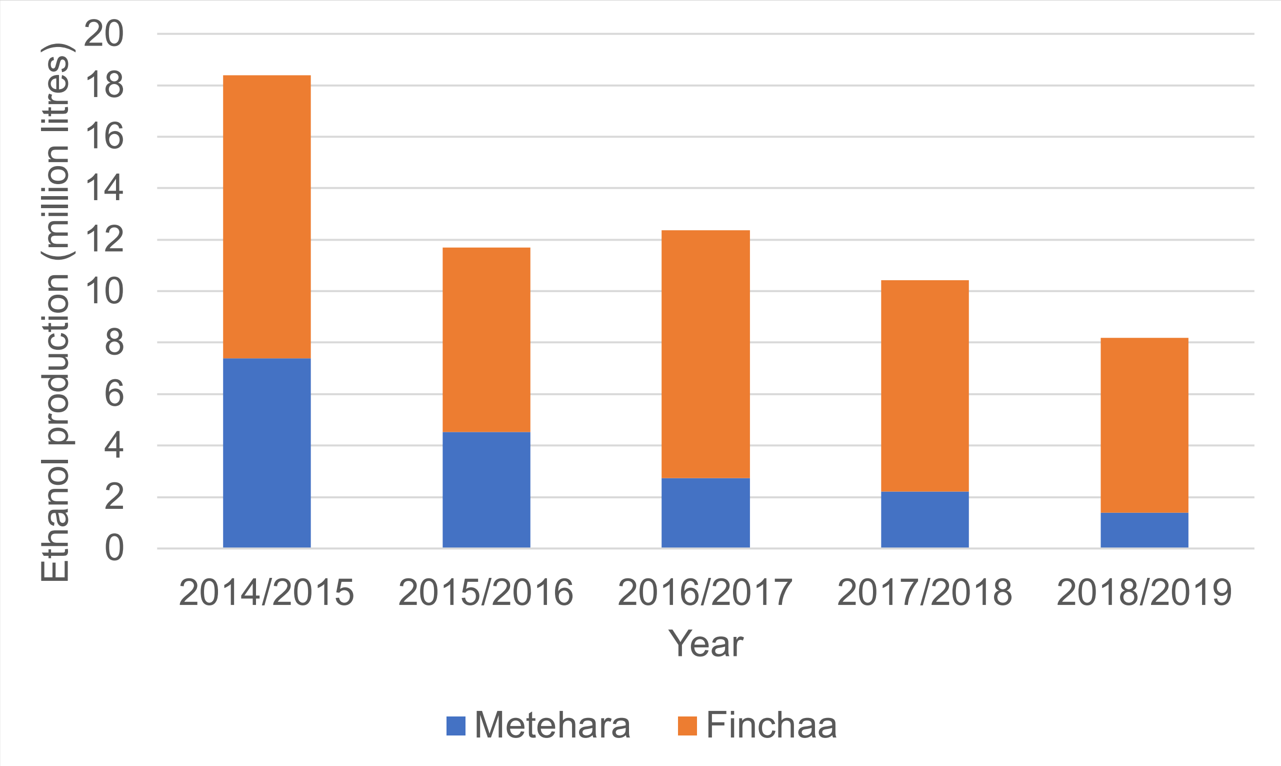

Figure 8: Ethanol Production in the Last Six Years

2.5.2 Transport and Logistics

Ethiopia has made considerable progress in infrastructure development in the last ten years. This includes road, railway, air, and sea transport.

Roads

Ethiopia is highly dependent on road transport for the movement of passengers and freight, as it is a land-locked country. The country's government has prioritised improving the road network and dedicated more than five percent of the GDP to road investments — one of the highest shares in Africa. As a result, the road network increased from 48,800 km in 2010 to 137,777 km in 2020[39]. At the same time, road density increased from 44.5 km/1000 km^2 to 125.3 km/1000 km^2 in the same year. Thus, the average time to reach the nearest all-weather road was reduced from 3.7 hours in 2009/10 to 1.33 hours by 2020[30].

39 Ethiopia Development Plan (Road to Prosperity), 2021-2031, Ethiopia Plan and Development Commission, 2021.

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Railways

Railway infrastructure development is one of the priority programmes of the Ethiopian government. The country's railway line length reached 904 km in 2020. A new electrified railway route eastward to Djibouti is being constructed. This route is the shortest distance from Addis Ababa to a seaport and expected to transport 11.2 million MT of freight. The country also constructed a 34 km Addis Ababa Light Rail Transit in 2015.

Construction of the Mekele-Hara-Gebeya (268 km), Hara-Gebeya-Semera-Assayita (229 km), and Awash-Kombolcha-Hara-Gebeya railway projects is underway. Ethiopia is also developing a rail industry to serve the broader region, including South Sudan, Somalia (Puntland), and northern Kenya[30].

Sea Transport

The state-owned Ethiopian Shipping and Logistics Enterprise is mandated with import and export movement of cargo to and from the seaports of neighbouring countries. The enterprise is currently operating two dry ports, located at Modjo and Semera — 73 km and 588 km from Addis Ababa, respectively. The enterprise is also operating another four sub-terminals, which are located at Dire Dawa, Mekele, Kombolcha, and Gelean — 515 km, 783 km, 376 km, and 34 km from Addis Ababa, respectively[30]. The shipping sector provides uninterrupted sea transport services in and around the above ports with own ships, as well as through slot chartering of major global carriers.

Telecommunications

All major cities in Ethiopia are connected through a telecommunications network. Mobile phones are the primary medium of communication, while internet access is available in major cities and towns. A 3G mobile data service was launched throughout the nation in January 2009, and 4G LTE and LTE Advanced were launched in Addis Ababa[40] in March 2015 and February 2020, respectively. The total number of mobile data subscribers is expected to rise strongly and is currently at 44 million. At present, mobile geographic coverage is 85.5% for 2G, 66% for 3G, and 4% for 4G.

2.6 Ethiopian Aviation Sector

Ethiopian Airlines is the largest airline group in Africa. It is one of Ethiopia's major industrial entities, with an operating profit of USD 260 million in the 2018/19 fiscal year, and it serves about 100 international and 21 domestic destinations.

As part of its fast and profitable growth plan, Ethiopian Airlines is busy implementing a 15-year growth strategy, planning to become a USD 25 billion company by 2035, from the current USD 4.1 billion. It is also building a new airport in Bishoftu, at a cost of USD 5 billion. By 2035, the airline

40 Ethiopia – Telecommunications Service Licenses Expression of Interest, ETHIOPIAN COMMUNICATIONS AUTHORITY, 2020.

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plans to transport more than 15 million tourists to Ethiopia. Based on this expansion plan, it has projected its fuel demand will reach about 5,678 million litres by 2030[41].

In Ethiopia, air transport and foreign tourists arriving by air are estimated to support 5.7% of the nation's GDP and about 1.1 million jobs [42]. The air transport industry, including airlines and its supply chain, are estimated to support US $1.54 billion of the Ethiopian GDP, with spending by foreign tourists supporting a further US $2.61 billion of the GDP.

Africa is the largest market for passenger flows to or through Ethiopia, followed by the Middle East and Asia-Pacific. In 2017, 4.3 million passengers arrived in Ethiopia from Africa (60% of total), 1 million passengers from the Middle East (14% of the total), and 900,000 passengers arrived from the Asia-Pacific (12%)[33].

Ethiopia's air transport market is predicted under the 'current trends' scenario to expand by 226% over the next 20 years, with annual passenger journeys increasing from 7.2 million in 2017 to 23.5 million per year by 2037. This would support approximately US $13.5 billion of the GDP and almost two million jobs[33].

Air transport is well-known as being an intensive emitter of GHG emissions. In 2010, Ethiopia's air transport contributed 23% of the country's transport-related emissions (1.1 Mt of CO2e) [43]. With the intention of achieving a low-carbon footprint, the country launched its Climate Resilient Transport Sector Strategy in 2017 to reduce or offset emissions of GHG produced through air transport as much as possible, with the following targets:

- Improve fleet fuel efficiency of 0.8% p.a. up to 2030.
- Introduce the use of biofuels (up to 10% of mix).
- Introduce operational as well as surface, terminal, and technical support facilities emission reductions of 20% every seven years.

The Ethiopian Civil Aviation Authority, as an aviation regulatory body, has prepared Ethiopia's draft state action plan[44] — a voluntary reporting tool for relaying information on actions to address CO2 emissions from international aviation to the ICAO. The country's draft action plan does not however specify SAF utilisation as a measure to mitigate CO2 emission.

41 Personal communication with steering committee member from Ethiopian Airlines.

42 The Importance of Air Transport to Ethiopia, 2020, IATA.

43 Ethiopia Climate Resilient Transport Sector Strategy, 2017.

44 Ethiopia's Draft State Action Plan for Reduction of CO2 in International Aviation, 2017, Ethiopian Civil Aviation Authority.

3. Analysis

3.1 Country-Level SWOT Analysis

The strengths, weaknesses, opportunities, and threats of Ethiopia regarding the production of SAF are summarised as follows:

Strengths

- Agriculture plays a leading role in the Ethiopian economy.
- Solid industrial development strategy and roadmap, including the creation of industrial parks.
- Rapid economic growth and the aspiration to achieve middle-income status by 2025.
- Expansion of the sugar industry in the country, which will lead to an increase in the concentration of molasses and bagasse (biofuel production feedstock).
- Strong commitment from the government to biofuel development.
- An attractive investment environment.
- Strong environmental policy.

Weaknesses

- Very shallow biofuel strategy.
- Absence of biorefineries other than sugar industries.
- Absence of broad-scale agriculture that could support the required volumes of feedstocks.
- Limited and low-quality seed varieties.
- No practical experience in advance sustainable fuel technologies.
- Absence of the institutional framework to enact many of its policies.
- Poor public infrastructure such as roads and utilities, hindering supply chain logistics and economics.
- Absence of sustainability certification for feedstock production.
- Lack of adequate financial and technical support for farmers.
- Limited research activities on seed varieties.
- Absence of proper information campaigns for farmers and consumers.
- No obligation for fuel suppliers to blend biodiesel.
- Lack of adequate support, such as pricing, quality control, and standards.
- Lack of harmonisation between policies and strategies.

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Threats

- Highly insecure political scene.
- Climate change poses a significant threat to the economic, social, and environmental well-being of the country.
- Chronic water shortages.
- Potential competing demands for feedstocks for ground-based fuels.
- Poor state of the country's farming sector.
- Deforestation.
- Insufficiently clear government support mechanisms for biofuel developers.

Opportunities

- Feedstock that may be utilised for SAF production is already cultivated in the country.
- Ethiopia's location is ideal for export to the international market.
- Benefits of reducing GHG emissions/carbon trade.
- Ample room to increase energy security as the country relies exclusively on fossil fuel imports.

3.2 Feedstock-Level Characteristic Analysis

The feedstock candidates identified in Section 2.3 Feedstock and Land Availability of this document exhibit varying availability and require varying agro-climatic cultivation conditions and collection mechanisms. The main advantages and disadvantages linked to each of the feedstocks are summarised in Table 4.

Table 4: Feedstocks and their advantages and disadvantages

Feedstock	Advantages	Disadvantages	Required Conversion technology
Sugarcane	• Proven high yields • Large scale plantations available • Non-invasive • Availability of irrigable land for sugarcane cultivation	• Needs irrigation • Is an intensive crop (requires mechanisation for harvesting) • Very few distilleries in the country • Sugarcane yield will decrease in the future	ATJ-SPK

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Feedstock	Advantages	Disadvantages	Required Conversion technology
	• Favourable climate conditions and type of soil • Supportive local policy and regulatory framework	because of change in climatic conditions • Food/fuel conflict relating to sugar and molasses	
Crop residue	• Abundant across the country • No additional land is required • Contributes towards the fulfilment of government's rural development strategy • Considered to be additional income for farmers	• Lack of necessary collection and logistics system • Potential feed/fuel conflict as it is currently used for animal feed • Extensively used for erosion prevention and as a mitigation measure against soil carbon depletion	FT-SPK
Municipal solid waste (MSW)	• Abundant across the country • Low-cost feedstock • Contributes to circular economy • Contributes to job creation • Supports integrated waste management	• Lack of a strong regulatory framework for collection • Waste collection systems do not exist in many areas • Poor disposal facilities • Variable supply • Low-density and heterogeneous feedstock	FT-SPK
Jatropha curcas	• Non-edible source • Proven high-yield oil production • Helps with soil erosion, especially in semi-arid areas • Seedcake, which is high in nitrogen, can be used to improve soil	• Takes five to seven years to reach maturity and full production • Seeds contain a highly toxic substance • Plantations cannot easily be mechanised • Considered invasive in many parts of the world	HEFA-SPK

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Feedstock	Advantages	Disadvantages	Required Conversion technology
		• Yields may be significantly reduced if grown on marginal, arid lands without significant additional inputs	
Castor seed	• Non-edible source • High oil content of up to 60% • Suitable for mechanisation on a large scale • Could be cultivated on marginal lands with relatively low water requirements • Seedcake can be used for biochar production	• Performs best on fertile, well-drained soils, therefore it may conflict with food uses on arable lands • Yields depend on location, management practices, and varieties • Growing global markets for use in industrial and pharmaceutical applications • Invasive plant that has medium tolerance to drought • Known to exhaust the soil very quickly and as such requires the addition of fertilisers • Oilseed is currently exported for an established market that uses it for other applications	HEFA-SPK
Ethiopian mustard	• Non-edible source • High oil content of up to 47% • High protein content of up to 45% • Oil is efficiently converted into aviation fuel	• Best grown on more fertile and well-drained soil • Could compete against bread wheat • Low average national yield per hectare in the country • Has similar ecology to bread wheat and barley	HEFA-SPK

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Feedstock	Advantages	Disadvantages	Required Conversion technology
	• Tolerant to both heat and drought • Resistant to many diseases • High-protein residue can be ground into a meal for use in cattle markets • Suitable for crop rotation and intercropping with food crops		
Prosopis juliflora	• Abundant in Ethiopia • Able to even grow in areas suffering from drought • Grows locally • Low-cost feedstock • Harnesses economic benefits of invasive species management	• Invasive species causing severe environmental degradation • Lack of necessary harvesting and logistics system • Current use for firewood, charcoal, and construction purposes	FT-SPK
Water hyacinth	• Perennial, abundant • Non-crop plant • Biodegradable, with high cellulose content • Grows locally • Low-cost feedstock • Harnesses economic benefits of invasive species management	• Has over 90% water content • Challenging harvesting (not easily mechanised) • Complicated logistics • Variable supply • Considerable impacts on biodiversity: displaces native vegetation, decreases light penetration, and prevents birds and other fauna from accessing water	FT-SPK
Solaris tobacco	• High yields could be achieved	• Intensive crop • As an annual and monocropping system, it	HEFA-SPK

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Feedstock	Advantages	Disadvantages	Required Conversion technology
	• Can participate in an integrated crop-livestock system and provide synergies towards more resilient climate-smart agricultural production systems	could threaten plant and animal biodiversity • Requires highly fertile soils that are prioritised for food production • High yields reported in literature not yet verified • Needs to pass through different screening at country level: adaptability, disease, and quarantine	

Given the fact that as of today and for the foreseeable future the sole commercial pathway to produce SAF is HEFA, emphasis should first be placed on the exploitation of **castor and Ethiopian mustard**. Solaris, although suitable in terms of mature conversion technology, needs to first be tested at pilot scale for the reported high yields to be confirmed.

Ethiopian mustard's economics are like those for any regular cash crop — meaning that inputs, yields, and market prices determine its profitability. While Ethiopian mustard does require more inputs than a normal cover crop to realise economic benefits, the crop is relatively easy to grow and can provide an economic return without major investment. It is worth noting that ICAO very recently included Ethiopian mustard (grown as a secondary crop that avoids displacement of other crops) as a renewable fuel feedstock for hydroprocessed esters and fatty acids (HEFA) pathway SAF, with a similar GHG footprint to waste and residuals — such as UCO — for SAF.

Castor, a non-food plant that is resistant to a hot, dry climate and to medium-salinity water, continuously gains ground in the agro-energy supply chains to produce biofuels. As mentioned already in Section 2.4 Investment Framework, Eni has already engaged in producing sustainable biofuels at semi-industrial scale from castor cultivated in a pre-desert area in Tunisia.

Once FT conversion technology becomes economically viable, abundant crop residues, MSW, *Prosopis juliflora*, and water hyacinth could be further investigated as viable solutions, although dedicated feasibility studies need to be initiated beforehand due to the shortcomings presented in Table 4.

4. Gap Analysis

Ethiopia intends to transform its economy over the next 10 years, to limit its net GHG emissions in 2030 to 145 Mt of CO2e or lower (i.e., 64% reduction from the business-as-usual scenario in 2030)[45]. This goal is reflected in the actions included in Ethiopia's Ten Years Perspective Development Plan for 2021–2030 ('The Pathway to Prosperity') where energy and agriculture are mentioned as enabling sectors. More specifically, the focus areas included are "Alternative sources of energy", "Investment and income in energy subsector", and "Improve agricultural output and productivity". Nevertheless, the new development plan does not specify biofuel utilisation — not to mention SAF — for climate change mitigation.

The biofuel industry is transversal in the sense that it touches upon several sectors, all of which are governed by different policies. Reviewing the existing legal and regulatory framework along the various stages of the SAF production value chain (for the value chain approach, see Figure 9) will help to identify gaps and develop targeted actions supporting the advancement of SAF in Ethiopia. The selected policies are also assessed within the prism of the RSB Sustainability Principles.

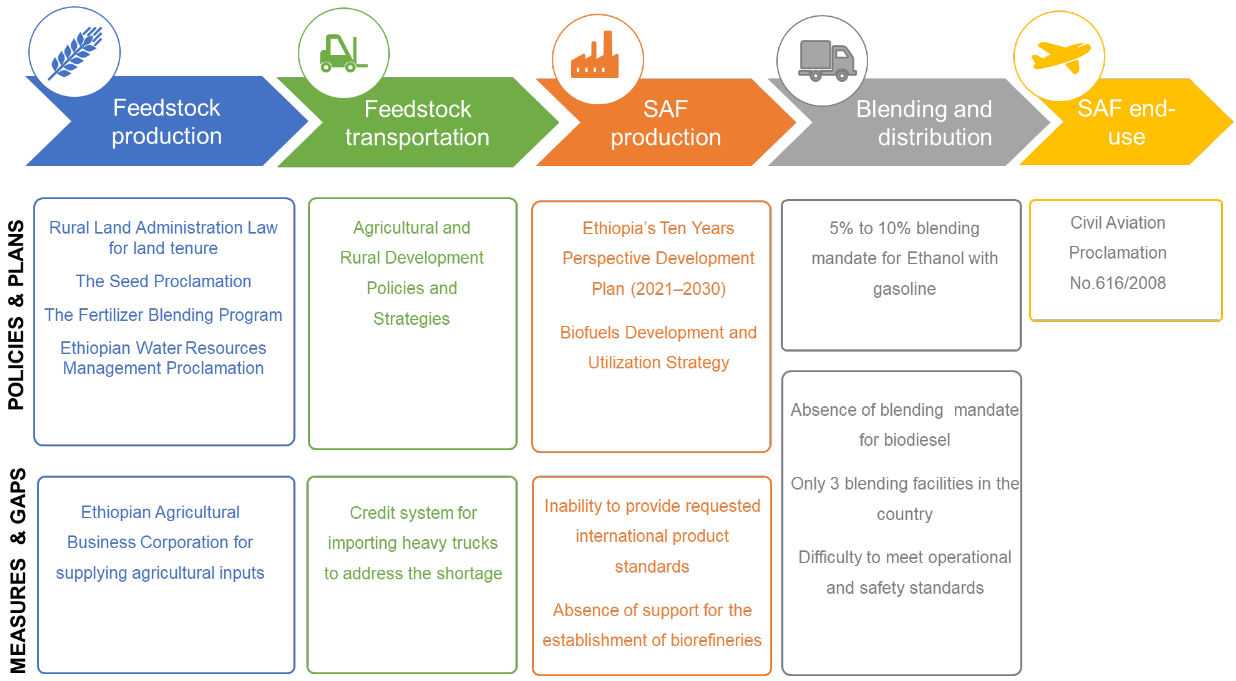

Figure 9: Mapping of Policies and Measures Along the SAF Production Value Chain

The Constitution of the Federal Democratic Republic of Ethiopia, Proclamation No. 1/1995

This proclamation is the basis for the formulation of most of the country's policies and laws. It is under this foundation that other policies and proclamations of the country base their principles. Article 43 of this proclamation states the rights and responsibilities of citizens to improved

45 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ethiopia%20First/INDC-Ethiopia-100615.pdf

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livelihood and development. In addition, Article 44 states that all persons have the right to a clean and healthy environment. Hence, the existing constitution **supports sustainable production and utilisation of biofuel in the country** in general.

Energy Policy (1994)

The Ethiopian Energy Policy states utilisation of indigenous energy resources with the aim of attaining self-sufficiency as the primary government objective in development of the energy sector. The policy encourages the development of alternative energy supplies for the purpose of increasing the national energy supply and also as a means to reduce the burden on the biomass resources, stresses that all development and utilisation of energy resources should be benign to the environment, and — while not explicitly mentioning development of biofuels — **clearly states the need for developing renewable energy resources and substitution of fossil fuels, particularly in the transport sector**. However, it **does not mention air and sea transport**. Therefore, additional directive/policy that explicitly addresses the production and utilisation of biofuel for each transport type is required.

Environmental Policy of Ethiopia (1997)

The environmental policy of Ethiopia was launched with the goals of improving and enhancing the health and quality of life for all Ethiopians, as well as promoting sustainable social and economic development through the sound management and use of natural, human-made, and cultural resources and the environment. The policy promotes the development of renewable energy sources and reducing the use of fossil energy resources — both for ensuring sustainability and protecting the environment — and restricts free movement of alien and genetically modified species without the issuance of permits from the relevant government organisations. It also contains the provision for the enactment of the Environmental Impact Assessment Proclamation.

Furthermore, the policy **promotes environmental impact assessments**, not only regarding physical and biological impacts, but also addressing social, socio-economic, political, and cultural conditions. In general, the policy has many provisions that meet some of the requirements of sustainability — particularly RSB Principle 2 (Planning, monitoring and continuous improvement). However, it still **lacks specific provisions regarding improving environmental and social performance in the biofuel sector**.

Agricultural and Rural Development Policies and Strategies (ARDPS, 2002)

The Agricultural and Rural Development Policies and Strategies (ARDPS) were adopted with the objective of combating desertification and mitigating the effects of drought.

This policy and strategy contain the following key principles: improving farming skills; improving the supply, replication, and dissemination of technologies; ensuring access to land and tenure security; resolving problems of drought-prone regions; improving the agricultural marketing systems; promoting rural finance; and developing the rural energy sector and rural telecoms.

The ARDPS recognises that the development effort in rural areas cannot be limited to agriculture alone. There is a **need for rural** infrastructure **and social development programmes,** and for trade and industry to build upon and support developments in agriculture. As such, the ARDPS addresses some of the sustainability requirements under RSB Principle 5 (Rural and social development). However, **no explicit standard is stated in the document to enforce the provision of rural development benefits to the local community by investors**. Hence, additional directives are required for the different sectors — including biofuels.

Environmental Impact Assessment (EIA) Proclamation (No.299/2002)

This Environmental Impact Assessment (EIA) Proclamation empowers the Environmental Protection Agency (EPA) to prepare procedures, regulations, guidelines, and standards to effectively implement and enforce EIA proclamations. Environmental guidelines are among the tools for facilitating the inclusion of environmental issues and principles of sustainable development into development proposals.

To guide mainstreaming of the principles of sustainability into sectoral projects, sectoral environmental impact assessment guidelines such as guidelines on agriculture, transport, industry, tanneries, and settlements have been prepared. In addition to these, a general guideline for facilitating EIA in all sectors has been prepared. The fundamental purpose of this guideline is to ensure that proponents, the government, and all other interested and affected parties can participate meaningfully in the EIA process.

Since the guideline explicitly states the responsibilities of each party, it helps to eliminate problems that may arise from a lack of understanding of the process, from acting beyond one's mandates and responsibilities or from negligence. Hence, except for the need for specific directives that enforce conducting impact assessments of projects, the **proclamation is adequate for meeting sustainability requirements under RSB Principle 2** (Planning, monitoring, and continuous improvement).

Biofuel Development and Utilization Strategy (2007)

The general objective of the Biofuels Development and Utilization Strategy is to produce biofuel energy from local resources for substituting imported petroleum products and for export purposes. Molasses is the chosen feedstock for ethanol production, while *Jatropha curcas*, castor, and palm are crop types suggested for producing biodiesel.

The strategy stated that 'marginal or degraded lands' should be used for cultivation of crops for biodiesel but failed to mention what 'marginal land' means. The strategy **does not state a target nor time frame for biofuel production** and utilisation in the country. Environmental Impact Assessment is not considered as mandatory for biofuel development. In addition, the strategy focuses on the utilisation of ethanol and biodiesel for land transport and domestic cooking, while **air transport is not mentioned** at all. As such, a new comprehensive strategy — which includes SAF — with clear targets and objectives should be formulated.

Ethiopia's Climate Resilient Transport Sector Strategy (2017)

The Climate Resilient Transport Sector Strategy was launched in 2017 to support the government's vision outlined in the Climate Resilient Green Economy Strategy. The vision of this

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strategy is "to ensure that Ethiopia's national development, poverty reduction and climate resilience goals are promoted by the transport sector". The expected outcomes of the strategy are to reduce exposure to the negative impacts of transport pollution on human health and safety as well as the environment, along with reducing the greenhouse gas (GHG) emissions from the transport network.

The strategy states **specific targets on reducing or offsetting GHG emissions produced for land, air, and sea transport**, among which is the introduction of up to **10% biofuels into the aviation fuels mix**. Hence, the existing strategy strongly supports the utilisation of SAF for air transport in the country.

Ethiopian Water Resources Management Proclamation (No. 197/2000)

The Ethiopian Water Resources Management Proclamation was launched with the purpose of protecting natural water sources from degradation, excessive use, and pollution. It gave authority to the Ministry of Water to issue licences for the development of water resources and permits to discharge wastes.

Article 18(1) of the Proclamation states that a River Basin Authority shall have a river basin plan, to provide a long-term framework for proper water resource management in the basin that will ensure equitable sharing, sustainable development, and use of water resources while maintaining the quality of aquatic ecosystems. As such, the existing Water Resources Management Proclamation meets the standard requirement with regards to RSB Principle 9 (Water), which states that biofuel operations shall include a water management plan that aims to use water efficiently and maintain or enhance the quality of the water resources that are used for biofuel operations.

Rural Land Administration and Land Use Proclamation (456/2005)

The Rural Land Administration and Utilization Proclamation specifies land use and the ownership framework in the country. Investors, including private, government, non-governmental organisations, and social institutions, have the right to acquire land for investment for a definite period — if priority is given to peasant farmers and pastoralists.

Land for investment in rural areas can be acquired on lease from individual rural landholders or from the local government for a specific period, based on the rural land administration law. Where the rural landholder is evicted by the federal government, the rate of compensation would be determined based on the federal land administration law. As such, the existing Rural Land Administration and Utilization Proclamation is adequate for meeting the standard requirement for SAF development with regards to RSB Principle 12 (Land rights).

Ethiopia Investment Proclamation (2020)

The Ethiopian Investment Commission (EIC) launched a new proclamation recently (Regulation No. 474/2020) and has been restructured to promote investment in the country and provide a one-stop shop service for issuing an Investment Permit, TIN certificate, and business licence. For agro-processing industries, the commission issues duty-free, work, and residence permits. The EIC also provides additional services to process the acquisition of land, utilities (e.g., water, electrical power, and telecommunication services) and bank loans.

In the framework of Ethiopia's strategy to attract foreign investors, the latter are offered various incentives — including exemption from income tax for a period of between three and five years — depending on agricultural value added and proportion of exportable products, and 100% import duty exemption for most capital items. Export taxes are also waived for most products[46].

Feedstock Transport

In Ethiopia, most of the rural roads are in poor condition and there is a shortage of heavy trucks in the country. This has imposed significant challenges on agricultural activities in general and increased the price of crops produced. The Government of Ethiopia has embarked on various programmes at one time or the other to address the issue by allocating up to 5% of the GDP every year — but Ethiopia's rural road network is still one of the least developed in Africa.

Recently, with the hope of easing problems in the logistics sector brought on by a shortage of heavy trucks, the Federal Transport Authority (FTA), under Ministry of Transport, and in collaboration with the National Bank of Ethiopia (NBE), initiated a credit system for importing heavy trucks. With the new initiative, the private sector will procure the trucks through a supply credit modality approved by the National Logistics Council.

Blending and Distribution

It is expected that the SAF produced will be sold to the fuel-blending wholesaler petroleum companies in whose depots the blending is done. Ethiopia already has some blending facilities[47] — namely Oil Libya, the National Oil Company (NOC), and Total Ethiopia — with a total of 550,000 litres of blended fuel in storage, which is used for ethanol that can also be used for SAF.

The Ethiopian wholesaler petroleum companies face several challenges, among which are low fuel margins, recurrent foreign exchange shortages, difficulty in meeting operational and safety standards, and operating under an outdated regulatory framework that is no longer in step with the sector's growth. Moreover, the scattered regulatory roles bestowed upon multiple government organs has made the decision-making process highly complex.

Research on Biofuel/SAF Production

Research on biofuel production is very limited and scattered. Addis Ababa University is the pioneer in starting a teaching-learning and research unit in biotechnology in the country, due to establishing the Institute of Biotechnology (IoB). Over the years, other public higher-learning institutions also started offering undergraduate and postgraduate education at MSc and PhD level.

Biodiesel crop selection, productivity, management, and other affiliated activities are performed by the Ethiopian Institute of Agricultural Research, and the Environment and Forestry Research

46 James Keeley, Large-scale land deals in Ethiopia: Scale, trends, features and outcomes to date, 2014.

47 Nile Petroleum, the country's first blending facility, has been shut down in the meantime.

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Institute also performs research on 2G-ethanol and biodiesel raw material. Melkassa Agricultural Research Center has conducted research on *Jatropha curcas* and palm oil and released two palm oil varieties, which are drought-resistant and have a short height suitable for harvesting. Wondo Genet Agricultural Research Center is also actively engaged in research on different biodiesel feedstocks.

Although research has been done on biofuel production at MSc and PhD level, most of it has focused on biofuel production for land transport and domestic cooking. Consequently, the country is in its infancy in terms of technology development — an essential ingredient for industrial development.

Human Resources

Human resources are vital for SAF development in the country, with feedstock processing requiring high-skilled workers — hence the country must continuously invest in human resource development. There is generally a short supply of technically competent and skilled workers in Ethiopia. Most technology-intensive industries still depend on expatriates.

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5. Roadmap

The information discussed in the previous chapters is critically assessed in the prism of putting together a 10-year roadmap and action plan to systematically evaluate the technical, economic, and sustainability aspects of the most prominent pathways; identify and mobilise the main actors and decision makers; and promote favourable policies and legislation to overcome the constraints and bottlenecks associated with the development of a national SAF industry. It is stressed that the success of the roadmap is inextricably linked to a prevailing politically stable and non-violent environment.

The roadmap itself is split into the following three phases (as illustrated in Figure 10):

1. Establish an enabling policy and regulatory environment (2021–2023).

2. Demonstrate the potential and ensure an open economy (2024–2028).

3. Forward-looking plan (2029–2030).

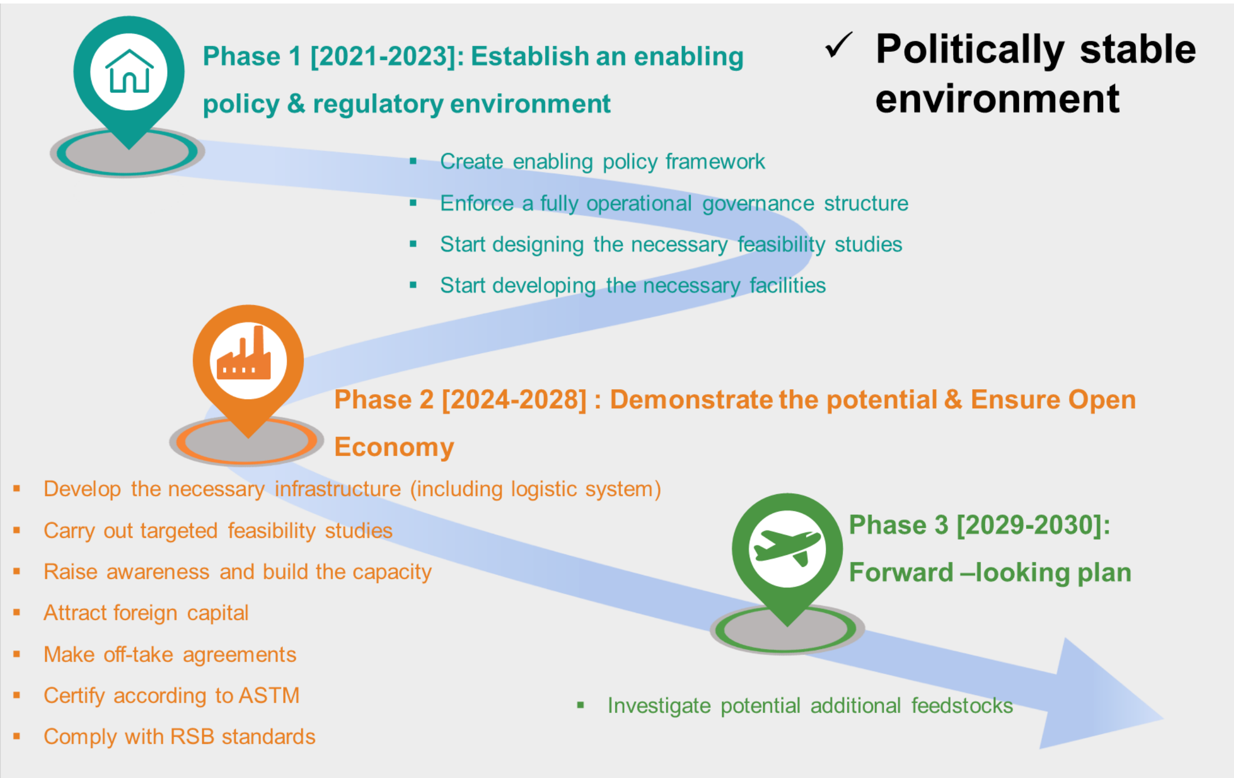

Figure 10: Roadmap Overview

An overview of the individual actions of the roadmap, alongside with the oversight and implementation bodies, is presented in

Table 5. Those actions have different thematic content and their placement in time (

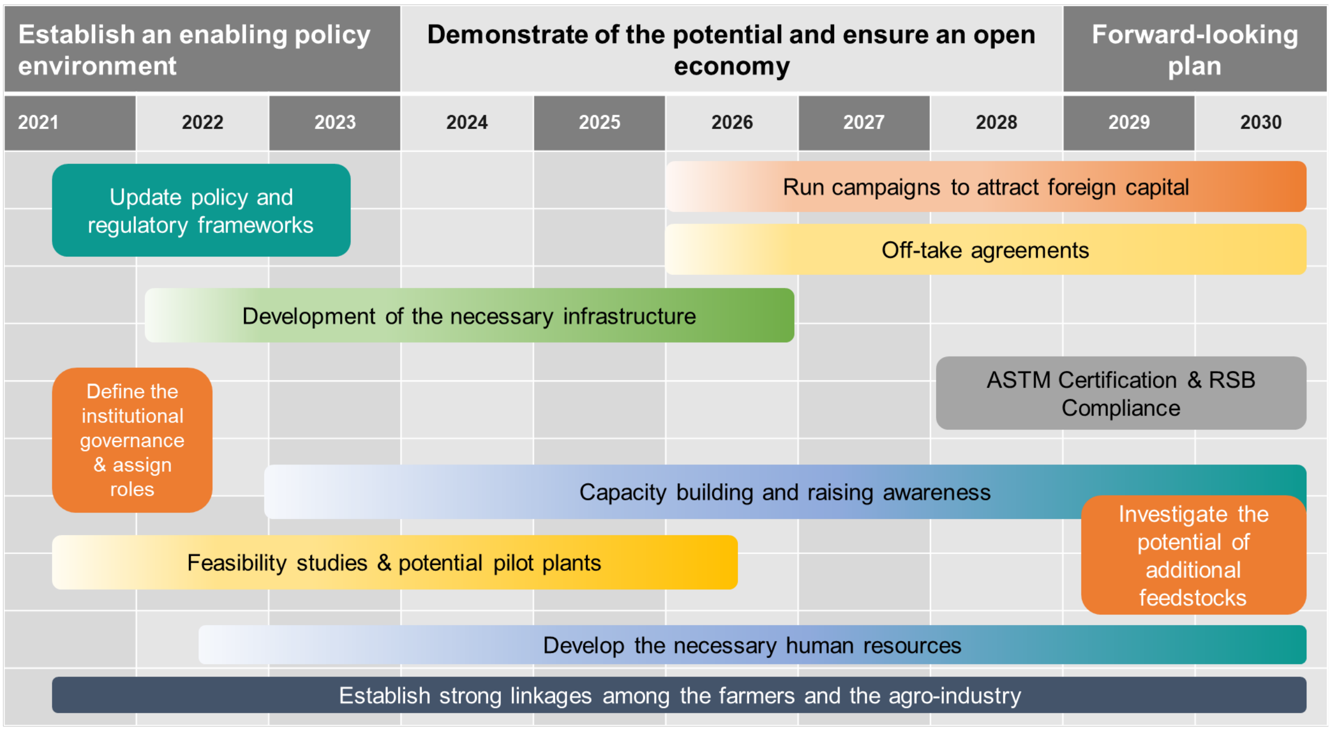

Figure 11) is indicative of the fact that some of them might be prerequisites of others to follow.

Table 5: Roadmap Actions

Phase	Thematic Context	Mandated Bodies	Focus Group (Implementation Bodies)	Targeted Group	Description	Comments
Phase 1: Establish an enabling policy environment	State policy and support	Ministry of Agriculture	Ethiopia Agriculture Research Council	Market players and actors throughout the whole supply chain	Update the biofuels strategy: • Capitalise on the lessons learnt from the unsuccessful version from 2007 • Identify and map the available land for biofuel production	The update of the policy and regulatory frameworks commences as soon as possible. However, knowing that the country is about to enter the elections period (June 2021), delays in the implementation of this action could be observed.
		Environment, Forest, and Climate Change Commission	Environment, Forest, and Climate Change Commission		Update the emission related work and environmental sustainability	
		Ministry of Finance	Ministry of Finance		Arrangement of Investment and finance for biofuel sector	
		National Planning and Developme	National Planning and Development Commission		Alignment to national strategy and policies on green development strategy	

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Phase	Thematic Context	Mandated Bodies	Focus Group (Implementation Bodies)	Targeted Group	Description	Comments
		nt Commission				
		Ministry of Water, Irrigation and Energy	Ministry of Water, Irrigation and Energy		Update the Biofuels Development and Utilization Strategy to include clear SAF targets	
		Ministry of Trade and Industry	Ministry of Trade and Industry		• Include blending mandates for biodiesel • Take into consideration the newly established Investment Proclamation (Regulation No. 474/2020) • Identify and adopt supporting measures, such as: ○ Tax relief ○ Expediting procedures for licensing, etc. ○ Subsidising farmers (e.g., inputs, mechanisation, etc.) ○ Offer protection against price peaks ○ Government buys feedstock at a minimum price if there is no demand	
		Ministry of Transport	Civil Aviation Authority	Market players and actors throughout the whole supply chain	Update of the Action Plan and inclusion of SAF as means to mitigate CO2 emissions	The update of the policy and regulatory frameworks commences as soon as possible. However, knowing that the country is about to enter the elections period (June 2021), delays in the implementatio

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Phase	Thematic Context	Mandated Bodies	Focus Group (Implementation Bodies)	Targeted Group	Description	Comments
						n of this action could be observed.
		Ministry of Peace	Ministry of Peace	Regional and governmental authorities	Ensure alignment of positions between the regional and governmental authorities, as well as clear separation of responsibilities	Considering the country is about to enter the elections period (June 2021), the constitution of the regional and governmental authorities could be altered and lead to a delay of this action.
Phase 2: Demonstrate the potential & Ensure Open Economy	Infrastructure & investments	Ministry of Trade and Industry	Ethiopian Investment Commission	International oil companies	Promote new initiatives like Africa Power Initiative (API)	Although it is part of testing the proof of concept, the action can be initiated as early as within 2022 and is expected to reach its peak once the enabling policy framework is in place.
		Ministry of Trade and Industry	Rural Energy Promotion and Development Centre	Pilot plant operators in the country	Scale up and modify pilot plants to produce SAF as well	
	Feedstock/agriculture	Ministry of Agriculture	Ethiopian Agricultural Research Center	Feedstock producers	Decide on possible crops to be used for *sustainable* SAF production based on targeted feasibility studies	Although it is part of testing the proof of concept, the action can be initiated as early as within 2021 and could stretch in the first years of Phase 2.
			Ethiopian Agricultural Research Center		For crop(s) not previously tested in Ethiopia, develop pilot plants to validate the expected yields	Pilot plants must most likely be combined with feasibility studies. Although it is part of testing the proof of concept, the action can be initiated as early as within 2021 and could stretch in the

Phase	Thematic Context	Mandated Bodies	Focus Group (Implementation Bodies)	Targeted Group	Description	Comments
						first years of Phase 2.
			Ethiopian Agricultural Research Council	Farmers' cooperatives and the public	Building capacity and raising awareness to invert the negative perception of biodiesel that prevails. Suggested activities: • Brief them on the concept • Provide training • Provide inputs and necessary mechanisation	A rather demanding action that should get started once the results from the first feasibility studies are in place, so that the capacity building can be more targeted and effective. Due to advancements in the field of agriculture (e.g., new inputs, etc.), this action can reasonably be expected to be ongoing.
	Infrastructure & investments	Ministry of Trade and Industry	Ministry of Transport	Fuel suppliers and regional distributors	Develop the necessary infrastructure and logistic system for the SAF to reach the country's airports	A time-consuming action that needs to conclude prior to the onset of systematic production of SAF in the country.
		Ministry of Trade and Industry	Ethiopian Investment Commission	International oil companies	Run a campaign to attract foreign capital	Once the enabling policy and regulatory frameworks are in place, along with the necessary feasibility studies, the country should capitalise on them and run the campaigns. This effort could be ongoing and occasionally intensified.
			Ethiopian Investment Commission	International oil companies	• Establish a selection procedure for	Needs to be in place prior to running a campaign. It

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Phase	Thematic Context	Mandated Bodies	Focus Group (Implementation Bodies)	Targeted Group	Description	Comments
					potential foreign investors • Investigate and assist the potential foreign investors with the acquisition of Africa Trade Insurance • Identify the role of the public sector in assisting with the procedure	is expected to be straightforward and brief. A prerequisite is functioning institutional governance with regional and governmental authorities having clear responsibilities and roles.
			Ministry of Trade and Industry	International Oil Companies	Explore possible offtake agreements	Runs in parallel to the campaigns targeted to foreign investors.
	Sustainability standards & certification of final product	Environment, Forest, and Climate Change Commission	Several ministries	SAF producers	Ensure that the value chain complies with RSB sustainability standards	An important action (obtain certification) to be pursued once the systematic production of SAF in the country has commenced.
		Ministry of Trade and Industry	Ethiopian Standard Agency Ethiopian Petroleum Supplies Enterprise	SAF producers	Obtain ASTM certification	To be pursued once the systematic production of SAF in the country has commenced. Typically takes from three to five years.
Phase 3: Forward-looking plan	Feedstock/Agriculture	Ministry of Agriculture Environment Forest and Climate Change Commission	Ethiopian Agricultural Research Center Environment and Forest Research Institute	Feedstock producers	Investigate the potential of additional feedstocks to be converted via the SAF pathways expected to become commercially available	Should commence a couple of years, prior to the end of the roadmap.

Throughout the whole planning period, a continuous effort should be carried out to **establish strong linkages among the farmers and the agro-industry**, as well as a leaner supply chain that avoids too many middlemen. To this end, the presence and operation of Integrated Agro-industrial Parks (IAIP)[48] should be exploited to the fullest, toward a successful integration of smallholder farmers, small-scale processing enterprises, and allied industries in commercial value chains. This will contribute to the transformation of Ethiopia into a significant oil feedstock producer — a prerequisite for the country to be able to deliver significant quantities of fuel in a reliable manner and in a realistic time frame.

A further and rather horizontal action, in the sense that it that should commence as soon as possible and transverse the entire time frame of the roadmap under consideration, is the initiation of curriculum programmes at Ethiopian universities to train the human resources required at the various stages of the value chain.

In **Phase 1**, the GoE should work towards **updating the policy and regulatory frameworks** that will enable and foster the sustainable production of non–fossil-based aviation fuels. Updating the outdated Biofuels Strategy, including air transport in the Energy Policy, and fine-tuning the Biofuels Development and Utilization Strategy to become more effective are a few examples of actions to be taken in the policy and regulatory scene of the country. Specifically, regarding the identification and mapping of the available land for biofuel production, it is noted that the work already performed by the Wondo Genet Agricultural Research Center should be taken into consideration.

Considering the available options from the arsenal of measures, the introduction of a modest blending mandate could have a catalytic effect, as it will incentivise the industry players to explore potential supply chains that are necessary for SAF production — while having a negligible impact on the jet fuel price. Identification and adoption of supporting measures (beyond blending mandates) is also part of this phase. It is proposed that the update of the policy and regulatory frameworks commences as soon as possible. To this end, an official announcement at the highest governmental level would be very useful. Considering that the country is about to enter the elections period (June 2021), possible delays in the implementation of this action are expected.

Institutional governance is also of paramount importance and should be addressed early in the roadmap. Ethiopia can benefit from the already-formed SAF Steering Committee and its members representing various key players in the public sector of the country. However, emphasis should be placed on including entities with leading roles across the whole supply chain, such as generation, utilisation, production, distribution, supply, and use of liquid biofuels. Once this is achieved, the SAF Steering Committee will gain a rounded understanding of the interests and challenges in the SAF sector and, consequently, be able to defend its role and operate in the country's best interest.

Knowing that the composition of the SAF Steering Committee stems from the public sector, this action is also dependent on the outcome of the forthcoming elections. As part of the governance exercise, it is important that the regional and governmental authorities align their positions and separate their responsibilities. Although the development of the necessary biorefineries and blending facilities infrastructure is part of the "demonstration of the potential" phase (i.e., Phase 2), this specific action should be initiated within Phase 1 and have a partial overlap with the implementation of the policy and regulatory arrangements, as it is a very time-consuming activity.

48 https://www.unido.org/sites/default/files/files/2018-08/Integrated-Agro-Industrial-Parks-in-Ethiopia-Overview-document.pdf

In **Phase 2**, where the proof of concept should be tested, the already running actions of the construction of plants and scaling up of the **few existing pilot projects** should be completed. Testing of the proof of concept also entails the initiation of **feasibility studies targeted specifically at the identified feedstocks** potentially suitable for use in indigenous SAF production. However, those feasibility studies can be initiated even earlier (i.e., in Phase 1), and can incorporate environmental and social aspects based on the RSB sustainability framework, giving a more accurate estimation of yields. Additionally, **liaison with farmers' cooperatives and conducting capacity building** is mandatory to raise awareness and ensure a receptive environment. Efforts to **develop and expand the necessary infrastructure and logistic system** for SAF to reach the country's airports are also foreseen in Phase 2.

Finally, investments in the **education and training of the necessary human resource force** should be initiated. In the second half of Phase 2, **attracting foreign investments** also becomes a priority. At this stage, Ethiopia should benefit from the achievements of the preceding phase — namely enablement of the policy and regulatory environment, establishment of strong institutional governance with clear responsibilities and agendas, and the elucidation of the potential in terms of specific sustainable feedstock availability (and ultimately more suitable infrastructure).

Presently, the country should capitalise on its developments and **run campaigns to attract foreign capital**. As part of this exercise, the Ethiopian Investment Commission should also investigate and assist the potential foreign investors with the acquisition of Africa Trade Insurance, which is a type of insurance against political risks and serves to protect investments, projects, assets, and contracts against risks associated with unlawful or questionable government actions that could lead to payment default and financial loss. At the same time, **offtake agreements with end-users** need to be secured, as these will drive the demand and render security to the investors. To this end, it is very important that the Ethiopian Investment Commission also identifies how, and to what extent, the public sector will engage with the foreign private sector. For example, will it be in the form of joint-ventures, public-private partnerships, loan guarantee programmes, or similar?

ASTM certification: The procedure to obtain ASTM Certification typically takes three to five years. When SAF fuels are meant to be blended with petroleum by up to 50%, they need to be D1655-approved ('Standard Specification for Aviation Turbine Fuels'). On top of that, they need to be D4054-approved ('Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives') and D7566-approved ('Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons').

For D4054, a range of fuel volumes need to already be generated early in the technology development stages, so that their properties, compositions, and performance can be tested.

RSB Certification: The SAF produced should aim to achieve RSB certification, with preparation for certification best started during the planning phase of any production facility. RSB's CORSIA Certification is for use by feedstock producers, refineries and traders globally to certify CORSIA-eligible SAF.

The Standard was recognised by the International Civil Aviation Organisation (ICAO) in December 2020 and specifies requirements for operators along the supply chain to produce SAF that is eligible under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), and complies with RSB's sustainability requirements — thus allowing aviation leaders to make powerful claims about GHG reductions and other important sustainability aspects, such as food security, environmental protection, and human rights. The procedure for achieving RSB certification is outlined in Sub-section 1.5.

Efforts to attract foreign investments, identify off-takers, and obtain the necessary certifications are ongoing activities from the time they commence.

Phase 3 is the concluding phase of the roadmap and focuses primarily on preparing the country for its extended future. Given the fact that in 10 years' time some of the SAF conversion pathways that are currently less-developed (e.g., AtJ, FT) will reach the necessary maturity for commercial availability, it is advised that Ethiopia **starts looking into additional feedstocks** that can be utilised — such as agricultural residues and the like.

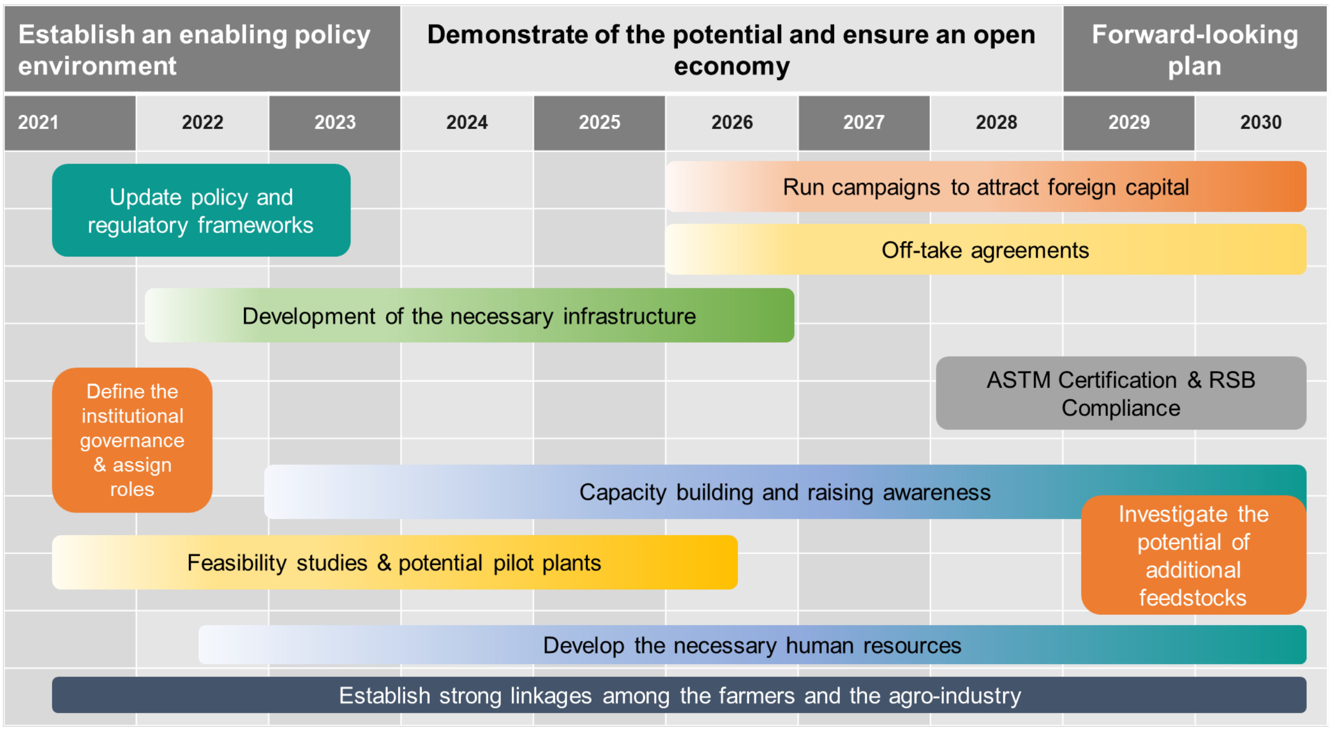

Figure 11: Visualisation of the Roadmap Actions Over the 10-Year Time Frame

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6. Conclusions

The proposed roadmap has been developed on the grounds of the Ethiopian Government's Ten Years Perspective Development Plan (2021–2030), in which energy and agriculture are mentioned as enabling sectors; Ethiopia's Climate-Resilient Green Economy initiative, in which the use of alternative renewable energy sources (including biofuel) is listed as a key activity; and Ethiopian Airlines' 15-year growth strategy, which prescribes a 10% SAF mix .

In short, the desk review assessment, international trends, and stakeholder feedback all suggest the following steps for Ethiopia to focus on:

Take advantage of oil-producing feedstocks that grow in the country and ensure uninterrupted production

Although several feedstocks seem promising for local SAF production, the roadmap focuses on castor and Ethiopian mustard. The former is already highlighted in the Biofuels Strategy of the country launched in 2007, whereas the latter is abundant in Ethiopia. Neither of them competes against food, and both can be converted to hydrogenated vegetable oil (HVO) with the HEFA pathway — the only commercially available pathway for industrial-scale production of SAF at present. In the long-term (i.e., beyond the time frame of the roadmap), however, abundant crop residues, as well as MSW, *Prosopis juliflora*, and water hyacinth could be considered — provided that the Fischer-Tropsch pathway becomes economically viable. A further prerequisite is that the necessary feasibility studies targeted at these feedstocks point towards viable cases that do not endanger the country's food security.

Ethiopia has as long way to go — primarily because it falls short in terms of the amounts of feedstock that need to be produced to be converted into SAF (for HEFA, the lower limit of feedstock is 360–400 million litres of lipids[49]), as well as due to the absence of the necessary biorefinery infrastructure to produce SAF.

Create an enabling policy and regulatory environment, build the necessary infrastructure, and attract foreign capital

The development of the SAF production facilities will necessitate blending mandates to drive demand and encourage new investments for scaling up the insufficient existing capacity. Aviation must be included in the country's plans and strategies, as well as sufficiently incentivised, as it is a common notion that feedstock is primarily channelled to other modes of transport.

Further supporting measures (e.g., public-private partnership schemes, loan guarantees, etc.) manifesting the country's commitment to this effort are necessary to improve Ethiopia's Foreign Investment Development (FID) attractiveness, which is hampered by its vulnerability to climate conditions, geographic isolation (i.e., landlocked), and unstable regional and national contexts — should also be seriously considered.

49 Values in metric tons were converted to litres using a density of 0.837 kg/L.

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Establish an operating institutional governance

An oversight committee for the entire petroleum supply chain should be defined, covering procurement, transportation, distribution, retailing, tariffs, margins, and licensing.

Provide early wins, create a positive perception of biofuels, and invest in education

Insufficient quantities of biodiesel are being produced in Ethiopia. There is also a very limited understanding of biofuels' potential to address the country's GHG emissions.

If biofuels are to be produced at large scale, it is imperative to start building knowledge and experience now around how to make and use biofuels successfully, and to build public confidence that they can be used effectively.

A lack of technical expertise and research experience in the field is also observed and needs to be addressed by launching relevant programmes such as fellowships and scholarships towards the development of SAF — based on current and future requirements.

In closing: Ethiopia needs to make significant efforts in all activities included in the SAF production value chain within the next 10 years, while at the same time demonstrating its serious commitment to this goal by creating an enabling policy and regulatory environment as well as adequate incentives.

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