The opportunity for biofuels in Africa

February 2026

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Context and objectives for this report

Context

This report was sponsored by the **UK Aid Manufacturing Africa** programme

All analysis was conducted **between August and December 2025.** Unless otherwise noted, numbers, findings, and case studies are current as of that date

This report is intended as the **first full assessment of the biofuels opportunity in Africa,** to create awareness among food and agriculture companies, fuel providers, investors, governments, and development partners of the opportunity and enablers required

Objectives

Provide an **overview of the current landscape of biofuels globally and in Africa**

Assess the potential size of the biofuels market in sub-Saharan Africa in 2035 across all fuel types and feedstocks

Synthesise priority enablers that the private sector, development partners, and governments can consider to develop the biofuels market

Our analysis of the biofuels market in Africa benefited from significant stakeholder and expert perspectives

NON-EXHAUSTIVE

▌Biofuel producers ▌Airlines ▌Distributors ▌Electricity generation ▌Others

15+ Stakeholder interviews with private companies

(including biofuel producers, equipment manufacturers)

- 5 ethanol players in Africa
- 1 bio-briquette / bio-pellet player
- 1 FAME biodiesel player
- 2 biogas players (for household as well as industrial use)
- 1 Syngas producer
- 1 UCO aggregator
- 2 Airlines
- 1 Fuel distributor
- 3 Manufacturers using biomass fuels

Sector experts (including research institutions, humanitarian organisations, investors)

- Clean Cooking Alliance
- Gates Foundation
- Gather Ventures
- Modern Energy Cooking Services (MECS)
- World Resource Institute
- Practical Action Kenya
- Kenya Biogas Association
- Clean Cooking Association of Kenya

Multiple data sources

- 10+ consumer interviews
- 30+ interviews with global experts
- Government reports
- Company reports
- FAOSTAT
- UN COMTRADE
- IMF
- World Bank Data
- World Economic Forum
- World Bank Commodity Markets Outlook

Multiple reports and articles

- IEA – A Vision for Clean Cooking Access for All
- People for Development – Cooking Behaviour Study: Main barriers and drivers towards the adoption of cleaner cooking solutions by households in 8 African countries (2024)
- United Nations Environment Programme – Africa Waste Management Outlook (2018)
- World Economic Forum – Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation

Terminology and abbreviations (1/2)

Term / abbreviation	Description
1G	first generation (feedstocks produced from food crops)
2G	second generation (feedstocks produced from non-food crops or waste products)
ACRE	name of a proprietary agriculture analytical tool used in this analysis
AMC	advance market commitments
APAC	Asia-Pacific
APNPP	l'association des pays non producteurs de pétrole (15 African countries' commitment in 2006 to support biofuels)
ATJ	alcohol-to-jet
avg	average
B5, B10, B20	FAME diesel blend with diesel, with the percent of the blend indicated by the number (e.g., B5 is 5% FAME diesel blend)
BESS	battery energy storage system
Biofuel	fuel derived from biomass
Blending mandate	Requirement by government to blend a certain share of biofuels with fossil fuels
Bn	billion
C&I	commercial and industrial
CAGR	compound average growth rate
CAPEX	capital expenditure
CC	clean cooking
CHP	combined heat and power
CO2eq	carbon dioxide equivalent
Conventional biofuel	For the purposes of this report, a conventional biofuel is a biofuel that is already commonly used globally (e.g., ethanol, FAME diesel) and has been for decades
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DDGS	distillers' dried grains and solubles
DFI	Development Finance Institution
DRC	Democratic Republic of Congo
Drop in fuel	a sustainable fuel that can fully replace a fossil fuel (no infrastructure, engine, or other changes required)
e-[fuel] - e.g., eSAF, e-gasoline	fuel produced via hydrogen process
E5, E10, E20, E85	ethanol blend with gasoline, with the percent of the blend indicated by the number (e.g., E5 is 5% ethanol blend)
EPA	Environmental Protection Agency
EPC	engineering, procurement, and construction
EU	European Union

Term / abbreviation	Description
EV	electric vehicle
FAME	fatty acid methyl ester
FAO	Food & Agriculture Organization
FAOSTAT	FAO statistics
feedstock	biomass input to production of biofuels
FID	final investment decision
Flex fuel	cars that can run on pure ethanol (modern cars can only handle up to E20 blends)
FTE	full time equivalent
FX	foreign exchange
GDP	gross domestic product
GDP PPP	gross domestic product purchasing power parity
gen-set	generator set
GEP	Global Energy Perspective (proprietary model projecting consumption of different fuels under different transition scenarios)
GHG	greehouse gas
GJ	gigajoule
GMO	genetically modified organism
GST	goods and services tax
GT	gigatonne
H2	hydrogen
ha	hectares
HEFA	hydroprocessed esters and fatty acids
HH	household
HVO	hydrotreated vegetable oil
ICS	improved cookstove
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
iLUC	indirect land use change
IMF	International Monetary Fund
Intensive or semi-intensive production	livestock production system in which livestock is raised in a zero or limited-grazing situation (e.g., in a barn)
IRR	internal rate of return

1. For the purposes of this report, sub-Saharan Africa excludes South Africa

Terminology and abbreviations (2/2)

Term / abbreviation	Description
Jet A-1	jet fuel
JV	joint venture
k	thousand
kg	kilogram
KNBS	Kenya Bureau of National Statistics
ktpa	thousand tons per annum
kW	kilowatt
kWh	kilowatt hour
L	litre
LCOE	levelized cost of electricity (the energy cost required for a fair rate of return on an energy investment)
LPG	liquified petroleum gas
LUC	land use change
m3	metres cubed
MECS	Modern Energy Cooking Services programme
MJ	megajoule
mmBTU	million British Thermal Units
Mn	million
MoU	memorandum of understanding
MW	megawatt
MWh	megawatt hour
Novel crop	alternative or less common plant grown for specialized markets (like food, fuel, fibre, or pharma)
OECD	Organisation for Economic Co-operation and Development
oil-based feedstock	feedstocks from oily crops (e.g., soybean, palm oil) or waste (like used cooking oil, tallow)
p.a.	per annum
PAYGO	pay-as-you-go
pH	measure of acidity
PPP	public-private partnerships
PTL	power-to-liquid
Purposefully-grown crops	inedible crops grown specifically for biofuel production
RD	renewable diesel

Term / abbreviation	Description
RNG	renewal natural gas
RON	research octane number
SAF	sustainable aviation fuel
SBTi	Science-Based Targets initiative
SDG	Sustainable Development Goals
SE4All	Sustainable Energy for All
SSA	sub-Saharan Africa
starch and sugar-based feedstock	feedstocks from starch or sugar-based crops such as maize, wheat, sugarcane, cassava, etc
t	tonne
TCO	total cost of ownership
TJ	terajoule
TRS	total recoverable sugars
UCO	used cooking oil
UK	United Kingdom
US	United States
US DFC	United States Development Finance Corporate
US RFS	United States Renewable Fuel Standard
USD	United States Dollar
VAT	value added tax
YTD	year-to-date

1. For the purposes of this report, sub-Saharan Africa excludes South Africa

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

Appendix 2: Use case deep-dives

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

Executive summary: Africa could unlock up to $10Bn in biofuels production by 2035 (1/3)

Africa could unlock up to $10Bn in biofuels production by 2035

Africa has the potential to unlock **up to $10 billion in biofuels production by 2035**, transforming its energy landscape while catalyzing agricultural development, rural livelihoods, and clean cooking adoption. Biofuels—ranging from 1G fuels made from food crops to 2G fuels produced from waste and non-food biomass—are already widely used globally. More than 70 countries mandate ethanol blending in road transport, and advanced fuels such as SAF and renewable diesel are gaining traction in Europe and the United States. In contrast, Africa's current biofuels market remains limited (~$200 million), despite significant resource availability.

A realistic assessment of market potential focusing on use cases that **require no subsidies, minimal cost differences (<5%) to consumers, proven technologies, and feasible feedstock availability**, shows that Africa could scale production to **$10 billion**. By 2035, this opportunity could generate **up to 325,000 jobs**, support **2.2 million farmers**, and help up to **15% of households** transition to cleaner cooking. Two countries—**Nigeria and South Africa—account for ~40%** of this potential, with Angola, Ethiopia, Tanzania, and Uganda also emerging as major contributors. The opportunity also brings a projected **$7 billion improvement in forex balance** through reduced fuel and wood imports.

Up to $1.7Bn in value could be unlocked with limited to no policy interventions

Approximately **$1.7Bn** in value could be captured by 2035 through use cases where the economics already make sense or where only light policy interventions (e.g., VAT exemptions) are needed. Three applications account for 80% of this opportunity:

- ***2G oil-based feedstock aggregation and processing ($0.5Bn).*** Africa can competitively supply UCO and purposefully-grown crops like castor to international SAF markets (EU, US), contingent on traceability systems, farmer offtake agreements, and enforcement of health regulations restricting UCO reuse.
- ***Ethanol for clean cooking ($0.7Bn).*** Viability is achievable in very specific cases for urban demand where LPG or electricity are unavailable or unreliable and where sufficient feedstock is available at low cost. Cost-competitiveness can be achieved with quality carbon credits.
- ***Bio-pellets for clean cooking ($0.2Bn).*** Suitable for rural or peri-urban households that purchase fuelwood (but not for those with free access). Scaling requires improvements in consumer awareness, distribution logistics, and co-location with biomass sources (e.g., sugar mills producing bagasse).

All these use cases have a range of existing players acting in the market. Ethanol for clean cooking is also the only use case in this scenario that requires 1G feedstock - 100,000 tonnes of cassava or 200,000 tonnes of sugarcane for a 15M litre plant. Non-staple food crops such as sugarcane and cassava (in East and Southern Africa) can be used.

Executive summary: Africa could unlock up to $10Bn in biofuels production by 2035 (2/3)

However, strong policy support will be required to reach full potential (~$10Bn by 2035)

Achieving the full potential requires substantial policy intervention consistent with global precedents. Key mechanisms include blending mandates, predictable procurement frameworks, PPP models, and policies limiting unsustainable wood harvesting.

Use cases that are viable with limited to no policy (e.g., export of 2G oil-based feedstocks, ethanol and bio-pellets for clean cooking) **scale to $5.5Bn** with further policy support (e.g., logging restrictions) as this supports the viability to a broader range of producers and/or consumers.

Strong policy such as mandates and PPPs also unlock three additional use cases that are not otherwise viable:

- ***Ethanol for road transport ($3.1Bn).*** Blending mandates of 5–10% could be viable in markets with high gasoline prices (where the cost to consumer of a blend has a low impact) and the capacity to scale crop production. Deployment would require approximately 20 ethanol plants (~$70 million each), primarily through PPP structures in countries such as South Africa, Nigeria, Uganda, Ghana, and Tanzania.
- ***Sustainable Aviation Fuel (SAF) refining ($1.1Bn).*** A $1.1Bn market for SAF production could be unlocked in countries with the potential to produce and aggregate sufficient oil feedstocks to meet minimum-viable scale for a HEFA plant (0.5 million tonnes, with an investment size of $0.75-1Bn). These would be South Africa (using 2G oil-based feedstocks such as UCO and castor oil) and Nigeria (using palm oil). However, viability is contingent on two considerations: (1) Global SAF mandates are assumed to continue to scale (i.e., while current SAF supply is over-capacity until 2030, this could shift to under-capacity as mandates scale post-2030); and (2) For Nigeria, given the sustainability concerns around palm oil in the EU (and to some degree in the US), this opportunity will depend on emerging supportive SAF regulation in Asian markets. Given the size of investment required, SAF production will likely require contracted offtake with the target export destinations.
- ***FAME diesel ($0.3Bn).*** While a smaller opportunity at $0.3Bn, this is largely concentrated in a single country (Nigeria), should that country consider a diesel blending mandate to stimulate palm oil production (as seen in some Southeast Asian countries). No other country could generate sufficient surplus of oil feedstocks to justify a similar mandate.

Achieving the full-scale opportunity will require an agriculture transformation…but biofuels might actually kick-start it

While nearly 50% of the full 2035 opportunity can be achieved with 2G feedstocks, reaching full-potential will require growing the production of 1G crops (maize, cassava, sugarcane, palm oil) and diverting some share to fuel production.

This is a controversial topic, particularly given Africa is a food insecure region and most regions that adopted biofuels started from a surplus position. However, there is no other economically viable feedstock option for use cases such as road ethanol. The market projections for ethanol require Africa to devote ~4% of its projected 2030 maize, cassava, and sugarcane production to biofuels (equal to 6% of *current* production).

Executive summary: Africa could unlock up to $10Bn in biofuels production by 2035 (3/3)

An alternate perspective could be that 1G biofuels might actually help spur an agriculture transformation. Africa is underperforming its yield potential and farmers often face a low incentive to invest in yield growth as excess production leads to gluts and price crashes. Biofuels production could provide offtake for that excess that could incentivise investment and contribute over time to yield growth and long-term food security. Countries that have adopted ethanol blending mandates for road fuels, for example, have seen growing investment in production.

That being said, any mandate needs to be carefully ramped up to avoid food price spikes and food-fuel competition and also needs to have a strong flexing mechanism to account for supply-side shifts (i.e., blending mandates are reduced when anticipated feedstock supply is low due to weather or other production challenges). This requires strong governance of the mandates with good information on projected supply-demand imbalances and patient capital to support the large capital investments in ethanol production facilities while mandates are being ramped up.

Investors, development partners, and governments can collaborate to unlock the market

For investors, the investments in the limited-to-no policy scenario are highly distributed in nature - across a large number of countries and smaller scale businesses (e.g., <$5Mn cooking ethanol plants, development of castor oil production and aggregation across multiple countries). These businesses will need patient capital to enable them to make the investments necessary for supply while driving the consumer buy-in for demand. Investors could consider setting up dedicated financing facilities (including, for clean cooking, a facility for carbon credits) to sufficiently scale across many smaller businesses. In the strong policy scenario, the nature of investments change, moving to much larger facilities (e.g., $70Mn road ethanol plants), typically requiring PPPs and project finance.

Governments can consider how biofuels can play a role in the sustainable fuel transition and provide a supportive, steady policy environment for investment. Governments can consider less complex policy interventions, such as VAT exemptions, consumer awareness campaigns, or enforcement of health regulations to restrict reuse of UCO. More complex interventions such as ethanol blending mandates or SAF refining require careful considerations of risks and the overall business case.

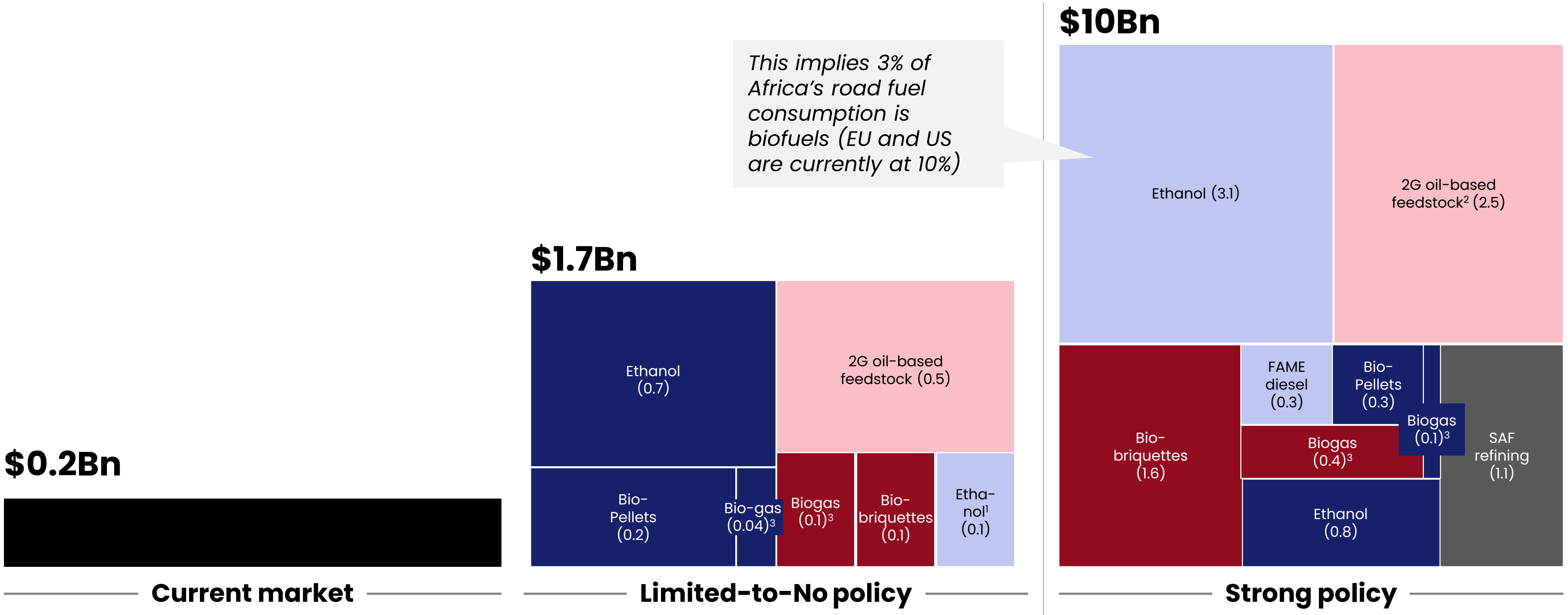
Development partners can support via concessional capital and agriculture value chain development across multiple use cases.

In all cases, choice of location matters. Countries are not equal in terms of availability and cost of feedstock and competing fuels. All investments and policy decisions there must be carefully made on a country-specific (and even region-specific) basis.

Africa could generate up to ~$10Bn in annual value from biofuels by 2035

Market potential under different scenarios, $Bn, 2035

Domestic use cases ■ Cooking ■ Industrial heat and power ■ Road **Export use cases** ■ Aviation ■ Feedstock export



This implies 3% of Africa's road fuel consumption is biofuels (EU and US are currently at 10%)

Estimated based on current blending mandates and clean cooking company revenues

Economics against alternatives sufficient to incentivise use or includes implementation of less complex policies (e.g., Tax or duty exemptions)

Implementation of more complex policies (e.g., road fuel blending mandates, PPPs, logging restrictions); however, no subsidies or other high-cost policies assumed

Post-2035, if mandates scale in Africa (for road fuels) and Europe (for SAF), market potential could grow to $18Bn (additional $3.4Bn for road biofuels and $4.2Bn for export of 2G oil-based feedstock to Europe for SAF production)

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1. Premium gasoline market only; assumed to be filled by imported blends given low volumes
2. Excludes South Africa feedstock production potential as this is assumed to be used for SAF production in this scenario
3. Biogas market sized using a cost for energy to enable apples-to-apples comparison with other fuel costs; however, in reality, it is an avoided cost as households or companies put in the onsite digesters and the energy in then at no-cost

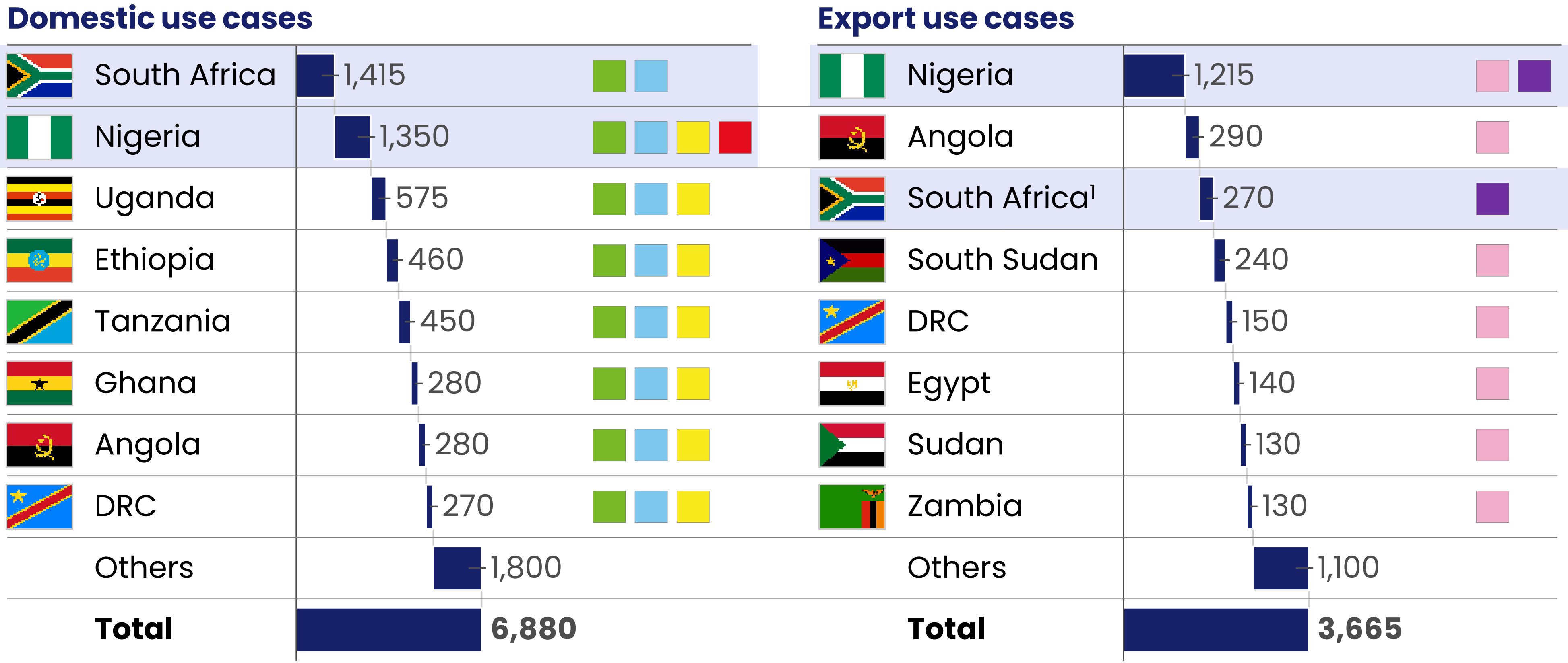
UKaid **Manufacturing Africa**

Source: Equity Axis, Sugar & Ethanol, US Grains, Mandatory blending in Zimbabwe: Examining implementation challenges and contemporary issues, Malawi's Shift to Ethanol: Pioneering a Sustainable Fuel Alternative, Malawi beckons investment in crops for biofuel production, Press search

South Africa and Nigeria make up ~40% of potential; other key markets are Angola, Ethiopia, Tanzania, and Uganda

Market potential per country (strong policy scenario), 2035, Mn USD

Major use cases: 🟥 FAME diesel 🟩 Road ethanol 🟪 SAF refining 🟨 Cooking(biogas, bio-pellets, ethanol) 🟦 Industrial heat and power (biogas and bio-briquettes) ▧ 2G oil-based feedstock | ⬜ 40% of total value



Domestic use cases

South Africa	1,415	🟩 🟦
Nigeria	1,350	🟩 🟦 🟨 🟥
Uganda	575	🟩 🟦 🟨
Ethiopia	460	🟩 🟦 🟨
Tanzania	450	🟩 🟦 🟨
Ghana	280	🟩 🟦 🟨
Angola	280	🟩 🟦 🟨
DRC	270	🟩 🟦 🟨
Others	1,800	
Total	**6,880**	

Export use cases

Nigeria	1,215	▧ 🟪
Angola	290	▧
South Africa[1]	270	🟪
South Sudan	240	▧
DRC	150	▧
Egypt	140	▧
Sudan	130	▧
Zambia	130	▧
Others	1,100	
Total	**3,665**	

Nigeria and South Africa could make up **~40% of the biofuels market** in Africa by 2035, primarily due to their **feedstock surplus potential** and **high fuel use** relative to other countries

This is driven largely by local **road ethanol and FAME diesel blending;** with potential for export of **2G oil-based feedstock** and **SAF export**

Other key markets could be **Angola, Ethiopia, Tanzania, and Uganda**

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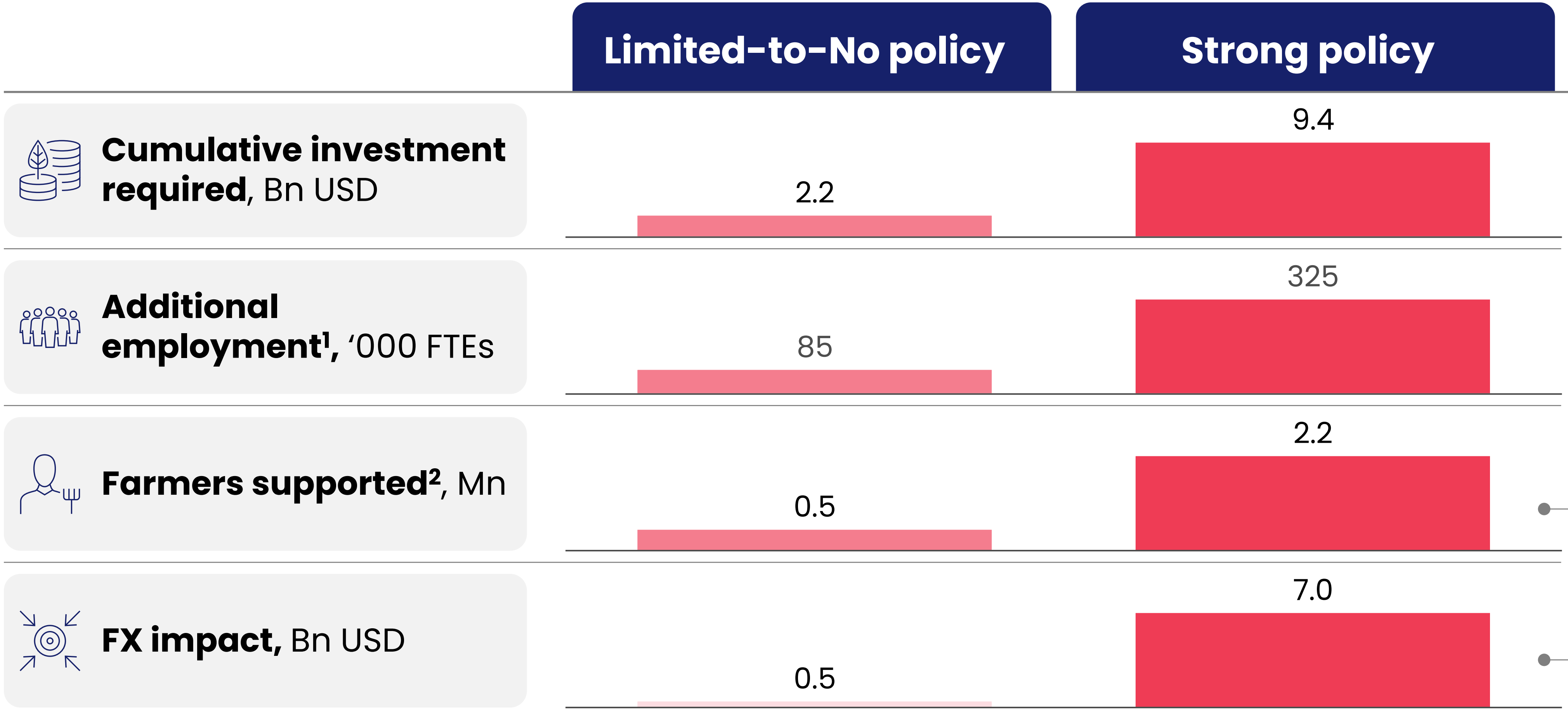
[1] Value only considers value addition from SAF refining (i.e., it nets out the value of feedstock produced and imported to South Africa from other countries (e.g, Zambia) to avoid double-counting

Manufacturing Africa Source: Manufacturing Africa team analysis

~$2-9Bn investment into biofuels could create up to 325,000 jobs, support ~2.2Mn farmers, and drive ~$7B FX impact

Summary of potential impact of biofuels adoption under different scenarios by 2035



~**7%** of ~33Mn smallholder farmers in Africa impacted

~60% improvement in Africa merchandise trade balance of ~$11Bn (2024 latest estimate)

1. Based on Africa-based industry benchmarks across multiple countries in the agro-processing and chemicals industries. Direct jobs benchmarks: Cooking and industrial – 0.3 jobs per $8000 revenue; SAF and 2G oil-based feedstock production – 1000 jobs per $2Bn investment; Road ethanol – 42 jobs per $70Mn investment; Road FAME diesel – 160 jobs per $200Mn investment. Indirect jobs multipliers per $1Mn revenue: 2G oil-based feedstock, ethanol, FAME diesel, and SAF production – 12; Bio-pellets, bio-briquettes – 56; Biogas – 11
2. Assumes 80% of production by smallholder farmers and 20% by commercial farms; smallholder farmer size assumed to be 1.5ha and commercial farms 250ha

Source: Manufacturing Africa jobs multiplier index, Iowa State University, IFAD, Africa Export-Import Bank: African Trade Report 2025, Press search, Expert input

With limited to no policy action, there are six biofuel investment opportunities, of which 3 are >80% of the value

Use cases making up 80% of the value in the limited-to-no policy scenario

| 1G | 2G

Use cases	Biofuel	Primary feedstock	Opportunity *(under limited-to-no policy scenario)*	Top 3 countries	Geographic concentration[1]	Investment concentration[2]
Cooking	**Bio-pellets**	Bagasse Saw dust	Build ~100 plants ($2-3M each) producing 24kpta each near sugar mills or sawmills to serve households or institutions (e.g., schools, hospitals)	Ethiopia Nigeria Tanzania	Medium	Low
	Biogas	Manure Farm waste	Deploy 20,000+ small-scale biogas digesters annually in 44 Sub-Saharan countries, focusing on rural households	Ethiopia Tanzania Kenya	Medium	Low
	Ethanol	Maize Cassava Sugar cane	Establish ~70 ethanol plants of 15Mn L each using non-staple 1G crops (e.g., cassava in East Africa) to produce cooking-grade ethanol in countries where alternates for urban cooking (e.g., LPG, electricity) are unavailable or unreliable; connect to carbon credit mechanisms to improve affordability	Ethiopia Tanzania Uganda	Medium	Medium
Industrial heat and power	**Biogas**	Manure Waste from food & beverage processing Municipal sludges	Invest in EPC companies to build 200 biogas plants for heat and power requirements (0.5 - 2 MW each) focusing on breweries, agro-processors, and wastewater treatment plants; and ~30,000 rural biogas mini-grids for power distribution	Nigeria South Africa Ethiopia	Low	Low
	Bio-briquettes	Bagasse Saw dust	Build >50 bio-briquette plants (~$3.5Mn each) across 22 countries to supply industrial clients largely in the agro-processing industry (linked to cooking bio-pellets plants)	South Africa Nigeria Egypt	Medium	Low
Feedstock export	**2G oil-based feedstock**	Waste oils (e.g., UCO), Castor oil	Set up business to collect waste oils (e.g., UCO, tallow) for export; test and scale castor oil production and refining for export supporting 200k farmers	Nigeria Angola South Sudan	Medium	Low

All these use cases scale with stronger policy support

1. Defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%
2. Defined by how market value is distributed across investments: Very high (1-3 largescale plants / investments), High (4-20 plants / investments), Medium (20-50 plants / investments), Low (>50 plants / investments)

Source: Manufacturing Africa team analysis

With strong policy action, there are three additional biofuel investment opportunities

🟦 1G 🟥 2G

Use cases	Biofuel	Primary feedstock	Opportunity *(under limited-to-no policy scenario)*	Top 3 countries	Geographic concentration[1]	Investment concentration[2]
Road	**Ethanol**	🟦 Maize Cassava Sugar cane	Invest up to $1.3Bn in 8-20 fuel-grade ethanol production facilities with 200Mn tonnes of annual capacity across 12 African countries, supported by blending mandates that ramp up gradually to enable 1G feedstock production and accompanies by governance mechanisms to flex mandates	South Africa Nigeria Uganda	High	High
	FAME diesel	🟦 Palm oil	Invest $0.2Bn in a FAME diesel production facility with 350M L of annual capacity in Nigeria to meet a 5% blending mandate that ramps up gradually to enable 1G feedstock production and accompanies by governance mechanisms to flex mandates	Nigeria	Very high	Very high
Aviation	**SAF refining**	🟦 Palm oil 🟥 Waste oils (e.g., UCO), castor, brassica carinata	Develop two SAF production plants—one in Nigeria and one in Southern Africa—each with a 500M-tonne annual capacity and export SAF and HVO. The Southern Africa plant could focus on 2G oil-based feedstocks (waste oils, purposefully-grown crops). The Nigerian plant would focus on 1G palm oil (with careful mitigation of deforestation risks)	Nigeria South Africa	Very high	Very high

1. Defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments), Medium (20-50 plants / investments), Low (>50 plants / investments)

Source: Manufacturing Africa team analysis

Unlocking Africa's full biofuels potential would require scaling of 1G feedstocks

✓ Feedstock required

Feedstock type	Use case	Scenarios	
		Limited-to-No policy	Strong policy
1G	**Road - ethanol**		✓
	Road - FAME diesel		✓
	Cooking - ethanol	✓ ~5Mn tonnes of feedstock required (~1% of production in Africa today[5])	✓
	Aviation - SAF refining[3]		✓
2G	**Cooking - bio-pellets**	✓	✓
	Cooking - biogas	✓	✓
	Industrial heat and power - biogas	✓	✓
	Industrial heat and power - bio-briquettes	✓	✓
	Aviation - 2G oil-based feedstock export	✓	✓
	Aviation -SAF refining[4]		✓

Biofuel production under strong policy would require agriculture transformation

In other cases, countries adopting biofuels such as ethanol used existing surplus supply of 1G crops. Countries in Sub-Saharan Africa would be the **first to adopt biofuels to drive agriculture production, starting from a deficit or supply/demand-balanced position**

This presents a challenge, but could also be an opportunity: Based on other countries' experiences, **biofuels demand can spur investment in increased agriculture production** by **creating greater demand and absorbing surplus** crop during glut times (potentially preventing price crashes). This may support food security over time[1]

Agriculture ramp-up is feasible, if Africa can **close the yield gap relative to peers** (e.g., India for maize, Brazil for cassava) and with **conservative land expansion**[2]

+60% of ethanol demand could be produced using cassava in Eastern or Southern Africa, where it is not staple crop, thereby **mitigating potential impact on food prices**

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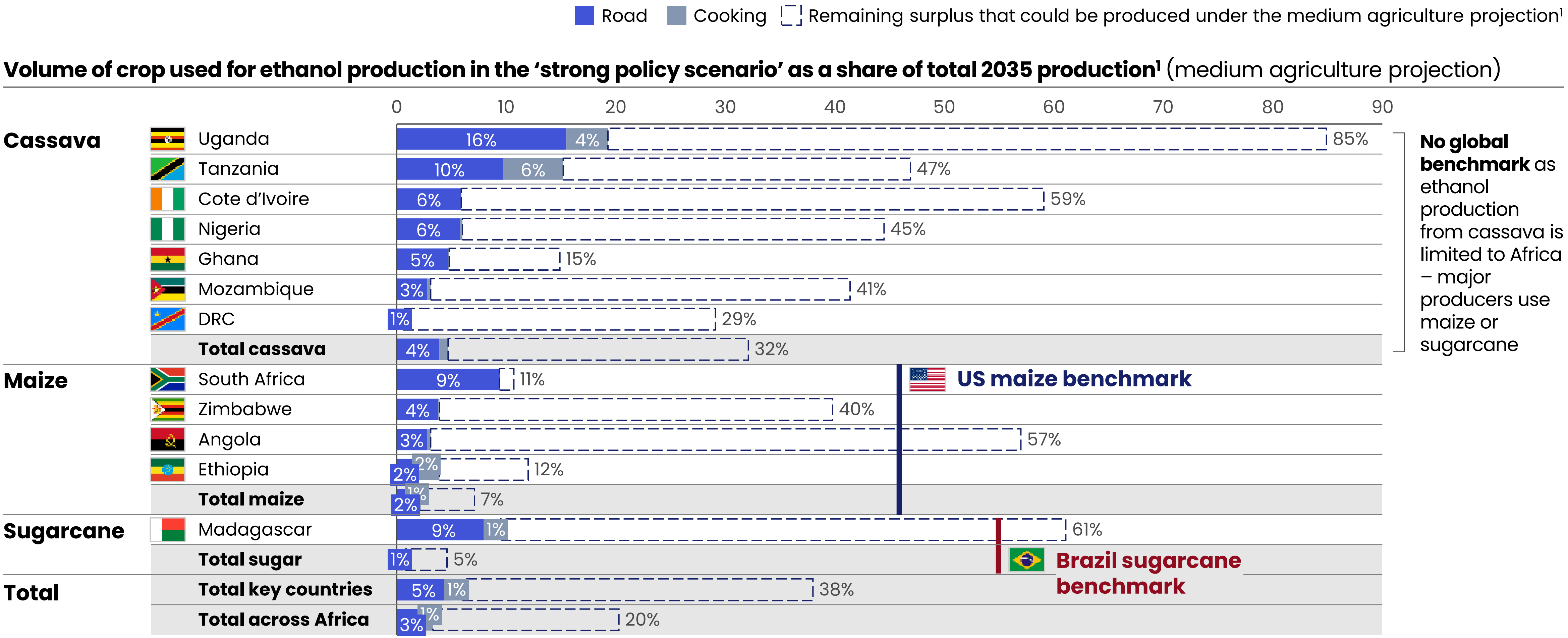
1. Locally it creates an incentive to grow feedstock for ethanol plants
2. Land expansion only leverages available land that is suitable for agriculture but is not protected or environmentally critical and is assumed in projections to be lower than historical rates (e.g., 1% p.a.)
3. SAF derived from palm oil
4. SAF derived from UCO and castor oil
5. Across 34 countries; 2022 production of maize, cassava, and sugarcane estimated ~400Mn tonnes

Source: Expert interviews

By 2035, ethanol could require up to ~4% of total production of cassava, maize, and sugarcane

Volume of crop used for ethanol production in the 'strong policy scenario' as a share of total 2035 production[1] (medium agriculture projection)



No global benchmark as ethanol production from cassava is limited to Africa – major producers use maize or sugarcane

For context, the 4% of total Africa production in 2035 equals 6% of 2022 production; for key countries, the 6% in 2035 equals 13% of 2022 production

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1. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: FAOSTAT, Resource trade. Earth, Press search, Expert interviews

Governments, investors, and development partners can consider options to support the scale-up of biofuels in Africa

NON-EXHAUSTIVE

			Options to consider		
	Use cases	**Top countries**	**Governments**	**Investors**	**Development partners**
Domestic	Road ethanol and FAME diesel Clean cooking (bio-pellets, biogas, ethanol) Industrial heat and power (biogas, bio-briquettes)	South Africa Nigeria Uganda Ethiopia Tanzania	Implement ethanol and FAME diesel **blending mandates** Set up **PPPs** for ethanol/FAME diesel production Set up **independent bodies** to regulate biofuels and flex mandates based on feedstock supply projections Include biofuels in **national clean cooking strategies** Implement **policies to support local production** (e.g., duties or VAT on imports)	Invest in **PPPs for ethanol / FAME diesel production** (with governments) Set up a **$650Mn clean cooking fund** to support investment into biofuels (bio-pellets, biogas, ethanol), with a link to carbon credits Invest in **EPC companies to implement industrial biogas solutions** (similar to seen with solar C&I)	Support **agriculture extension** to smallholders, linked to offtake for ethanol/FAME production Support **carbon credit methodology development** and scaling for clean cooking
Export	2G oil-based feedstock Sustainable aviation fuels (SAF) refining	Nigeria Angola South Africa South Sudan DRC	Enforce **health regulations** for cooking oil reuse and create a **traceability system** to aid compliance for aggregation of UCO Set up **controls on export of oil-based feedstock** in countries with SAF production potential	Invest in **testing and scaling** of 2G oil crops (e.g., carinata) Develop **innovative tech-based solutions** for UCO collection Set up **JVs/PPPs for SAF refining with offtakers** in export countries	Support **piloting of 2G oil crops**

Source: Manufacturing Africa team analysis

Overall implications from the analysis

Location matters	Countries are not equal in terms of availability and cost of feedstock and competing fuels. All investments must consider country-specifics (and even look at sub-regions within countries)
Supportive policies critical for use cases to scale	While expensive policies like subsidies or incentives for high-cost biofuels are not assumed, even in cases where the economics can make sense, supportive policies enable scaling by: • creating stable demand (e.g., through blending mandates) • improving feedstock supply (e.g., through health regulations that make UCO more available for aggregation) • reducing investment barriers (e.g., through tax or other incentives)
1G biofuels can be controversial, but a case may exist	Countries have used 1G biofuels as a way to create a demand sink for excess production, thus stimulating agriculture investment; however, careful ramp-up of any mandates and a clear understanding of demand-supply balance to flex mandates is required This analysis assumes conservative ramp up on yield and very low land expansion in all 1G feedstock projections

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

Appendix 2: Use case deep-dives

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

Biofuels overview | This report focuses on conventional and 'drop-in' biofuels

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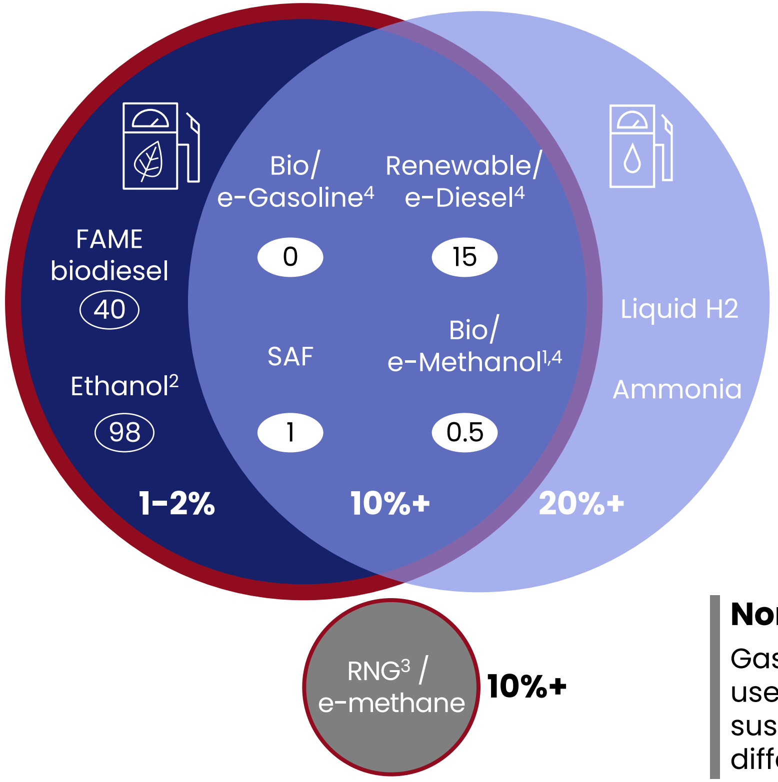
○ Focus of this report   % Representative market CAGR (%), 2020-2030   X 2020 demand, Million tonnes per annum

'Drop-in' sustainable fuels
Fuels fully compatible with existing infrastructure (blended up to 100%) and can be produced from either bio-based or hydrogen-based sources

Conventional biofuels
Carbon-based with compatibility restrictions (blend walls) with existing combustion engines



FAME biodiesel (40)

Ethanol[2] (98)

1-2%

Bio/ e-Gasoline[4] (0)

Renewable/ e-Diesel[4] (15)

SAF (1)

Bio/ e-Methanol[1,4] (0.5)

10%+

Liquid H2

Ammonia

20%+

RNG[3] / e-methane 10%+

Hydrogen
Fuels which require new infrastructure (e.g., not 'carbon' based)

Non-liquids
Gaseous based products which use similar feedstocks to sustainable liquids, but have different market dynamics

Use cases in scope

Passenger cars ✓

Trucks ✓

Aviation ✓

Marine ✓

Cooking ✓

Industrial heat and power generation ✓

---

1. Methanol and ethanol can be upgraded to various drop-in fuels but by themselves are not a 100% drop-in fuel
2. Includes MTBE (methyl tertiary butyl ether) and ETBE (ethyl tertiary butyl ether)
3. Renewable natural gas
4. e-fuels are produced from hydrogen and are not in scope for this report; the bio-based version of these fuels (e.g., renewable diesel/HVO) are in scope

Source: Expert interviews

Biofuels overview | Each biofuel can be produced from different combinations of feedstocks and technologies

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Feedstocks			Examples	Conventional biofuels				'Drop-in' biofuels			
				Ethanol	FAME-diesel	Biogas	Bio-methane	Bio-gasoline	Renewable diesel (HVO)	SAF	Bio-methanol
1G (First generation feedstocks)	Food crops	Sugar and starch crops	Maize, sugar cane	1					2	2	
		Oil crops	Palm oil, sunflower seeds		3				4	4	
2G (Second-generation feedstocks)	Advanced	Fibrous/ woody plant	Switchgrass, miscanthus, short-rotation woody crops					6b 7b	6b	6b	7b
		Non-edible oil plants[1]	Camelina, jatropha, brassica carinata		3				4	4	
	Waste	Waste oils and fats	Used cooking oil, industrial waste oils, animal fats								
		Manure	Manure from cows, pigs, etc.			8	8				
		Fibrous/ woody waste	Bagasse, rice husks, corn stalks, forestry residues	1				6b 7b		6b	7b
		Municipal waste	Everyday garbage or trash generated by households						5		

Pathways

1. Fermentation
2. Fermentation + alcohol-to-X
3. Transesterification (FAME)
4. Hydrogenation (HVO)
5. Pyrolysis or Torrefaction

Fischer-Tropsch:
- 6a Via water-gas shift
- 6b Via gasification

Methanol synthesis:
- 7a Via water-gas shift
- 7b Via gasification

8. Anaerobic digestion

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[1] Includes algae

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Source: Expert interviews

Biofuels overview | Globally, the economic viability of different biofuels depends on the feedstock and degree of policy support

NOT EXHAUSTIVE – PRIMARY PATHWAYS ONLY

🟩 Cost-competitive versus alternatives 🟨 Some cost differential but <10% 🟧 High cost differential (>10%) but still not prohibitive 🟥 Prohibitively high cost – currently not done

				Traditional biofuels				Advanced biofuels			
	Feedstocks		**Examples**	**Ethanol**	**FAME-diesel**	**Biogas**	**Bio-methane**	**Bio-gasoline**	**Renew-able die-sel (HVO)**	**SAF**	**Bio-methanol**
1G (First generation feedstocks)	**Edibles**	**Sugar and starch crops**	Maize, sugar cane	🟨						🟧	
		Oil crops	Palm oil, sunflower seeds		🟨				🟧	🟧	
2G (Second-generation feedstocks)	**Advanced**	**Fibrous/ woody plant**	Switchgrass, miscanthus, short-rotation woody crops					🟥	🟥	🟥	🟥
		Non-edible oil plants[1]	Camelina, jatropha, brassica carinata		🟧				🟧	🟧	
	Waste	**Waste oils and fats**	Old cooking oil, industrial waste oils, animal fats		🟧				🟧	🟧	
		Manure	Manure from cows, pigs, etc.			🟨	🟨				
		Fibrous/ woody waste	Bagasse, rice husks, corn stalks, forestry residues	🟧		🟨	🟨	🟥	🟥	🟥	🟧
		Municipal & industrial waste	Everyday garbage or trash generated by households			🟨	🟨	🟥	🟥	🟥	🟧

Economic viability mainly driven by technology costs. Policy support needed globally to achieve cost parity and hence uptake

1. Includes algae

Source: Expert interviews

Global trends | Countries support biofuel adoption to support local agriculture production, and improve trade and FX balance

NOT EXHAUSTIVE; EXAMPLES ONLY

● Primary driver ◌ Secondary driver

	Ethanol producers					FAME producer	SAF	
Reasons for mandate adoption	**US**	**Brazil**	**India**	**UK**	**EU**	**Indonesia**	**EU**	**Details**
Absorb surplus production	● Sugar & corn surplus	●	●			● Palm oil surplus		Feedstock producers (e.g., sugarcane in Brazil/India & corn in the US) **pushed for blending mandates** to **create an alternative market** in times of surplus supply In India, the sugar industry pushed for higher mandates (E5-E20) **to create a market for their excess sugar**
Improve trade and FX balance	◌	●	●	◌	◌	●		India viewed ethanol as a potential pathway to **improve its oil trading balance** – of the **~350 million tonnes** of oil consumed annually, **only 20-30 million tonnes** are produced domestically
Reduce GHG emissions	◌	◌	◌	●	●	◌	●	**UK and EU** introduced E10 blending mandates to reduce emissions from road transport sector **EU** introduced SAF mandate to reduce emissions from airline sector
Improve air quality and health outcomes	●	◌	◌	◌	◌	◌		US Introduced the **1970 Clean Air Act**, leading to ethanol blending standards (ethanol improves fuel quality) – mandates were officially introduced 30+ years later

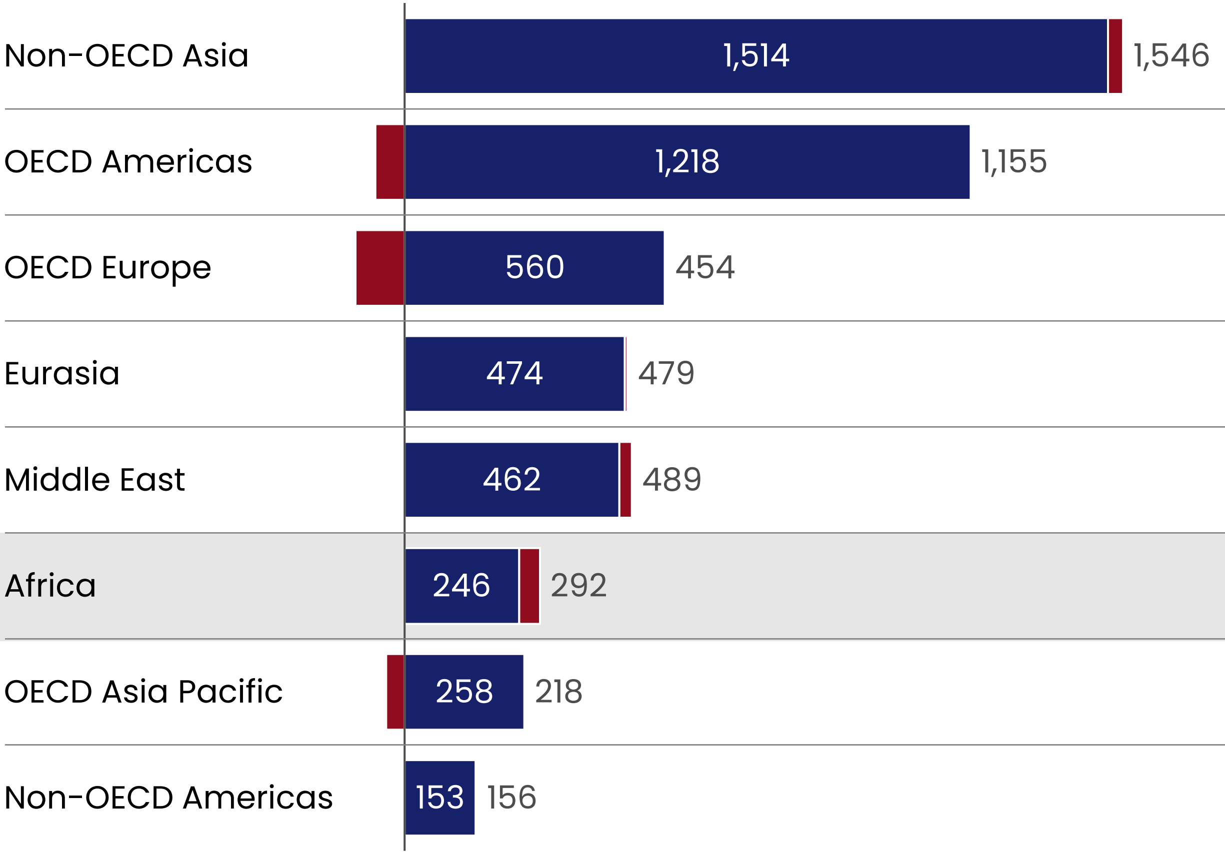
Source: Expert interviews, Reuters, EIA, EIA, Indian Sugar, Advanced Biofuels USA, Grains.org

Scope of this report | We look at all Africa and all fuels out until 2035

Geography	All countries in Africa, but specific focus on *Manufacturing Africa* focus countries (Ethiopia, Kenya, Nigeria, Tanzania, Rwanda, and Senegal)
Fuels and feedstocks	All conventional and "drop-in" biofuels All feedstocks considered (1G and 2G), with assessment of availability and risks
Time period	Market sizing and investment projections until 2035 Ten-year time horizon chosen given most relevant for investment decision-making
Use cases	Use cases include road, cooking, industrial heat and power, 2G feedstock export, aviation, and maritime

Africa fuels ecosystem | Africa contributes 5% to global fuel demand, but is expected to grow fastest

Global fuel market size (excluding renewables), Bn USD[1,2]



	2025	2035	**Share of total**, 2025	**CAGR**, 2025-35
Non-OECD Asia	1,514	1,546	31%	1.9%
OECD Americas	1,218	1,155	25%	-7.6%
OECD Europe	560	454	11%	-17.0%
Eurasia	474	479	10%	0.9%
Middle East	462	489	9%	5.2%
Africa	246	292	5%	16.5%
OECD Asia Pacific	258	218	5%	-13.9%
Non-OECD Americas	153	156	3%	1.7%

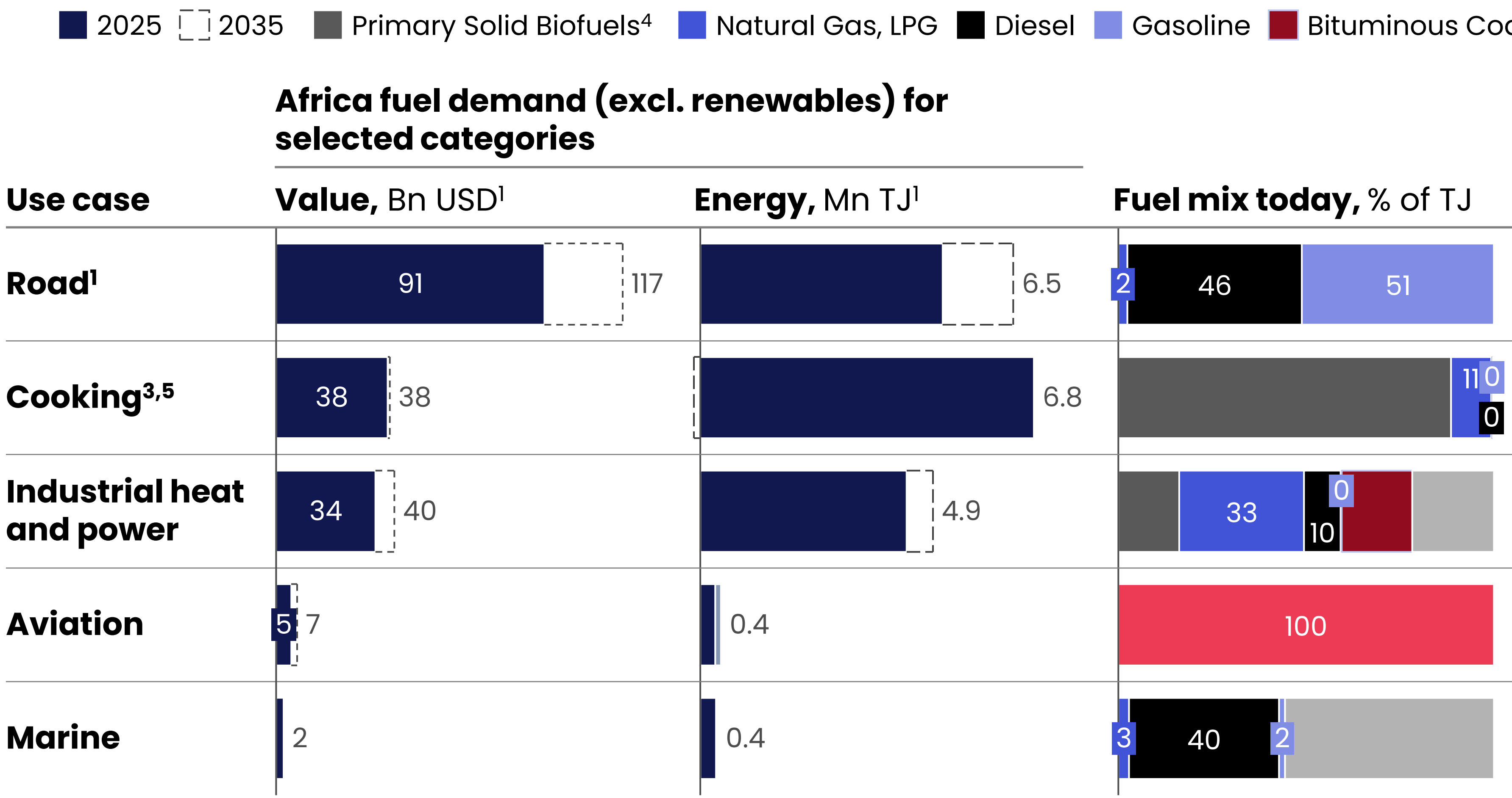
Switch to renewables over time is taken into account, with decreasing demand in some regions driven by that (e.g., due to SAF mandates in the EU, growing adoption of EVs in North America, Europe, and Asia)

In Africa, lower starting point on fuel consumption, more rapid population and GDP growth, and lower expectation on renewables adoption in some segments (e.g., EVs) contribute to fastest growth

1. Excludes fuel demand back-up generation in some countries and includes primary and secondary energy consumed by transformation industries
2. Africa pricing based on average market price for Nigeria, Kenya, South Africa, and Morocco. For other regions, regional data used where available. Global indices from the World Bank Pink Sheet used where regional data was not available

Source: IEA, McKinsey Global Energy Perspective 2025, World Bank Pink Sheet 2025, Press search

Africa fuels ecosystem | Technically, a high portion of Africa's fuel demand can be substituted with biofuels



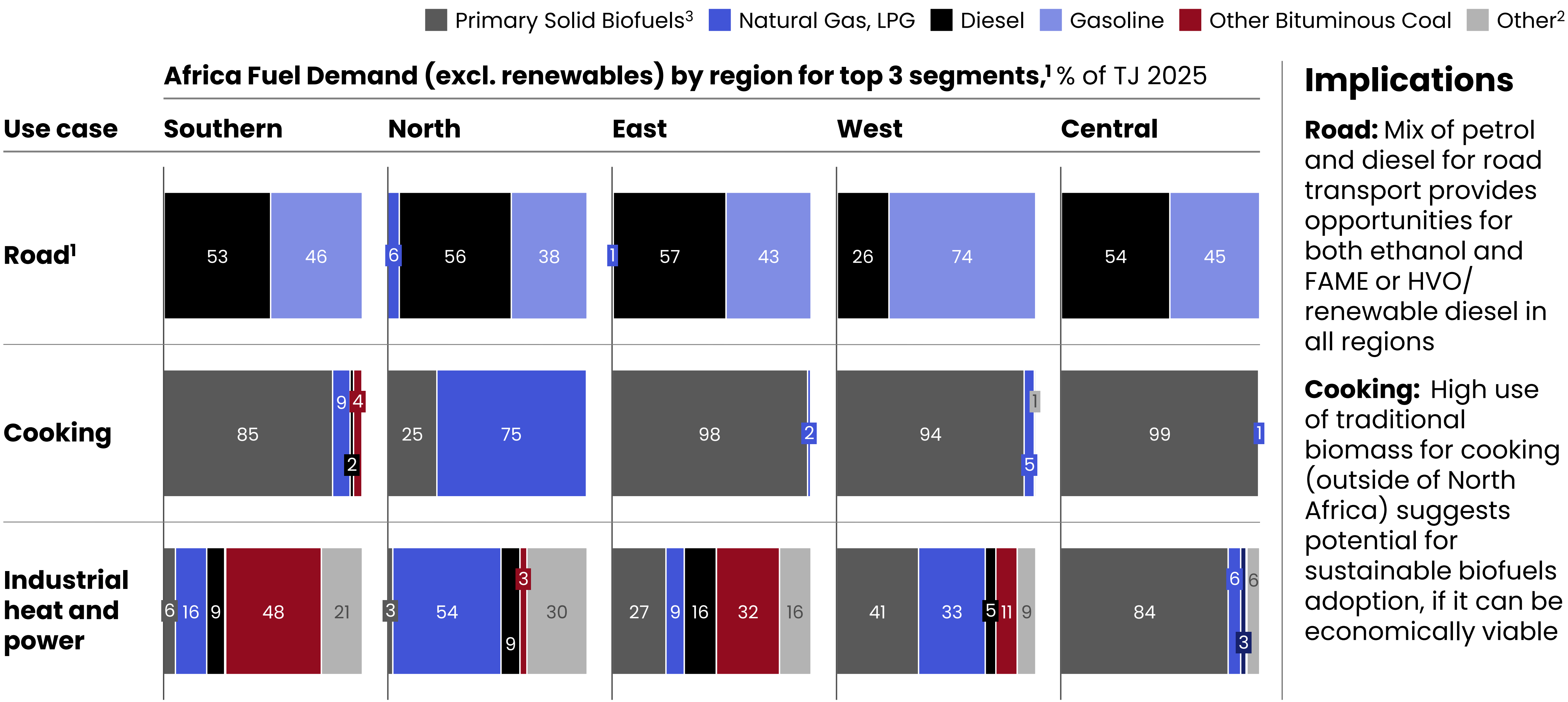
Use case	**Example applicable biofuels** (bolded fuels can fully substitute fossil fuels)
Road[1]	Ethanol, FAME diesel, **Bio-gasoline, Renewable Diesel (HVO)**
Cooking[3,5]	**Bio-pellets, Ethanol, Biogas**
Industrial heat and power	**Bio-briquettes, Biogas, Bio-methanol**
Aviation	**SAF**
Marine	FAME diesel, **Bio-methane, Renewable Diesel (HVO)**

1. Excludes fuel demand from back-up generation in some countries and includes primary and secondary energy consumed by transformation industries
2. Includes Refinery Gas, Crude Oil and more
3. Decline is driven by shift towards more efficient cooking fuels like LPG and Biogases
4. Primarily wood and charcoal
5. Excludes electricity
6. Includes Sulphur fuel oil

Source: IEA

Africa fuels ecosystem | Regional differentiation of fuel type also provides different opportunities

Africa Fuel Demand (excl. renewables) by region for top 3 segments,[1] % of TJ 2025



Implications

Road: Mix of petrol and diesel for road transport provides opportunities for both ethanol and FAME or HVO/ renewable diesel in all regions

Cooking: High use of traditional biomass for cooking (outside of North Africa) suggests potential for sustainable biofuels adoption, if it can be economically viable

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1. Excludes electricity
2. Includes Refinery Gas, Crude Oil and more
3. Primarily wood and charcoal

Manufacturing Africa

Source: IEA

Biofuels ecosystem | Some support for biofuels adoption exists across African countries

Biofuels commitment indicators for selected countries in Africa

AS OF AUGUST 2025

🟢 Positive for biofuels adoption 🔴 Negative for biofuels adoption

	Egypt	Ethiopia	Kenya	Morocco	Nigeria	Rwanda	Senegal	South Africa	Tanzania
Has a biofuels strategy been published in the past 5 years?	🔴 ✗	🟢 ✓ Development Strategy 2025	🟢 ✓ Biofuels guidelines launched in 2022	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗
Have any biofuel guidelines, standards, or specification requirements been introduced in the past 5 years?	🔴 ✗	🟢 ✓ Part of development strategy	🟢 ✓ Biofuels guidelines launched in 2022	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗
Are there mandates, requirements, or plans for use of biofuels?	🔴 ✗	🟢 ✓ E10 blending mandate for gasoline (stated)	🔴 ✗ No national mandate; one county-level (Kisumu)	🔴 ✗	🟢 ✓ E10 for gasoline and B20 for diesel (stated)	🔴 ✗	🔴 ✗	🟢 ✓ E2-E10, B5 blending mandate (partially in effect)	🔴 ✗
Membership in any voluntary organizations or commitments that support use of biofuels?[1]	🟢 ✓	🔴 ✗ Wiil join CORSIA in 2027	🟢 ✓ Member of CORSIA	🟢 ✓ Member of APNPP	🟢 ✓ Member of CORSIA	🟢 ✓ Member of CORSIA	🟢 ✓ Member of APNPP	🔴 ✗ Deferred CORSIA till 2nd Phase in 2027	🟢 ✓ Member of CORSIA
Are there fuel subsidies or policies that support fossil fuels?	🔴 ✓ Recently reduced subsidy	🟢 ✗ Lowered in 2024 and removed 2025	🟢 ✗ Only to stabilise prices	🔴 ✓ Phase-out in 2015, re-introduced 2023	🟢 ✗ Removed in 2023	🔴 ✓	🔴 ✓ Could be removed (IMF negotiations)	🔴 ✓	🔴 ✓
Has there been a Nationally Determined Contribution that has been set for biofuels?	🟢 ✓ Part of Sust. Energy Dev plan	🟢 ✓ Policy for biofuel use	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗	🔴 ✗	🟢 ✓ Bioenergy in power generation

Manufacturing Africa

Source: Press search, IEA

Biofuels ecosystem | Country strategies for biofuels exist (although many outdated); however, actual regulation is limited in Africa

NOT EXHAUSTIVE; AS OF AUGUST 2025

		Issuing body	Key highlights
Kenya Bioenergy Strategy (2020 -2027)	🇰🇪	Kenya Ministry of Energy	Supports blending mandates by 2027 (E10 and B5/B10) with framework around standards, quality control, and compliance monitoring 100% clean cooking solutions (including suggested ~30% ethanol in mix)
Nigerian Biofuel Policy and Incentives (2007)	🇳🇬	NNPC[1]	Legal framework for biofuel production with a target of 10% ethanol blend in gasoline.
National Renewable Energy Action Plan (NREAP) (2015–2030)	🇳🇬	Federal Ministry of Power	Translates the NREEEP[2] adopted in 2015 into actionable targets, including achieving 1.8Mn litres/day of ethanol and 0.3Mn litres/day of biodiesel by 2030 Supports 10% ethanol blending (E10) in gasoline and 20% biodiesel blending (B20) in diesel
Revised Ethiopian Biofuels Development Strategy (2025)	🇪🇹	Ministry of Energy and Water	Proposes a minimum of 10% ethanol and 3% biodiesel blends by 2030
Climate-Resilient Green Economy (CRGE) Strategy (2011)	🇪🇹	Government of Ethiopia	By 2030, replace 0.28Bn L of diesel and 0.09Bn L of petrol with blends of 5% biodiesel and 15% ethanol
Sustainable energy for all action agenda (2016-2030)	🇷🇼	Ministry of Infrastructure	Country-specific SEforALL action agenda aligned to universal access, doubled renewables share, doubled efficiency through to 2030
Senegal Bioenergy Action Plan (2020 – 2030)	🇸🇳	Ministry of Energy, Petroleum, and Mines	Increase the share of bioenergy in the national energy to 40% by 2030 Increase clean cooking access by 11.3% annually, adding 15.8Mn users by 2030.
National Strategy for Clean Cooking Fuels and Biofuels (2025–2035)	🇸🇳	Ministry of Energy, Petroleum, and Mines	Reduce reliance on traditional wood fuels, which currently account for 42% of household energy use
Tanzania National Energy Policy (2015)	🇹🇿	Ministry of Energy and Minerals	Promote sustainable energy development and increase access to modern energy services. There are no clear target figures outlines to be achieved
National Energy Compact for the United Republic of Tanzania (2025)	🇹🇿	Government of Tanzania	75% access to clean cooking by 2030, and mobilizing financing to support energy development, targeting a total of $12.9Bn

1. NNPC : Nigerian National Petroleum Corporation
2. NREEP : National Renewable Energy and Energy Efficiency Policy

Source: Public reports and strategies as listed on the page

Biofuels ecosystem | At the same time, Africa is affected by several international regulations and trends

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Feedstock sourcing restrictions

The EU's **Renewable Energy Directive II and III** limits sourcing of feedstock to those that match strict GHG emissions and minimal/low land use change requirements. This explicitly restricts feedstocks such as palm oil

US RFS Requirements similarly requires that feedstocks meet specific GHG lifecycle thresholds

Refuelling requirements

The **EU's RefuelEU Aviation** regulation requires aviation fuel suppliers at major EU airports to blend a minimum share of SAF into all jet fuel. **FuelEU Maritime** regulation requires ships calling at EU ports to progressively lower the GHG intensity of their fuels—compelling African shipping lines on EU routes to adopt cleaner fuel alternatives to stay compliant

Investment restrictions

DFIs adhere to strict sustainability standards, which often implicitly or explicitly rule out investing in biofuels from 1G feedstocks or those that lead to land-use conversion (e.g., US DFC Biofuels investment guideline) or investing in assets that may involve fossil fuels (e.g., blending facilities for biofuels into fossil fuels)

Implications for Africa

Requirements mainly create demand for waste oils and 2G purposefully-grown oil crops, out of which ~60% will likely need to be imported by 2030 Palm oil is restricted in the EU and will be phased out

No domestic (in-Africa) impact. However, African airlines or ships refuelling in Europe must use sustainable fuels to match requirements

Projects seeking investment may face challenges from investors such as DFIs if using 1G feedstocks or engaging with fossil fuels (even if for blending)

Source: Press search, EU, expert interviews, US DFC Environmental Guidance Renewable Energy – Biofuels Projects

Biofuels ecosystem | Some analysis has been done on opportunity for biofuels in Africa; identified publications are on cooking and SAF

Similarities and differences between this report with other published reports on Africa biofuels opportunity

NON-EXHAUSTIVE

	Clean cooking			Sustainable Aviation Fuels (SAF)
Report	Africa Energy Commission Sustainable Scaling: Meeting the Clean Cooking Challenge in Africa (2022)	Kenya Ethanol Cooking Fuel Masterplan (2021)	Nigeria Integrated Energy Plan (2022)	Fuelling Africa's Flight: A Techno-Economic Assessment of Sustainable Aviation Fuels in Africa (2025)
Similarities to this report	Similar findings on key barriers (e.g., upfront costs, infrastructure, limited investment support)	Emphasis that ethanol is not cost-competitive compared to LPG and note the presently small scale of ethanol production for clean cooking in Kenya	High potential for clean cooking fuels uptake based on current penetration, affordability, and lack of alternatives	Assesses Africa's SAF potential, compares costs to conventional Jet A1 fuel, and offers insights on key unlocks to governments, investors and airlines
Key differences to this report	Focuses on broader clean cooking potential (including LPG and electricity), with a 2030 timeframe	Focuses only on ethanol, with limited focus on other clean cooking biofuels (e.g., bio-pellets and biogas); scope is only Kenya	Focuses on broader clean cooking potential (including LPG and electricity), with a 2030 timeframe; scope is only Nigeria	Focuses on four detailed country-level case studies and project examples related to different production pathways

Source: MECS, Dalberg, SEforALL, World Bank Group

Biofuels ecosystem | African players produce biofuels from various 1G and 2G feedstocks

NOT EXHAUSTIVE – AS OF FEBRUARY 2026

Use cases	Biofuel	Company	Primary feedstock(s)	Country
Road	**Ethanol**	Green Fuel (Chisumbaje)	Sugarcane	Zimbabwe
	FAME diesel	Giloil	UCO	Kenya
Cooking	**Biogas**	Sistema Bio	Manure	Kenya
		Home Biogas	Manure	Kenya
	Ethanol	*KOKO Networks (shut down as of February 2026)*	*NA – no own production*	*Kenya* *Rwanda*
		Giraffe Bioenergy	Cassava	Kenya
		Bukona Agro-distillery	Cassava	Uganda
		Asanita	Cassava	Nigeria
		Moto Safi	NA – no own production	Kenya Tanzania
		CleanStar Mozambique	Cassava	Mozambique
		Green Energy Biofuels	Sawdust and water hyacinth	Nigeria
Industrial heat and power	**Biogas**	Qube Renewables	Agri-waste (flower farm waste)	Kenya
		Pyrogenesis	Agri-waste	
		Biowatt Energy Holdings	Manure	South Africa
		Cummins Cogeneration Ltd	Woody biomass	Kenya
	Bio-briquettes/ bio-pellets	Tamuwa	Agricultural residues (bagasse)	Kenya
		Ecocharge	Sawdust and bagasse	Kenya
2G feedstock export		Eni	Castor oil	Kenya; Democratic Republic of the Congo
		Muenzer	UCO	Kenya

Source: Press search, company websites

Biofuels ecosystem | Several players have attracted small-scale investment in biofuels in Africa; one large investment was made into feedstock production

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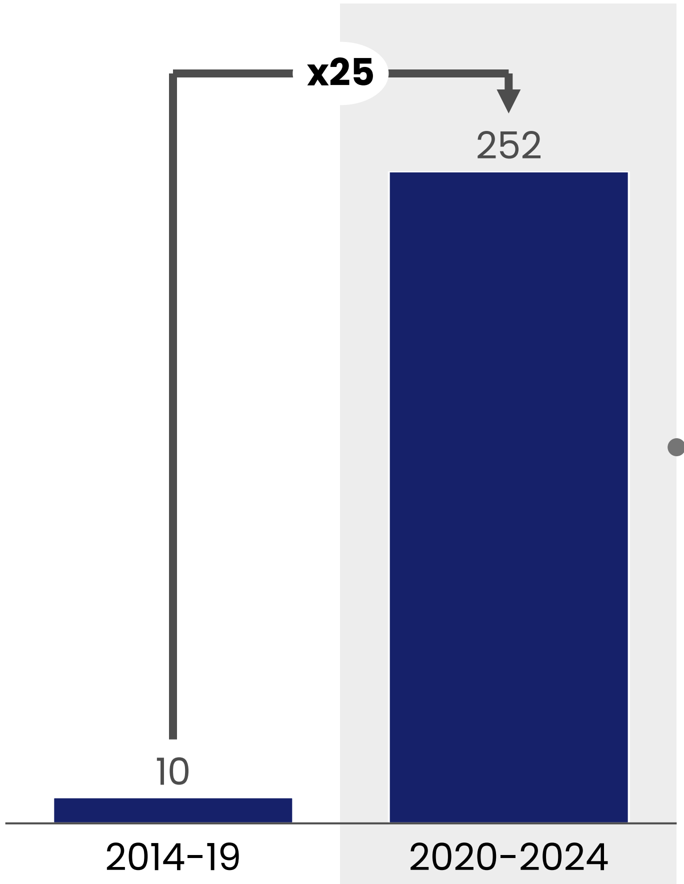
Total investments received by biofuel companies[1]



Deal details 2020-2025 (May YTD)

Country of investment	Target (Investee)	Deal size, USD Mn	Year	Details on Investment	Investors
Kenya	eni	210.0	2024	Debt financing for production of feedstock	IFC Italian Climate Fund
South Africa	bio-watt Energy Holdings	38.5	2023	Equity investment to scale up biogas plant	Climate Fund Managers
Kenya	GIRAFFE BIOENERGY	1.8	2023, 2024	Equity investment (seed round+seed extension)	Delta40 OPES LCF Other investors
Nigeria	Green Energy BioFuels	0.8	2016	Seed fund	Acumen
Kenya	Vuma BIOFUELS	0.8	2020	Seed fund	Hooge Rated Social Ventures Bestseller Foundation
Kenya		0.1	2018	Loan to scale up bio-briquettes production	Kenya Climate Innovation Center
Kenya	ACACIA INNOVATIONS	0	2022	Concessional equity financing to enhance production capacity	Kenya Climate Ventures
Kenya	KOKO	Undisclosed	2024, 2025	Debt facility/carbon finance loan	Mirova Rand Merchant Bank
Rwanda	BioMassters	Undisclosed	2024	Undisclosed	Acumen

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1. Companies that produce biofuels: ethanol, biogas, biodiesel, bio-briquettes and clean cooking stoves

Source: Press Search

Contents

Executive summary

Biofuels overview, scope, and context in Africa

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Appendix 1: Africa biofuel feedstock availability assessment

Appendix 2: Use case deep-dives

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Methodology | We followed a six-step process to assess the opportunity for biofuels in Africa

	Initial screening			Market sizing		
	A	B	C	D	E	F
Activity	**Identified a long list of biofuels opportunities that could be viable in Africa in the next 10 years**	**Assessed availability of feedstocks in Africa for those biofuels in specific countries**	**Determined feasibility of different biofuels**	**Estimated the market potential under two different scenarios**	**Outlined the investment potential & impact**	**Identified critical enablers**
Method	Created a **long list of 11 biofuels opportunities** based on intersection of end-use and feedstocks **Excluded use cases** that are expected to be prohibitively expensive, have low technological maturity, are unproven, or require heavy regulation even globally within 10 years	Determined the **demand and supply for 1G (food crop) feedstocks** to determine if it is possible for Africa to generate a surplus and under what conditions Determined **availability of waste feedstocks and potential to grow non-food 2G crops** Screened countries that could generate a minimum viable scale of different feedstocks to produce different biofuels	For specific end-uses, where feedstock is available at sufficient scale in specific countries, determined **the economic case focused on local production and competitiveness against other fuels** Excluded fuels for further analysis if no economic viability	Sized each opportunity based on a **limited-to-no policy scenario, and a strong policy scenario by 2035**	Determined the potential **investment size for the market potential under different scenarios** Assess resulting potential impact on **GDP, FX balance, and job creation** under different scenarios	Determined requirements for short-listed opportunities to scale

Step A | We identified 11 viable biofuel opportunities for Africa

🔵 1G ◐ 1G/2G 🔴 2G

Use case	Traditional fuel	Biofuel	Relevant feedstocks in Africa	Technical considerations
Road	Gasoline	🔵 1 Ethanol	Maize, cassava, sugar cane	Maximum blend is 20% with conventional gasoline without flex cars[4]; minimum economic scale production plant of 100Mn liters[3]
	Diesel	◐ 2 FAME diesel	Palm oil, UCO, tallow, castor, brassica carinata	Typical blends are up to 20%, but can be higher (up to 30%) given warm climate; production plants can be small (minimum scale less relevant)
		◐ 3 HVO[1]	Palm oil, UCO, tallow, castor, brassica carinata	Produced as a by-product of SAF production
Cooking	Wood, kerosene, etc.	🔴 4 Bio-pellets	Bagasse, saw dust	-
		🔴 5 Biogas	Manure, farm waste	Household-level biogas stoves require biomass feedstock equivalent to manure from 2 cows
	LPG, electricity	🔵 6 Ethanol	Maize, cassava, sugarcane	Minimum economic scale for production is a 15Mn litre distillery[3]
Industrial heat and power	Any non-green fuel for power or heat generation	🔴 7 Biogas	Manure, waste from food processing, sludges	-
		🔴 8 Bio-methane	Manure, waste from food processing, sludges	-
		🔴 9 Bio-briquettes	Bagasse, saw dust	-
Feedstock export		◐ 10 2G oil-based feedstock[2]	UCO, tallow, castor, brassica carinata	-
Aviation	Kerosene (Jet A1)	◐ 11 SAF refining	Palm oil, UCO, tallow, castor, brassica carinata	Minimum economic scale HEFA plant is 0.5Mn tonnes (requiring 0.6Mn tonnes of oil)

1. As a by-product from potential SAF production and use case in niche applications (e.g., off-grid power for mining companies)
2. Waste oils and purposefully-grown crops for SAF and HVO
3. Ethanol for cooking is a lower purity (70%) and can be produced at a smaller scale; Fuel-grade ethanol is 99% purity and requires much higher CAPEX therefore larger minimum scale
4. Flex cars largely unavailable in Africa and assumed to be so given that majority of the fleet is used vehicles from markets such as Japan, where flex cars are not primarily used

Source: Expert interviews

Step A | We excluded use cases (including for certain feedstocks) that are technologically immature or too expensive to be viable, based on global experience

DETAILED RATIONALE FOR EXCLUSION IN APPENDIX 4

🔵 1G ◐ 1G/2G 🔴 2G

				Rationale for exclusion		
Use case	**Traditional fuel**	**Biofuel**	**Feedstock**	**High cost relative to alternatives**	**No proven use case**	**Unviable technology until post-2035**
Road	Gasoline	Ethanol	🔴 Bagasse, rice husk, corn stalks	✓		✓
		Renewable gasoline	🔴 Agriculture or municipal waste, purposefully grown dry matter	✓		✓
	Diesel	HVO	🔴 Agriculture or municipal waste, purposefully grown dry matter	✓		
			🔵 Maize, cassava, sugar cane	✓		✓
Cooking		Bio-methane	🔴 Manure, farm waste	✓	✓	
		Ethanol	🔴 Bagasse, rice husk, corn stalks	✓		
Industrial heat and power	Wood, gas, LPG, coal	Renewable diesel (HVO)	◐ Palm oil, UCO, tallow, castor, brassica carinata	✓		
			🔴 Agriculture or municipal waste, purposefully grown dry matter	✓		
		FAME diesel	◐ Palm oil, UCO, tallow, castor, brassica carinata	✓		✓ Most diesel gen-sets not rated to take blends
Aviation	Kerosene	SAF refining	🔵 Maize, cassava, sugar cane	✓		
			🔴 Agriculture or municipal waste, purposefully grown dry matter	✓		
Maritime	Natural Gas	Bio-methane	🔴 Manure, agriculture or municipal waste	✓		
	Diesel	FAME diesel	◐ Palm oil, UCO, tallow, castor, brassica carinata		✓	
		Renewable diesel (HVO)	🔴 Municipal waste or purposefully grown dry matter	✓		
			🔵 Maize, cassava, sugar cane	✓		

Source: Expert interviews

Step B | We assessed the availability of 1G and 2G feedstocks as a constraint on potential biofuels use in Africa

Factors considered to assess feedstock surplus available for biofuels projection

1G (First generation feedstocks)

- **Starch and sugar-based**
- **Oil-based**

Supply	−	**Demand**	−	**Trade Balance**	×	**Minimum viable scale**
Under different agriculture projections (low/medium/high projection assuming different rates of yield growth based on historical and peer benchmarks; limited land expansion to avoid conversion of natural land for fuel production)		Different growth rates for different crops (e.g., some staples grow with population only; higher value crops grow in part with income)		Surplus countries trade with deficit countries along established trade corridors Some regions assumed to still import from international sources where it makes sense[1]		Surplus remaining in each country must meet minimum viable scale for a production plant, where applicable (e.g., for road-ethanol and SAF plants)

2G (Second-generation feedstocks)

Purposefully-grown crops (e.g., castor)

Potential production	×	**Feasibility**
Based on land suitability analysis for different crops (removing land with high biodiversity criticality)[2]		Assuming adoption only in limited areas to avoid competition with food crops or large land expansion

Waste (e.g., UCO, manure)

Availability	×	**Collectability**
Total waste generated for individual feedstocks (e.g., manure, tallow)		Based on factors such as presence of large farms (allowing large scale aggregation of manure), collection rates for used cooking oil in line with peer benchmarks, expected quality of waste (e.g., post-consumer waste largely considered too low quality)

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1. E.g., North Africa is assumed to remain food deficit, but assumed to continue to largely import from the world given high demand for crops such as wheat, where sub-Saharan Africa has low growing suitability
2. Including protected areas and relatively intact landscapes (e.g., East and Southern African miombo woodland, Central Africa rainforest)

Source: Manufacturing Africa team analysis

Step B | Africa could have sufficient feedstock for biofuels production with limited land expansion if it matched yield to peer countries

⬚ Projection used for market sizing

Surplus, 2035, Mn tonnes

	Selected feedstocks	Feedstock type	**Low projection** Historical yield growth, 1% p.a. land growth, waste oils collection rate persists	**Medium projection**[2] Yield matches peer countries 1% p.a. land growth, oil collection matches India benchmark	**High projection** Same as medium projected, but 2% p.a. land growth, oil collection matches Indonesia benchmark
1G	**Starch and sugar-based**	**Maize**	-	45	65
		Cassava	70	155	215
		Sugarcane	-	35	50
	Oil-based	**Palm oil**	-	10	13
2G	**Purposefully grown oil crops**	**Castor oil**	1.2		
		Brassica carinata oil	3.5		
	Waste oils	**UCO/Tallow**	0.5	0.8	1.6
	Other waste feedstock	**Bagasse**	30	45	50
		Sawdust	15		
		Manure	15		
		Municipal waste	450		

Surplus here is total that **can be used for biofuel production**[1]

However, **not all this surplus is used**, given that market potential is also constrained by economics against competing fuels and minimum scale requirements (i.e., a country may have a surplus but insufficient to meet minimum viable scale. A single road ethanol plant requires **0.5 Mt maize, 1.3 Mt cassava, or 2.7 Mt sugarcane.** A SAF plant requires **>0.6 Mt oil feedstock**)

1. For 1G starch, sugar, and oil crops, available surplus is shown: this surplus adjusts the potential surplus (raw projected production-demand) to account for trade to meet food and feed demand in deficit countries
2. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

Step B | Some biofuels use cases are constrained by feedstock availability; however, no use case is eliminated due to feedstock

🟩 Sufficient surplus in+ 20 countries
🟧 Sufficient surplus in 5-20 countries
🟨 Sufficient surplus in < 5 countries
🟥 No country
⬜ Not relevant/ no minimum requirement
⬚ Projection used for market sizing

● 1G ◐ 1G/ 2G ● 2G

Use case	Biofuel or product	Feedstock type	**Low projection** Historical yield growth, 1% p.a. land growth, waste oils collection rate persists	**Medium projection**[1] Yield growth to match peer countries, 1% p.a. land growth, oil collection matches India benchmark	**High projection** Same as medium projected, but 2% p.a. land growth, oil collection matches Indonesia benchmark
Road	1 Ethanol	Cassava, maize, sugarcane	🟨	🟩	🟩
	2 FAME diesel	UCO, castor oil, palm oil	🟩	🟩	🟩
	3 HVO	UCO, castor oil, palm oil	🟥	🟨	🟨
Cooking	4 Bio-pellets	Saw dust, bagasse	🟧	🟧	🟧
	5 Biogas	Manure	🟩	🟩	🟩
	6 Ethanol	Cassava, maize, sugarcane	🟨	🟧	🟩
Industrial power & Heat	7 Biogas	Manure, municipal waste	*No minimum scale required (biogas plants are for onsite use and can be scaled with feedstock size)*		
	8 Bio-methane	Manure, municipal waste	*No minimum scale required*		
	9 Bio-briquettes	Saw dust, bagasse	🟩	🟩	🟩
Feedstock export	10 2G oil-based feedstock	UCO, castor oil	*No minimum scale*		
Aviation	11 SAF refining	UCO, castor oil, palm oil	🟥	🟨	🟨

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1. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

Step C | However, not all use cases are economically viable, with two eliminated; others only serve specific market segments

Impact: 🟩 High (below par) 🟨 Medium (roughly at par) 🟥 Low (above par) ⬜ Negligible to no impact 🔵 1G ◐ 1G/ 2G 🔴 2G

Use case	Biofuel	Traditional fuel	Economic considerations[1] Cost competitiveness	 FX impact	Economic viability, and for which market segments
Road	🔵 1 **Ethanol**	Gasoline	🟨 E5-E10 blends can have negligible effect (<5%) on pump price in high-gasoline price countries with low feedstock costs	🟩 Replace gasoline imports	✓ Only scales with mandates in countries with high gasoline prices
	◐ 2 **FAME diesel**	Diesel	🟨 B5-B10 blends can have negligible effect on pump price (<5%) with low feedstock costs	🟩 Replace diesel imports	✓ Only scales with mandates in countries with low feedstock costs
	◐ 3 **HVO**	Diesel	🟥 3-6x more expensive than diesel; even with a blend, would increase pump price >10%	🟩 Replace diesel imports	✗ Too expensive for local demand; however, produced as a SAF by-product so only exported as such
Cooking	🔴 4 **Bio-pellets**	Wood, kerosene, etc.	🟨 Competitive against purchased wood or kerosene; not against harvested wood	⬜ Not assumed to compete with LPG so no effect on FX[2]	✓ Only for households currently purchasing wood or kerosene (likely in peri-urban or some rural areas); logging restrictions can increase viability
	🔴 5 **Biogas**	Wood, kerosene, etc.	🟩 If household has sufficient own-feedstock (e.g., 2 cows produce sufficient manure)	⬜ Not assumed to compete with LPG so no effect on FX[2]	✓ Only for households with available own-biomass (minimum 2 cows in an intensive or semi-intensive production system to allow manure collection)
	🔵 6 **Ethanol**	LPG, electricity	🟨 At par only with carbon credits and in inland countries with high logistics costs for LPG	⬜ Not assumed to compete with LPG so no effect on FX[2]	✓ Only for households with higher incomes who cannot use traditional fuels (due to inability to burn indoors) and lack access to alternates such as LPG or reliable electricity
Industrial heat and power	🔴 7 **Bio-gas**	Wood, gas, LPG, coal	🟨 vs. fossil fuels 🟥 vs. wood	🟨 Some possible substitution of imported fuels like coal	✓ Only for industries with wet biomass waste which have combined heat and power needs and low-to-medium heat requirements
	🔴 8 **Bio-methane**	Wood, gas, LPG, coal	🟥 20-30% more expensive than biogas, already pricing it out of range	🟨 Some possible substitution of imported fuels like coal	✗ Not economical versus alternatives
	🔴 9 **Bio-briquettes**	Wood, gas, LPG, coal	🟨 vs. fossil fuels 🟥 vs. wood	🟨 Some possible substitution of imported fuels like coal	✓ For companies burning biomass already without access to a fossil fuel alternative and close to a feedstock source
Feedstock export	◐ 10 **2G oil-based feedstock**	NA	⬜ NA	🟩 Export potential	✓ Largely for export given demand for feedstock to fulfil SAF production internationally; can also be locally produced for SAF production; increasing SAF mandates globally can increase demand
Aviation	◐ 11 **SAF refining**	Kerosene	🟥 5-10% blend rates would increase the price of jet fuel by ~10-15%	🟩 Export potential	✓ Only for export given high cost for local adoption and no expected or likely domestic mandates; increasing global SAF mandates can increase demand

1. Biofuels may have other considerations beyond economics. These include health benefits, energy access, and agriculture co-benefits (e.g., biogas produces fertiliser as a by-product; ethanol blending mandates may stimulate agriculture production). However, we looked primarily at the economic case
2. All cooking biofuels are expected to add to clean cooking penetration where clean alternates like LPG or reliable electricity are not available; they are not assumed to compete with LPG or electricity (given those are often cheaper)

Source: Manufacturing Africa team analysis

Step D | We then evaluate market potential based on economics across two different scenarios

	Limited-to-No Policy	Strong Policy
Local Policy	Biofuels adopted when **economically viable against alternatives** or with "less complex"[1] policies like **VAT** or **duty exemptions**	"More complex"[1] actions like **mandates for low-cost biofuels, import restrictions, or PPPs** adopted to drive biofuels use
Global Policy on SAF use	Global sustainability policies **remain at current level**	EU and US increase policy efforts to reduce CO2 emissions, including **increase of SAF blending mandates**
Example impact on market sizing	Ethanol demand for road **only driven by premium segment** (e.g., Shell V-Power) For clean cooking, **ethanol** only adopted in countries with low availability of alternatives (e.g., LPG, electricity) and access to carbon credits	**Mandates for ethanol blends** in road transport **drive at-scale uptake** **Increased SAF use in EU** supports greater investment into 2G oil-based feedstocks for export in Africa **Ban of firewood** use creates **higher demand for biofuels** as these become relatively more competitive

We do not assume any costly policies such as subsidies or mandates for high-cost biofuels (e.g., SAF mandates in Africa) given the economic reality in Africa

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[1] Less complex policies are those where there is widespread precedence for implementation in Africa, in a range of industries; more complex policies have fewer (if any) examples at the scale required

Source: Manufacturing Africa team analysis

Step D | Resulting in a $1.7–10Bn market potential for biofuels in Africa

● 1G ◐ 1G/ 2G ● 2G

Market potential always only targets customer segments where the economics of switching to biofuels make sense based on different policy scenarios, and where sufficient feedstock is available

		Estimated market potential, $Bn, 2035		**Opportunity characteristics**	
Use cases	**Biofuel**	**Limited-to-No policy**	**Strong Policy**	**Geographic concentration**[2]	**Investment concentration**[3]
Road	1 Ethanol	0.1	3.1	High	High
	2 FAME diesel	–	0.3	Very high	Very high
Cooking	4 Bio-pellets	0.2	0.3	Medium	Low
	5 Biogas[1]	0.04	0.1	Medium	Low
	6 Ethanol	0.7	0.8	Medium	Medium
Industrial heat and power[1]	7 Biogas	0.1	0.4	Low	Low
	9 Bio-briquettes	0.1	1.6	Medium	Low
Feedstock export	10 2G oil-based feedstock	0.5	2.5	Medium	Low
Aviation	11 SAF	–	1.1	Very high	Very high
Total		**1.7**	**10.1**		

These use cases can scale in size post-2035 to an addition $7.6B in value if mandates increase (global mandates for SAF and 2G oil-based feedstocks; domestic mandates for ethanol and FAME diesel)

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1. Market sizing for biogas and energy use cases assumes the equivalent electricity price; in reality, these use cases have no revenue to them but are rather CAPEX investments to reduce costs (e.g., a municipal waste facility may install biogas to replace electricity use for its heat requirements)
2. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%
3. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments), up to 20 ethanol plants to meet the full market potential

Source: Manufacturing Africa team analysis

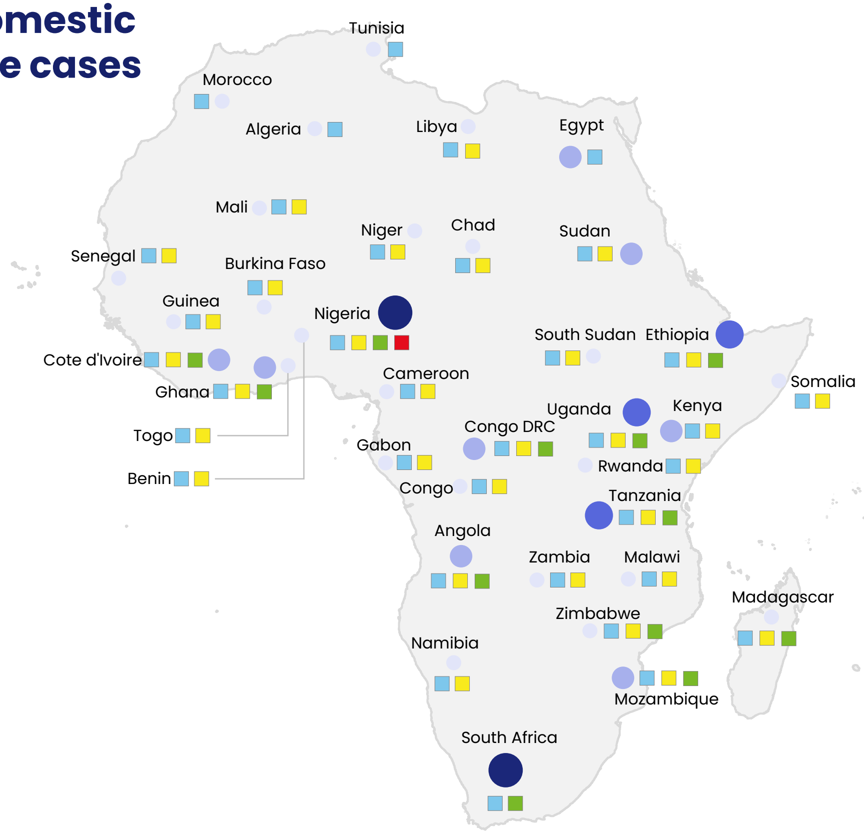
Step D | South Africa and Nigeria make up ~40% of potential; other key markets are Angola, Ethiopia, Tanzania, and Uganda

Market potential: ● 1,000+ ● 400-1,000 ● 100-400 ● ≤100

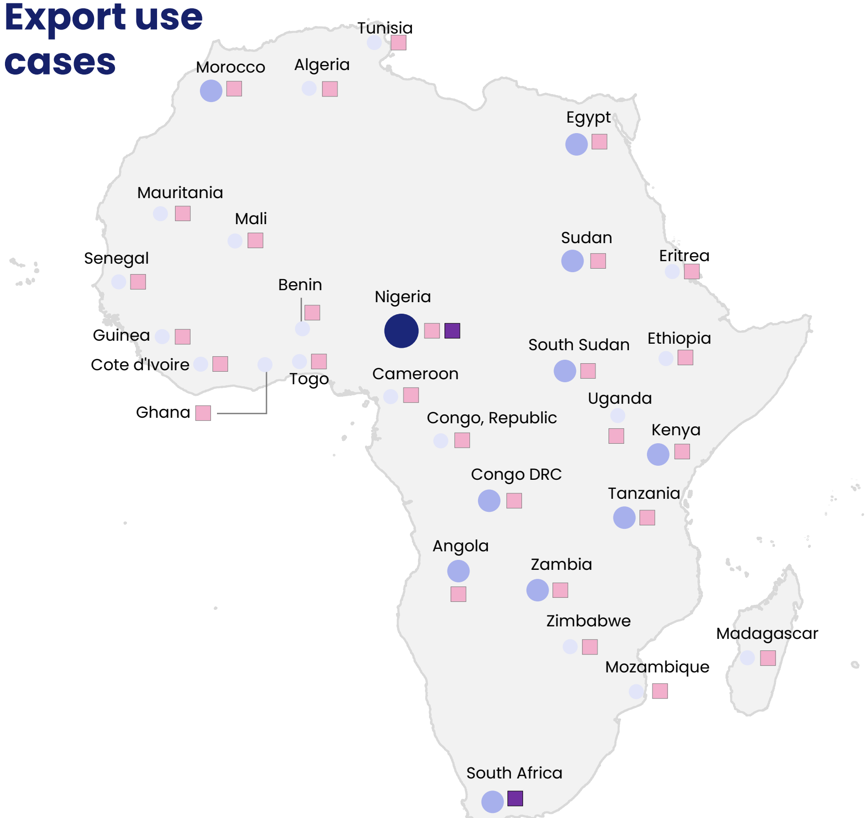
Market potential per country (Strong policy scenario), 2035, $Mn[1]

Major opportunities: 🟥 FAME diesel 🟩 Road ethanol 🟪 SAF refining 🟨 Cooking(biogas, bio-pellets, ethanol) 🟦 Industrial heat and power (biogas and bio-briquettes) ■ 2G oil-based feedstock

Domestic use cases



Export use cases



- Nigeria and South Africa could make up **~40% of the biofuels market** in Africa by 2035, primarily due to their **feedstock surplus potential** and **high fuel use** relative to other countries
- This is driven by local **road ethanol and FAME diesel blending**, and **industrial heat and power generation;** with potential for export of **2G oil-based feedstock** and **SAF export**
- Other key markets could be **Angola, Ethiopia, Tanzania, and Uganda**

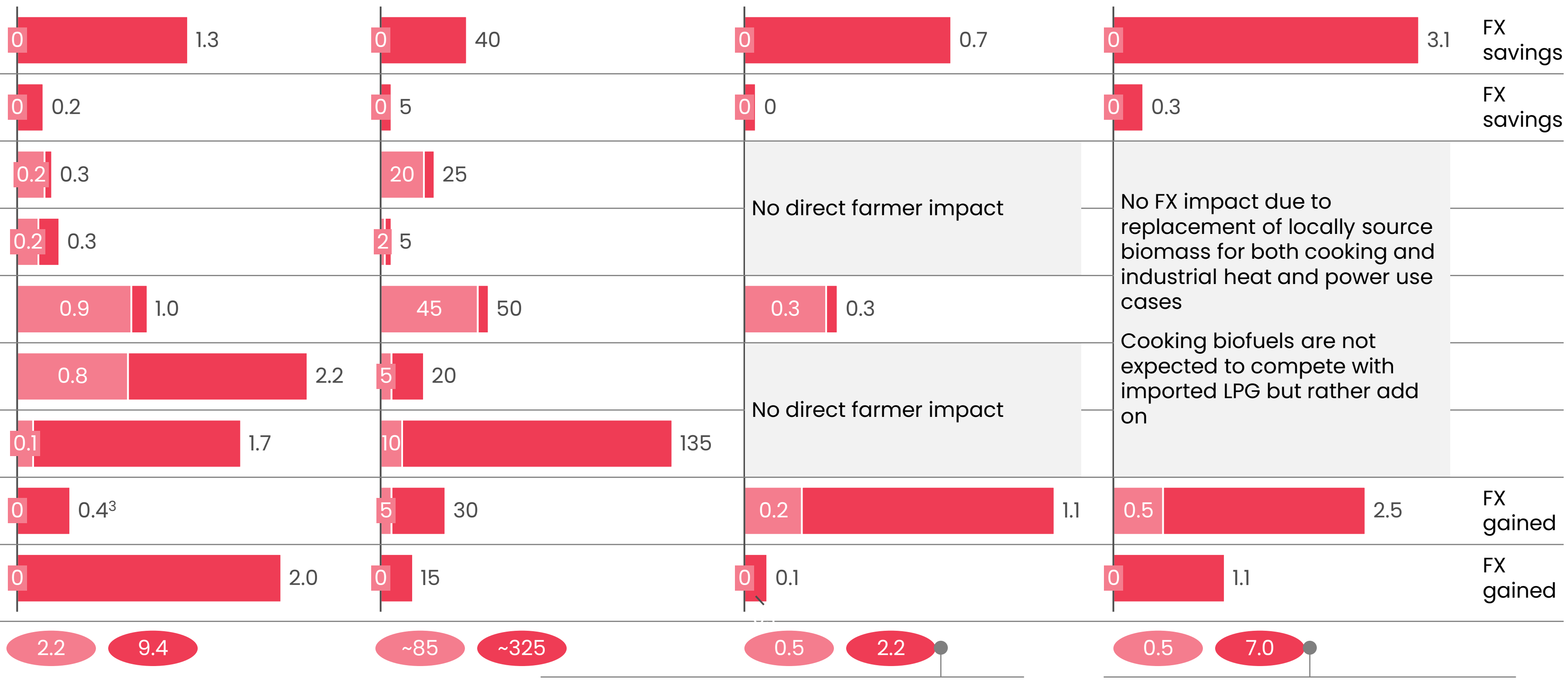
1. Countries with <$10Mn estimated market opportunity not shown

Source: Manufacturing Africa team analysis

Step E | $2-9Bn investment into biofuels could create up to 325,000 jobs, support ~2.2Mn farmers, and drive ~$7Bn FX impact

Potential impact of biofuels adoption under different scenarios by 2035

🟥 Limited-to-no policy 🟥 Strong policy



Use case	Biofuel	**Cumulative investment**, Bn USD		**Additional employment**, '000 FTEs[1]		**Farmers supported**, Mn[2]		**FX impact**, Bn USD		
Road	1 Ethanol	0	1.3	0	40	0	0.7	0	3.1	FX savings
	2 FAME diesel	0	0.2	0	5	0	0	0	0.3	FX savings
Cooking	4 Pellets	0.2	0.3	20	25	No direct farmer impact		No FX impact due to replacement of locally source biomass for both cooking and industrial heat and power use cases Cooking biofuels are not expected to compete with imported LPG but rather add on		
	5 Bio-gas	0.2	0.3	2	5					
	6 Ethanol	0.9	1.0	45	50	0.3	0.3			
Industrial heat and power	7 Bio-gas	0.8	2.2	5	20	No direct farmer impact				
	9 Briquettes	0.1	1.7	10	135					
Feedstock export	10 2G feedstock	0	0.4[3]	5	30	0.2	1.1	0.5	2.5	FX gained
Aviation	11 SAF	0	2.0	0	15	0	0.1	0	1.1	FX gained
Total		2.2	9.4	~85	~325	0.5	2.2	0.5	7.0	

To the 2.2Mn farmers - ~60% increase in Africa trade balance of ~$11Bn (2024 latest estimate)

To the $7B FX impact - ~7% of ~33Mn smallholder farmers in Africa impacted

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1. Direct jobs benchmarks: Cooking and industrial – 0.3 jobs per $8000 revenue; SAF and 2G oil-based feedstock production – 1000 jobs per $2Bn investment; Road ethanol – 42 jobs per $70Mn investment; Road FAME diesel – 160 jobs per $200Mn investment & Indirect jobs benchmarks (jobs per $1Mn revenue): 2G oil-based feedstock, ethanol, FAME diesel, and SAF production – 12; Bio-pellets, bio-briquettes – 56; Biogas – 11
2. Assumes 80% smallholder farmer and 20% nucleus commercial farms; Smallholder farmer size assumed to be 1.5ha
3. No low-end range of investment and low-end opportunity equal to what Eni is already doing where investment has already been secured

Manufacturing Africa

Source: Manufacturing Africa jobs multiplier index, Iowa State University, IFAD, Africa Export-Import Bank: African Trade Report 2025, Press search, Expert input

1 | Road – ethanol: summary of opportunity

Potential investors

Governments, primarily through national oil companies or Public-Private Partnerships (PPPs)

Top markets

South Africa

Nigeria

Uganda

Potential impact

Range based on policy scenarios

Market potential, $Bn	0.1 - 3.1
Investment needed, $Bn	0 - 1.3
Jobs created, '000	0 - 40
FX impact, $Bn	0 - 3.1
Geographic concentration[1]	High
Investment concentration[2]	High
Primary feedstock(s)	Cassava

Opportunity (strong policy scenario)

Invest up to $1.3Bn in 8-20 fuel-grade ethanol production facilities with 200Mn tonnes of annual capacity across 12 African countries[3], supported by blending mandates that ramp up gradually to enable 1G feedstock production and accompanies by governance mechanisms to flex mandates

Example set up

Create a PPP to set up an ethanol plant with an annual capacity of ~200Mn litres producing fuel-grade ethanol at 99.9%+ purity

+

Government **establishes a mandate** and an **independent body** to regulate and adjust blending based on harvest forecasts

Example operations

Annual feedstock needs for a plant in tonnes (ha)[5]:
Maize:
0.5Mn (0.16Mn)
Cassava:
1.3Mn (0.09Mn)
Sugarcane:
2.7Mn (0.03Mn)

Reaching **full surplus capacity may take years**, so governments might permit maize imports to maintain operations

Early surpluses can be stored, especially maize; cassava and sugarcane spoil faster after harvest

Transported to regional blending plants and **mixed with gasoline and additives**

Trucked to fuel stations

Sold to customers as blend (e.g., E5-10 blends) and is compatible with most modern cars

Limited fuel cost impact – in high-price gasoline markets

Burns **cleaner** and produces less **GHG emissions**

Retail revenue per plant is **~$170Mn**[4]

Who is already doing this?

South Africa: ABF SUGAR | **Malawi:** ethco | **Zimbabwe:** greenfuel

Enablers for consideration

Blending mandates with flexing mechanism

PPP for investment ($70Mn for a 200Mn litre plant)

Protection of local ethanol production from ethanol imports

Other considerations ⚠

Food vs. fuel: Opportunity relies on increased yields and conservative land expansion – could be driven by cassava and maize, with sugarcane more limited

Only 4% of cassava, 2% of maize, and 2% of sugarcane production potential in Africa is estimated to be used by 2035

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1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%; Top 3 countries (South Africa, Nigeria, Uganda) account for ~50% of the estimated market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments), up to 20 ethanol plants to meet the full market potential
3. Uganda, Mozambique, Zimbabwe, South Africa, Tanzania, DRC, Ethiopia, Ghana, Madagascar, Cote d'Ivoire, Angola, Nigeria
4. Assumed average estimated pump price of ethanol of 0.85 USD/L
5. Assumed yields are 3.1–3.8 t/ha for maize, 15 t/ha for cassava, and 97–111 t/ha for sugarcane

Source: Manufacturing Africa team analysis

2 | Road – FAME diesel: summary of opportunity

Potential investors

Governments, primarily through national oil companies or Public-Private Partnerships (PPPs)

Opportunity (strong policy scenario)

Invest $0.2Bn in a FAME diesel production facility with 350M L of annual capacity in Nigeria to meet a 5% blending mandate that ramps up gradually to enable 1G feedstock production and accompanies by governance mechanisms to flex mandates

Enablers for consideration

Blending mandates with flexing mechanism

PPP for investment ($200Mn for one 350Mn litre plant)

Top markets

Nigeria

Potential impact

Range based on policy scenarios

Market potential, $Bn	0 - 0.3
Investment needed, $Bn	0 - 0.2
Jobs created, '000	0 - 5
FX impact, $Bn	0 – 0.3
Geographic concentration[1]	Very high
Investment concentration[2]	Very high
Primary feedstock(s)	Palm oil

Example set up

Create a PPP[1] to set up a FAME diesel plant with an annual capacity of ~350,000 tonnes

+

Government **establishes a mandate** and an **independent body** to regulate and adjust blending based on harvest forecasts

Example operations

Annual feedstock needs for a plant in tonnes (ha)[7]:

Palm oil:
300k (75k)[3]

Transported to regional blending plants and **mixed with diesel and additives**

Trucked to fuel stations

Sold to customers as a B5 blend and is compatible with most modern vehicles

Limited fuel cost impact – on par with diesel when blended at low volumes

Burns **cleaner** and produces less **GHG emissions**

Reaching **full surplus capacity may take years,** hence might require the government to support

Early surpluses can be stored, especially maize; cassava and sugarcane spoil faster after harvest

Other considerations ⚠

Food vs. fuel: Opportunity relies on increased yields and conservative land expansion (to limit deforestation)

Only 3% of palm oil production potential in Nigeria is estimated to be used by 2035

Who is already doing this? (none currently supporting a road mandate)

Nigeria: fortafric | **South Africa:** | **Kenya:** Giloil

---

1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Nigeria accounts for 100% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments), only 1 plant in Nigeria
3. Assumes scale of 300,000 tonnes annual capacity of palm oil needed with a yield of 4t/ha (i.e., 18t/ha for the fruit and 0.22 conversion factor into oil)

Source: Manufacturing Africa team analysis

4 | Cooking – bio-pellets: summary of opportunity

Potential investors

Impact Investors

Top markets

Ethiopia | Nigeria | Tanzania

Potential impact

Range based on policy scenarios

Market potential, $Bn	0.2 - 0.3
Investment needed, $Bn	0.2 – 0.3
Jobs created, '000	20 - 25
FX impact, $Bn	N/A
Geographic concentration[1]	Medium
Investment concentration[2]	Low
Primary feedstock(s)	Bagasse

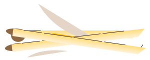
Opportunity (limited-to-no policy scenario)

Build ~100 plants ($2-3M each) producing 24kpta each near sugar mills or sawmills to serve households or institutions (e.g., schools, hospitals)

Example operations

Feedstock

Bagasse



Sawdust

Rice / wheat husk

Other Agricultural Residues

~1.3-2 tonnes of feedstock per tonne of bio-pellets

Production

Dry to low moisture content (ideally <10%)

Crush under high pressure

Bio-pellet formed

Packaging and distribution

Impact

4.7M peri-urban and households

2.4M tonne annual demand

>30% cost savings versus purchased wood[3]

Who is already doing this?

TAMUWA

Eco Charge

BioMassters THE CLEAN COOKING SOLUTION

ACACIA INNOVATIONS

BOLD BIOGAS

Enablers for consideration

Logging restrictions to increase demand for sustainable fuels

Patient capital to enable at scale production to optimise costs while building demand

Organise offtakers / anchor buyers (e.g., schools, hospitals) to create predictable demand

Other considerations ⚠

Transition fuel: Bio-pellets (and all cooking biofuels) may be a transition fuel, displaced by electricity and/or LPG over time. In some countries, this might be over a 10-20 year horizon still making biofuels a worthwhile investment. In Uganda, in particular, given potential LPG production from oil developments, that transition might happen sooner

---

1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Top 3 countries account for ~40% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments)
3. Savings can vary depending on country

Source: Manufacturing Africa team analysis

5 | Cooking – biogas: summary of opportunity

Potential investors

Impact Investors

Opportunity (limited-to-no policy scenario)

Establish 2-3 regional EPC companies to deploy 20,000+ small-scale biogas digesters annually in 44 Sub-Saharan countries, focusing on rural households 2+ cows (to generate sufficient manure). Create a combined model of digesters, cookstoves, and maintenance with financing (e.g., PAYGO)

Enablers for consideration

Access to financing to scale biogas production and distribution

Partnerships with development agencies and government to integrate biogas into national clean cooking strategies

Targeted grant funding to drive innovation in downstream activities (e.g., improved cookstoves, local distribution models, etc)

Top markets

Ethiopia

Tanzania

Kenya

Example operations

Clean cooking biogas players often integrate across the value chain to offer full service to customers. This is also key for managing user experience

EPC	EPC / 3RD Party	EPC / 3RD Party	EPC / 3RD Party
Manufacturing, sale and installation of biogas digesters	Manufacturing and sale of related equipment e.g., stoves	Financing for consumers	Maintenance and Repair; after-sale service

~$700

investment requirement per digester

~$25

monthly payments for households with 2-year financing

Potential impact

Range based on policy scenarios

Market potential, $Bn	0.04-0.1[3]
Investment needed, $Bn	0.2-0.3
Jobs created, '000	2 - 5
FX impact, $Bn	N/A
Geographic concentration[1]	Medium
Investment concentration[2]	Low
Primary feedstock(s)	Manure

Other considerations

Transition fuel: Biogas (and all cooking biofuels) may be a transition fuel, displaced by electricity and/or LPG over time. In some countries, this might be over a 10-20 year horizon still making biofuels a worthwhile investment.

Who is already doing this?

HOMEBIOGAS

SISTEMA.bio

LANFORCE ENERGY

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1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Top 3 countries account for ~30% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments)
3. Represented the annual value of the energy output of the biogas digester (based on LCOE)

Source: Manufacturing Africa team analysis

6 | Cooking – ethanol: summary of opportunity

Potential investors

Impact Investors

Top markets

Ethiopia Tanzania Uganda

Potential impact

Range based on policy scenarios

Market potential, $Bn	0.7 - 0.8
Investment needed, $Bn	0.9 - 1.0
Jobs created, '000	45 - 50
FX impact, $Bn	N/A
Geographic concentration[1]	Medium
Investment concentration[2]	Medium
Primary feedstock(s)	Cassava

Opportunity (limited-to-no policy scenario)

Establish ~70 ethanol plants of 15Mn L each using non-staple 1G crops (e.g., cassava in East Africa) to produce cooking-grade ethanol in countries where alternates for urban cooking (e.g., LPG, electricity) are unavailable or unreliable; connect to carbon credit mechanisms to improve affordability

Example operations

(For a single plant)

Feedstock Requirements

Ethanol plant with annual capacity; ~5M-15M litres producing low purity ethanol

Maize:
14.25-42.75Mn tonnes (4.5-13.6Mn ha)

Cassava:
30-90Mn tonnes (2-6Mn ha)

Sugarcane:
67.75-203.25Mn tonnes (0.7-2Mn ha)

Fuel Requirements

Burn bagasse, stover or waste as the primary fuel

Impact

4.7M
peri-urban and households

>20%
cost savings versus alternatives where carbon credits are available

Who is already doing this?

Green Energy BioFuels, GIRAFFE BIOENERGY, CleanStar Mozambique, BOLD BIOGAS, Bukona Agro

Enablers for consideration

Enable carbon markets to finance clean cooking

Patient capital facility to invest in production while demand is being scaled

Reduction of VAT for ethanol, expand storage and distribution networks

Other considerations ⚠

Food vs. feed: Ethanol plants can use various feedstocks; however, cassava has lower competition with food in some regions

Country strategy: Where LPG or electricity is already advanced, ethanol may not be viable. But in countries still early in clean-cooking adoption, ethanol can play a role in the transition

Transition fuel: Ethanol (and all cooking biofuels) may be a transition fuel, displaced by electricity and/or LPG over time. In some countries, this might be over a 10-20 year horizon still making biofuels a worthwhile investment.[3]

---

1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Top 3 countries account for ~30% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments)
3. In Uganda, in particular, given potential LPG production from oil developments, that transition might happen sooner

Source: Manufacturing Africa team analysis

7 | Industrial heat and power – biogas: summary of opportunity

Potential investors

Impact Investors

Top markets

Nigeria

South Africa

Ethiopia

Potential impact

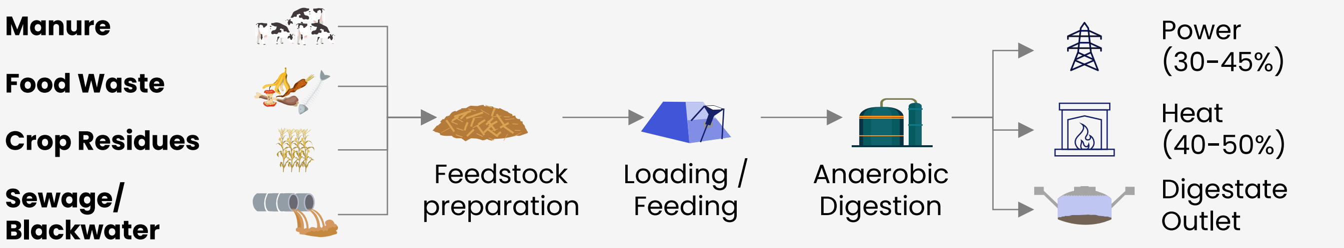
Range based on policy scenarios

Market potential, $Bn	0.1 – 0.4
Investment needed, $Bn	0.8 – 2.2
Jobs created, '000	10 - 135
FX impact, $Bn	N/A
Geographic concentration[1]	High
Investment concentration[2]	Low
Primary feedstock(s)	Manure

Opportunity (limited-to-no policy scenario)

Invest in EPC companies to build 200 biogas plants for heat and power requirements (0.5 - 2 MW each) focusing on breweries, agro-processors, and wastewater treatment plants; and ~30,000 rural biogas mini-grids for power distribution

Example operations



Manure

Food Waste

Crop Residues

Sewage/ Blackwater

Feedstock preparation

Loading / Feeding

Anaerobic Digestion

Power (30-45%)

Heat (40-50%)

Digestate Outlet

Market potential

Biogas potential is highest for industries who produce wet waste and have both heat and power demand. High potential industries include:

- Wastewater management facilities
- Breweries
- Food and beverage manufacturers

While cheaper fuel alternatives exist (natural gas, coal, solar, wood), there are industries with higher willingness to pay

Potential challenges

Markets are decentralised and regionally fragmented

High capital intensity – significant upfront working capital

Talent and capability gaps – shortage of skilled engineers and project managers for complex multidisciplinary projects

Enablers for consideration

Mandate renewable energy utilisation, particularly in government-operated wastewater management sites

Implement restrictions on open dumping or untreated waste discharge to drive adoption of anaerobic digestion solutions

Integrate biogas in national energy and waste management policies

Who is already doing this?

safisana

biogasafrica renewable energies

bio-watt Energy Holdings

Industry players using biogas in Africa

HEINEKEN

WATERLEAU

OLIVADO Taste the goodness

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1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Top 3 countries account for ~15% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments)

Source: Manufacturing Africa team analysis

9 | Industrial heat and power – bio-briquettes: summary of opportunity

Potential investors

Impact Investors

Opportunity (limited-to-no policy scenario)

Build >50 bio-briquette plants (~$3.5Mn each) across 22 countries to supply industrial clients largely in the agro-processing industry (linked to cooking bio-pellets plants)

Enablers for consideration

Logging restrictions to increase demand for sustainable fuels

Patient capital to enable at scale production to optimise costs and manage consistency of delivery while building demand

Support producers to secure multi-year contracts to enable large investment in production

Top markets

South Africa
Nigeria
Egypt

Example operations

Acquire feedstock (bagasse rice husk sawdust) - ~1.3-2.2 tonnes of waste/tonne of bio-briquette → Dry to low moisture content (ideally <10%) → Crush under high pressure → Bio-briquette pressed into final product → Packaging and distribution

Potential impact

Range based on policy scenarios

Market potential, $Bn	0.1 – 1.6
Investment needed, $Bn	0.1 – 1.7
Jobs created, '000	10 - 135
FX impact, $Bn	N/A
Geographic concentration[1]	Medium
Investment concentration[2]	Low
Primary feedstock(s)	Bagasse

Market potential

Bio-briquettes are more expensive than high quality wood, natural gas, or coal making this an ideal option for:

- Industries that do not have access to affordable alternatives **(high quality wood, natural gas or coal)**
- Industries with sustainability targets or high willingness to pay for cleaner fuels

Additional considerations

Feedstock availability: Dependent on consistent local biomass supply, which can be seasonal or dispersed

Logistics mismatch: Bio-briquette production is optimal close to the feedstock (rural), while demand is concentrated in urban and peri-urban areas

Low and medium heat: Bio-briquettes are well-suited for companies with low to medium heat needs, especially those shifting away from traditional biomass fuels

Who is already doing this?

TAMUWA
Eco_Charge
COEGA BIOMASS CENTRE
Kabaru Energy Manufacturers of Briquettes

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1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Top 3 countries account for ~45% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments)

Source: Manufacturing Africa team analysis

10 | Aviation – 2G oil-based feedstock export: summary of opportunity

Potential investors

Could involve joint ventures with European-based SAF producers

Top markets

South Africa

Nigeria

Angola

Potential impact

Range based on policy scenarios

Market potential, $Bn	0.5 – 2.5
Investment needed, $Bn	0 - 0.4[3]
Jobs created, '000	5 - 30
FX impact, $Bn	0.5 – 2.5
Geographic concentration[1]	Medium
Investment concentration[2]	Low
Primary feedstock(s)	UCO Castor oil

Opportunity (limited-to-no policy scenario)

Set up business to collect 0.5Mn tons of waste oils (e.g., UCO, tallow) for export; test and scale castor oil production and refining for export supporting 200k farmers

Example operations

UCO: increase collection of UCO through re-use bans, collection apps, and aggregation centres

Castor oil: test and scale castor production

UCO: Process and pre-teat the UCO

Castor oil: refine castor seeds to oil

UCO/castor oil: export to aggregators in EU and Asia

Enablers for consideration

Offtake agreements with EU markets for UCO and castor as an input into EU-based SAF production

Cooking oil health regulation (e.g., ban on re-use for health purposes)

Investment in testing and scaling 2G purposefully-grown oil crops (e.g., carinata) to validate business case

Who is already doing this?

Kenya: eni Giloil MÜNZER

South Africa: Globalis Trading SA

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1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Top 3 countries account for ~30% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments)
3. No low-end of investment as market in that scenario is equivalent to Eni's active project where investment has already been secured

Source: Manufacturing Africa team analysis

11 | Aviation – SAF refining: summary of opportunity

Potential investors

Could involve joint ventures with European-based or Asian-based SAF producers

Top markets

South Africa

Nigeria

Potential impact

Range based on policy scenarios

Market potential, $Bn	0 – 1.1
Investment needed, $Bn	0 – 2.0
Jobs created, '000	0 – 15
FX impact, $Bn	0 – 1.1
Geographic concentration[1]	Very High
Investment concentration[2]	Very High
Primary feedstock(s)	Palm oil UCO Castor oil

Opportunity (strong policy scenario)

Develop two SAF production plants—one in Nigeria and one in Southern Africa—each with a 500M-tonne annual capacity and export SAF and HVO. The Southern Africa plant could focus on 2G oil-based feedstocks (waste oils, purposefully-grown crops). The Nigerian plant would focus on 1G palm oil (with careful mitigation of deforestation risks)

Example operations

Nigeria 1G SAF plant

- Increase palm oil production through increased yields and conservative land expansion
- Refine to oil and use as feedstock for SAF in a 0.5Mn tonne HEFA plant

  A typical plant uses 0.6M tonnes of oil
- Export 0.5M tonnes of SAF/HVO from Nigeria to Asia

South Africa 2G SAF plant

- Southern Africa (Angola, Mozambique, Zambia, Zimbabwe, South Africa) could aggregate potential UCO and castor oil to support SAF refining
- Export 0.5M tonnes of SAF/HVO from South Africa to Europe

! HEFA process produces HVO as a by-product (share of HVO depends on process design); both HVO and SAF need to be exported (very limited domestic HVO use due to high cost)

Enablers for consideration

Increased production of palm and castor

Evaluate business case based on whether mandates scale in EU and Asia (SAF currently in overs-supply until 2030; post-2030, could become under-supply if increased mandates in other regions)

Mitigate deforestation risks associated with palm oil (e.g., via certifications / traceability requirements)

Set up offtake agreements in Asian markets – palm oil potential could serve select Asian markets

Set up financing for SAF plants (potentially through joint ventures)

Aggregate of UCO and 2G oil-based feedstock in South Africa from neighbours (e.g., Angola, Zambia)

Who is already doing this?

N/A (one Power-to-Liquid facility in early-stage discussions in South Africa)

---

1. Geographic concentration defined by market potential concentrated within top 3 countries: Very high (+75%), High (50-75%), Medium (25-50%), Low <25%;; Top 2 countries account for ~100% of the market potential
2. Defined by how market value is distributed across businesses: Very high (1-3 largescale plants / investments), High (4-20 plants / investments)

Source: Manufacturing Africa team analysis

Step F | A phased approach can be adopted to unlock biofuels in Africa

● 1G ◐ 1G/ 2G ● 2G

Use case	**Phase 1: Development** (Year 1-3)	**Phase 2: Ramp-up** (Year 3-5)	**Phase 3: Execution** (Year 5-10)	**Phase 4: Expansion** (Year 10+)
1 2 **Road ethanol / FAME diesel**	Announce planned **blending mandates** (E5–E10/B5); launch **PPPs**; set up **oversight body**; ramp up **feedstock production**	Construct **ethanol & biodiesel plants**; **collect and store feedstock** as production ramps up	Full **E5–E10/B5 implementation**	**Increase blends** (e.g., E20/B10)
4 5 6 **Clean cooking bio-pellets, biogas, ethanol**	Embed biofuels **into clean cooking strategies** at country level; launch education campaigns for households Set up a **clean cooking fund** to offer patient capital to producers, with link to carbon credits	**Improve logistics** between rural and peri-urban to improve access Implement **logging restrictions** to encourage adoption of cleaner fuels		
7 **Industrial biogas**	Set up companies to **installs digesters at industries**; **promote and market** digesters to industries with own-waste (e.g., wastewater facilities, breweries, agro-processors) Governments to consider requiring wastewater facilities to use biogas (common in many regions globally)			
9 **Industrial bio-briquettes**	Secure **patient capital** to set up bio-briquette factories; Build factories	**Improve logistics** between rural and peri-urban to improve access to bio-briquettes; p**romote and market** bio-briquettes to industries using wood		
10 **2G oil-based feedstock export**	Pilot **UCO/tallow collection** and **castor oil production**; announce **health regulation** banning re-use of cooking oil and **establish traceability system** for cooking oil		Scale **UCO/tallow collection** and **expand castor oil** production; pilot other 2G crops (e.g., carinata)	Diversify into **other oil crops** (e.g., brassica carinata)
11 **Aviation (SAF refining)**	Evaluate business case based on **mandate evolution in export regions (Asia, EU)**	Structure **JVs with global SAF producers**; **secure offtake** and **financing** (based on guaranteed offtake agreements); Test 2G oil crops and expand palm oil production; establish UCO/tallow collection network	Construct **HEFA plants in Nigeria & South Africa**; **expand regional oil feedstock** production/collection network	

Source: Manufacturing Africa team analysis

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

- 1G feedstocks
- 2G feedstocks

Appendix 2: Use case deep-dives

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

Important context for 1G feedstock opportunity assessment for Africa

We acknowledge that the **use of 1G feedstock in the African context is controversial due to food security concerns,** with some investors restricting investment in biofuels from 1G crops

However, given that there is **no economically viable alternative for 1G feedstock** for many major biofuels (e.g., ethanol), **this report would be incomplete without looking at the 1G opportunity**

Moreover, a case could be made based on other countries' experiences that **biofuels demand can spur investment in increased agriculture production** by **creating greater demand and absorbing surplus** during glut times (potentially preventing price crashes) – this may support food security over time

Our analysis aims to take a **pragmatic and conservative perspective on the potential for 1G crop production** in Africa, including:

- **Realistic yield growth potential** based on historical baseline or smallholder-farmer peer country benchmarks and even discounting these benchmarks for some countries to account for climatic impacts (e.g., recurrent droughts)
- **Limiting land expansion potential** to below or at historical rates (also to ensure natural land conversion does not happen to produce fuel)

Case studies show that biofuels can boost crop production, provide crop price floors, improve external balances, but can inflate food prices…

Potential impacts of ethanol adoption based on case studies for US, Brazil, and India

DETAILS IN APPENDIX 3

Impact supports biofuels adoption

↘ Headwind ↗ Tailwind

Impact		Insights
Increase local agriculture production	↗	🇺🇸 Since the introduction of the blending mandate in 2005, corn production has risen by an **average of 20%**, while corn acreage has expanded by **14% on average**
		🇧🇷 In the **first 10 years** of the programme, sugarcane production **grew 10% p.a.** as the mandate increased from **E11 to E20; 5% p.a.** ramp up from **2004 to 2015** when the mandate grew from **E20 to E27** also noted
		🇮🇳 While still inconclusive due to nascency of the programme, sugarcane production has increased on **average 2%** since the **revision of the blending mandate in 2018**
Reduce crop price volatility	→	🇺🇸 **Literature and data inconclusive** on ethanol's potential to create a price "floor" for feedstock. As a second market, ethanol can **absorb oversupply and reduce price drops** (e.g., processors in Brazil/ US can shift 40–60% of output between sugar/corn and ethanol). But, in shortage years (e.g., 2007/08), mandates have **amplified price increases.**
		🇧🇷 **Brazil has often flexed** to stabilise its sugarcane market (critical export crop) to counter ethanol market volatility.
Inflate food prices	↘	🇺🇸 **Increased fuel demand** from emerging markets (e.g., India, China) in 2008 led to **higher ethanol demand driving up corn prices** in the short term. In the long-term, US real corn prices **increased by +10% since 2005. 2013 EPA paper** concluded that each billion-gallon ethanol expansion can yield **2-3% increase in long-run corn prices**
		🇮🇳 India's recent ramp up of corn ethanol from 2021 led to **62% p.a. higher prices** on average by 2023
Improve trade and FX balance	↗	🇮🇳 Since 2014, India has **saved 15.5Bn+ on FX** by reducing oil imports with gasoline blending
		🇧🇷 In August 2025, Brazil expanded their mandate **from E27 to E30** which could cut annual gasoline consumption by up to **1.36Bn litres**, enabling Brazil to **cease being a net importer** of gasoline

Source: Expert interviews, OECD-FAO Agricultural Outlook 2022-2031, FAOSTAT, Reuters, EIA, EIA, University of Illinois, OPIS, CGIAR, Advanced Biofuels USA, Grains.org, EPA-NCEE

…while also improving fuel quality, reducing air pollution, and GHG emissions, without significantly impacting fuel cost

Potential impacts of ethanol adoption based on case studies for US, Brazil, and India

DETAILS IN APPENDIX 3

Impact supports biofuels adoption

↘ Headwind ↗ Tailwind

Impact		Insights
Change in fuel cost	→	**While ethanol is cheaper than gasoline on a per litre basis, range differences make it more expensive.** Data shows that global ethanol spot price on **average 7% been lower than gasoline over the last 10 years**. While fuel range impact on E5 blends can considered **negligible,** E10 blends have a **1-2% range disadvantage** due to lower energy content of ethanol implying up to **1% cost increase per kilometre.** Range impact can be higher on E20 blends **(3-6%)** implying up to **3%+ cost increase per kilometre.**
Cost effectively improve fuel quality	↗	Ethanol could be a **cost-effective, cleaner octane enhancer for gasoline**. At 500–600 USD/tonne, it is cheaper than most alternatives (biobutanol 900+, MTBE/ETBE[1] 700+, reformate[2] 800+, alkylate[2] 600+, aromatics 1200+) and less toxic/corrosive than methanol (< 400)
Reduce GHG emissions	↗	Ethanol blends can support GHG emission reduction. Ethanol from corn and sugar have on average **25% and 61% lower emission content** than gasoline. At 5% or 10% blending rate this suggests a **1,25-3% or 0.5-4% emission reduction per km** after adjusting for the fuel efficiency impact. Significantly higher emission reductions could be achieved with ethanol from 2G feedstocks (90-110% emission reduction), but at significantly higher costs.
Improve air quality & health outcomes	↗	Higher ethanol volume fuel (E85) can contain **85%+ less sulphur, aromatics, and benzene** compared to gasoline

1. Methyl Tertiary Butyl Ether (MTBE); Ethyl Tertiary Butyl Ether (ETBE)
2. Purposefully produced at oil refineries

Source: Expert interviews, OECD-FAO Agricultural Outlook 2022-2031, FAOSTAT, Reuters, EIA, EIA, University of Illinois, OPIS, CGIAR, Advanced Biofuels USA, Grains.org

Overall findings | Africa could have sufficient 1G and 2G feedstocks to support production and use of biofuels

⬚ Projection used for market sizing

Surplus[1], 2035, Mn tonnes

	Selected feedstocks	Feedstock type	**Low projection** Historical yield growth, 1% p.a. land growth, waste oils collection rate persists	**Medium projection**[2] Yield matches peer countries 1% p.a. land growth, oil collection matches India benchmark	**High projection** Same as medium projected, but 2% p.a. land growth, oil collection matches Indonesia benchmark
1G	**Starch and sugar-based**	**Maize**	-	45	65
		Cassava	70	155	215
		Sugarcane	-	35	50
	Oil-based	**Palm oil**	-	10	13
2G	**Purposefully grown oil crops**	**Castor oil**	1.2		
		Brassica carinata oil	3.5		
	Waste oils	**UCO/Tallow**	0.5	0.8	1.6
	Other waste feedstock	**Bagasse**	30	45	50
		Sawdust	15		
		Manure	15		
		Municipal waste	450		

Surplus here is total that **can be used for biofuel production** (where we use medium projection for market sizing)

However, **not all this surplus is used**, given that market potential is also constrained by economics against competing fuels and minimum scale requirements

1. For 1G starch, sugar, and oil crops, available surplus is shown: this surplus adjusts the potential surplus (raw projected production-demand) to account for trade to meet food and feed demand in deficit countries
2. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

- 1G feedstocks
- 2G feedstocks

Appendix 2: Use case deep-dives

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In Africa, 1G feedstock availability is assessed based on current and future demand and supply dynamics

Demand (food and feed)

Current demand estimated based on **2022 production plus average net imports** from 2018-2022[1]

Future food demand forecasted based on **population and income growth,**[1] with basic staples (e.g., maize) growing with population but more high value food crops growing also with income (e.g., sugar) in line with consumption curves seen in other countries

Future animal feed demand is forecasted based on **dairy, meat and egg consumption** and **level of intensification of production**

−

Supply

Supply forecasted for three projections with different levels of **yield growth** and **additional land under cultivation:**

- **Low projection:** Yields grow based on historical trend and conservative land growth (1% p.a.)
- **Medium projection:** Yields match peer countries (with discounts for semi-arid/arid countries to account for climate risks)2 and conservative land growth (1% p.a.)
- **High projection:** Same yields as medium projection, but moderate land growth (2% p.a.)

Implied land expansion conservative - restricted to avoid low land use change impact[3]

=

Surplus

Surplus (demand minus supply under the 3 projections) filtered downward as follows:

- **Potential surplus**: Future demand minus supply for each country
- **Available surplus:** Surplus in each country further adjusted downward, assuming some surplus is absorbed in regional trade to deficit countries (**to minimise competition with food and feed needs in the region**)
- **Useable surplus:** Available surplus filtered further to focus only on countries with **sufficient surplus to meet minimum feedstock requirements for biofuels that have a minimum viable scale:**[3]
    - 200Mn litres for road ethanol (requires 0.5Mn tonnes maize, 1.3Mn tonnes cassava or 2.7Mn tonnes sugarcane)
    - 15Mn litres for clean cooking (requires 0.04Mn tonnes maize, 0.1Mn tonnes cassava, 0.2Mn tonnes sugarcane)
    - 0.5Mn tonnes of SAF production (requires 0.6Mn tonnes of oil feedstock)

---

1. Income growth is proxied by growth in GDP per capita value at constant purchasing power parity
2. 80% cap; countries includes Algeria, Botswana, Chad, Burkina Faso, etc.
3. Available land capped based on geospatial analysis that excludes existing agriculture land, protected areas, forests, other critical habitats and land unsuitable for farming; land expansion then assumed to be even more conservative against available land

Source: Manufacturing Africa team analysis

1G starch and sugar-based feedstocks | **Deep-dive**

🟥 Focus for this section

⬚ Projection used for market sizing

Surplus[1], 2035, Mn tonnes

	Selected feedstocks	Feedstock type	**Low projection** Historical yield growth, 1% p.a. land growth, waste oils collection rate persists	**Medium projection**[2] Yield matches peer countries 1% p.a. land growth, oil collection matches India benchmark	**High projection** Same as medium projected, but 2% p.a. land growth, oil collection matches Indonesia benchmark
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2G	**Purposefully grown oil crops**	**Castor oil**	1.2		
		Brassica carinata oil	3.5		
	Waste oils	**UCO/Tallow**	0.5	0.8	1.6
	Other waste feedstock	**Bagasse**	30	45	50
		Sawdust	15		
		Manure	15		
		Municipal waste	450		

Surplus here is total that **can be used for biofuel production** (where we use medium projection for market sizing)

However, **not all this surplus is used**, given that market potential is also constrained by economics against competing fuels and minimum scale requirements

1. For 1G starch, sugar, and oil crops, available surplus is shown: this surplus adjusts the potential surplus (raw projected production-demand) to account for trade to meet food and feed demand in deficit countries
2. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

1G starch and sugar-based feedstocks | SSA could realise maize, cassava, and sugarcane surpluses with yield improvements

Estimated demand, production and available surplus (2035), Mn tonnes

🟩 Surplus ⬜ Balance 🟨 Deficit

⬚ Projection used for market sizing

Feedstock	Region	Estimated demand Mn tonnes, 2035	Projected production			Potential surplus/deficit[4]			Available surplus/deficit[4]		
			Low[1]	Medium[2]	High[3]	Low[1]	Medium[2]	High[3]	Low[1]	Medium[2]	High[3]
Maize	Eastern Africa	61	50	84	94	(10)	23	34	(10)	22	33
	Southern Africa	23	24	25	28	2	2	5	(1)	3	6
	Western Africa	45	39	46	52	(6)	1	7	(5)	3	9
	Central Africa	10	7	27	31	(3)	17	21	(2)	16	19
Cassava	Eastern Africa	48	50	86	98	2	38	50	(36)	39	50
	Southern Africa	0	0	0	0	(0)	(0)	(0)	(18)	(0)	(0)
	Western Africa	144	140	229	260	(4)	85	116	69	85	118
	Central Africa	85	66	117	132	(18)	32	48	(27)	32	48
Sugarcane	Eastern Africa	62	48	74	83	(14)	12	21	(3)	16	27
	Southern Africa	12	28	29	33	16	17	21	(0)	18	22
	Western Africa	32	11	25	29	(21)	(7)	(3)	(21)	(7)	(4)
	Central Africa	12	6	16	18	(6)	4	6	(1)	–	–

! North Africa excluded – expected to remain in a deficit (given limited arable land) but to fulfil that deficit largely outside of SSA given high demand for crops such as wheat, which do not grow well in SSA due to agro-ecology

1. Crop yields forecasted based on historical trend and conservative land growth (1% p.a.)
2. Crop yields forecasted to match peer countries and conservative land growth (1% p.a.)
3. Crop yields forecasted to match peer countries and moderate land growth (2% p.a.)
4. Potential surplus is projected supply minus forecasted demand while available surplus adjusts the potential surplus to account for trade to meet food and feed demand in deficit countries

Source: FAOSTAT, Expert interviews, Press search, Resourcetrade.earth

1G starch and sugar-based feedstocks | Analysis focuses on maize, cassava, and sugarcane as key potential feedstocks for ethanol

Favourability: ■ High ■ Medium □ Low

What are starch and sugar crops used for?

Primary use is for **ethanol**, for which there is no commercially viable feedstock alternative (e.g., waste alternatives like fibrous and woody waste have high cost)

There is technically a use in advanced biofuels like **SAF**, but these use commercially non-viable processes (e.g., alcohol-to-jet, which is 60% more expensive than HEFA[4])

Maize, sugar, and cassava used as main feedstocks due to higher biofuel yield

Crop	Yield, T/ha[1]	Conversion efficiency, L/t	Biofuel yield, L/ha	Other considerations
Sugar cane[2]	65	70	4,550	Not a staple crop, so mitigates food-fuel conflict
Cassava	12	180	2070	Not a staple crop in some regions, mitigating food-fuel conflict
Maize	4.9	400	1960	Potential impact on staple crop price if biofuel demand is not ramped up gradually, but use for biofuel could create incentive for farmers to invest in additional production
Other starch crops[3]	1.3-2.8	340-380	494-952	

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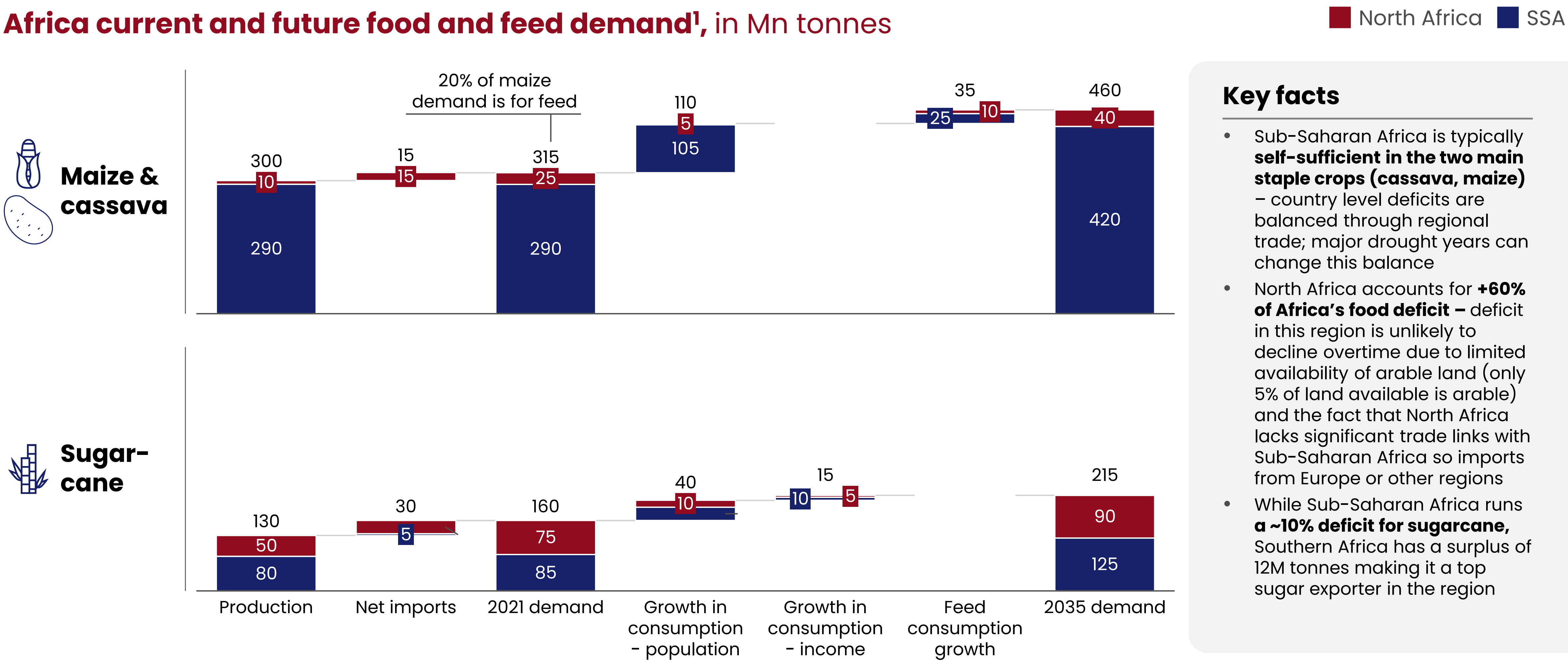
1. Global average
2. Sugar beets have even higher biofuel yield (5 060 litres per ha), which is however less commonly grown in Africa due to warmer climate
3. e.g., wheat, sorghum
4. Hydro-processed Esters and Fatty Acids

Source: FAO (2008). The State of Food and Agriculture. Biofuels: Prospects, risks and opportunities

1G starch and sugar-based feedstocks | Demand: 2035 demand for maize, cassava, and sugarcane could reach ~675Mn tonnes

Africa current and future food and feed demand[1], in Mn tonnes



Key facts

- Sub-Saharan Africa is typically **self-sufficient in the two main staple crops (cassava, maize)** – country level deficits are balanced through regional trade; major drought years can change this balance
- North Africa accounts for **+60% of Africa's food deficit –** deficit in this region is unlikely to decline overtime due to limited availability of arable land (only 5% of land available is arable) and the fact that North Africa lacks significant trade links with Sub-Saharan Africa so imports from Europe or other regions
- While Sub-Saharan Africa runs **a ~10% deficit for sugarcane,** Southern Africa has a surplus of 12M tonnes making it a top sugar exporter in the region

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1. Assessment excludes other starch crops (e.g., rice, wheat, millet, sorghum) which could be used for biofuels given their limited availability and use. Staple crops, such as maize and cassava are projected to growth with population. High value crops, such as wheat in SSA and rice in all regions, except Western Africa, as well as the sugar demand are projected to grow with population and income measure by GDP per capita at constant 2021 Purchasing Power Parity prices. The growth factor for income is determined based on global benchmarks for the income and per capita consumption relationship for each crop. Feed consumption is forecasted based on FAO forecasts for meat, egg and dairy consumption as well as projected intensification of production

Source: FAOSTAT, TradeMap, Resourcetrade.earth, Press Search, Expert Interviews

1G starch and sugar-based feedstocks | Supply: Assumptions for yield growth and land expansion were benchmarked against historical and peer data

Projection levels

Projection level	Yield growth	Land expansion
Low	**0.22-1.26%** p.a. yield growth based on 2013-2022 **historical yield growth**, except for maize in North Africa where yields already high	Current agriculture land plus **1% land expansion rate**
Medium	**3.3-6.5%** p.a. yield growth based 2022 **yields achieved in benchmark countries**	Current agriculture land plus **1% land expansion rate**
High	**3.3-6.5%** p.a. yield growth based 2022 **yields achieved in benchmark countries**	Current agriculture land plus **2% land expansion rate**

Benchmark yields, t/ha[1]

Crop	Current	Bench-mark	Benchmark countries
Maize	0.9–2.7	3.1–3.8	India
Cassava	0.9–12	15	Brazil
Sugar cane	97–111	97–111	Regional peers[5]

- Only countries with comparable factors (e.g., no irrigation, no GMO seeds, mainly smallholder farming, similar agroecology) were selected
- Some countries in Africa already exceed these yield benchmarks; for those, historical growth rates applied[2]
- For 23 countries with significant share of arid and semi-arid land, yields are only grown up to 80% of the benchmark yields to account for drought risks[3]

Land expansion

- Assumed land expansion rates are conservative relative to 2013-22 historical land expansion rates (2% maize, 3% cassava, 1% sugarcane)
- Implied absolute land expansion is compared against available (unused) suitable land to ensure that expansion is feasible without deforestation.
- If new agriculture land for maize and cassava exceeded 60% of land potential in any of the three projections, the land expansion was discounted to minimise risk of crop competition

1. Tonnes/hectare
2. Countries above benchmark: 10 for maize, 11 for cassava, and 4 for sugar
3. e.g., Burkina Faso, Botswana, South Africa, Kenya
4. Egypt for North Africa, Chad for Central Africa, Senegal for West Africa, Malawi for East Africa
5. 0.9t/ha is the yield achieved in Southern Africa where cassava production is limited

Source: FAOSTAT, TradeMap, Resourcetrade.earth, USDA, Press Search, Expert Interviews

1G starch and sugar-based feedstocks | Surplus: Available surpluses consider inter-country supply and demand dynamics

Illustrative intra-Africa trade patterns for maize, cassava, and sugarcane

Maize Cassava Sugarcane

Maize

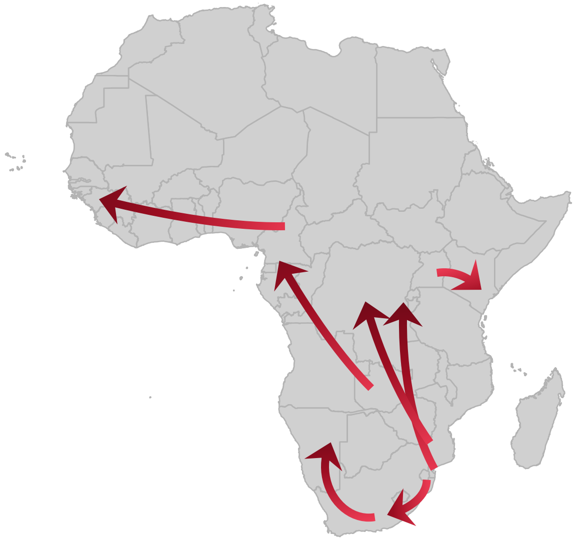
Primarily flows **within Eastern and Southern Africa and into Central and Western Africa**, with key trade routes like Zambia–DRC

Cassava

Movement is less widespread but travels within **Western Africa**, and between **Eastern and Central Africa**

For example, Nigeria serves as a major cassava supplier, trading with Cameroon

Sugarcane



Trade is from **Southern into Eastern and Central Africa**

For example, Mauritius exports sugar to countries like Kenya

Key considerations

- Surplus balancing required to account for **regional food security needs**
- **North Africa trade with Sub-Saharan Africa for the selected crops is limited**, with stronger links present with the Middle East and Europe

Source: Resource trade. Earth, Press search, Expert interviews

1G starch and sugar-based feedstocks | Maize surplus: Available maize surplus estimated at 45-65Mn tonnes by 2035

Projected available maize surplus, 2035

⬚ Projection used for market sizing   ■ Limited or no surplus

Low projection

Crop yields forecasted based on historical trend and conservative land growth (1% p.a.)

Medium projection

Crop yields forecasted to match peer countries and conservative land growth (1% p.a.)

High projection

Crop yields forecasted to match peer countries and moderate land growth (2% p.a.)

	Low projection	Medium projection	High projection
Total available surplus, Mn tonnes, 2035	-	45	65

Source: FAOSTAT, Resourcetrade.earth, Press search, Expert interviews

1G starch and sugar-based feedstocks | Cassava surplus: Available cassava surplus estimated at 70-215Mn tonnes by 2035

Projected available cassava surplus, 2035

⬚ Projection used for market sizing

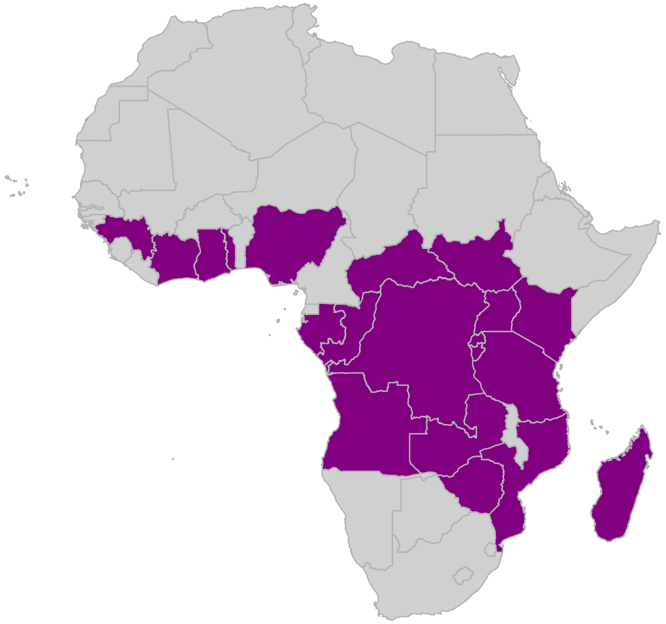
▨ Limited or no surplus

Low projection

Crop yields forecasted based on historical trend and conservative land growth (1% p.a.)

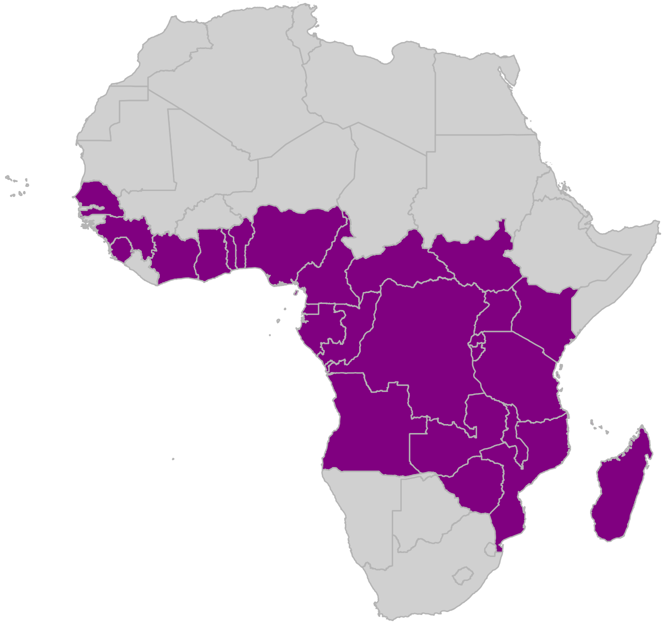
Medium projection

Crop yields forecasted to match peer countries and conservative land growth (1% p.a.)



High projection

Crop yields forecasted to match peer countries and moderate land growth (2% p.a.)



Total available surplus, Mn tonnes, 2035	70	155	215

Source: FAOSTAT, Resourcetrade.earth, Press search, Expert interviews

1G starch and sugar-based feedstocks | Sugarcane surplus: Available sugarcane surplus likely 20-50Mn tonnes by 2035

Projected available sugarcane surplus, 2035

⬚ Projection used for market sizing

▨ Limited or no surplus

Low projection

Crop yields forecasted based on historical trend and conservative land growth (1% p.a.)

Medium projection

Crop yields forecasted to match peer countries and conservative land growth (1% p.a.)

High projection

Crop yields forecasted to match peer countries and moderate land growth (2% p.a.)

Total available surplus, Mn tonnes, 2035	-	20	50

Source: FAOSTAT, Resourcetrade.earth, Press search, Expert interviews

1G oil-based feedstocks | Deep-dive

▨ Focus for this section ⬚ Projection used for market sizing

Surplus[1], 2035, Mn tonnes

	Selected feedstocks	Feedstock type	**Low projection** Historical yield growth, 1% p.a. land growth, waste oils collection rate persists	**Medium projection**[2] Yield matches peer countries 1% p.a. land growth, oil collection matches India benchmark	**High projection** Same as medium projected, but 2% p.a. land growth, oil collection matches Indonesia benchmark
1G	**Starch and sugar-based**	**Maize**	-	45	65
		Cassava	70	155	215
		Sugarcane	-	35	50
	Oil-based	**Palm oil**	-	10	13
2G	**Purposefully grown oil crops**	**Castor oil**		1.2	
		Brassica carinata oil		3.5	
	Waste oils	**UCO/Tallow**	0.5	0.8	1.6
	Other waste feedstock	**Bagasse**	30	45	50
		Sawdust		15	
		Manure		15	
		Municipal waste		450	

Surplus here is total that **can be used for biofuel production** (where we use medium projection for market sizing)

However, **not all this surplus is used**, given that market potential is also constrained by economics against competing fuels and minimum scale requirements

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1. For 1G starch, sugar, and oil crops, available surplus is shown: this surplus adjusts the potential surplus (raw projected production-demand) to account for trade to meet food and feed demand in deficit countries
2. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

1G oil-based feedstocks | West Africa could realise a palm oil surplus of 10-13Mn tonnes by 2035

SSA estimated demand (2022-35), production and available surplus (2035) – palm oil

⬚ Projection used for market sizing 🟩 Surplus ⬜ Balance 🟨 Deficit

Feedstock	**Region**	**Estimated demand,** Mn tonnes, 2035	**Projected production,** Mn tonnes, 2035			**Available surplus/deficit,** Mn tonnes, 2035		
			Low [1]	**Medium** [2]	**High** [3]	**Low** [1]	**Medium** [2]	**High** [3]
Palm oil	Eastern Africa	4.2	0.0	0.1	0.1	(4.0)	–	–
	Southern Africa	0.4	0.0	0.0	0.0	(0.4)	(0.4)	(0.4)
	Western Africa	8.1	5.5	21.9	24.8	(2.7)	10.1	13.3
	Central Africa	1.5	0.8	2.0	2.2	(0.7)	–	–

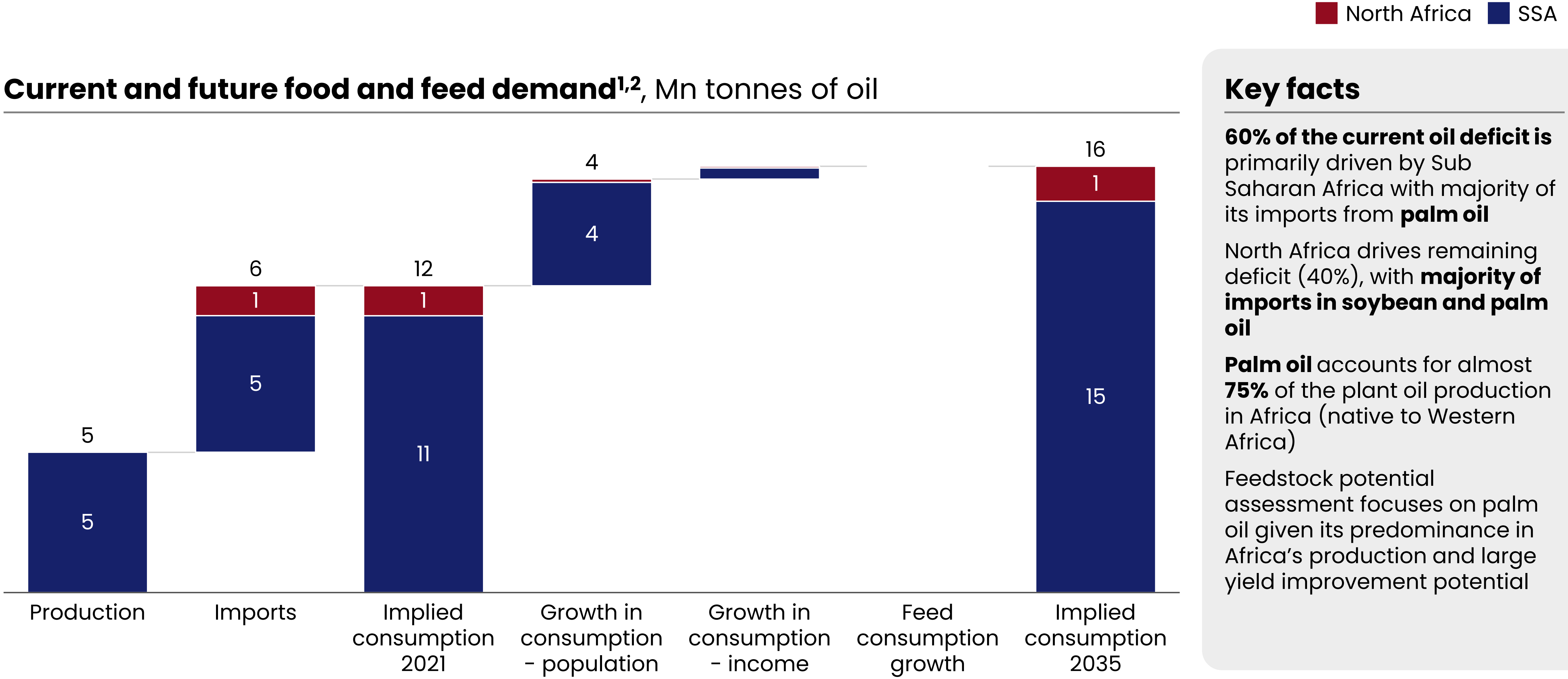
! North Africa excluded as they are expected to remain in deficit and have limited trading links to SSA

1. Crop yields forecasted based on historical trend and conservative land growth (1% p.a.)
2. Crop yields forecasted to match peer countries and conservative land growth (1% p.a.)
3. Crop yields forecasted to match peer countries and moderate land growth (2% p.a.)

Source: FAOSTAT, Expert interviews, Press search, Resourcetrade.earth

1G oil-based feedstocks | Demand: Today, Africa demands 12Mn tonnes of palm oil; expected to grow to 16Mn tonnes by 2035

Current and future food and feed demand[1,2], Mn tonnes of oil



Key facts

60% of the current oil deficit is primarily driven by Sub Saharan Africa with majority of its imports from **palm oil**

North Africa drives remaining deficit (40%), with **majority of imports in soybean and palm oil**

Palm oil accounts for almost **75%** of the plant oil production in Africa (native to Western Africa)

Feedstock potential assessment focuses on palm oil given its predominance in Africa's production and large yield improvement potential

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1. Oil crops projected to grow with population and income measured by GDP per capita at constant 2021 Purchasing Power Parity Prices. The growth factor for income is determined based on global benchmarks for the income and per capita consumption relationship for each crop. Palm oil is not primarily used for animal feed
2. Other oil crops (e.g., sunflower, soybeans) were explored but de-prioritised given their limited production in Africa (compared to palm oil)

Source: FAOSTAT, TradeMap, Resourcetrade.earth, Press Search, Expert Interviews

1G oil-based feedstocks | Supply: Assumptions for yield growth and land expansion were benchmarked with historical and peer data

Projection levels

Projection level	Yield growth	Land expansion
Low	**0.06%** p.a. yield growth based on 2013-22 **historical yield growth**, except for maize in North Africa where yields already high	Current agriculture land plus **1% land expansion rate**
Medium	**2.2%** p.a. yield growth based 2022 **yields achieved in benchmark countries**	Current agriculture land plus **1% land expansion rate**
High	**2.2%** p.a. yield growth based 2022 **yields achieved in benchmark countries**	Current agriculture land plus **2% land expansion rate**

Benchmark yields, t/ha[1]

Crop	Current	Bench-mark	Benchmark countries
Palm oil	2-8	18	Indonesia, Malaysia

- Only countries with comparable factors (e.g., no irrigation, no GMO seeds, mainly smallholder farming, similar agroecology) were selected
- Some countries in Africa already exceed these yield benchmarks; for those, historical growth rates applied[2]
- For 23 countries with significant share of arid and semi-arid land, yields are only grown up to 80% of the benchmark yields to account for drought risks[3]

Land expansion

Assumed land expansion rates are conservative relative to 2013-22 historical land expansion rates (4% palm oil)

Implied absolute land expansion is compared against available (unused) suitable land to ensure that expansion is feasible without deforestation.

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1. Tonnes/hectare
2. Countries above benchmark: 2 for palm oil
3. e.g., Burkina Faso, Botswana, South Africa, Kenya

Source: FAOSTAT, TradeMap, Resourcetrade.earth, USDA, Press Search, Expert Interviews

1G oil-based feedstocks | Surplus: Available palm oil surplus considers regional trade balancing

Illustrative intra-Africa trade patterns for palm oil

Palm oil

West Africa shows stronger intra-regional flows with Ghana and Nigeria as key players. In **Central Africa**, flows extend from countries like Equatorial Guinea and DRC towards markets further south

Key considerations

Surplus balancing required to account for **regional food security needs**

North Africa trade with Sub-Saharan Africa for the selected crops is limited, with stronger links present with the Middle East and Europe

Manufacturing Africa

Source: Resource trade. Earth, Press search, Expert interviews

1G oil-based feedstocks | Surplus palm oil: Available palm oil surplus likely 10-13Mn tonnes by 2035

Projected available palm oil surplus, 2035

⬚ Projection used for market sizing ⬜ Limited or no surplus ■ Sufficient surplus

	Low projection[1]	Medium projection[2]	High projection[3]
			
Total available surplus, Mn tonnes, 2035	-	10	13
Share of total crop production (SSA), 2035	-	55%	60%

---

1. Crop yields forecasted based on historical trend and conservative land growth (1% p.a.) |
2. Crop yields forecasted to match peer countries and conservative land growth (1% p.a.) |
3. Crop yields forecasted to match peer countries and moderate land growth (2% p.a.)

Source: FAOSTAT, Resourcetrade.earth, Press search, Expert interviews

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

- 1G feedstocks
- 2G feedstocks

Appendix 2: Use case deep-dives

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

2G oil-based feedstocks | Deep-dive

▨ Focus for this section ⬚ Projection used for market sizing

Surplus[1], 2035, Mn tonnes

	Selected feedstocks	Feedstock type	**Low projection** Historical yield growth, 1% p.a. land growth, waste oils collection rate persists	**Medium projection**[2] Yield matches peer countries 1% p.a. land growth, oil collection matches India benchmark	**High projection** Same as medium projected, but 2% p.a. land growth, oil collection matches Indonesia benchmark
1G	**Starch and sugar-based**	**Maize**	-	45	65
		Cassava	70	155	215
		Sugarcane	-	35	50
	Oil-based	**Palm oil**	-	10	13
2G	**Purposefully grown oil crops**	**Castor oil**	1.2		
		Brassica carinata oil	3.5		
	Waste oils	**UCO/Tallow**	0.5	0.8	1.6
	Other waste feedstock	**Bagasse**	30	45	50
		Sawdust	15		
		Manure	15		
		Municipal waste	450		

Surplus here is total that **can be used for biofuel production** (where we use medium projection for market sizing)

However, **not all this surplus is used**, given that market potential is also constrained by economics against competing fuels and minimum scale requirements

---

1. For 1G starch, sugar, and oil crops, available surplus is shown: this surplus adjusts the potential surplus (raw projected production-demand) to account for trade to meet food and feed demand in deficit countries
2. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

2G oil-based feedstocks | Africa may have potential for ~1.2Mn tonnes of castor, ~3.5Mn tonnes of carinata, and 0.5-1.6Mn of waste oils by 2035

⬚ Projection used for market sizing

Potential feedstock, Mn tonnes, 2035

		Low projection	**Medium projection**	**High projection**
Feedstock	**Region**	*5% urban collection rate for oil, based on current Africa average*	*10% UCO urban collection rate (India benchmark); purposefully grown 2G oil crops estimated based on land suitability and 5% adoption rate*	*25% urban collection rate (Indonesia benchmark)*
Castor oil	Eastern Africa	0.6		
	Southern Africa	0.0		
	Western Africa	0.2		
	Central Africa	0.3		
	North Africa	0.1		
Carinata oil	Africa[2]	3.5		
Waste oils – UCO[1] & tallow	Eastern Africa	0.1	0.2	0.3
	Southern Africa	0.2	0.2	0.3
	Western Africa	0.1	0.2	0.5
	Central Africa	0.0	0.0	0.2
	North Africa	0.1	0.2	0.3

1. UCO - Used Cooking Oil; Tallow - animal fat waste
2. Country-level assessment not conducted

Source: FAOSTAT, Expert interviews, Press search, Resourcetrade.earth

2G oil-based feedstocks – Purposefully grown crops | Rotational crops and perennial trees can be used for biofuel production

Selected purposely grown oil crops for fuel production (not exhaustive)

🟨 Shows promise in Africa but remains unproven ⬜ Proven globally but has limited potential in Africa 🟩 Potential proven at scale in Africa ⬚ High-level potential assessment follows

	Annual (rotational)			Perennial (not rotational)			
Crop	🟨 **Carinata**	⬜ **Camelina**	⬜ **Pennycress**	⬜ **Macauba**	⬜ **Pongamia**	⬜ **Jatropha**	🟩 ⬚ **Castor**
Description	Currently most promising rotational crop type, can adapt to semi-arid climates and has high oil content	Camelina is mostly produced in Europe and Asia and its a short-season crop that takes 85 to 100 days to mature	Flowering plant native to Eurasia and common in North America - primarily a temperate seed crop used as a winter cover crop	Palm tree found in arid and semiarid regions in South America; yields like palm oil but less restrictions on temperature & precipitation	Leguminous tree crop, native to Southeast Asia and targeted at subtropical land and degraded soils	A perennial woody shrub/tree, originally from Central America, grows in arid and semi arid areas	Indigenous to tropical Africa, commercially grown for pharmaceutical or industrial use, or biofuels (e.g., Eni)
Cultivation period	~6 months	~3-4 months	~ 3 months				
Yield, t oil/ ha	1-1.3	0.4-0.6	0.4-0.6	5-6	2-4	1.5	1
Suitability to growing in Africa	◕ Well adapted to semi-arid conditions; traditionally cultivated in Ethiopia	◔ Grown mostly in Europe and North America	◔ Temperate climates	◕ Palm oil native to Africa, Macauba more flexible	◑ Well adapted to tropical climate	◑ Grows in arid/semi arid areas	◕ Drought resistant Cultivated in Ethiopia, Mozambique and Zambia
Other consideration	Non usable by-product			Yields of macauba and pongamia not proven at scale		Initial trials suggest no economic viability	Relatively high price

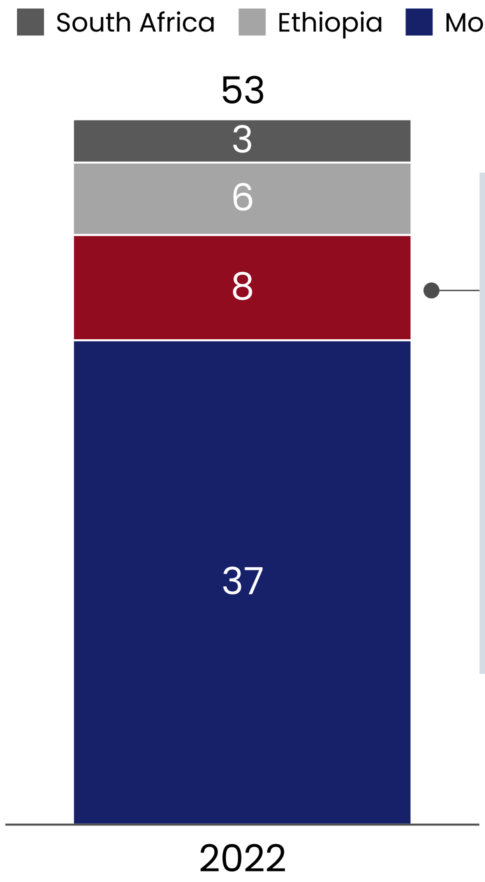
1. Detailed regional potential dependent on local boundary conditions (e.g., climate, infrastructure, technology)

Source: USDA; Science Direct, McKinsey analysis

2G oil-based feedstocks - Purposefully grown crops | Both castor and brassica carinata are grown in Africa today at limited scale

Castor is grown today across Africa for industrial use, including biofuels

Castor oil production, in ktpa

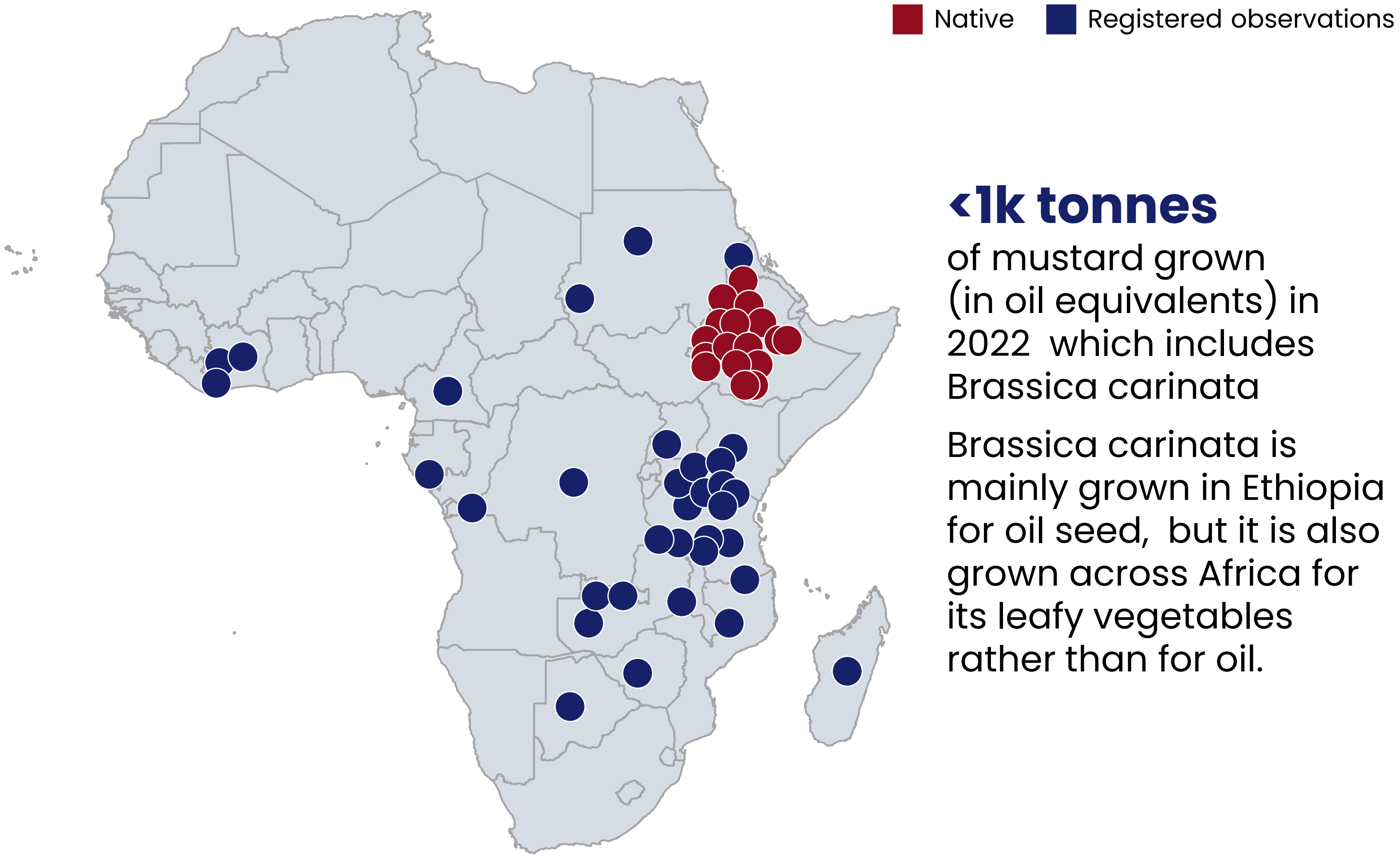


Eni invested in Kenya to support castor cultivation for biofuel

In 2023, a pilot project produced about 0.7k tonnes

Brassica carinata is grown at lower scale and mainly in Ethiopia

Know observations of Brassica Carinata



<1k tonnes

of mustard grown (in oil equivalents) in 2022 which includes Brassica carinata

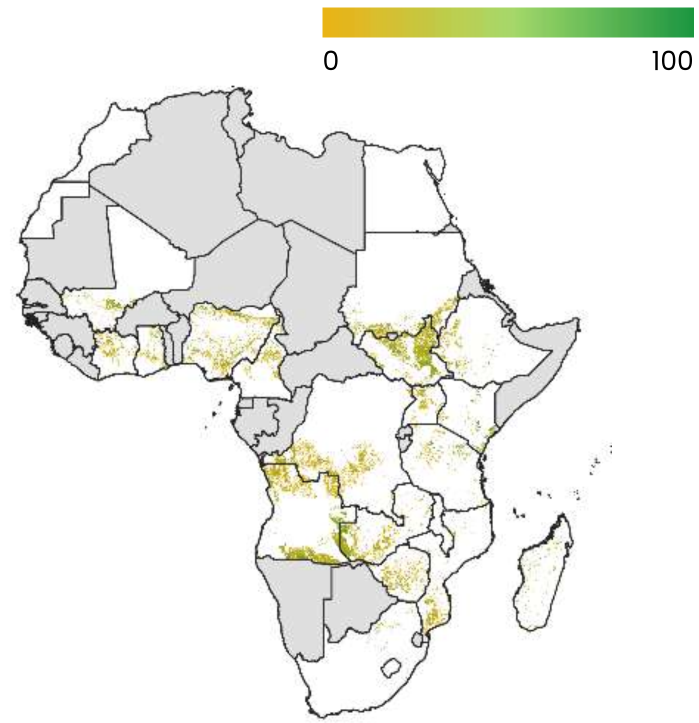
Brassica carinata is mainly grown in Ethiopia for oil seed, but it is also grown across Africa for its leafy vegetables rather than for oil.

Source: Eni website, FAOSTAT, Press Search

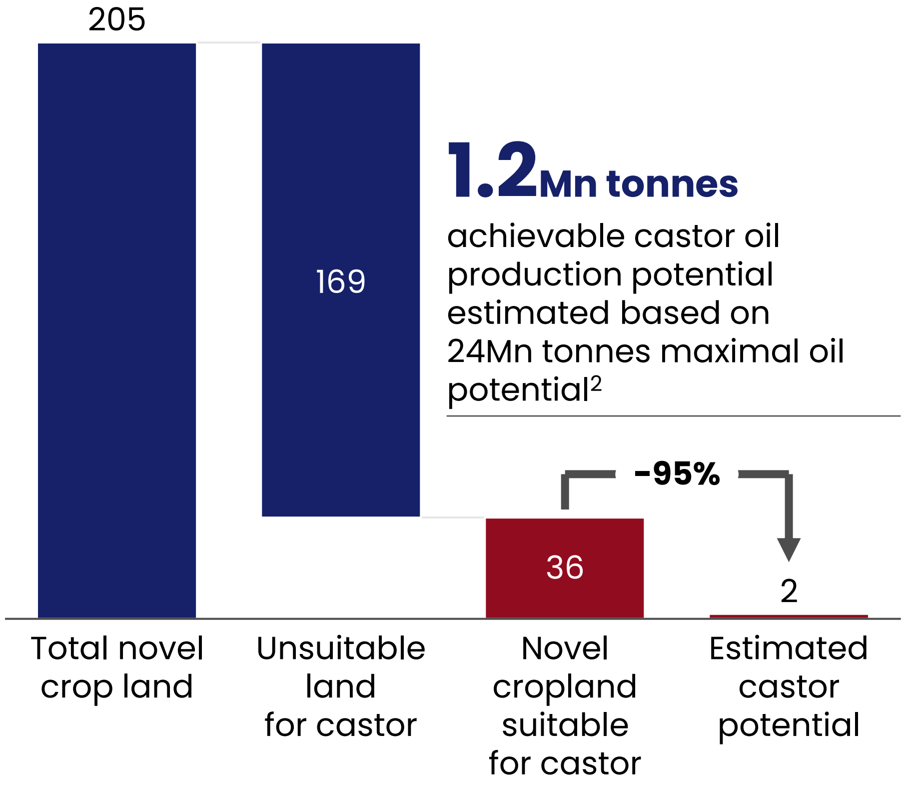
2G oil-based feedstocks – Purposefully grown crops | ~1.2Mn tonnes potential for castor oil identified across 20+ African countries

Illustration: Novel crop land suitable for castor cultivation[5]

Novel suitable cropland concentration, %



Novel crop land suitable for castor and estimated potential, Mn ha



1.2Mn tonnes

achievable castor oil production potential estimated based on 24Mn tonnes maximal oil potential[2]

Methodology

First, **novel crop land was identified** at 1km granularity by excluding unsuitable land, protected or environmentally critical land (e.g., forest land, critical habitats, protected areas), current crop land and areas unsuitable for mechanised farming (i.e., land with >15% slope)[3]

Among the novel crop land, **suitable land was identified** based on **climate, soil pH level and soil depth**

Only 5% of novel crop land is assumed to be available for non-food crop production in line with global benchmark of today's crop land split

---

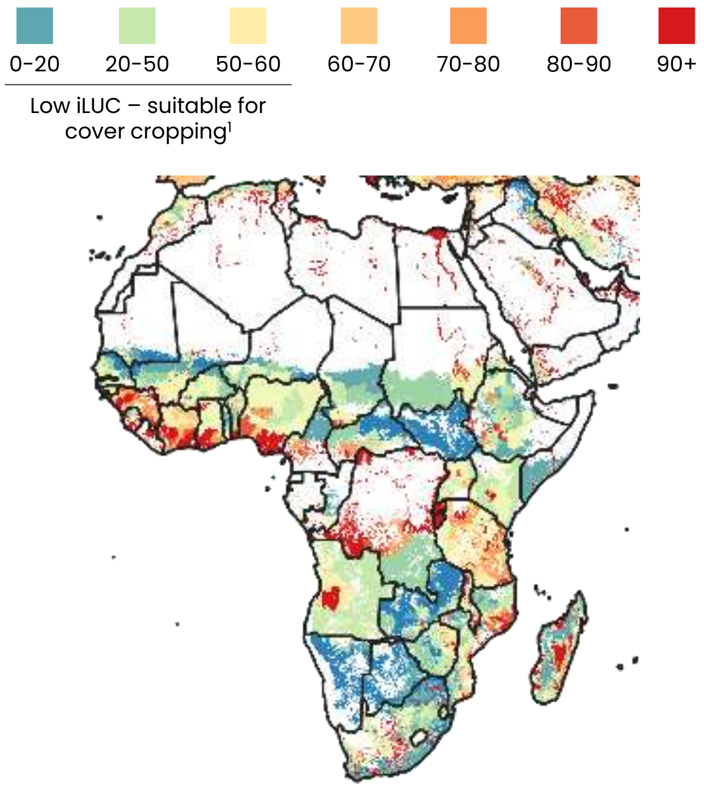
1. Forest land, critical habitats, protected areas
2. Assuming 0.7 tonnes of oil per hectare on average across Africa and only 20% of crop land is used for non-food crops (based on global benchmark)
3. Unsuitable land includes, e.g., urban land, water bodies; protected or environmentally critical land includes, e.g., forest land, critical habitats, protected areas; areas unsuitable for mechanised farming are defined as areas with >15% slope
4. including land with barriers to farming
5. Countries in grey not assessed due to already expected low potential for castor oil suitability

Source: UNEP WCMC, EarthEnv, CHELSA, HUMERIS, ISRIC, Ianda et. al (2020) Optimising the Cooperated "Multi-Countries" Biodiesel Production and Consumption in Sub-Saharan Africa, Our World in Data

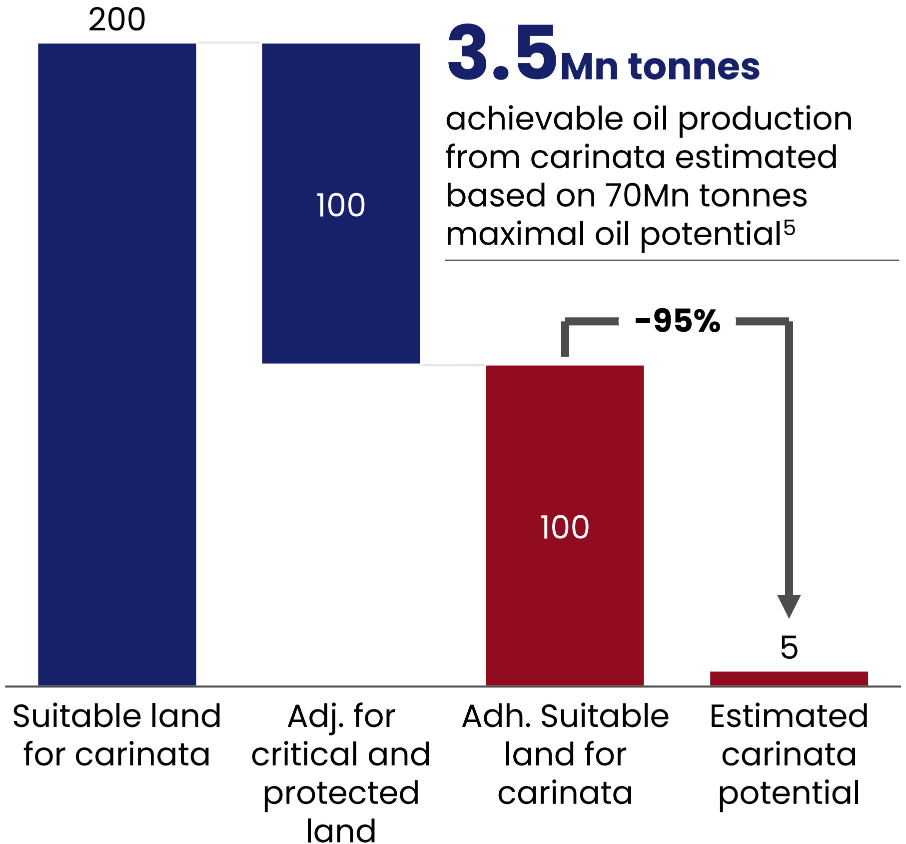
2G oil-based feedstocks – Purposefully grown crops | ~3.5Mn tonnes potential for carinata; but viability still remains unproven

Illustration: Suitable land for brassica carinata as rotational crop

Crop duration ratio, %, number of days a field is cropped per year



Crop land suitable for carinata as rotational crop and estimated carinata potential, Mn ha



3.5Mn tonnes achievable oil production from carinata estimated based on 70Mn tonnes maximal oil potential[5]

Methodology

Identified highly or very highly suitable locations for carinata production based on 20 bioclimatic variables[2]

Identified low-iLUC areas as areas that are cropped less than 7 months per year leaving space for crop rotation[3]

Additionally, high water stress areas are filtered out

Resulting 200Mn ha is reduced by 50% accounting for potential overlap with critical habitat areas[4]

Assume only 5% of farmers are willing to adopt rotational crops

! **Carinata unproven** given no valuable end-use for by-product which makes economic case non-viable. Not used in market projections as a result

---

1. Low indirect land use change; only land suitable for carinata based on climatic conditions
2. High and Very high correspond to probability bands of 65-89% and 80-100% respectively
3. Based on % of year that the yield is cropped. If crop duration is <60%, land is considered suitable for crop rotation
4. Including forests, protected areas, and critical habitats | 5. Assuming 0.7 t oil/ha

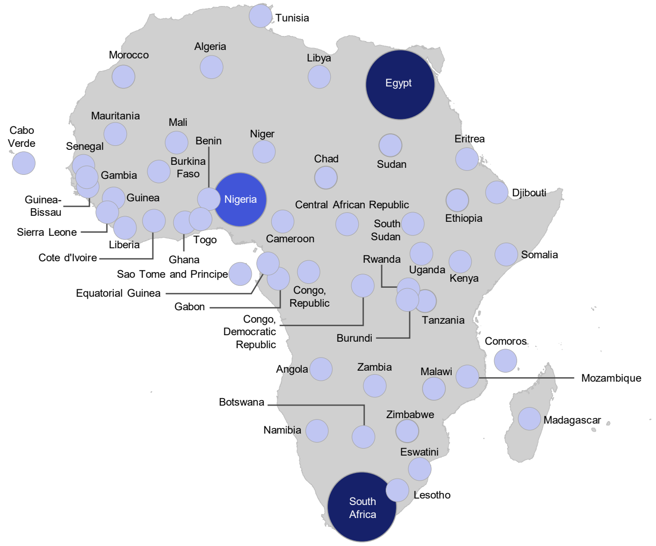
Source: ACRE analysis, Press Search, Expert input

2G oil-based feedstocks – Waste oils | Africa could have 0.5-1.6Mn tonnes of UCO/tallow by 2035, varying based on collection rate

Countries projected production of waste oils (UCO, and Tallow[1]), tonnes 2035

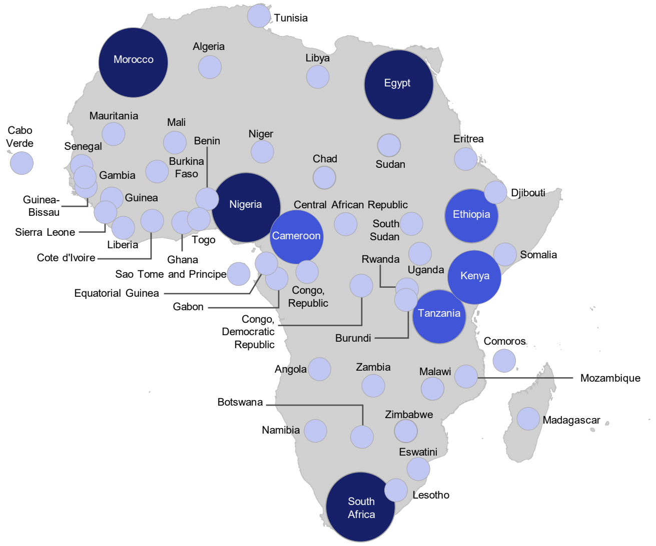
⬚ Projection used for market sizing ● <50,000 ● 50,000-99,999 ● 100,000+

Low projection – 5% UCO urban collection rate, based on current Africa average



Medium projection – 10% UCO urban collection rate, midpoint (India benchmark)

High projection – 25% urban collection are based on peer country (Indonesia) assuming regulation[2]



Total potential usable surplus, Mn tonnes, 2035	0.5	0.8	1.6

---

1. Based on assumed consumption of cooking oil and share of processed meat (for tallow) with different collection rates
2. Introduction of ban on reusing used cooking oil

UKaid **Manufacturing Africa**

Source: ACRE Analysis, Gatsby Report, Press search, OECD-FAO Agricultural Outlook 2025-2034

2G other waste feedstocks | Deep-dive

🟥 Focus for this section ⬚ Projection used for market sizing

Surplus[1], 2035, Mn tonnes

	Selected feedstocks	Feedstock type	**Low projection** Historical yield growth, 1% p.a. land growth, waste oils collection rate persists	**Medium projection**[2] Yield matches peer countries 1% p.a. land growth, oil collection matches India benchmark	**High projection** Same as medium projected, but 2% p.a. land growth, oil collection matches Indonesia benchmark
1G	**Starch and sugar-based**	**Maize**	-	45	65
		Cassava	70	155	215
		Sugarcane	-	35	50
	Oil-based	**Palm oil**	-	10	13
2G	**Purposefully grown oil crops**	**Castor oil**		1.2	
		Brassica carinata oil		3.5	
	Waste oils	**UCO/Tallow**	0.5	0.8	1.6
	Other waste feedstock	**Bagasse**	30	45	50
		Sawdust		15	
		Manure		15	
		Municipal waste		450	

Surplus here is total that **can be used for biofuel production** (where we use medium projection for market sizing)

However, **not all this surplus is used**, given that market potential is also constrained by economics against competing fuels and minimum scale requirements

1. For 1G starch, sugar, and oil crops, available surplus is shown: this surplus adjusts the potential surplus (raw projected production-demand) to account for trade to meet food and feed demand in deficit countries
2. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

2G other waste feedstocks | Africa may have a potential for 500Mn+ tonnes waste feedstock by 2035

⬚ Projection used for market sizing

Potential feedstock, Mn tonnes, 2035

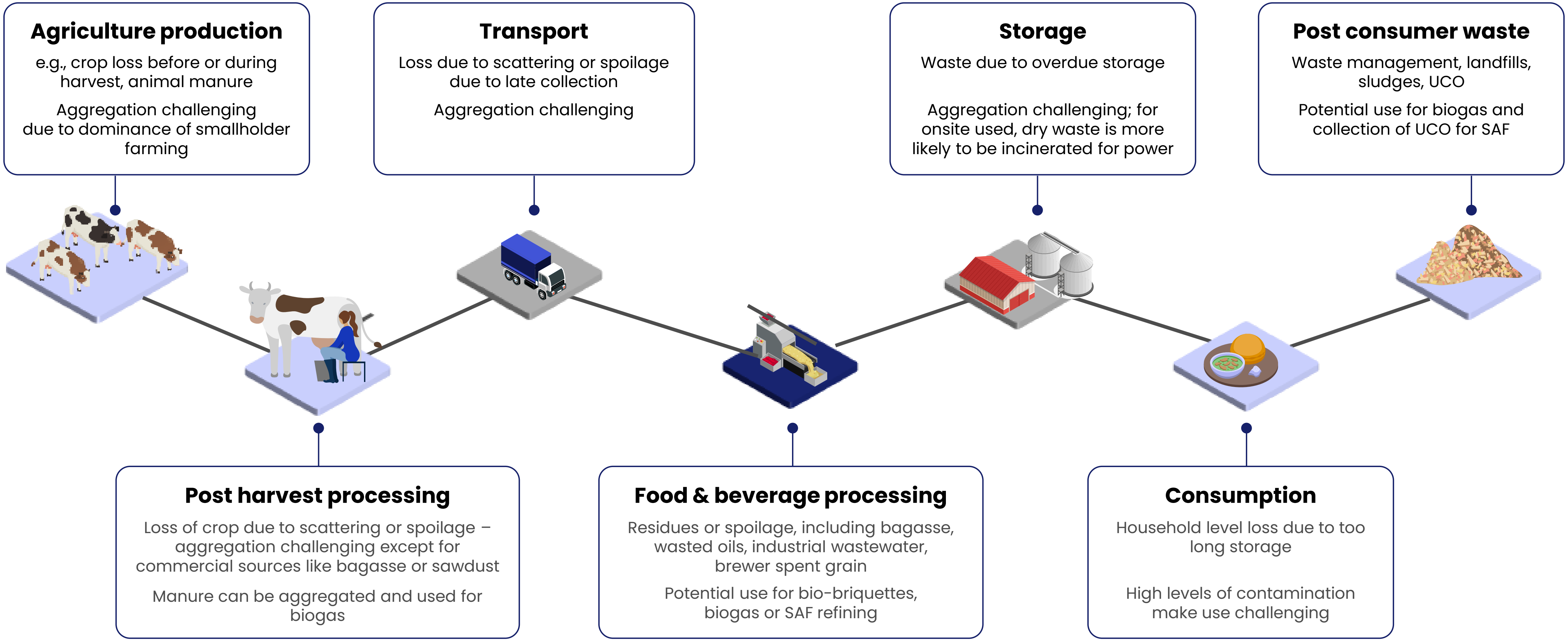
Feedstock	**Low projection** *Yields forecasted based on historical trend and 1% p.a. land growth*	**Medium projection** *Yields forecasted to match peer benchmarks and 1% p.a. land growth*	**High projection** *Yields forecasted to match peer benchmarks and 2% p.a. land growth*	**Methodology**
Bagasse	30	45	50	Total bagasse is equal to 30% of projected sugarcane production; 10% of bagasse is expected to be used (e.g., burned for power use in sugar mills), leaving the remainder as surplus
Sawdust	15			Assumed to be 15% of projected output from forestry industry in Africa – forecasted from 2023 level based on historical trend
Manure	15			Estimated total collectible livestock manure based on expected manure production and level of intensification (only animals in intensive of semi-intensive systems allow for collection)
Municipal waste	450			Calculated based on projected Africa population by 2035 and average wastewater per capita; collection assumes 24% sanitation coverage, 30% of which is safely treated

Source: FAOSTAT, World Bank Data, NRF – Global and regional potential of wastewater as a water nutrient and energy source, GLW, ENGIE, AFDB, UN Habitat, Expert interviews, Press search

2G other waste feedstocks | Waste for biofuels are most accessible at the food and beverage processing level

Illustration of waste sources food supply chain and biofuels' suitability

■ Suitable ■ Partially suitable ■ Not suitable



Agriculture production

e.g., crop loss before or during harvest, animal manure

Aggregation challenging due to dominance of smallholder farming

Transport

Loss due to scattering or spoilage due to late collection

Aggregation challenging

Storage

Waste due to overdue storage

Aggregation challenging; for onsite used, dry waste is more likely to be incinerated for power

Post consumer waste

Waste management, landfills, sludges, UCO

Potential use for biogas and collection of UCO for SAF

Post harvest processing

Loss of crop due to scattering or spoilage – aggregation challenging except for commercial sources like bagasse or sawdust

Manure can be aggregated and used for biogas

Food & beverage processing

Residues or spoilage, including bagasse, wasted oils, industrial wastewater, brewer spent grain

Potential use for bio-briquettes, biogas or SAF refining

Consumption

Household level loss due to too long storage

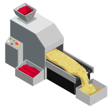
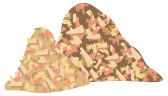
High levels of contamination make use challenging

Source: Expert interviews

2G other waste feedstocks | Potential for waste feedstock for biofuels is limited by collectability

Illustration of crop waste along food supply chain and useability for biofuels

🟩 High 🟨 Medium 🟥 Low

Agriculture and food value chain	Feedstock type	Waste	Most Viable use case	Availability	Collectability
Agriculture production 	**Manure**	Cow manure, wet farm waste	Biogas	🟩 Large number of cattle in Africa	🟨 Only for intensive / semi-intensive production
	Manure	Cow manure, wet farm waste	Bio-methane	🟩 Lack of large-scale farms	🟨 Only for intensive / semi-intensive production
Post harvest processing 	**Fibrous/woody waste**	Agriculture residues (e.g., corn stalks)	Direct incineration	🟥 More likely to be incinerated	🟥 Difficult to collect due to fragmentation
Processing 	**Fibrous/woody waste**	Dry food processing waste (e.g., bagasse)	Bio-briquettes	🟨 For large sources like bagasse and sawdust	🟨 For large sources like bagasse and sawdust
	Municipal & industrial waste	Food processing waste e.g., brewery waste, tomato waste etc.	Biogas	🟩 Large scale production of waste	🟩 For onsite use
	Waste oils and fats	UCO, tallow	Biogas	🟩 Commonly used	🟨 From commercial / industrial sources
Household consumption 	**Waste oils and fats**	UCO	FAME, SAF	🟩 Commonly used	🟥 Aggregation challenges
Post consumer waste 	**Municipal & industrial waste**	Sludge/wastewater	Biogas	🟩 Large scale production of waste	🟩 For onsite use
	Organic municipal waste and landfills	Waste	Biogas	🟥 No waste separation and closed landfills	🟥 No waste separation and closed landfills

Source: FAO, expert interviews

Contents

Executive summary
Biofuels overview, scope, and context in Africa
Details on approach for sizing the opportunity for biofuels in Africa
Appendix 1: Africa biofuel feedstock availability assessment
Appendix 2: Use case deep-dives
  1, 2 Road – Ethanol, FAME diesel
  4, 5, 6 Cooking – bio-pellets, biogas, ethanol
  – Context
  – 4 Bio-pellets
  – 5 Biogas
  – 6 Ethanol
  7, 9 Industrial Heat and Power – biogas, bio-briquettes
  10 Aviation - 2G oil-based feedstock export
  11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

Use case deep-dives: Recap – $1.7-10Bn market potential for biofuels in Africa

● 1G ◐ 1G/ 2G ● 2G

Market potential always only targets customer segments where the economics of switching to biofuels make sense based on different policy scenarios, and where sufficient feedstock is available

		Estimated market potential, $Bn, 2035	
Category	**Use case**	**Limited-to-No policy**	**Strong Policy**
Road	1 Ethanol	0.1	3.1
	2 FAME diesel	–	0.3
Cooking	4 Bio-pellets	0.2	0.3
	5 Biogas[1]	0.04	0.1
	6 Ethanol	0.7	0.8
Industrial heat and power[1]	7 Biogas	0.1	0.4
	9 Bio-briquettes	0.1	1.6
Feedstock export	10 2G oil-based feedstock	0.5	2.5
Aviation	11 SAF refining	–	1.1
Total		**1.7**	**10.1**

These use cases can scale in size post-2035 to an additional $7.6B in value if mandates increase (global mandates for SAF and 2G oil-based feedstocks; domestic mandates for ethanol and FAME diesel)

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1. Market sizing for biogas and energy use cases assumes the equivalent electricity price; in reality, these use cases have no revenue to them but are rather CAPEX investments to reduce costs (e.g., a municipal waste facility may install biogas to replace electricity use for its heat requirements)

Source: Manufacturing Africa team analysis

Contents

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Appendix 1: Africa biofuel feedstock availability assessment
Appendix 2: Use case deep-dives
    1, 2 Road – Ethanol, FAME diesel
    4, 5, 6 Cooking – bio-pellets, biogas, ethanol
    – Context
    – 4 Bio-pellets
    – 5 Biogas
    – 6 Ethanol
    7, 9 Industrial Heat and Power – biogas, bio-briquettes
    10 Aviation - 2G oil-based feedstock export
    11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

1,2 | Road: Ethanol and FAME diesel are currently blended into fossil fuels for use in internal combustion engines

Overview of sustainable road biofuels

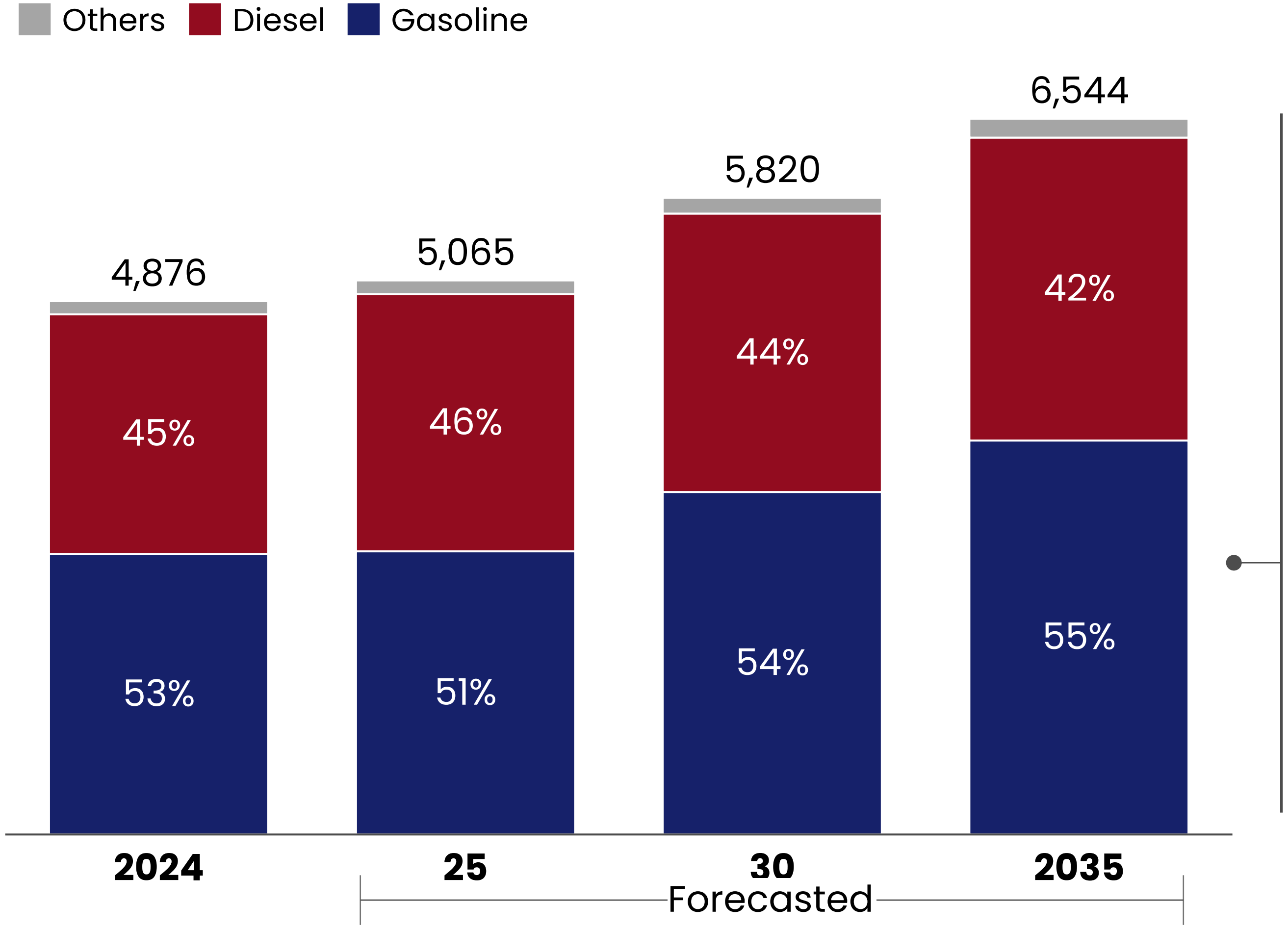
🟦 xx Primary application

	Selected fuels	
Biofuel	***Ethanol***	***FAME diesel***
Compatible fossil fuel	***Gasoline***	***Diesel***
Description	Gasoline is blended with ethanol E5-E20 (5-20% ethanol) more common; Higher blends of up to E100 can be achieved with converters or flex fuel cars	Diesel is blended with FAME diesel B5-B20 (5-20% FAME diesel) more common; Higher blends can be achieved in warmer climates
Main applications	🟦 Passenger car	🟦 Passenger car
	🟦 Light commercial vehicle (LCV)	🟦 Light commercial vehicle (LCV)
	Medium duty truck (MDT)	🟦 Medium duty truck (MDT)
	Heavy duty truck (HDT)	🟦 Heavy duty truck (HDT)
	Bus	🟦 Bus

Source: Expert interviews

1,2 | Road: Road fuel energy demand in Africa is relatively evenly split between gasoline and diesel until 2035

Africa road fuel energy demand by type, TJ[1], 2022-2035



Potential role for ethanol in replacing gasoline

- Ethanol could address blending needs for **gasoline, 50%+ of road** fuel demand
- Modern cars can use ethanol blends of **up to 20% without significant modifications** – older engines could have compatibility issues
- Higher ethanol volumes (above 20%) would require **flex fuel cars[2] or converters[3]** in standard cars
- Flex fuels are **unlikely to see broad adoption in Africa** since they are rare in markets Africa imports from (e.g., Japan)
- Converters may gain some traction, but **mainly among niche users** (e.g., performance enthusiasts, experimenters)

---

1. 1 TJ is equivalent to ~30k litres of gasoline
2. A flex fuel car runs on any gasoline–ethanol mix, with engines adjusting automatically for best performance (more common in Brazil)
3. Converters use a calibrated engine control module , ethanol-compatible components, and sensors that adjust injection and timing to optimise performance and prevent corrosion

Source: McKinsey Global Energy Perspective

1 | Road – ethanol: Road ethanol may have a $3.1Bn market with $1.3Bn investment by 2035, driven by blending mandates

Potential opportunity for road ethanol in Africa

🟥 Limited-to-No policy 🟥 Strong policy

	Description	Market potential, Bn USD, 2035	Potential investment size, Bn USD, 2035
Road ethanol	• For limited-to-no policy scenario (premium market), ethanol can be imported to improve gasoline quality (25+ countries) • For strong policy scenario, assumed blending mandates for ethanol with gasoline across 12 countries in Africa	0.1 3.1 *Premium market assumes 5-10% ethanol mix for 1% of gasoline consumed – India benchmark for premium gasoline share* *For strong policy, 5-10% mandates assumed on projected gasoline consumption – projected to be ~110B litres by 2035*	- 1.3 *No major investment for premium gasoline – limited quantities assumed to be imported* *10-20 ethanol plants assumed across 12 countries. CAPEX assumed to be $20,000 per barrel of daily capacity (i.e., $70Mn for 200Mn litres annual capacity)*

Source: Manufacturing Africa team analysis

1 | Road – ethanol: Three countries in Africa have blending mandates, but enforcement has been limited due to feedstock concerns

State of mandate implementation in Africa

NON-EXHAUSTIVE **AS OF SEPTEMBER 2025**

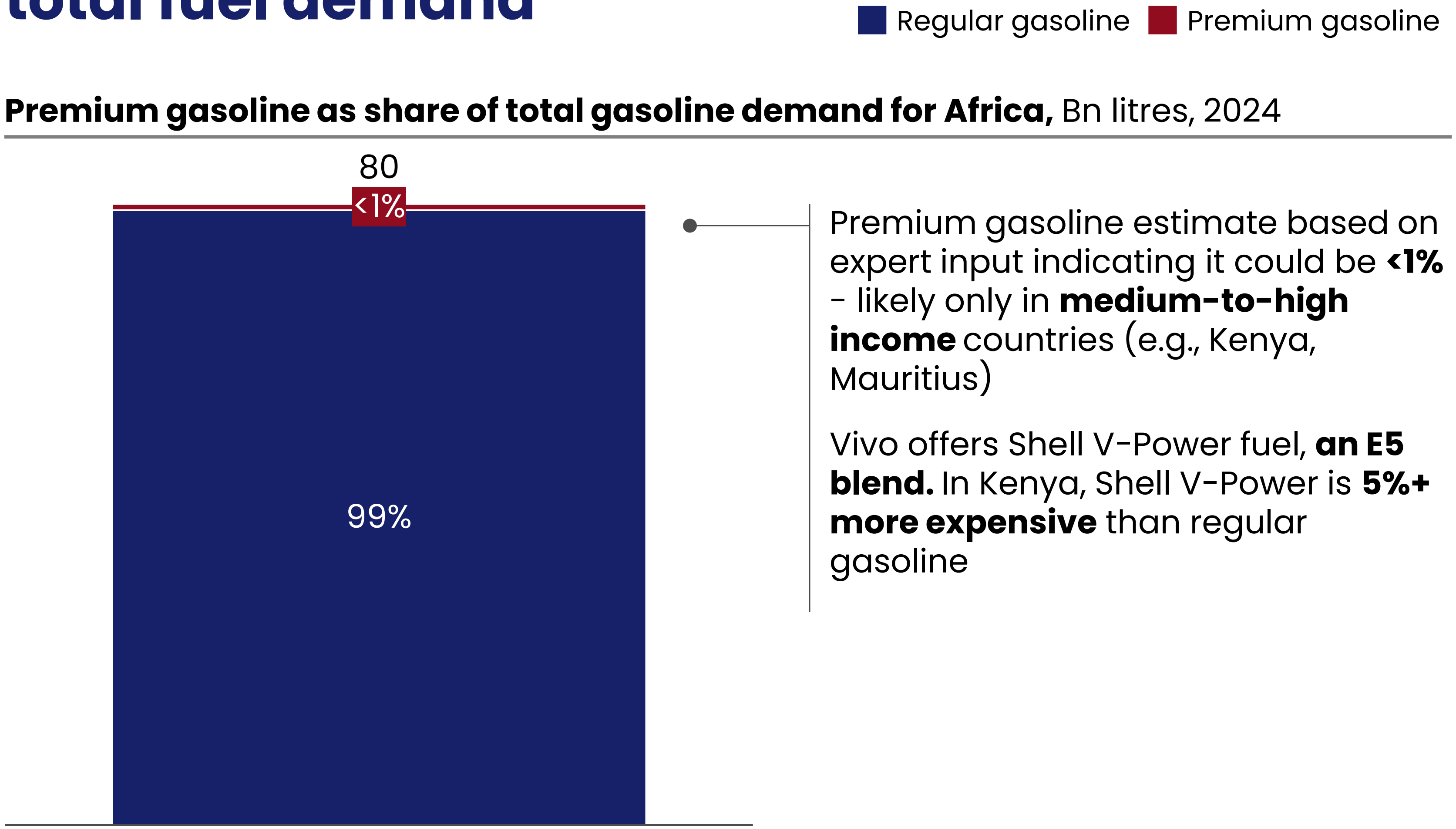
✓ Imports required to supplement supply ✓ Local production present

State	Country	Planned ethanol blending rate	Actual blending rate	Considerations	Source of ethanol: Domestic	Source of ethanol: Imported
Active	**South Africa**	2-10%	1-2%	Limited by pricing challenges and feedstock supply	✓	✓
	Malawi	20%	~10%	Limited by molasses supply and feedstock shortages	✓	✓
	Zimbabwe	15%	~15%	Mandate enforced, moving towards 20%	✓	✓
Planned	**Uganda**	5%	NA	Mandate planned from 2026	✓ Planned local production	

Source: Equity Axis, Sugar & Ethanol, US Grains, Mandatory blending in Zimbabwe: Examining implementation challenges and contemporary issues, Malawi's Shift to Ethanol: Pioneering a Sustainable Fuel Alternative, Malawi beckons investment in crops for biofuel production, OECD-FAO Agricultural Outlook 2022-2031, The economywide impact of bioethanol production in South Africa, RATIN –Africa's food biofuels balancing act

1 | Road – ethanol: Currently, ethanol is also used in premium fuel blends which account for <1% of total fuel demand

Premium gasoline as share of total gasoline demand for Africa, Bn litres, 2024



Premium gasoline estimate based on expert input indicating it could be **<1%** - likely only in **medium-to-high income** countries (e.g., Kenya, Mauritius)

Vivo offers Shell V-Power fuel, **an E5 blend.** In Kenya, Shell V-Power is **5%+ more expensive** than regular gasoline

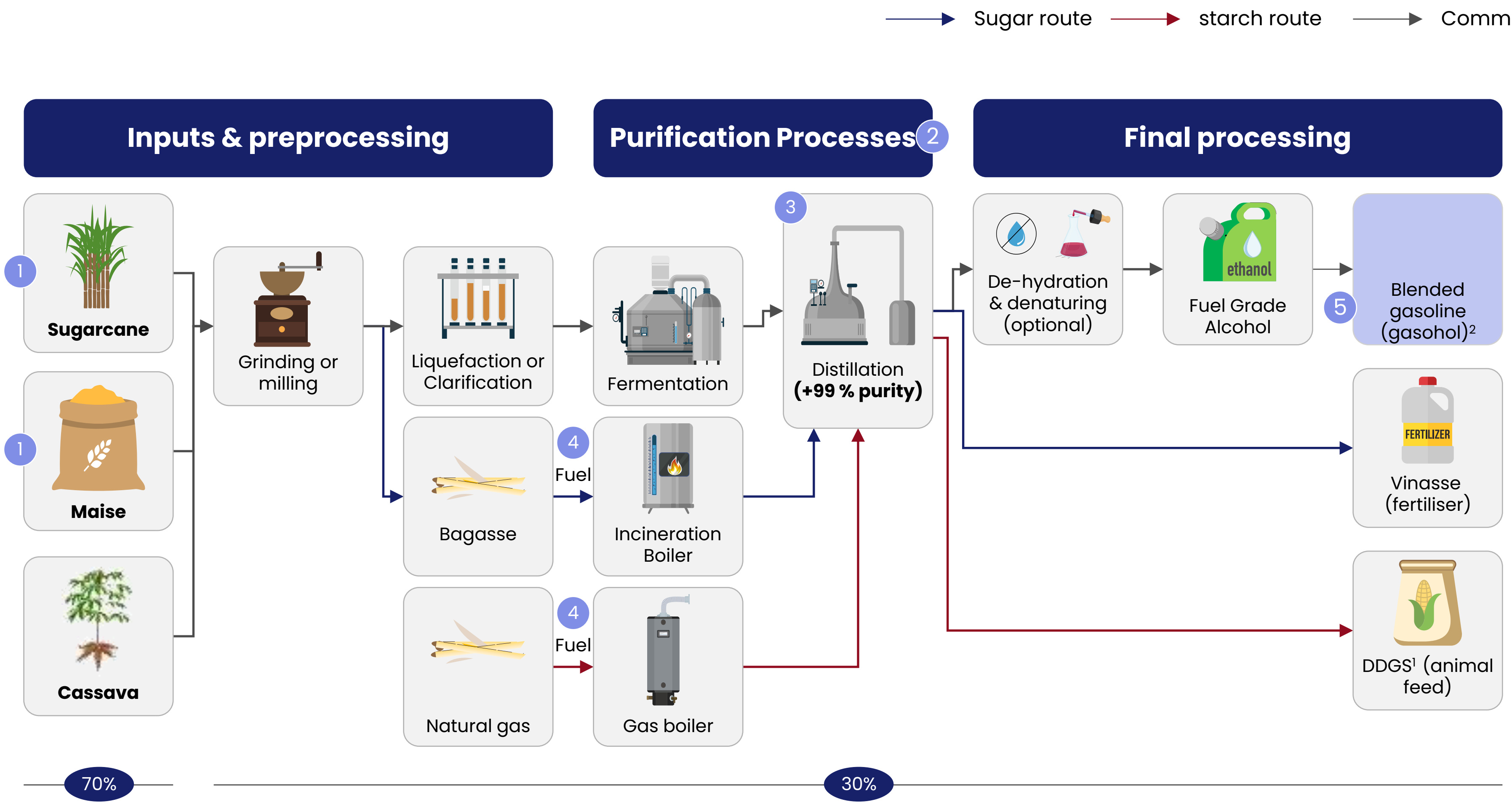
Demand for premium gasoline with higher-than-average octane **(RON >98)[1] is limited,** given premium fuel comes with a higher price point targeting **niche customers who focus on brand or performance**

---

1. Research Octane Number; a measure of a fuel's resistance to knocking or pinging during combustion in spark-ignition engines

Source: Expert input, Press Search, Vivo

1 | Road – ethanol: Road ethanol has high scale and purity requirements which drive up CAPEX cost



→ Sugar route → starch route → Common route ● % of total production cost

Inputs & preprocessing

① **Sugarcane**

① **Maise**

Cassava

Grinding or milling

Liquefaction or Clarification

Bagasse

Natural gas

Purification Processes ②

Fermentation

④ Fuel

Incineration Boiler

④ Fuel

Gas boiler

③ Distillation **(+99 % purity)**

Final processing

De-hydration & denaturing (optional)

Fuel Grade Alcohol

⑤ Blended gasoline (gasohol)²

Vinasse (fertiliser)

DDGS¹ (animal feed)

70%

30%

① **Some plants can co-ferment different feedstocks**, though operations get complex since corn needs pretreatment unlike sugar

② Road ethanol plants require **significant scale** (100Mn+ litres/year)

③ Road ethanol requires **higher purity** (~99%+) vs. cooking ethanol (~70%), thus, needing **additional distillation**

④ For sugar ethanol production, **bagasse** is typically use as fuel. For starch ethanol, natural gas is commonly used as fuel due to lack of suitable crop residue

⑤ Blending is relatively **simple and low cost**

1. DDGS - Dried Distillers Grains with Solubles | 2. Anhydrous ethanol (<1% water content) is blended with gasoline at different rates, with additives added to improve stability and limit corrosion of fuel systems

Source: Team analysis, Expert discussions, Ministry of petroleum and natural gas

1 | Road – ethanol: Access to sufficient and affordable energy for ethanol distillation could be a potential constraint for production

Comparison of quantity of energy required from alternatives for distillation process of ethanol[1]

NON-EXHAUSTIVE

Source	Energy content, MJ/kg	**Potential energy requirement for ethanol distillation at different scales**, '000 tonnes[2] 190 million	380 million	Viability
Corn stover	~17	90	181	✗ As scale expands, aggregation and storage becomes an operational challenge; collection of stover from 10-20k hectares of corn needed
Natural gas	~55	28	56	✓ Typically used due to higher energy density and ease of storage; potentially available in <15 African countries (e.g., Nigeria, Ghana)
Bagasse	~7.5	205	409	✓ Used primarily in sugar ethanol distilleries since its an immediate by-product; potentially South Africa, Uganda, Kenya, Malawi, etc.
Wood bio-pellets	~19	81	162	✓ Unsustainable sourcing can lead to deforestation; Available in countries with a large milling industry (e.g., Ethiopia, Ghana, Nigeria)

Additionally, **heat pumps** could be considered — use electricity to transfer heat from low-temperature sources (e.g., waste heat, air, water) to high-temperature sinks (e.g., steam, hot water, industrial heating)

Considerations:

- Technology well proven for low-heat ranges required for distillation process
- Higher CAPEX
- Reliable electricity access required
- Utilisation can be improved through co-use for other industrial processes[3]

---

1. Excluded dirty energy forms (e.g., coal, diesel)
2. Typical energy requirement for distillation is 8.08 MJ/litre
3. Ethanol distillation happens in batches resulting in idle time for heat pump

Source: Press Search, Expert Input

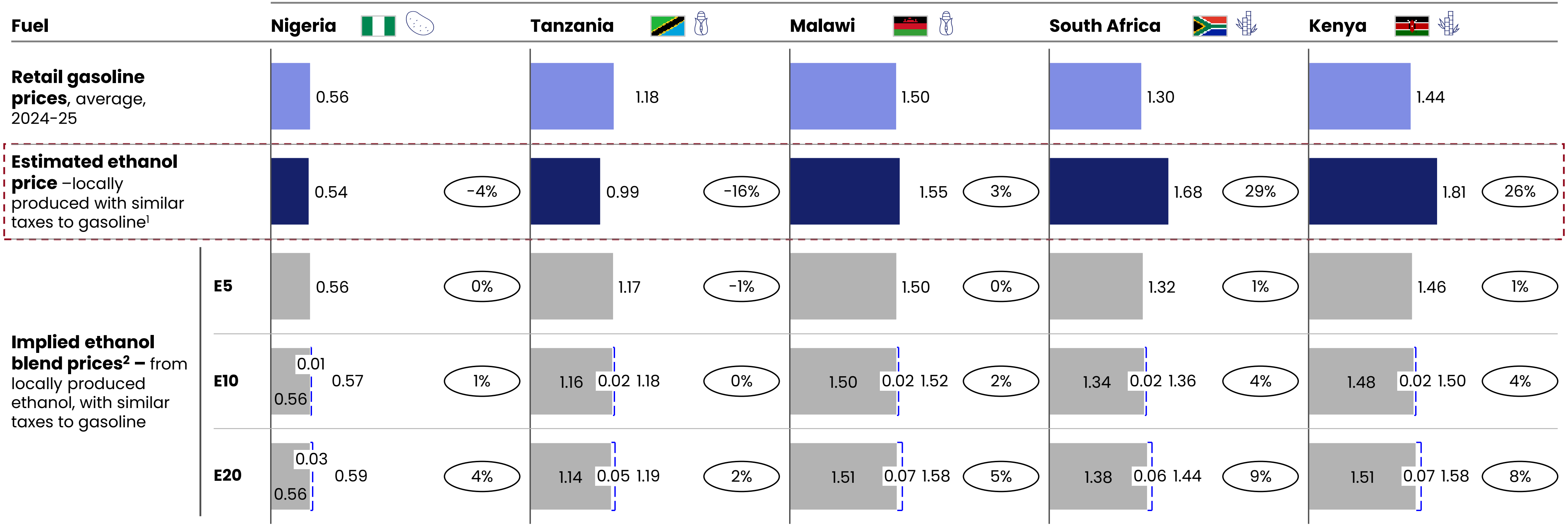
1 | Road – ethanol: Locally produced ethanol could have low impact on pump prices, especially at lower blends and where gasoline prices are high

AS OF SEPT 2025

Cassava based   Maize based   Sugar based   (xx) Potential cost impact compared to gasoline (including range impact)

Details follow   Additional cost due to range impact from lower ethanol energy content compared to gasoline

Cost of blended ethanol vs. gasoline, USD/litre



1. Ethanol feedstock price used is average of feedstock prices between 2020 and 2025, except for Nigeria (2025). Assumed VAT and gasoline related taxes (Tanzania: 0.15USD/L excise duty, 0.2 USD/L fuel levy, 0.04 USD/L petroleum levy; Malawi 0.07 USD/L fuel levy, 0.02 USD/L price stabilisation fund, 0.03 USD/L rural electrification levy, 0.08 USD/L road levy, 0.01 USD/L energy regulation levy, 0.002 USD/L distribution fund; Nigeria: 5% surcharge; South Africa: 0.06USD/L general fuel levy and road accident fund; Kenya: 0.17 USD/L excise duty, 0.19 USD/L road maintenance levy, 0.04 USD/L petroleum development levy, 0.01 USD/L petroleum regulation levy, 0.01 USD/L railway development levy; Ethiopia: only VAT). Excluded carbon taxes in South Africa and Malawi
2. Implied blend price – reflects the weighted average price based on fuel mix percentages; Range impact is assumed to be negligible for E5, 1-2% for E10 (1.5% used for calculations), and 3-6% for E20 (4.5% used for calculations)

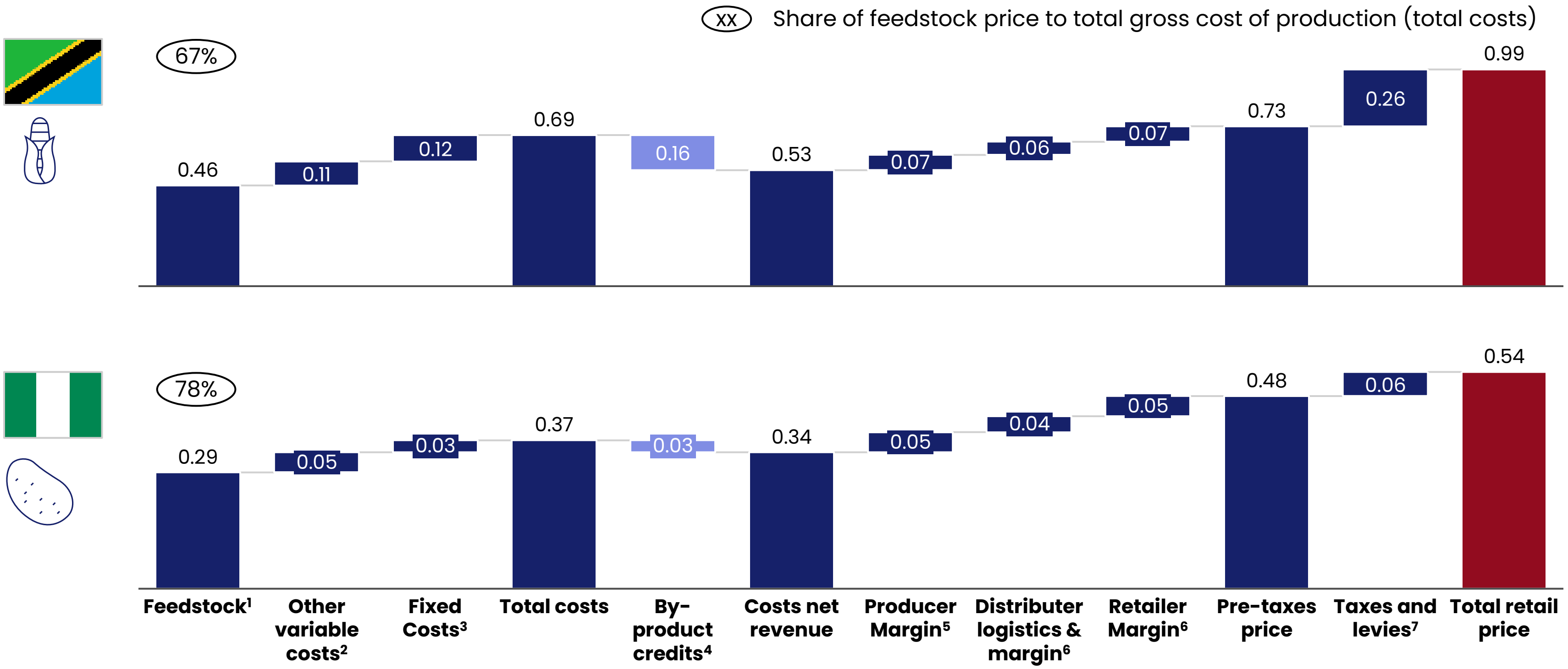
Source: Global fuel prices – World Bank, Expert interviews

1 | Road – ethanol: Potential surplus producers with low feedstock prices can achieve lower costs

Estimated cost breakdown for maize in Tanzania and cassava in Nigeria

AS OF SEPT 2025

Estimated cost for locally produced ethanol, assumed plant size of 200Mn litres annual capacity, USD/litre



- Feedstock costs account for **65-80% of production costs** (before by-product sales, margin, and taxes), making it the most significant cost driver
- **DDGS sales as a maize by-product can reduce production costs by up to 25%** - securing offtake for DDGS will be critical to ensure consistency cost benefits
- Moreover, DDGS could be an alternative to directly using maize as **animal feed**
- For cassava, peel mash could reduce costs by **~15% of feedstock costs**

---

1. Average of maize and cassava prices between 2020 and 2025
2. Includes chemicals, utilities, maintenance and transport, etc. Does not include fuel cost - assumes that the plant can be fuelled by maize stover & other agricultural waste
3. Includes interest, labour & management and depreciation of $150Mn CAPEX
4. Maize: Distillers Dried Grains with Solubles (price based on sale of waste output for animal feeds); Cassava: Peel mash animal feed
5. Required margin to result in 20-25% IRR
6. Assuming 10% for logistics and distributor and retailer margins
7. Includes similar taxes applied to gasoline (Tanzania: 0.15USD/L excise duty, 0.2 USD/L fuel levy, 0.04 USD/L petroleum levy; Nigeria: 5% surcharge)

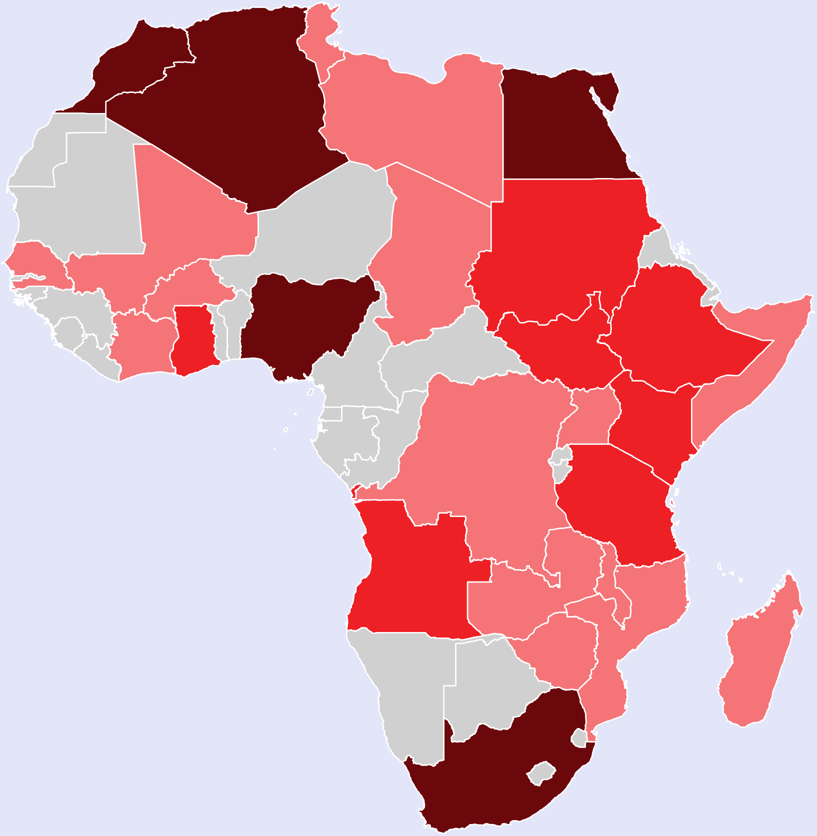
Source: Expert inputs, African Markets Observatory, S&P Global IHSMarkit, FAOSTAT

1 | Road – ethanol sizing methodology: Road ethanol market and investment opportunity sized under different scenarios

Scenario	**Forecasted gasoline demand**	**Tiered countries**	**Forecasted ethanol demand**	**Assessed economic impact**
No-to-limited policy – premium fuels market	**Forecasted gasoline demand** for all countries – annual estimated consumption for Africa at **~111Bn litres by 2035**	Assumed market to primarily exist in **medium-to-high income countries** (estimated 2035 GDP per capita purchasing power parity >$4,000)	Forecast assumes up to a **10% voluntary blending rate** for premium fuel Premium fuels share assumed to **match India benchmark** (1%)	**Market:** assumed estimated landed price for imported ethanol (1.0 USD/L) Import focus could imply limited investment and FX savings
Strong policy – mandated market		De-prioritised countries with **limited gasoline consumption** (<15,000 barrels per day) Remaining countries were tiered: • **Tier 1** – feedstock surplus and assumed lower gasoline costs • **Tier 2** – feedstock surplus and assumed higher gasoline costs • **Tier 3** – no feedstock surplus We assume a **proxy for gasoline costs** (crude oil exports) – net crude oil exporters / oil producers typically have lower fuel prices because they have less incentive to impose high fuel taxes	**Tier 1** – higher ethanol adoption (5-10% blending rates) **Tier 2** – lower ethanol adoption (up to 5% blending rates) **Tier 3** – likely no ethanol adoption	**Market:** assumed estimated retail pump prices for four select countries covering different feedstocks and regions; applied an average for the rest – South Africa (maize): 1.07 USD/L; Nigeria (cassava): 0.54 USD/L; Madagascar (sugarcane): 0.79 USD/L; average used for the rest: 0.85 USD/L **Investment:** assumed set up of ~200Mn annual ethanol facilities at a CAPEX of ~$70Mn each **FX impact:** assumed savings based on share of gasoline imports corresponding to ethanol blending rate **Job creation potential:** assumed 0.3 jobs per $8,000 of revenue potential benchmark

1 | Road – ethanol: We estimate that 26 countries could have sufficient fuel consumption for road ethanol adoption

Africa gasoline demand by country, barrels per day, 2035



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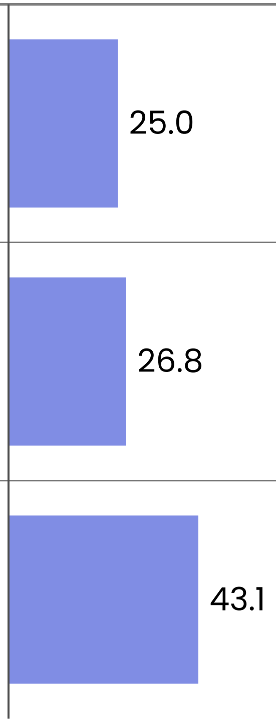
1. To fully utilise a minimum viable scale of 3,500-bpd ethanol facility (~200Mn litres of ethanol annually) at an assumed maximum blending ratio of 20% ethanol (E20), the minimum gasoline demand required is ~15,000 barrels per day (bpd)

Source: McKinsey Global Energy Perspective 2025, Expert input

1 | Road – ethanol: We developed three country tiers when assessing the market potential for mandated road ethanol

xx Number of countries in tier



Tier	**Description** **Surplus available**[1]	**Higher assumed gasoline costs**[2]	**Estimated gasoline consumption**, Bn litres, 2035		**Example countries**	**Assumed blending mandate**, % (strong policy scenario)	
1	✓	✓	25.0	10		5%	10%
2	✓	✕	26.8	2		0%	5%
3	✕	✕	43.1	14		0%	0%

---

1. Crop yields forecasted to match peer countries and conservative land growth (1% p.a.)
2. We assume oil-producing (net crude oil exporting) countries typically have lower fuel prices because they have less incentive to impose high fuel taxes

Source: McKinsey Global Energy Perspective, Expert interviews

1 | Road – ethanol: Ethanol demand for road is could reach ~4Bn litres, with a potential market of up to $3.1Bn, driven by mandates

Gasoline and ethanol demand in 2035 (Tier 1 and 2 countries only)

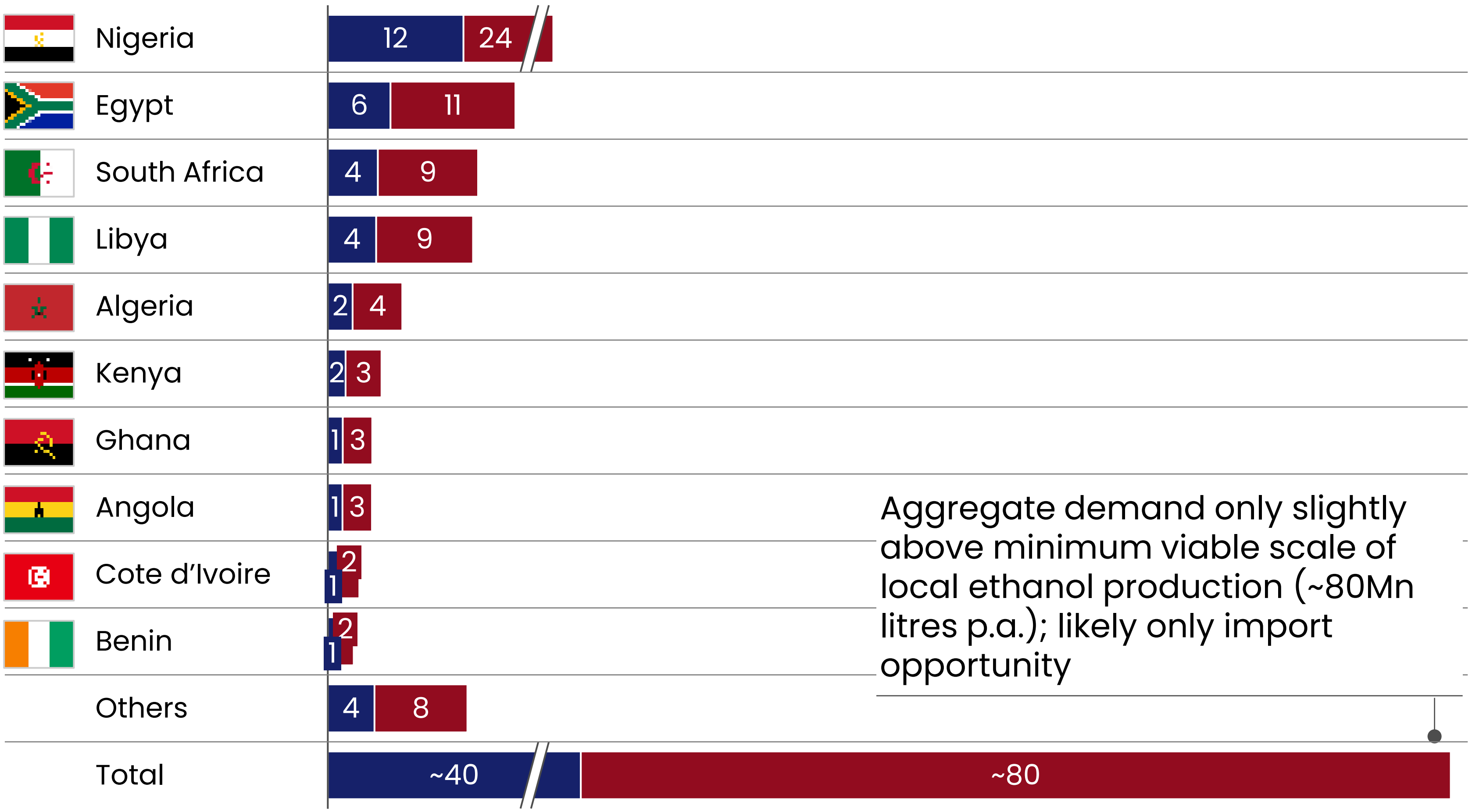
Scenario	**Future gasoline demand**, Bn litres	**Assumed blending mandate**, %	**Potential ethanol demand**, Bn litres	**Estimated ethanol market**, Bn USD[1]	**Potential share of total African gasoline consumption[2]**, %
Limited-to-no policy scenario – premium fuels market	0.9 Premium fuels only	5-10%[3]	0.04-0.08	0.04-0.08	<1%
Strong policy scenario – mandated market	51.8	0-10%[4]	1.2-3.8	1.2-3.1	1-3%

1. Assumed estimated retail pump prices for four select countries covering different feedstocks and regions; applied an average for the rest – South Africa (maize): 1.07 USD/L; Nigeria (cassava): 0.54 USD/L; Madagascar (sugarcane): 0.79 USD/L; average used for the rest: 0.85 USD/L
2. Projected to be ~111Bn litres by 2035
3. For premium fuel, 5-10% blending rate is assumed
4. Tier 1: 5-10%; Tier 2: 0-5%

Source: McKinsey Global Energy Perspective, Expert interviews

1 | Road – ethanol: In the limited-to-no policy scenario, 2035 premium market for ethanol could be 80Mn litres; likely insufficient scale for local production

Estimated ethanol opportunity for premium gasoline market, Mn litres, 2035



Aggregate demand only slightly above minimum viable scale of local ethanol production (~80Mn litres p.a.); likely only import opportunity

Definition premiums market	Premium market for ethanol likely in octane enhancing (RON[1] 98 and above)
Sizing approach	**Market potential:** Assumed to reach 1% of total gasoline demand by 2035 based on market data for India **Exclusion criteria:** Assumed to be relevant in medium to high income countries (projected 2035 GDP per capita purchasing power parity[2] >$4,000) **Blending rate:** 5-10%

1. Research Octane Number; a measure of a fuel's resistance to knocking or pinging during combustion in spark-ignition engines
2. Gross domestic product per capita at purchasing power parity

Source: McKinsey Global Energy Perspective, Stratos Advisors, Expert interviews

1 | Road – ethanol: With strong policy, South Africa and Nigeria could have the largest road ethanol markets in Africa by 2035

Gasoline and ethanol demand in 2035, Bn litres – example countries

Tier	Country	**Assumed blending rate,** % (strong policy scenario)		**Future gasoline demand forecast**	**Estimated ethanol demand** (lower blending rate)	**Estimated ethanol demand** (higher blending rate)
Tier 1	South Africa	5%	10%	8.9	0.4	0.9
	Uganda			5.0	0.2	0.5
	Ghana			2.7	0.1	0.3
	Tanzania			2.4	0.1	0.2
	Cote d'Ivoire			1.9	0.1	0.2
	Others[1]			4.1	0.2	0.4
Tier 2	Nigeria	0%	5%	24.2		1.2
	Angola			2.6		0.1
	Total			**51.8**	**1.2**	**3.8**

[1] Includes DRC, Ethiopia, Zimbabwe, Mozambique, and Madagascar

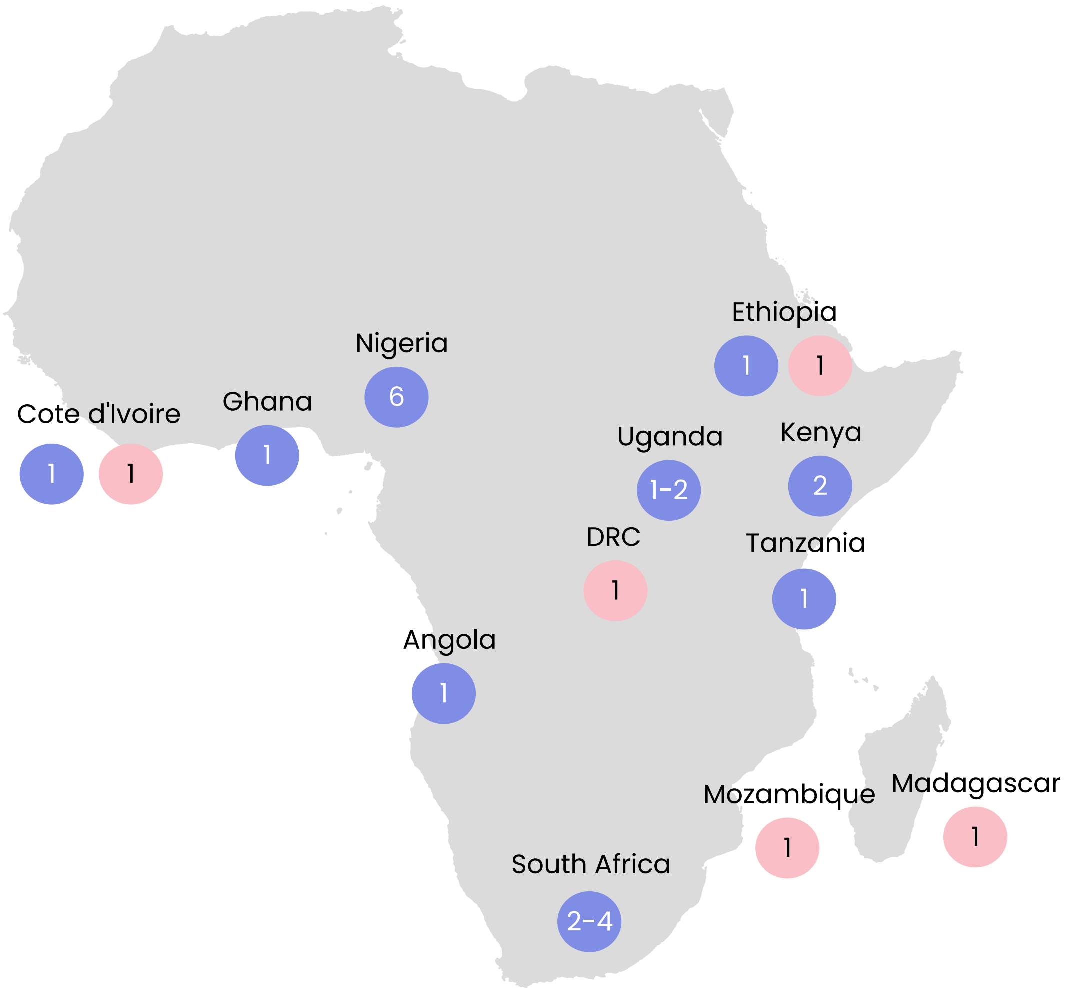
Source: McKinsey Global Energy Perspective, Expert interviews

1 | Road – ethanol: Road ethanol could have a up to a $1.3Bn investment potential

Potential ethanol production facilities under strong policy scenario[1], 2035

xx 100Mn litres annual capacity

xx 200Mn litres annual capacity



$0.5-1.3Bn

Investment potential for **8-20** potential small to medium-sized road ethanol production plants (100Mn-200Mn litre annual capacity)

Cote d'Ivoire, Ethiopia, DRC, and Mozambique may have **smaller facilities because their lower gasoline use** limits ethanol blending potential

There is a **potential production cost impact** with reduced scale from 200Mn to 100Mn annual capacity

---

1. Assumes a CAPEX investment of ~20,000 USD per barrel of daily capacity for a 200Mn litres annual capacity (~70Mn USD) and 100Mn litres annual capacity (~35Mn USD); excluded existing facilities (e.g., Green Fuel Chisumbanje Plant in Zimbabwe (120Mn L capacity)

Source: McKinsey Global Energy Perspective 2025, Expert input

1 | Road – ethanol: Adoption of blending mandates may drive up to $3.1Bn in FX savings through reduced gasoline imports

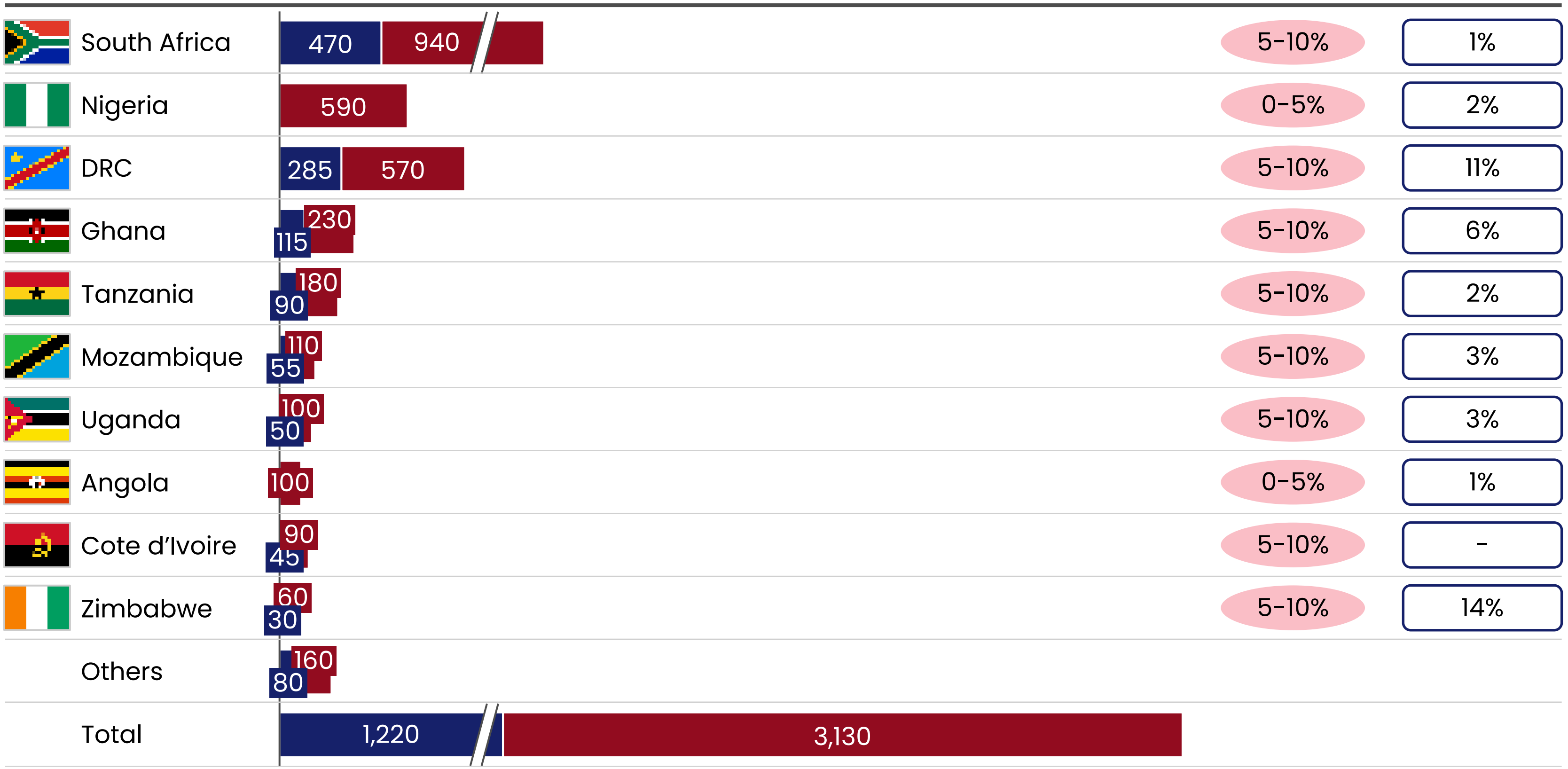
🟦 Assumed savings with lower blending rates

🟥 Assumed savings with higher blending rates

xx% Potential maximum savings as a share of countries' FX reserves[1]

xx% Assumed blending rates based on strong policy scenario

Estimated potential FX savings from ethanol mandate adoption, Mn USD (based on 2022 data)



Potential FX savings based on country level import value data for refined oil from 2022; gasoline is assumed to account for ~50% of imports based on 2022 fuel consumption split

Majority of the top 10 countries are assumed to be tier 1 countries with a potential blending rate of 5 to 10% in limited and strong policy scenarios, respectively

While Nigeria could have lower potential blending rates, its **higher fuel consumption could still result in larger potential FX savings**

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1. Latest available data from The World Factbook; no available credible data found for Cote D'Ivoire

Source: UNCOMTrade, McKinsey Global energy perspective, The World Factbook

2 | Road – FAME diesel: FAME diesel use in Africa may be limited due to feedstock shortages, competition, and lower diesel prices

Potential opportunities for FAME diesel in Africa

AS OF OCT 2025

🟥 Limited-to-No policy 🟥 Strong policy

	Description	**Market potential,** Bn USD, 2035	**Potential investment size,** Bn USD, 2035
Large scale FAME diesel production (blending mandate)	• Nigeria could potentially produce enough oil feedstock to support FAME diesel blending • While FAME diesel is likely more expensive than regular diesel in Nigeria (i.e., 0.85 vs. 0.68 USD/L), a low B5 blend would have negligible fuel cost impact (implied cost of 0.69 USD/L for B5)	- 0.3 *Assuming a 5% blending rate in Nigeria (approximately 350Mn litres of FAME diesel), with Nigeria's projected diesel consumption reaching around 7 billion litres by 2035* *The price applied in the market sizing estimate is $0.85 per litre*	- 0.2 *Indonesia benchmark cost of $200Mn – include core processing (transesterification) plus supporting infrastructure (feedstock pretreatment, storage tanks, utilities, glycerol recovery, wastewater treatment, etc.)*
Small scale FAME diesel production (niche plays)	• Small scale applications like industrial fuels and limited blending (e.g., for organisations with sustainability goals and might be willing to pay the premium) • Oil feedstocks still likely more valuable for SAF over time so scaling of this opportunity challenging	Opportunity likely fragmented and not sized	

---

1. Estimated cost of FAME diesel in Nigeria assuming 0.58 USD/L production cost, 30% margin, 7.5% VAT, 5% fuel surcharge

Source: McKinsey Global Energy Perspective 2025, Press search, Expert Interviews

2 | Road – FAME diesel: FAME diesel feedstocks vary, offering clear benefits that have led to adoption

AS OF OCT 2025

Feedstock sources for FAME diesel

Edible oil crops
(e.g., palm oil, soybean, rapeseed, and other vegetable oils)

Non-edible oil crops
(e.g., castor, jatropha, carinata, moringa)

Waste oils
(e.g., used cooking oil, tallow)

Benefits of FAME diesel

Lower GHG emissions given reduced hydrocarbon use

Burns cleaner hence has lower toxic emissions

Improved engine performance due to increased cetane (55+ in FAME diesel vs. 45-55 in regular diesel)[1]

State of FAME diesel application

FAME diesel blending mandates and implementation timelines

B5	India	2030
	South Korea	2030
B7	USA	2030
B7/10	EU	2030
B15	Brazil	2026
B20	Philippines	2030
	Malaysia	2025
B30	Indonesia	2025

No FAME diesel blending mandates identified for Africa

At present, there are **few producers of FAME diesel**, and their operations are of **limited scale** to meet a national blending requirement

For several major participants (such as Giloil in Kenya), the primary offtake or end market consists mainly of **industrial fuel**, with **limited use in transportation**, particularly among companies aiming for decarbonisation goals

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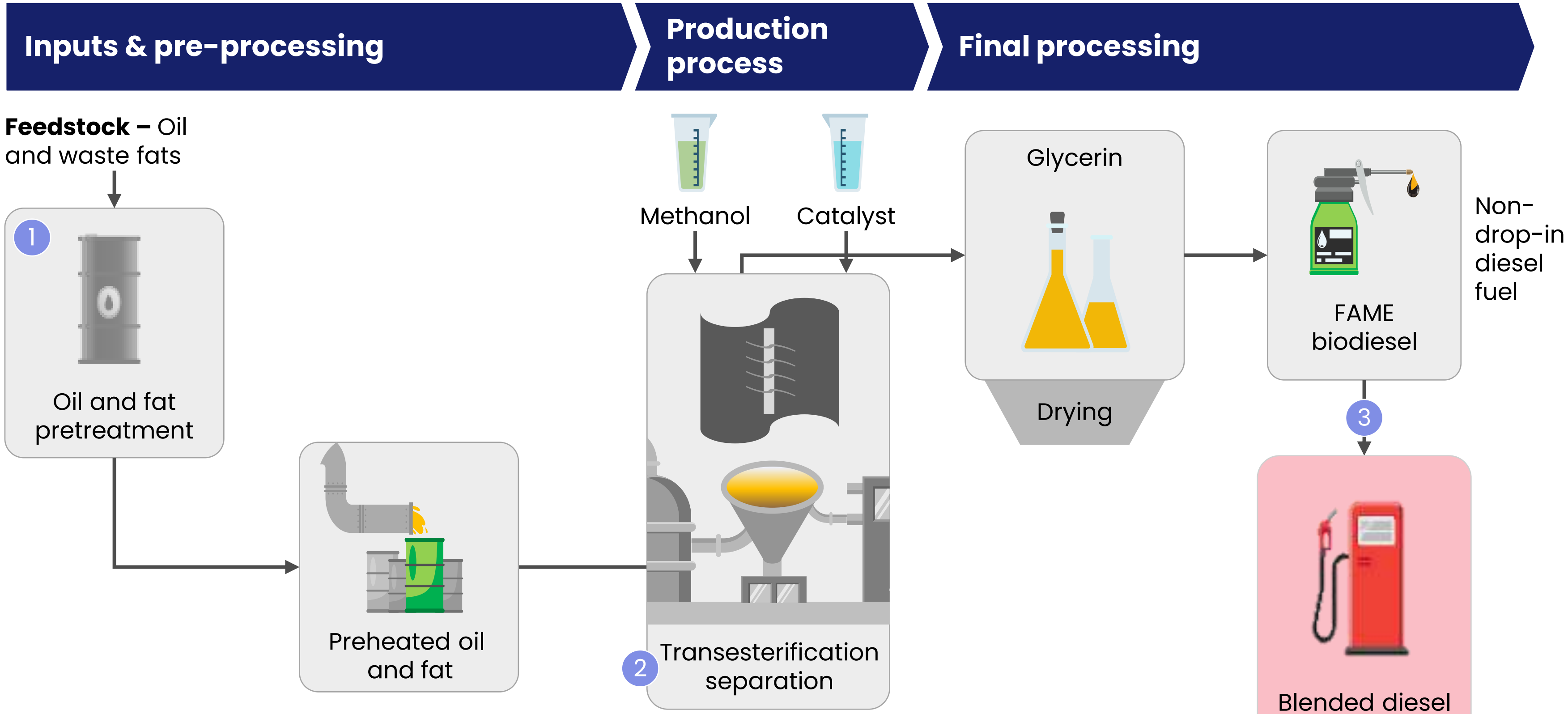
1. Warmer temperatures in Africa may allow for higher blending rates

Source: Press search, Expert interviews

2 | Road – FAME diesel: FAME diesel production relies on simple technology that can utilise different oil feedstock

FAME (Fatty Acid Methyl Ester) biodiesel production process

ILLUSTRATIVE



Inputs & pre-processing

Production process

Final processing

Feedstock – Oil and waste fats

1 Oil and fat pretreatment

Preheated oil and fat

Methanol

Catalyst

2 Transesterification separation

Glycerin

Drying

FAME biodiesel

Non-drop-in diesel fuel

3

Blended diesel

Polyester production technology

1. Different oil feedstocks could be used together, as long as proper pre-treatment is conducted
2. FAME plants may be small because it could be a simple batch process that doesn't require continuous operation
3. FAME biodiesel is blended with regular diesel at different rates (typically, 5-20%). Other than road applications, blended FAME diesel can be used in some back up generators, but only where specifications allow (not common)

Source: Gerveni, M., T. Hubbs and S. Irwin. "Biodiesel and Renewable Diesel: What's the Difference?" farmdoc daily (13):22, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 8, 2023

1, 2 | Road – ethanol and FAME diesel: Enablers to support implementation (1/2)

Similar enablers apply for both ethanol and FAME diesel

Feasibility[1] ○ Low ● High ▢ Deep-dives next

			Stakeholders				
Category	**Enablers for consideration**	**Details**	**Government**	**Development partners**	**Research institu-tions**	**Private sector**	**Feasi-bility**
Policy & demand certainty	**Blending mandates (ramp-up 3–5 years)**	National blend targets set with a phased ramp to give investors demand visibility while supply scales	✓				◔
	Mandate-flexing mechanism	Transparent triggers (e.g., harvest forecasts, prices) tied to temporary mandate adjustments to protect food/feed markets	✓		✓		◔
	Protect local production during market build	Duties/quotas to prevent cheap ethanol imports to allow local production to scale	✓				◕
Financing & partnership model	**Patient, affordable capital for biorefineries**	Long-tenor, low-cost financing to cover high upfront CAPEX during early scale-up	✓	✓		✓	◑
	Public–private partnership (PPP) framework	PPP to coordinate agriculture, plant build-out, logistics, and regulation with clear roles and governance	✓				◑
Feedstock & agriculture readiness	**Out-grower schemes**	Smallholder farmer support via contracts, training, and services to expand reliable feedstock supply	✓	✓		✓	◕
	Inputs & technical assistance	Access to seeds, fertilisers, and agronomy support to lift yields and consistency	✓	✓		✓	◕

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1. Feasibility based on: High - proven enabler demonstrated in multiple African countries (even if in other industries); Medium (1/2 moon) - proven enabler demonstrated in peer countries (e.g., India); Low - high complexity intervention, unproven in any developing economy

Manufacturing Africa

Source: Manufacturing Africa team analysis

1, 2 | Road – ethanol and FAME diesel: Enablers to support implementation (2/2)

Similar enablers apply for both ethanol and FAME diesel

Feasibility[1] ○ Low ● High ☐ Deep-dives next

			Stakeholders				
Category	**Enablers for consideration**	**Details**	**Government**	**Development partners**	**Research institutions**	**Private sector**	**Feasibility**
Feedstock & agriculture readiness	**Bulk-buying, logistics, and storage systems**	Aggregation of feedstock and streamlined transport from farm to plant to reduce costs and losses Drying/chipping/ silos to buffer seasonality and maintain plant utilisation	✓			✓	◑
	Targeted, temporary imports	Limit feedstock imports when needed to keep plants utilised without distorting markets	✓				◑
Infrastructure & market operations	**Industrial heat alternatives**	Access to reliable processing heat (e.g., natural gas or biomass) to improve plant efficiency	✓	✓		✓	◕
	Fuel standards & quality oversight	Blend and fuel quality standards implemented with an independent body for testing and compliance	✓		✓		◕
	Distribution & retailing readiness	Depots and fuel stations equipped with tanks, meters, and blending gear in priority regions, expanding as supply grows	✓			✓	◑

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1. Feasibility based on: High - proven enabler demonstrated in multiple African countries (even if in other industries); Medium (1/2 moon) - proven enabler demonstrated in peer countries (e.g., India); Low - high complexity intervention, unproven in any developing economy

Source: Manufacturing Africa team analysis

1, 2 | Road – ethanol and FAME diesel: An independent authority could be set up to oversee the blending mandate and fuel standards

Role of the independent authority

Mandate regulation

- **Forecast demand** from food and feed for select feedstock crop
- **Project expected harvests**– this could be done pre-harvest while crops are still in the field
- **Estimate expected surplus** volumes for select feedstock crop
- **Set expected blending volumes** from the select feedstock to ensure food/fuel balance

+

Fuel standard regulation

- Set and monitor gasoline and ethanol standards to ensure **compatibility when blending**

Example features requiring standardisation

Gasoline	**Ethanol**
✓ Volatility curve	✓ Water content
✓ Octane levels	✓ Denaturing
✓ Cleanliness	✓ Contaminants

Examples

Country	Relevant bodies	Legal instrument	Mechanism for setting blending mandate	How/why the mandate changes
Brazil	National Energy Policy Council **(CNPE)**	Blend limits and authority set in law; CNPE adjusts by resolution	CNPE sets a **fixed % blend for ethanol** in gasoline within a legal band; ANP[1] enforces	CNPE changes % based on **supply, energy security, performance testing and price dynamics** (e.g., cut to E20 in 2011 on low availability; lift to E30 in 2025 to curb gasoline imports)
India	Ministry of Petroleum & Natural Gas **(MoPNG)**	Ethanol Blended Petrol Programme (EBP)	MoPNG uses an **administered price mechanism** for ethanol and **OMC[2] tenders** to procure volumes Actual annual blending is the result of supply contracted	Blend levels rise as **capacity and feedstock** expand; can be phased by region, with policy levers (prices, finance, logistics) used to hit the target rather than altering a statutory % each year
USA	U.S. Environmental Protection Agency **(EPA)**	Renewable Fuel Standard (RFS) under the Clean Air Act	EPA **"sets" volumes considering statutory criteria** (environment, energy security, expected production, infrastructure, consumer costs, and food impacts)	Volumes are updated by rulemaking; EPA can use waivers or adjustments when **supply, technology, or market conditions** shift. Courts periodically review EPA's decisions

1. The Brazilian National Agency of Petroleum, Natural Gas and Biofuels (Portuguese: Agência Nacional do Petróleo, Gás Natural e Biocombustíveis – ANP)
2. Oil Marketing Companies

Source: Press search, Expert interviews

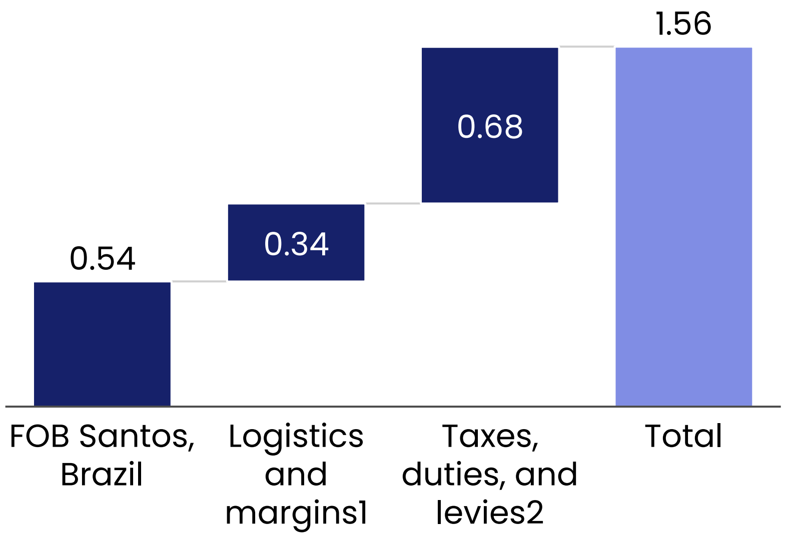
1 | Road – ethanol: In some countries, higher local ethanol costs than imports could necessitate protection of domestic production

Kenya example with higher feedstock (maize) prices

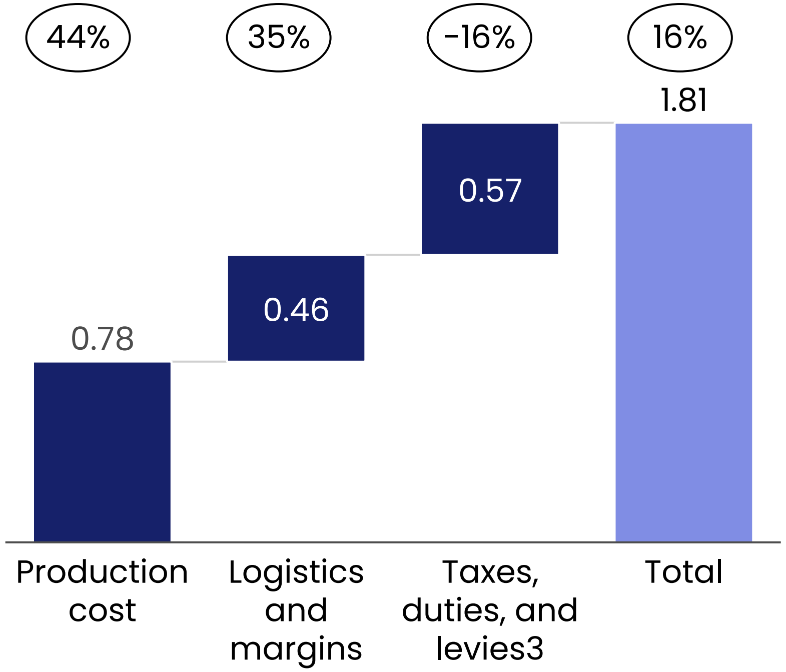
AS OF SEPT 2025

(XX) Percentage difference between locally produced and imported ethanol estimates

Estimated cost of imported ethanol, $/litre



Estimated cost of locally produced ethanol (maize), $/litre



Locally produced ethanol may be ~16% more expensive than imported ethanol in Kenya

Key drivers:

- ↗ **Higher feedstock cost** (0.48 USD/kg vs. lower cost Tanzania case of 0.20 USD/kg)
- ↗ **Higher margins** of local producers to ensure sufficient return given higher costs (0.78 vs. 0.54 USD/litre)
- ↘ No import duties and levies

In some countries, higher local ethanol costs than imports could support protective measures, justified by broader economic and environmental benefits, with the potential for costs to decline as surplus production grows

1. Sea freight($0.11/litre)– Average of freight cost for ethanol from Brazil to Singapore, South Korea, EU, China, and India; Freight insurance ($0.002/litre) – 0.3% of FOB price, Trader margin ($0.05)– 10% of FOB price, Distributor margin ($0.12) – 10% of price post inland transport, Inland transport ($0.05/litre) – US benchmarks on railcar transport for ethanol (similar distance between NBI and MSA; adjusted for inflation)
2. 35% import duty, 16% VAT, and others (e.g., petroleum development levy, road maintenance levy, import declaration fee)
3. Includes similar taxes, duties, and levies to imported ethanol other than import duty, import declaration levy, etc.

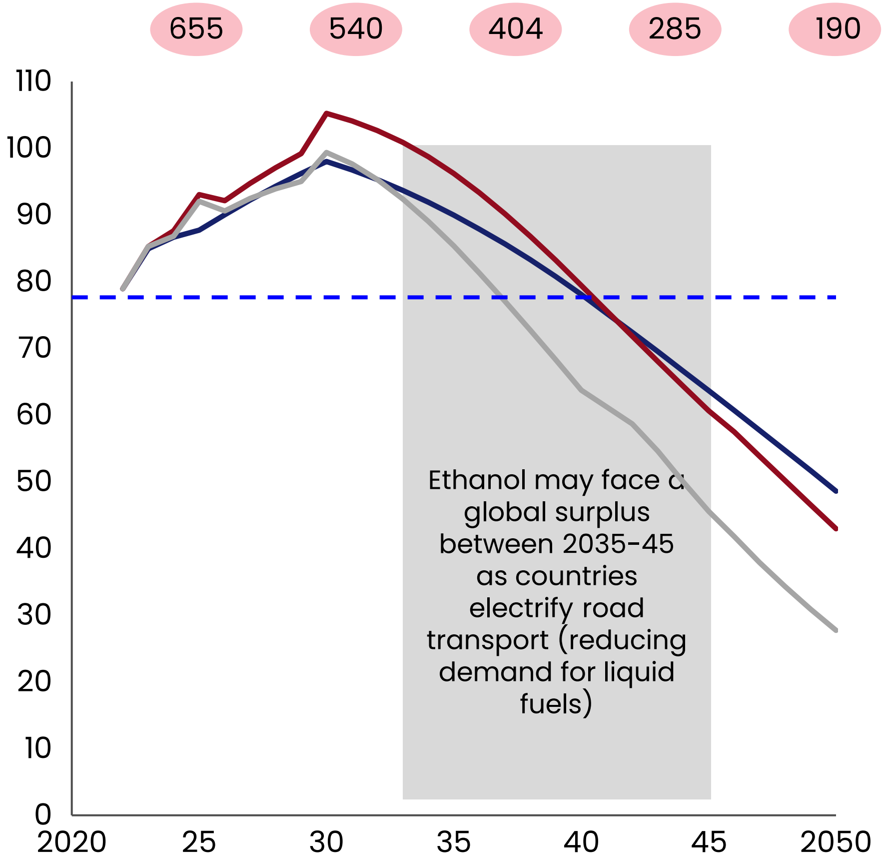
Source: US Grains & Bioproducts Council, Cabrella,, Grain Journal, ITC Market Access Map, USDA, CPI Inflation Calculator, Science Direct, Press search, Expert Interviews

1 | Road – ethanol: Competition from cheaper ethanol imports could become a risk given a potential global surplus starting between 2035-45

xx Estimated gasoline demand for selected countries, tonnes, 2025-2050

- - - Estimated 2022 demand level for ethanol, tonnes — Slow evolution (SE) — Continued momentum (CM) — Sustainable transformation (ST)

Estimated ethanol demand from top countries under different scenarios[1], million tonnes, 2022-50



Ethanol may face a global surplus between 2035-45 as countries electrify road transport (reducing demand for liquid fuels)

Maximum assumed blending rates

	SE	CM	ST
USA	10%	12%	15%
EU + UK	6%	6%	7%
China	2%	9%	14%
Brazil	45%	45%	35%
India	18%	25%	25%
Indonesia	1%	9%	9%

Ethanol producers may pursue options to sell surplus

Export of surplus to emerging markets (e.g., Africa): could face potential trade barriers from countries protecting upcoming local producers

Push for increased blending rates in key markets: impact may be limited as electric vehicle adoption drives down gasoline use — may be viable in Brazil due to flex fuel car technology

Shift end market to polyethylene (PE) production: bio-based PE is the second cheapest source after fossil-based PE – this is an emerging opportunity already proven in Brazil

Repurpose capacity to produce SAF[2] Alcohol-to-Jet (ATJ): market growth remains constrained by poor economics – second most affordable SAF pathway after HEFA[2]

Ramp down capacity: feasible response to reduced demand

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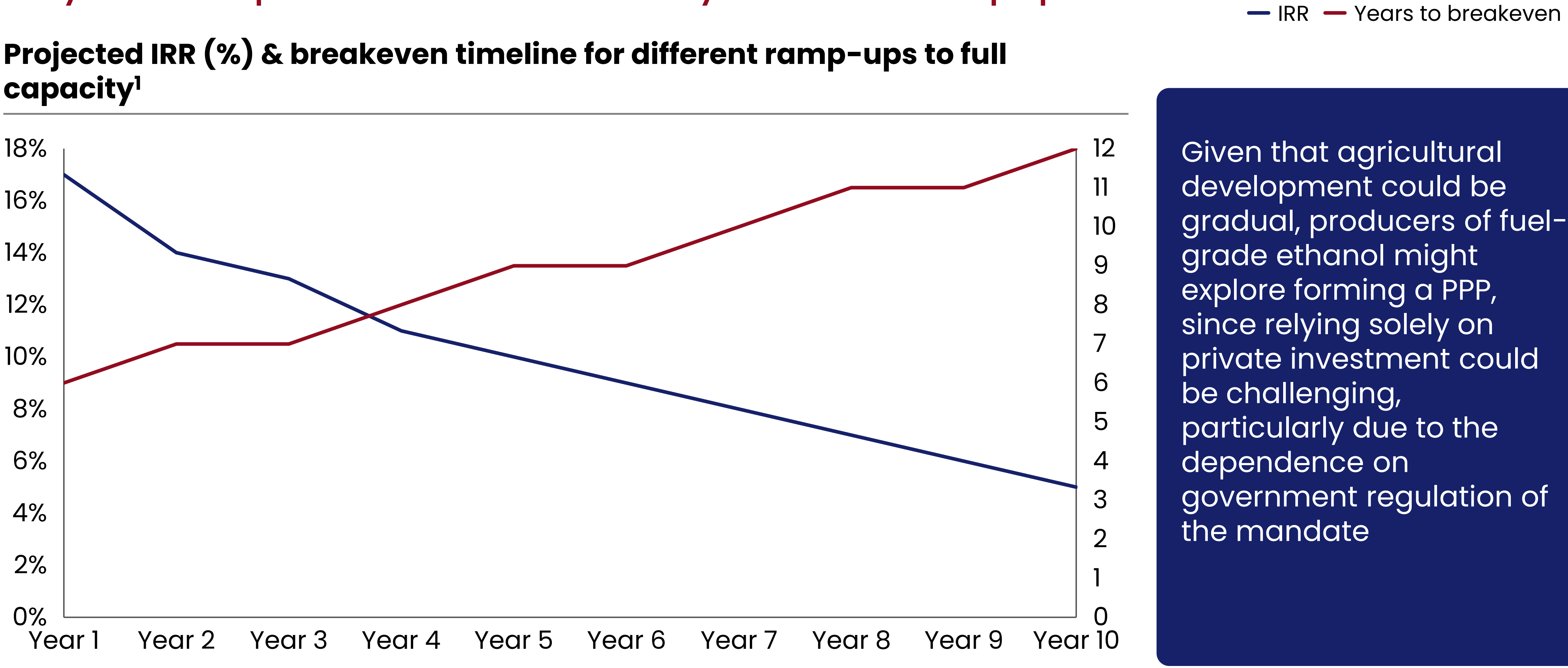
1. Make up 90%+ of current ethanol demand; scenarios based on different rates of sustainable fuel adoption (see appendix for details)
2. SAF – Sustainable Aviation Fuels; HEFA – Hydro-processed Esters and Fatty Acids

Source: McKinsey Global Energy Perspective, Press search

1 | Road – ethanol: Concessional capital is needed to improve the business case due to risk of a slow ramp-up of agricultural surplus

Analysis of ethanol plant IRR and breakeven sensitivity in relation to the ramp-up duration

Projected IRR (%) & breakeven timeline for different ramp-ups to full capacity[1]



Given that agricultural development could be gradual, producers of fuel-grade ethanol might explore forming a PPP, since relying solely on private investment could be challenging, particularly due to the dependence on government regulation of the mandate

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1. Projected for Tanzania maize ethanol production plant with capacity of 190Mn tonnes; $70Mn CAPEX (70% debt); 13% debt interest rate (9% overnight lending rate for USD denominated loans + 4 % assumed risk premium); No terminal value / exit scenario; IRR calculated for 15 years

Source: Manufacturing Africa team analysis

1 | Road – ethanol: Existing and planned fuel-grade ethanol facilities in Africa have mostly utilised PPPs for funding

	Zimbabwe		**South Africa**	**Uganda**		
Plant name	Green Fuel (Chisumbaje)	Sunbird Bioenergy Zim	Mabele Fuels Bothaville	Kakira sugar ethanol	Hoima sugar ethanol	Bukona Agro Distillery
Estimated capacity, million litres per year	120	120	154	20	20	8.5
Status	Operational	Planned	Planned	Planned	Planned	Planned
Funding model	Public-private JV	JV with strategic player for equity (MoU with local government and other partners)	Equity from public funding and debt	Equity and commercial debt	Equity	Public-private JV, with grant funding
Funding partners	Agricultural and Rural Development Authority (ARDA) Macdom and Rating company	Sunbird (UK) Government of Zimbabwe China New Energy	Mabele fuels National Empowerment Fund (NEF) China CHMC (EPC) Standard Bank	Madhvani family Praj (India)	Rai group National Empowerment Fund (NEF) China CHMC (EPC)	Bukona Agro Processors Ltd Government of Uganda United States African Development Foundation (USADF)

Source: Company websites, Press releases

1, 2 | Road – ethanol and FAME diesel: Agricultural ramp-up may require a mix of commercial production, out-growers, and imports

Illustration of potential feedstock sourcing mix for ethanol to achieve production capacity of >80%

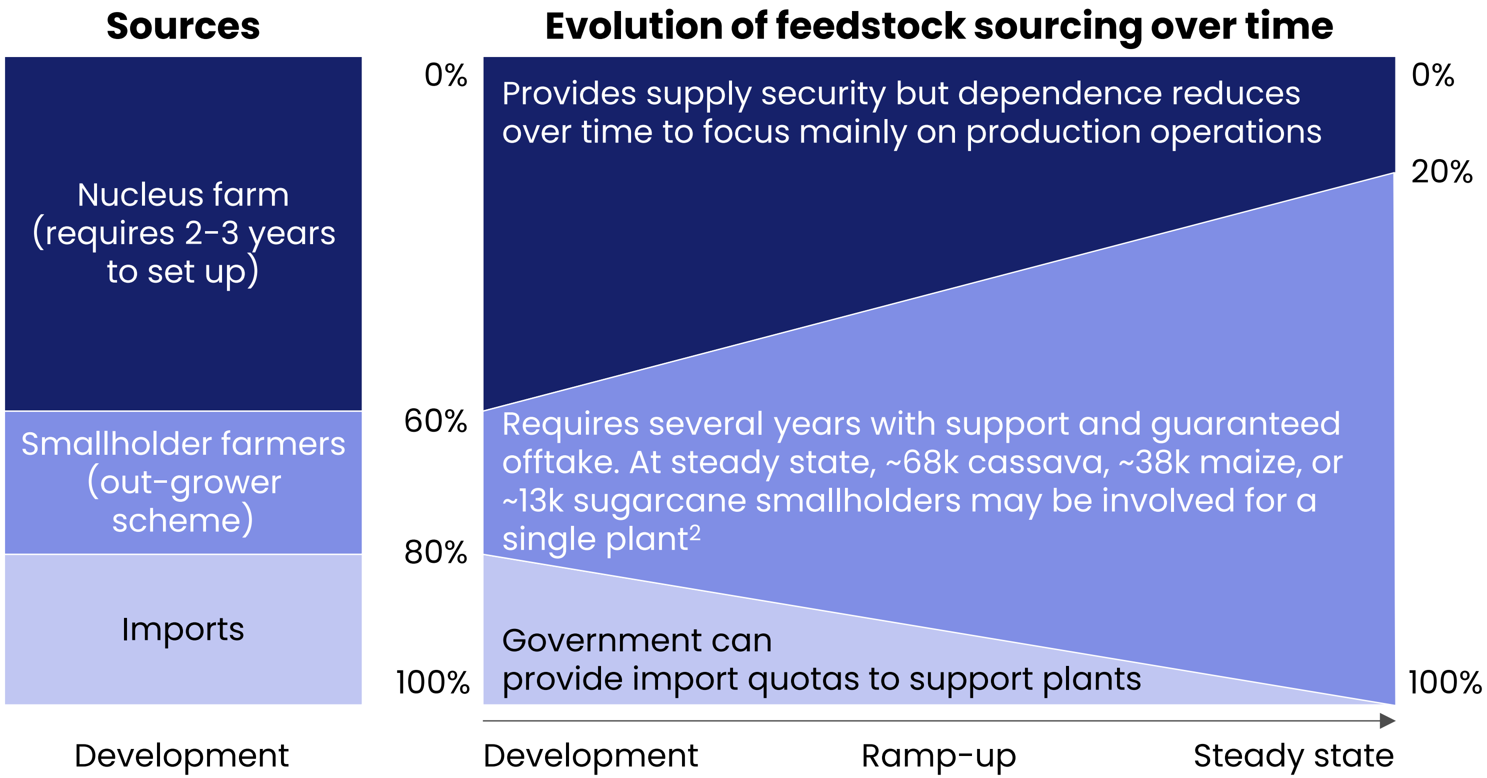
Crop	**Target feedstock scale**, tonnes	**Estimated feedstock cost**[1], Mn USD
Cassava	**1Mn**	**74**
Maize	**0.4Mn**	**80**
Sugar-cane	**2.2Mn**	**43**

High **working capital may be restrictive**, regardless of the feedstock source (i.e., self-production, smallholders, or imports)

Producers could consider getting **commercial working capital financing** lines or **pre-sales** from offtake partners

↔

Illustration of potential evolution of feedstock souring for ethanol plants



Provides supply security but dependence reduces over time to focus mainly on production operations

Requires several years with support and guaranteed offtake. At steady state, ~68k cassava, ~38k maize, or ~13k sugarcane smallholders may be involved for a single plant[2]

Government can provide import quotas to support plants

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1. Assumed $0.07/kg for cassava, 0.2/kg for maize, and $0.02/kg for sugarcane; Conservative estimate as it does not include transport and logistics costs, and potential margins
2. Assumed scale for smallholder farmers: 1.5ha; smallholder farmers would account for ~80% of required feedstock supply (20% may come from a nucleus farm)

Source: Manufacturing Africa team analysis

1, 2 | Road – ethanol and FAME diesel: Implementation roadmap

Category	**Phase 1: Signalling intent & agriculture ramp up** (Year 1-2)	**Phase 2: Plant construction & planning** (Year 3-5)	**Phase 3: Production ramp up** (Year 5+)
Ethanol or FAME diesel plant set up & operations	Establishment of a **PPP framework** to coordinate stakeholders	**Construction** of the production plant commences	**Plant operations** begin using stored feedstock + current harvest
	Fundraising for plant development and related infrastructure		**Gradual increase in production** as agricultural output expands
	Announcement of an **ethanol or FAME diesel plant project**, with construction to begin in 2028		
Agriculture ramp-up	**Support for agricultural expansion** through: • Development of an **out-grower scheme** by ethanol plant investor to integrate smallholder farmers • Increased access to improved **seeds, fertilisers,** and **technical assistance**		
	Announcement on willingness to buy feedstock in **specific quantities and prices** (adjusted based on harvest to avoid affecting food/feed demand)		
	Set up of **bulk-buying system** to streamline feedstock collection and logistics	Storage of **surplus feedstock** from farmers (under right conditions) • Maize can be dried and stored for **12-36 months** • Cassava can be chipped, dried, and stored for **up to 24 months**	
Government support and regulation	Declaration of a **national blending mandate** to take effect from year 5; additionally, new fuel standards need to be set Appoint **independent body to oversee blending** - ensure quality and adjust blending volumes		**Can flex blending requirements** to align with feedstock supply
			Can permit limited feedstock imports to boost plant use
Distribution and retailing		Gasoline distributors & retailers set up **infrastructure to support gasoline blending** (e.g., ethanol tanks) in select regions (this can be expanded as feedstock & production scale)	

Manufacturing Africa

Source: Manufacturing Africa team analysis

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

Appendix 2: Use case deep-dives

- 1, 2 Road – Ethanol, FAME diesel
- 4, 5, 6 Cooking – bio-pellets, biogas, ethanol
  - Context
  - 4 Bio-pellets
  - 5 Biogas
  - 6 Ethanol
- 7, 9 Industrial Heat and Power – biogas, bio-briquettes
- 10 Aviation - 2G oil-based feedstock export
- 11 Aviation - SAF refining

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

Contents

Executive summary
Biofuels overview, scope, and context in Africa
Details on approach for sizing the opportunity for biofuels in Africa
Appendix 1: Africa biofuel feedstock availability assessment
Appendix 2: Use case deep-dives
  1, 2 Road – Ethanol, FAME diesel
  4, 5, 6 Cooking – bio-pellets, biogas, ethanol
    Context
  – 4 Bio-pellets
  – 5 Biogas
  – 6 Ethanol
  7, 9 Industrial Heat and Power – biogas, bio-briquettes
  10 Aviation - 2G oil-based feedstock export
  11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

Cooking | In Africa, non-clean cooking technologies are still dominant, with ~70% use

▬ Clean cooking technologies – Others ▬ Clean cooking technologies – Biofuels ▬ Non-clean cooking technologies **xx%** % of African households using technology

Firewood

Solid biomass fuel made from logs or branches, typically burned in traditional stoves for cooking

50%

Charcoal

Solid biomass fuel produced by carbonising wood, typically formed into chunks or blocks for household cooking

15%

Kerosene

Liquid fuel derived from oil solid in small canisters that attach to a simple burner, and when burned emits hazardous fumes

3%

LPG[1]

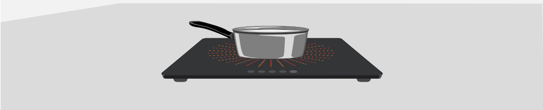
Clean-burning fossil fuel stored in cylinders, widely used in modern gas stoves that uses a stable mixture of propane and butane

20%

Electricity

Energy carrier supplied from the grid or solar systems, powering electric hotplates, induction cookers, or other appliances

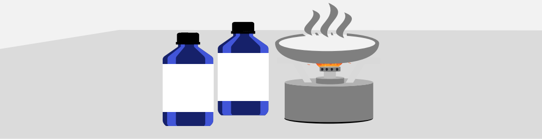
5%



Ethanol

Liquid biofuel produced from crops such as sugarcane or cassava, used in specially designed ethanol stoves

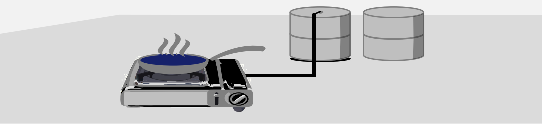
3%



Biogas

Gas derived from organic matter (e.g., animal manure, agriculture residues, food waste) through anaerobic digestion is connected to a simple gas burner

<1%



Bio-briquettes

Compressed solid biofuels made from residues like sawdust or agricultural waste, used as a substitute for firewood or charcoal

<1%

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[1] Liquified Petroleum Gas

Source: IEA Universal Access to Clean Cooking in Africa 2023

Cooking | Improving access to clean cooking facilities greatly enhances the health and quality of life for impacted families

Environmental impact

Reducing GHG-emissions

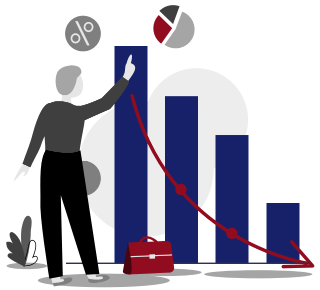
Greenhouse gas emissions from incomplete biomass combustion and deforestation would see a **net reduction of 1.5 GT CO2eq by 2030,** equal to emissions from aviation and shipping today

Reducing deforestation

Basic cooking methods using **wood** and **charcoal** often contribute to **deforestation**

The demand for firewood and charcoal results in the loss of forests the size of Ireland each year, with the worst effects concentrated in places like East and Southern Africa

Life quality & health



Reducing pre-mature deaths

A lack of clean cooking contributes to **3.7Mn premature deaths globally annually**, with women and children most at risk

Poor indoor air quality is a leading cause of premature death worldwide

Increasing productivity

Households without clean cooking spend an average of **5 hours daily** collecting fuel and cooking

Lost time and **productivity results** in a significant economic cost

Improving outcomes for women and children

Women and children account for 60% of early deaths in Africa related to smoke inhalation and indoor air pollution

Further negative consequences include preventing access to education and financial independence

Source: IEA Universal Access to Clean Cooking in Africa 2023

Cooking | Across Africa, there is a strong push to achieve universal clean cooking access by 2030 with moderate focus on biofuels

EXAMPLES - NOT EXHAUSTIVE

Africa-Wide (IEA)

~80% of households *(1.2Bn people)* in Africa rely on traditional cooking methods

Fuel split in "Access for All" scenario (by 2040):

45% LPG

32% Improved biomass (e.g., bio-briquettes)

12% electricity

10% biogas or ethanol

$37Bn investment required, primarily for infrastructure (LPG, grid enhancements, stoves, cylinder and other CAPEX)

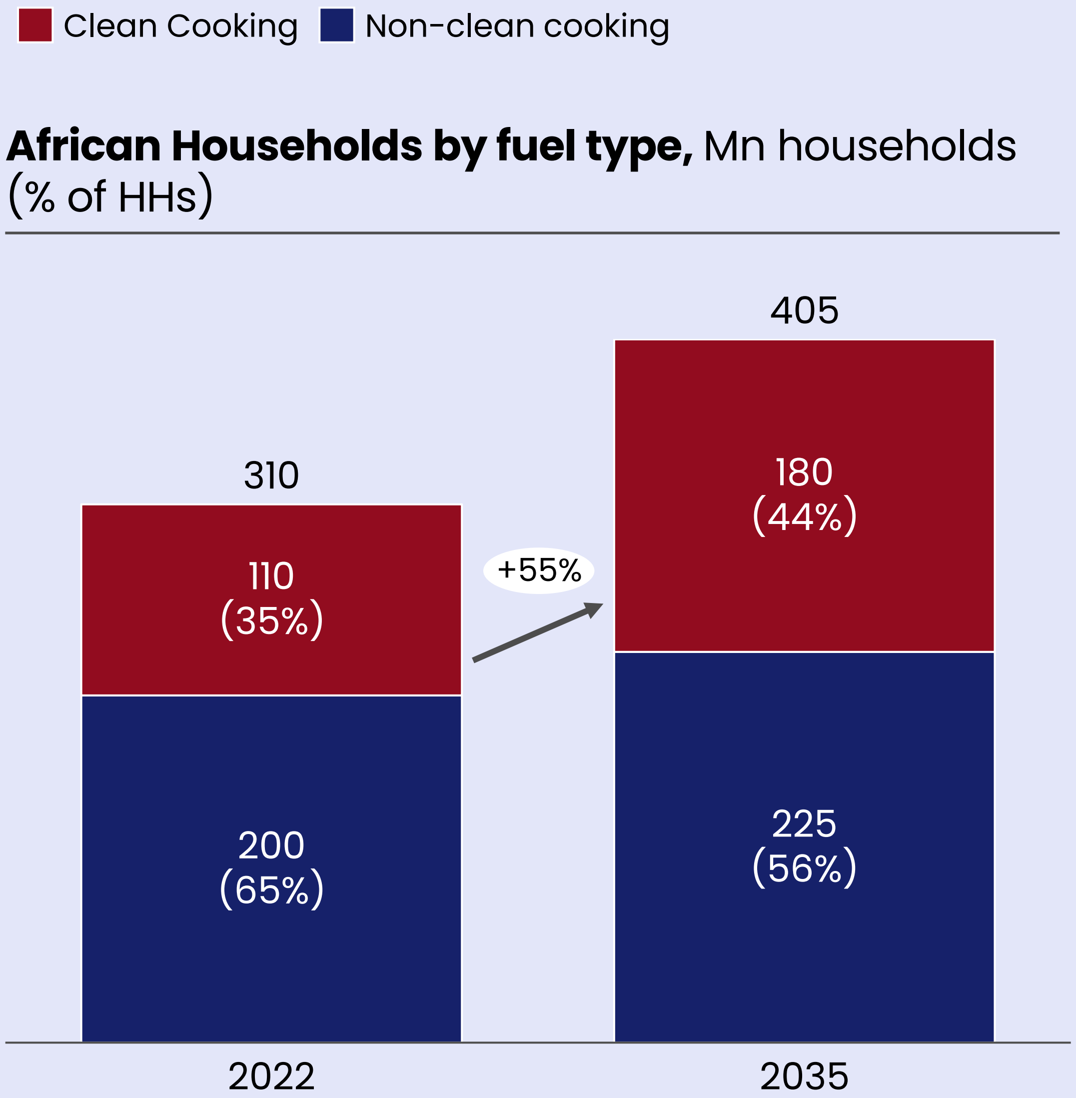
$2.2Bn mobilised and new national policies developed for 12 countries in 2024 with objectives of reaching the 2030 SDG7 goal of universal clean cooking access across Africa

	Kenya	**Nigeria**	**Ethiopia**
National Strategy:	Universal clean cooking access by 2030 from ~35% in 2022	Universal clean cooking access by 2030 from ~25% in 2020:	75% clean cooking access by 2035 (from 10% in 2024)
Target fuel mix:	50% LPG 30% ethanol 10% electricity 10% biogas, bio-pellets, other	54% LPG 20% electricity 13% improved biomass 8% bio-pellets & biogas 5% ethanol	Electricity with interim fuels (e.g., LPG, bioethanol and biogas)
Policy Promotors:	LPG: Zero-rated VAT & Duty	LPG: Zero-rated VAT & Duty	$3.5Bn government investment in infrastructure, notably electricity and LPG
Unlocks:	Zero-rated VAT & Duty for ethanol (from 16% VAT and 35% duty) Expansion of rural electricity access	Expansion of electricity access (from 60%, however reliability is a big challenge) Zero-rated VAT & Duty for ethanol	Expansion of electricity access (from 55%)

Source: Government national strategies, MECS, Clean Cooking Alliance, IEA Universal Access Report

Cooking | 70Mn households are projected to transition to clean cooking fuels by 2035

African Households by fuel type, Mn households (% of HHs)



Key insights

Clean cooking penetration is projected to increase by 9% p.a. between 2022 and 2035 based on historic benchmarks of annual clean cooking transition rates in peer countries[1]

70Mn additional clean cooking households projected by 2035

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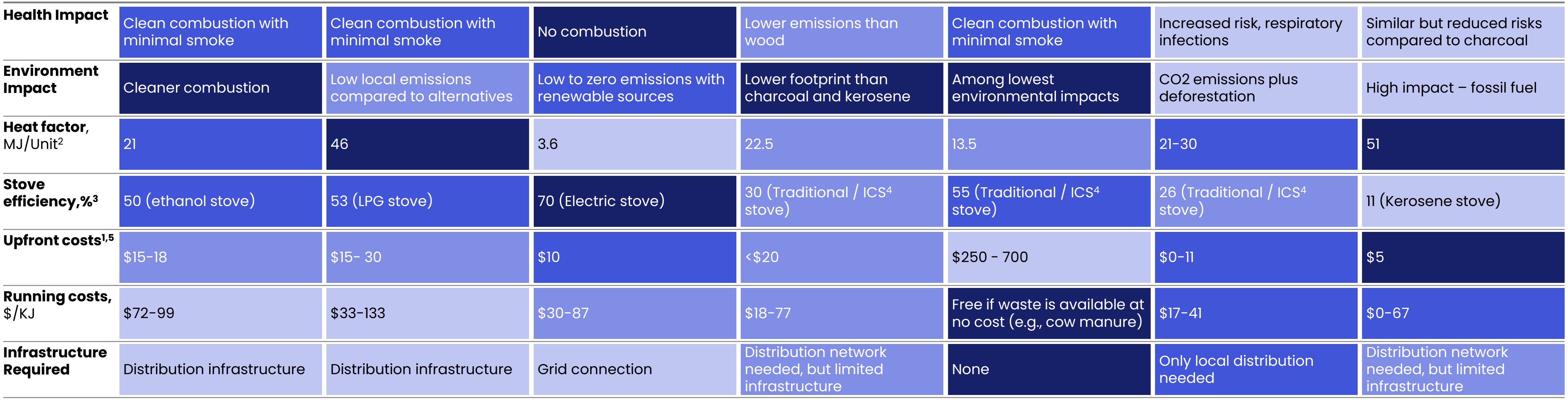
1. Based on average annual transition rates for peer countries including India, Pakistan, Philippines, Sri Lanka and Kenya

Source: IEA Universal Energy Access 2023, World Bank Clean Cooking Penetration, World Bank Population Data, Press Search

Cooking | There are several factors for countries and households to consider when transitioning to clean cooking fuels

Favourability vs. other fuels within segment

■ Very high ▩ High ▨ Medium □ Low



Segment	**Urban fuels** Suitable due to higher willingness to pay for clean cooking, restrictions on certain fuels (cannot burn indoors), and limited availability of waste for biogas			**Peri-urban/rural** Suitable due to lower willingness to pay for clean cooking, limited alternatives, fewer restrictions on certain fuels, and higher availability of waste for biogas			
Key Trade-offs	**Ethanol**	**LPG**	**Electricity**	**Bio-pellets**	**Biogas**	**Wood and Charcoal**	**Kerosene**
Health Impact	Clean combustion with minimal smoke	Clean combustion with minimal smoke	No combustion	Lower emissions than wood	Clean combustion with minimal smoke	Increased risk, respiratory infections	Similar but reduced risks compared to charcoal
Environment Impact	Cleaner combustion	Low local emissions compared to alternatives	Low to zero emissions with renewable sources	Lower footprint than charcoal and kerosene	Among lowest environmental impacts	CO2 emissions plus deforestation	High impact – fossil fuel
Heat factor, MJ/Unit[2]	21	46	3.6	22.5	13.5	21-30	51
Stove efficiency,%[3]	50 (ethanol stove)	53 (LPG stove)	70 (Electric stove)	30 (Traditional / ICS[4] stove)	55 (Traditional / ICS[4] stove)	26 (Traditional / ICS[4] stove)	11 (Kerosene stove)
Upfront costs[1,5]	$15-18	$15- 30	$10	<$20	$250 - 700	$0-11	$5
Running costs, $/KJ	$72-99	$33-133	$30-87	$18-77	Free if waste is available at no cost (e.g., cow manure)	$17-41	$0-67
Infrastructure Required	Distribution infrastructure	Distribution infrastructure	Grid connection	Distribution network needed, but limited infrastructure	None	Only local distribution needed	Distribution network needed, but limited infrastructure
Other considerations	Sticky, attracts insects; leakages	Easy use, but safety concerns where there is illegal filling (leading to incorrect pressure in cylinders)	Easy use, but dependent on stable grid	Refill can be unhandy	Requires optimised stove to generate sufficient heat Handling of waste cumbersome	High familiarity of users and tends to be preferred for heat	High familiarity of users and tends to be preferred for heat

1. For equipment such as stove, digester, etc.
2. kg / Litre / kWh
3. Percentage of the fuel's energy that is converted into useful heat for cooking, rather than being lost as smoke or waste heat
4. Improved Cooking Stove (ICS)
5. For equipment such as stove, digester, etc.

Source: US Department of Energy, Francesco Nerini et al, The cost of cooking a meal. The case of Nyeri County, Kenya. 2017, FAO, World Nuclear Association, , JICA Energy Report

Cooking | Up to ~30Mn households can potentially adopt biofuels for clean cooking

Fuel	**Addressable market characteristics**	**Total addressable market** 2035 Mn households (HHs)
Ethanol	- 50Mn new clean cooking households projected in countries with feedstock availability for ethanol - 42Mn are in urban and peri-urban areas - ~27Mn meet income requirements[1]	27
Bio-pellets	- 25Mn new clean cooking households projected in countries with scaled feedstock availability - 7.5Mn are rural and peri-urban households within 10km of town centre and >$1,000 annual income[2]	8 *Not included in total – overlap with ethanol and biogas*
Biogas	- 39Mn households have 2+ cows, of which ~2Mn are projected to transition to clean cooking	2

1. Assuming ~$0.65 / litre, ~320 litres annually and maximum 5% of household income spent on household fuel
2. Assuming $0.12 / kg, ~450kgs annually and maximum of 5% of household income spend on household fuel

Source: IEA Universal Energy Access 2023, World Bank Clean Cooking Penetration, World Bank Population Data, Press Search

4,5,6 | Cooking: Biofuels for clean cooking could generate revenue of ~$0.9-1.2Bn by 2035, requiring $1.3-1.6Bn investment

● Limited-to-No policy ● Strong policy

Use case	Top 3 countries	**CC households,** Mn HHs, 2035		**Market potential,** Bn USD, 2035[1]			**Investment potential,** Bn USD, 2035			**Estimated biofuel penetration rate,** % of 2035 total CC households		
		Limited-to-No policy	Strong policy	Limited-to-No policy	Strong policy		Limited-to-No policy	Strong policy		Limited-to-No policy	Strong policy	
4 **Bio-pellets**	Ethiopia Tanzania Kenya	4.7	5.7	0.2	0.3	70-80% adoption for rural and peri-urban HHs purchasing fuels (not harvesting wood)	0.2	0.3	100+ plants at $2-3Mn for a 24kpta	12%	15%	Equal to 5-7% of all households **10%** biofuel penetration projected in IEA clean cooking penetration in 2035 universal access scenario with additional 50% from LPG and 20% from electricity
5 **Biogas**	Ethiopia Tanzania Kenya	<0.3	<0.5	0.04	0.1	15-30% adoption for HHs in rural and peri-urban areas with at least 2 cows in an intensive or semi-intensive system (to collect manure) Market value based on value of energy use based on LCOE of $0.05/kWh	0.2	0.3	$700 for a biogas digester			
6 **Ethanol**	Ethiopia Tanzania Uganda	3.2	3.7	0.7	0.8	Adoption rates vary based on archetypes of country based on availability of alternatives like LPG and cost of ethanol based on feedstock costs	0.9	1.0	70-78 plants of 15Mn capacity at $12Mn each			

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1. Ethanol and bio-pellets markets are sized based on fuel use; Biogas market potential is based on equivalent energy use and a price equal to LCOE of biogas to ensure apples-to-apples comparison. In reality, the revenue for a biogas company is based on the equipment sold so investment potential is a greater indication of revenue potential

Source: IEA Universal Access to Clean Cooking Africa

4,5,6 | Cooking – enablers: Several enablers could help build a market for biofuels in clean cooking (1/2)

Feasibility[1] ○ Low ● High ▢ Deep-dives next

Category	Enabler	Details	Stakeholders				Feasibility
			Government	Development partners	Research institutions	Private sector	
Overarching	**Carbon Credits**	Support clean cooking companies in gaining accreditation and building robust monitoring and verification systems to access fair voluntary carbon market pricing; include in national registries	✓			✓	◕
	Finance	Set up a $650Mn biofuels clean cooking fund, focused on biogas, bio-pellets, and ethanol, providing patient capital and a connection to carbon credits		✓		✓	◑
	Country strategies	Embed biofuels for clean cooking in country strategies (where LPG or electricity unlikely to be available at-scale in the near-term) and develop financing and infrastructure support mechanisms (as described below)	✓				◕
	Consumer Awareness	Conduct consumer awareness campaigns particularly for bio-pellets	✓	✓			●
Ethanol	**Increase feedstock**	Invest in or provide incentive for investment to increase feedstock surplus by increasing agricultural productivity for ~2.5-3k farmers per plant (~4-4.5k hectares)[2]	✓			✓	◑
	Infrastructure	Develop and strengthen infrastructure for ethanol storage, transport, and distribution, with a focus on ensuring efficient and reliable supply in urban and peri-urban areas	✓			✓	◑

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1. Feasibility based on: High - proven enabler demonstrated in multiple African countries (even if in other industries); Medium (1/2 moon) - proven enabler demonstrated in peer countries (e.g., India); Low - high complexity intervention, unproven in any developing economy
2. Based on average cassava and maize requirements for a 15M litre plant and assuming 1.5 hectares per smallholder farmer

Source: Manufacturing Africa team analysis

4,5,6 | Cooking – enablers: Several enablers could help build a market for biofuels in clean cooking (2/2)

Feasibility[1] ⚪ Low ● High ▢ Deep-dives next

			Stakeholders				
Category	**Enabler**	**Details**	**Government**	**Development partners**	**Research institutions**	**Private sector**	**Feasibility**
Bio-pellets	**Logging restriction**	Implement and enforce restriction on cutting of firewood to protect the environment and accelerate a shift away from conventional biomass for cooking	✓				◑
	Stove innovation	Develop new stove types that enhance user experience by ensuring sufficient heat for cooking and enable reloading of the cook stove from bottom		✓	✓	✓	●
Ethanol	**Consumer financing**	Provide consumer financing or other payment models (e.g., pay-as-you-go) to help households finance the high upfront cost for the biodigester				✓	●
	Stove innovation	Develop stove and digester systems that enables sufficient gas flow for high heat cooking by building on existing successful models				✓	●

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1. Feasibility based on: High - proven enabler demonstrated in multiple African countries (even if in other industries); Medium (1/2 moon) - proven enabler demonstrated in peer countries (e.g., India); Low - high complexity intervention, unproven in any developing economy

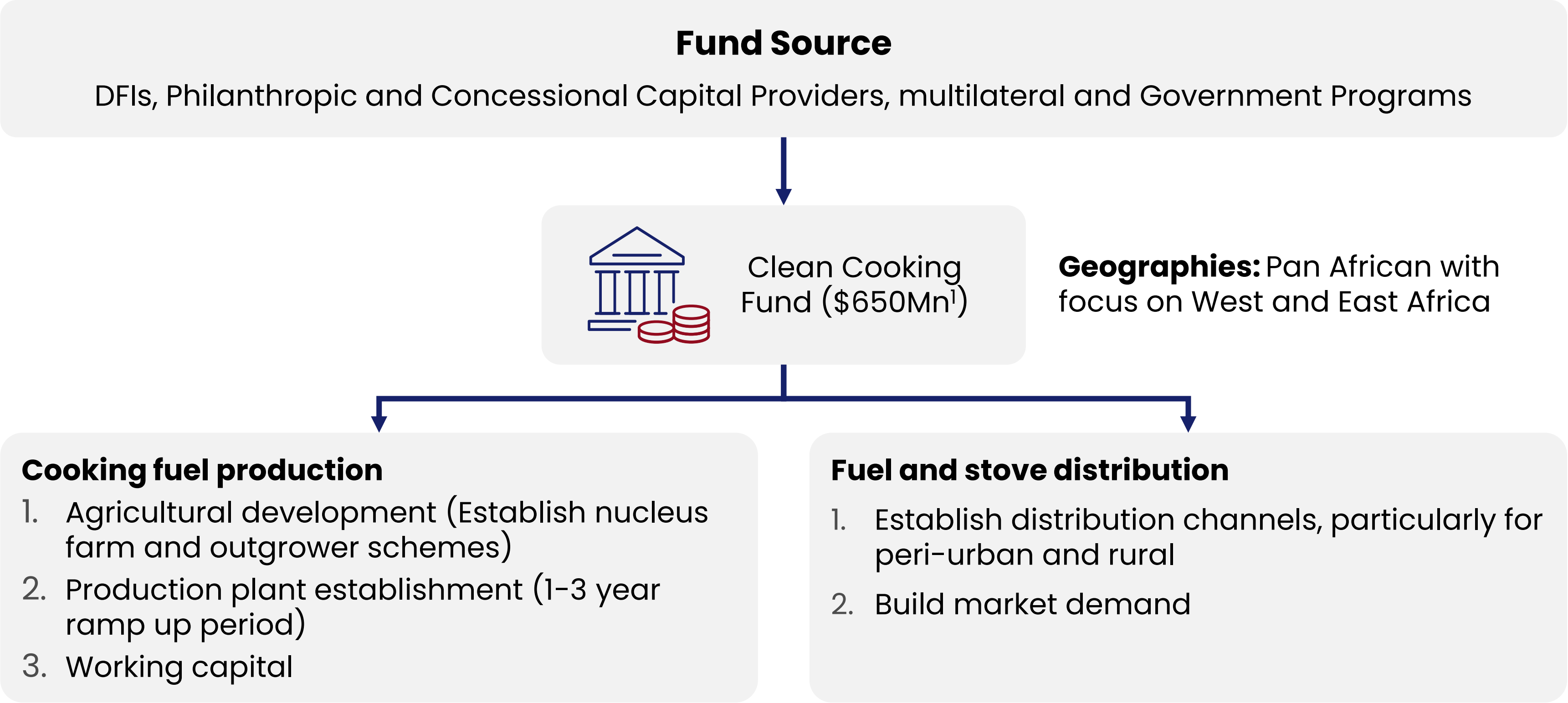
Source: Manufacturing Africa team analysis

4,5,6 | Cooking: There is potential to establish a $650Mn fund to finance cooking biofuels

Opportunity

Establish a **dedicated clean-cooking investment fund** focused on establishing and scaling sustainable biofuel production including ethanol, bio-pellets, and biogas to accelerate access to affordable, low-emission cooking solutions in Africa

Results-based financing or social impact bonds can also be used (versus carbon credits) as an incentive for roll-out of stoves / fuel to households



Fund Source

DFIs, Philanthropic and Concessional Capital Providers, multilateral and Government Programs

Clean Cooking Fund ($650Mn[1])

Geographies: Pan African with focus on West and East Africa

Cooking fuel production

1. Agricultural development (Establish nucleus farm and outgrower schemes)
2. Production plant establishment (1-3 year ramp up period)
3. Working capital

Fuel and stove distribution

1. Establish distribution channels, particularly for peri-urban and rural
2. Build market demand

Carbon credits can improve the commercial viability of biogas and ethanol projects by offsetting high early costs and enabling lower fuel prices. Yet price volatility and shifting eligibility rules make overreliance risky. **Dedicated clean cooking funds** can provide technical assistance for project accreditation and help assess or buffer dependence on carbon revenues through blended finance structures

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1. Assumes investment in average sized ethanol, bio-pellet and biogas plants required to reach full market potential with 15% IRR and average exit in 5 years

Source: Manufacturing Africa team analysis

4,5,6 | Cooking: While carbon credits provide price subsidies, they also create risk due to price volatility

Context[2]

- Clean-cooking credits are **emissions-avoidance** units from improved efficiency or **fuel-switch.** They are primarily traded on voluntary markets
- Carbon credits are essential to many biofuel clean cooking models, but can create risk in the business model if not available:
    - **Ethanol:** Requires high tier carbon credits ($11-25 per tCO2e) to be competitive versus LPG and electricity in countries that already have high availability of these fuels
    - **Biogas:** Subsidises up to 70% of the total cost of digesters significantly reducing upfront cost barrier to adoption
    - **Bio-pellets:** While carbon credits are less essential for cost competitiveness, they can support commercial viability of projects

Potential enablers

- **Support companies to navigate accreditation and adopt monitoring tools:** Clean cooking projects need reliable ways to measure and verify how much carbon they save.
- **Carbon market roadmaps need to be defined for each country:** Governments could define who owns and can sell carbon credits and establish simple approval processes. This clarity reduces disputes and builds investor confidence.
- **Set up an Advanced Market Commitment:** Given carbon prices fluctuate, long-term offtake or minimum-price agreements can give developers certainty and attract investment. Initiatives like the Advance Market Commitment (AMC) for African carbon credits aim to guarantee floor prices and secure early buyer commitments. Advancing such initiatives will be key

1. Carbon prices are based on average carbon prices transacted on leading exchanges across selected project categories as of end of 2023 (left-hand side) and the end of 2024 (right-hand side)
2. Bio-pellets have lower dependence on carbon credits to be cost competitive

Source: ClimateFocus, 2023 Clean Cooking Alliance Industry Snapshot, ACMI Status and Outlook Report 2024

4,5,6 | Cooking – roadmap: Clean cooking players can establish production and distribution in three key stages

Ethanol Bio-pellets Biogas Overarching

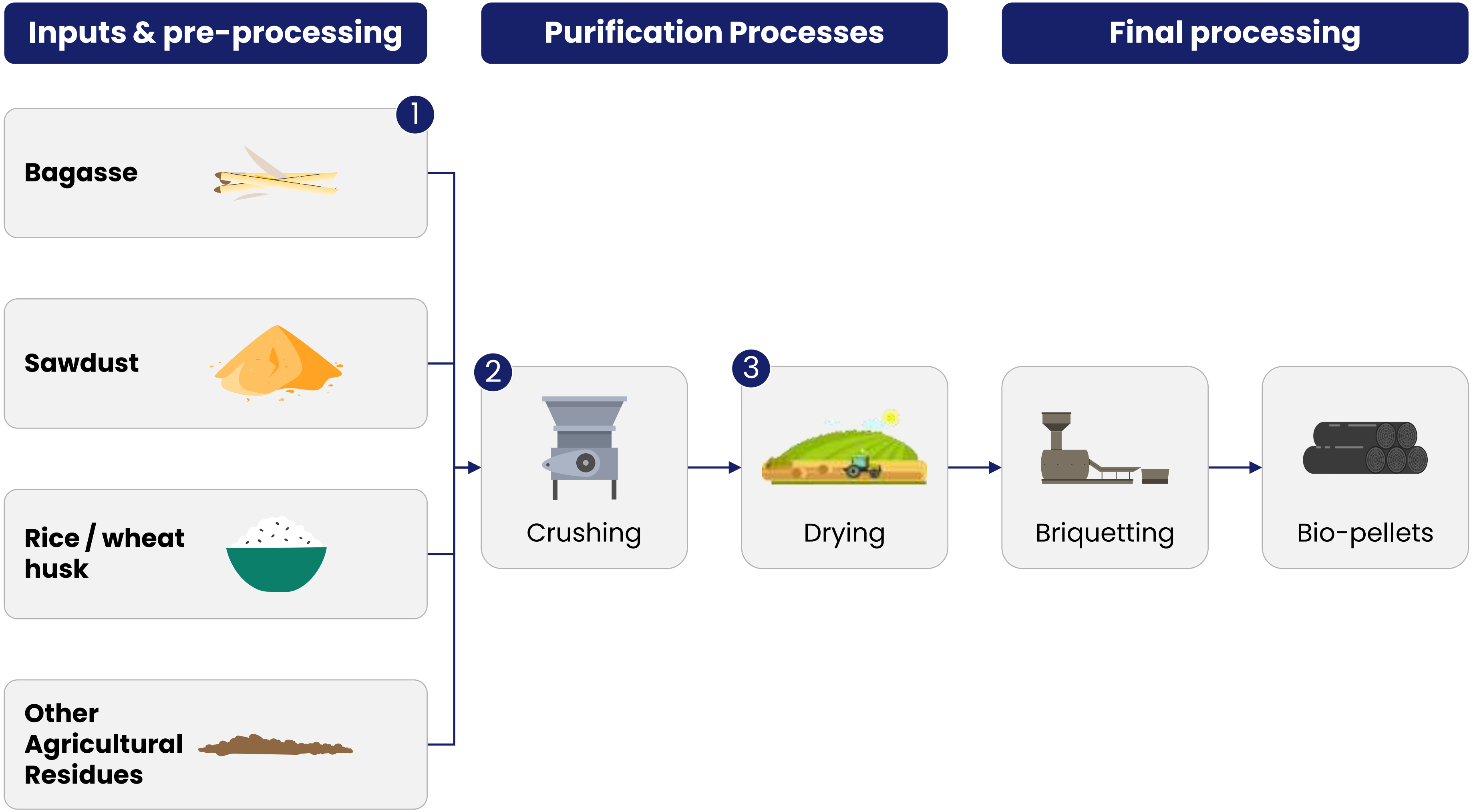
Category	**Phase 1: Set up fuel production** (Year 1)	**Phase 2: Build demand and distribution for biofuels** (Year 2+)	**Phase 3: Scale by establishing additional plants** (Year 2+)
Production plant set up & operations	Ensure feedstock availability by mobilising farmers to grow or supply dedicated crops (e.g., cassava in areas where it's not a staple)	Build out fuel distribution infrastructure for ethanol (install storage tanks, deploy tanker trucks, set up local fuel "ATM" dispensers)	Expand production plants nationally and regionally, as high-potential markets may require multiple facilities to meet demand. Prioritise scaling in markets with proven demand and adequate feedstock before entering new markets
	Secure biomass supply chains by partnering with agricultural residue producers (like sugar mills, forestry industries, etc.)	Establish distribution networks for bio-pellets (partner with local retailers or set up dedicated outlets)	
	Train local masons and technicians to construct and maintain biodigesters, and target communities with sufficient organic waste		
Financing & carbon credits	Establish a dedicated clean cooking fund targeted at proving patient capital, debt facilities and equity funding to companies based on the stage of operation and financial need		
	Design projects for eligibility and secure accreditation under major methodologies (e.g. Gold Standard	Partner with buyers offering multi-year offtake contracts for carbon credits to improve pricing stability and lower project risk	
Government support and regulation	Explicitly integrate biofuels in part of clean cooking strategies where in makes sense. For ethanol, set fuel standards and include ethanol in national plans		
	Offer consumer incentives to accelerate adoption – for instance, incentives for stoves		
		Invest in enabling infrastructure (e.g., roads) to support fuel distribution, particularly to peri-urban and rural areas	

Source: IEA Clean Cooking Infrastructure

Contents

Executive summary
Biofuels overview, scope, and context in Africa
Details on approach for sizing the opportunity for biofuels in Africa
Appendix 1: Africa biofuel feedstock availability assessment
Appendix 2: Use case deep-dives
  1, 2 Road – Ethanol, FAME diesel
  4, 5, 6 Cooking – bio-pellets, biogas, ethanol
  – Context
    4 Bio-pellets
  – 5 Biogas
  – 6 Ethanol
  7, 9 Industrial Heat and Power – biogas, bio-briquettes
  10 Aviation - 2G oil-based feedstock export
  11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

4 | Cooking – bio-pellets: High quality bio-pellets are produced in a 5-step process requiring simple machinery



Inputs & pre-processing

Purification Processes

Final processing

① **Bagasse**

Sawdust

Rice / wheat husk

Other Agricultural Residues

② Crushing

③ Drying

Briquetting

Bio-pellets

① Consistent, dry feedstock supply is essential for production. Co-location is optimal to reduce operational costs

② The process is manual, labour-intensive, and challenging to manage, limiting scalability

③ The process is manual, labour-intensive, and challenging to manage, limiting scalability

③ High Energy Efficiency: High energy density and <10% moisture (vs. >25% in wood) enhance combustion efficiency

Source: Team analysis, Expert discussions, Ministry of petroleum and natural gas

4 | Cooking – bio-pellets: There are several bio-pellets companies in Africa operating across three different production scales

NON-EXHAUSTIVE

○ Low ● High

Dimensions	Large scale businesses	Small scale businesses	Micro businesses
Description	• 2,000+ tonnes per month • Requires multiple high-capacity presses, dedicated dryers • Operated with significant workforce	• 100 - 2000 tonnes /month • Can operate with simple manual machinery • Operated by <10 peoples	• <100 tonnes /month Manual presses • 1-3 individuals required
Cost Competitiveness	● • Economies of scale allow lowest unit cost per tonne • Transport cost per tonne minimised if co-located with feedstock source • Labour cost per tonne can be lower due to automation	◐ • Moderate to high unit costs due to lower economies of scale • More likely to not be co-located with feedstock source and hence higher transport cost	○ • Highest unit cost per tonne due to low economies of scale and need to transport feedstock, but low capital requirements
Examples	LEAN OTAMUWA CSE COEGA BIOMASS CENTRE HVE WOOD PELLETING CC.	BioMassters ACACIA INNOVATIONS ECOSAFI pro pellets africa	brightgreen WEYE Clean Energy Company Ltd

Source: Press Search, Expert Input

4 | Cooking – bio-pellets: Bio-pellet producers face three primary barriers to establishing large scale production

Feedstock availability

- Bio-pellet production requires **scaled and consistent availability of dry feedstock** (e.g., bagasse, rice husk, sawmill dust)
- Optimised unit economics often requires **co-location with waste production sites** (e.g., sugar, rice or sawmills) to reduce transportation costs
- **Wet feedstock**—especially during the rainy season—can **disrupt business continuity**

Availability of (perceived) lower cost alternatives

- Widespread **availability of free or low-cost alternatives like firewood** reduces the incentive for households to pay for bio-pellets
- Even households that purchase wood often **perceive wood as the cheaper** cooking fuel based on the **price per kg**, thereby neglecting the lower cost per unit of energy (bio-pellets outcompete wood in the latter mainly due to lower moisture content)

Ability to aggregate demand

- Aggregating demand for bio-pellets in rural and peri-urban areas is challenging because **households are geographically dispersed**
- **Large, scaled producers typically prioritise industrial markets** (e.g., tea factories, schools, hospitals) since they offer concentrated demand and are still relatively underserved

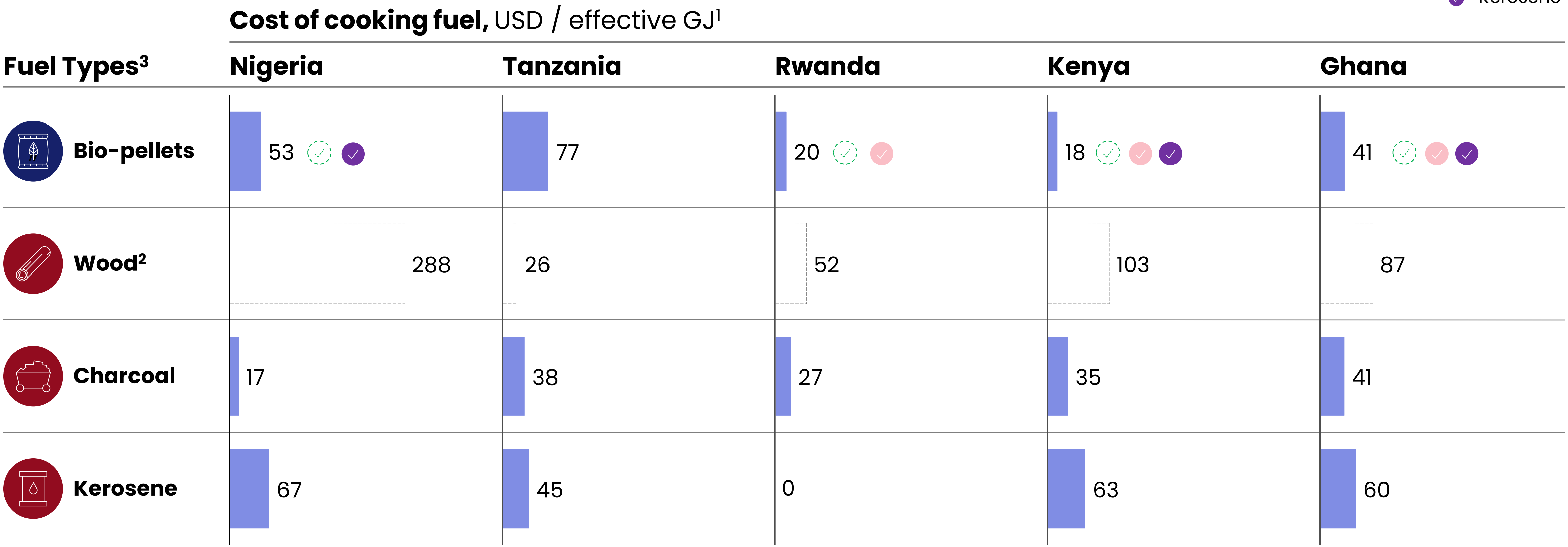
Source: Industry interviews

4 | Cooking – bio-pellets: Bio-pellets are cost competitive for households who purchase wood and those who use kerosene

AS OF SEPTEMBER 2025

● Non-clean Cooking ● Clean Cooking

Cost competitive vs: ✓ Wood² ✓ Charcoal ✓ Kerosene



Cost of cooking fuel, USD / effective GJ[1]

Fuel Types³	Nigeria	Tanzania	Rwanda	Kenya	Ghana
Bio-pellets	53 ✓ Wood ✓ Kerosene	77	20 ✓ Wood ✓ Charcoal	18 ✓ Wood ✓ Charcoal ✓ Kerosene	41 ✓ Wood ✓ Charcoal ✓ Kerosene
Wood²	288	26	52	103	87
Charcoal	17	38	27	35	41
Kerosene	67	45	0	63	60

Bio-pellets are cost-competitive vs. paid wood and kerosene across many markets suggesting potential to capture market, particularly as wood fuel access becomes more constrained. Cost optimisation will be required for competitiveness vs. charcoal in Nigeria

1. Price includes the fuel cost, stove efficiency and fuel efficiency
2. No cost for gathered wood, upper bound reflects purchased wood
3. Assuming bio-pellets competes against fuels widely available in rural and peri-urban areas shown here and is not competing against LPG and electricity

Source: KNBS, Total energies, KOKO Networks, MECS, Clean Cooking Alliance, Government Reports

4 | Cooking – bio-pellets: We identified 16 countries with sufficient feedstock for at scale bio-pellets production

	Considerations	Viability	Required volume	Countries[2]	
Bagasse	Common in sugar-producing regions, widely used due to its availability	● Can achieve low moisture content (12-14%)	7,500 tonnes surplus bagasse (from 25,000 tonnes of sugarcane)[1]	Eswatini Kenya Madagascar Malawi Mozambique	Sudan Tanzania Uganda Zambia Zimbabwe
Sawdust and wood shavings	Procured from sawmills and carpentry shops Available in countries with large forestry industries	● Can be used directly for briquetting, if moisture content is sufficiently low	24,000 tonnes of sawdust	Cameroon Democratic Republic of the Congo Equatorial Guinea	Ethiopia Ghana Mozambique Nigeria Uganda
Rice and wheat husk	Widely available year-round Low bulk density leading to higher logistics costs	◐ ~50% calorific value vs. sawdust driven by high ash content. Requires combination with other feedstock to improve viability	Exact values are not available; however, viability is highest in countries with scaled production	Algeria Ethiopia Guinea	Madagascar Mali Nigeria Tanzania
Straw, leaves, grass and other organic waste	Not widely used at scale as they require additional pre-treatment and mixture with other feedstock	○ See left	N/A		

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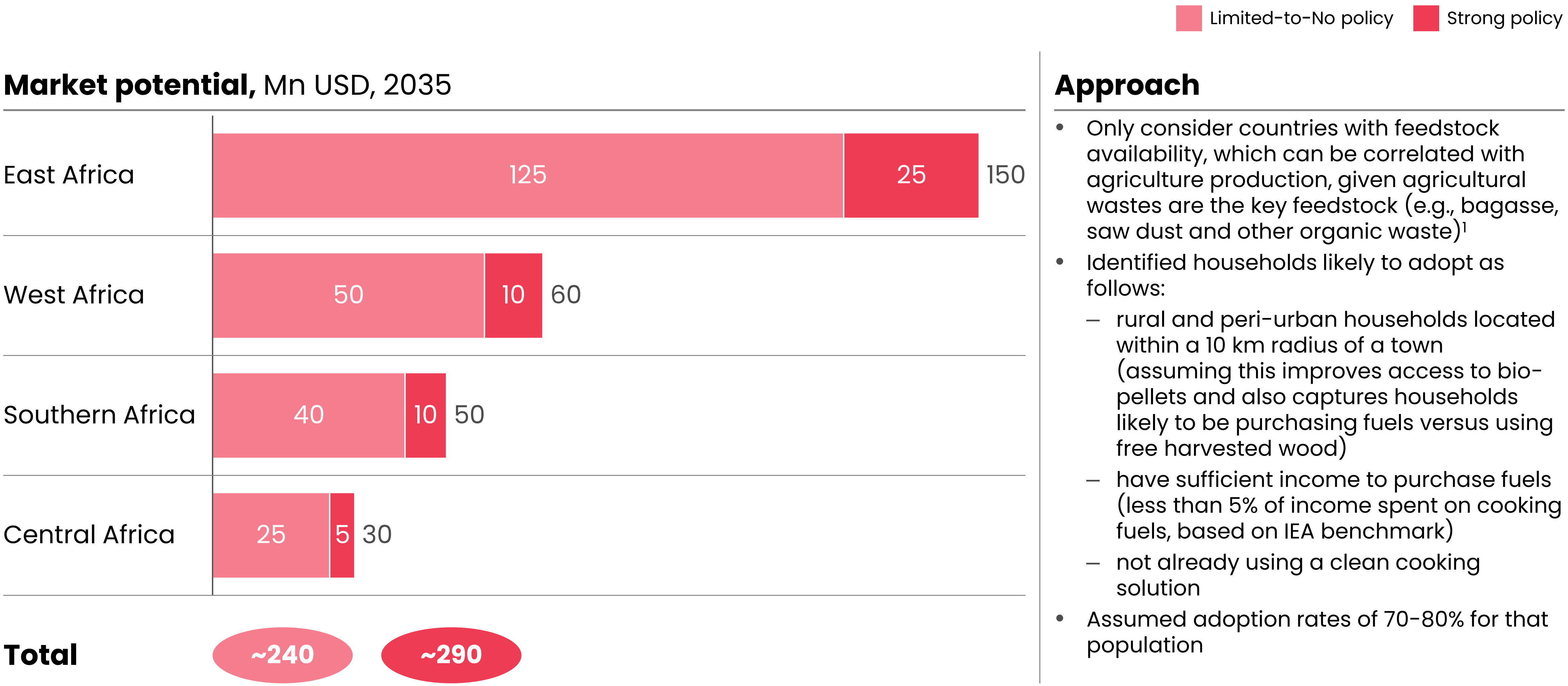
1. Kenya report estimate only 25% of bagasse is used for power generation which is likely in the upper range of African markets. Availability of bagasse may be affected in the medium-long term if higher proportions are used for power generation
2. Countries with sufficient feedstock and low clean cooking penetration

Source: JICA Bio-briquette Production

4 | Cooking – bio-pellets: The bio-pellets market has $0.2-0.3Bn potential in countries with scaled availability of feedstock

Market potential, Mn USD, 2035



Approach

- Only consider countries with feedstock availability, which can be correlated with agriculture production, given agricultural wastes are the key feedstock (e.g., bagasse, saw dust and other organic waste)[1]
- Identified households likely to adopt as follows:
  - rural and peri-urban households located within a 10 km radius of a town (assuming this improves access to bio-pellets and also captures households likely to be purchasing fuels versus using free harvested wood)
  - have sufficient income to purchase fuels (less than 5% of income spent on cooking fuels, based on IEA benchmark)
  - not already using a clean cooking solution
- Assumed adoption rates of 70-80% for that population

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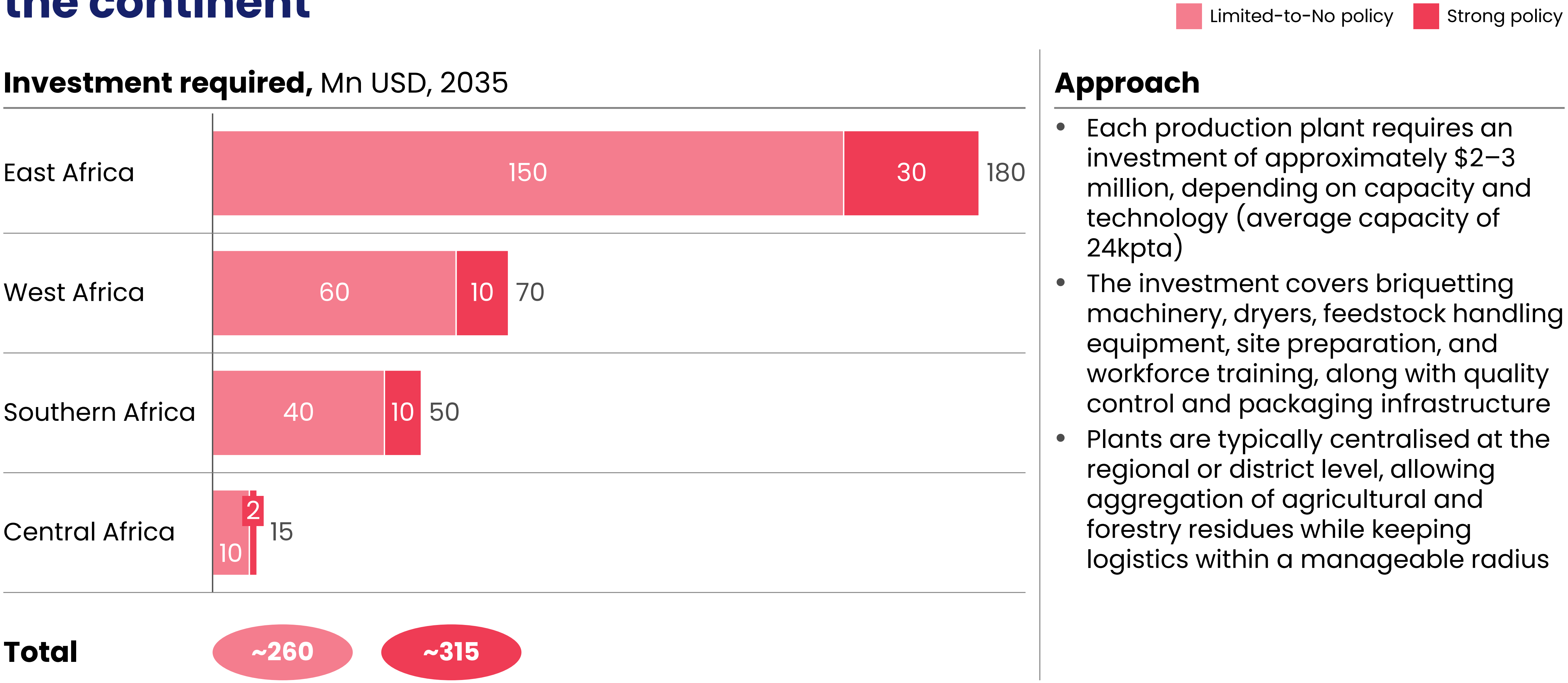
1. 2 countries deprioritised: Eswatini, Equatorial Guinea

Source: World Bank Population 2022, World Bank GDP PPP 2025, IEA

4 | Cooking – bio-pellets: Bio-pellet production will require investment of $0.2-0.3Bn to realise the full potential across the continent

Investment required, Mn USD, 2035



Approach

- Each production plant requires an investment of approximately $2–3 million, depending on capacity and technology (average capacity of 24kpta)
- The investment covers briquetting machinery, dryers, feedstock handling equipment, site preparation, and workforce training, along with quality control and packaging infrastructure
- Plants are typically centralised at the regional or district level, allowing aggregation of agricultural and forestry residues while keeping logistics within a manageable radius

Source: Expert interviews

Contents

Executive summary
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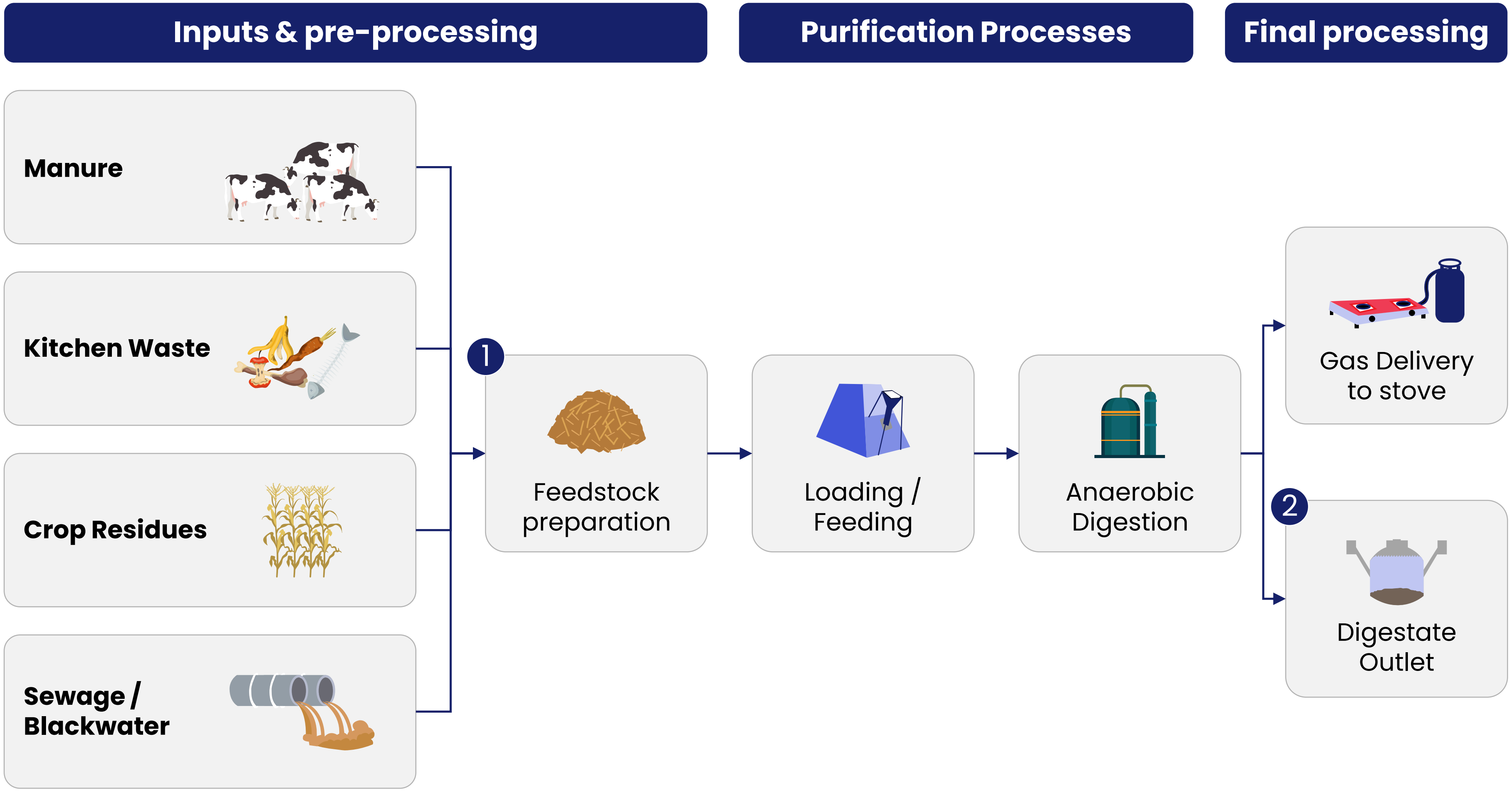
  – Context
  – 4 Bio-pellets
  5 Biogas
  – 6 Ethanol
  7, 9 Industrial Heat and Power – biogas, bio-briquettes
  10 Aviation - 2G oil-based feedstock export
  11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

5 | Cooking – biogas: High quality biogas is produced in a 5-step process requiring simple machinery



Inputs & pre-processing

Purification Processes

Final processing

Manure

Kitchen Waste

Crop Residues

Sewage / Blackwater

① Feedstock preparation

Loading / Feeding

Anaerobic Digestion

Gas Delivery to stove

② Digestate Outlet

① Waste is collected, chopped/shredded (if needed), and mixed with water to create a slurry (~8–10% solids)

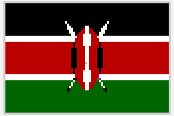
② Digestate is a nutrient-rich organic fertiliser that can be used to increase crop yield

Source: Industry interviews

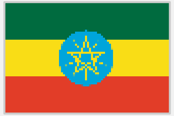
5 | Cooking – biogas: While penetration of biogas is low, there are several companies growing distribution of digesters across Africa

NON-EXHAUSTIVE

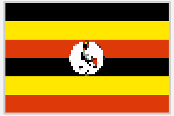
Biogas has low penetration across African markets…



>22,000 digesters installed in Kenya



>30,000 digesters installed in Ethiopia



>7,500 digesters installed in Uganda

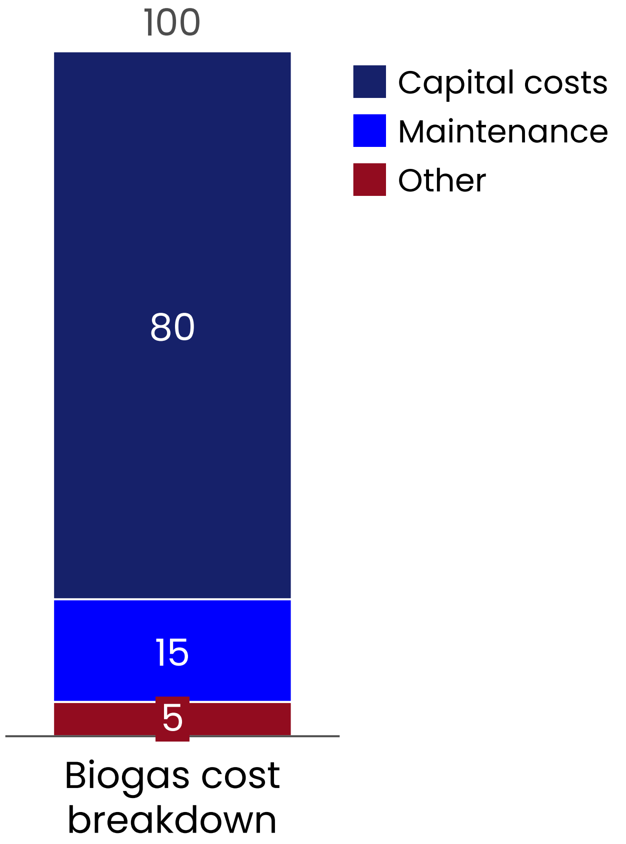
…however, there are several companies distributing biogas digesters across the continent

Company examples	Countries	Comments
SISTEMA.bio	Ethiopia Ghana Kenya Malawi Morocco Mozambique Nigeria Senegal Tanzania Uganda Zambia Zimbabwe	Leading biogas player, installed over 12,000 digesters in Africa
LANFORCE ENERGY Going Green For Future Generations	Zimbabwe	Modern Cooking Facility supported biogas company
HOMEBIOGAS®	Kenya	Modern Cooking Facility supported biogas company
BOLD BIOGAS	Uganda	>350 biogas digesters installed in Uganda
MeleGreen BIOGAS	Tanzania	Small scale biogas digester player

Source: FAO Biogas Energy Status in Kenya, WBA Bioenergy Magazine 2020, Sistema Bio, Press Search

5 | Cooking – biogas: Capital cost is the highest contributor to the cost of cooking for households using biogas

Biogas cost breakdown, % of total cost of cooking



Capital Costs

- High upfront capital cost (USD 500–1,000+ for small systems) is the main barrier to adoption
- Once installed, fuel is essentially free if households have consistent access to waste like manure

Maintenance Costs

- Maintenance and repair costs are relatively small but can be a burden if technical support is limited
- Providers may bundle this into the core product offering limiting additional expenditure

Other

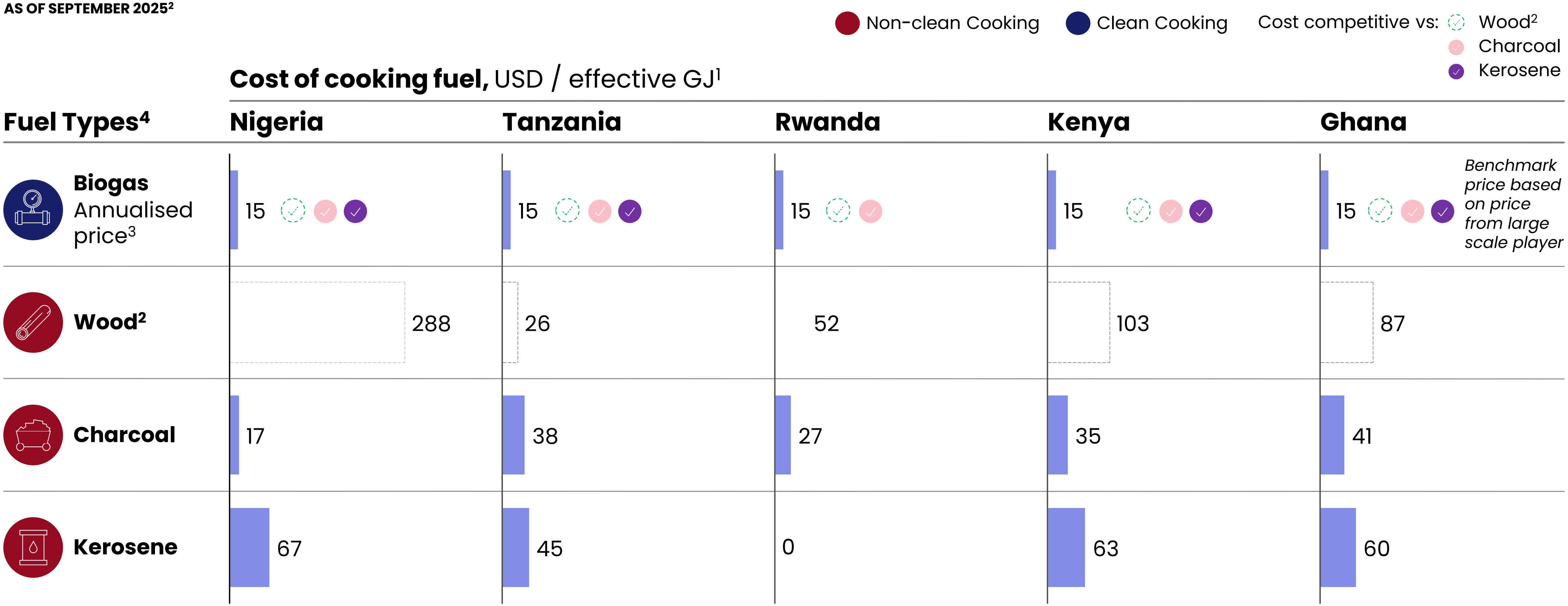
- Additional costs may include the cost of interest for payment plants and labour required to manage waste

Households with 2–3 cows can be self-sufficient in cooking fuel, but only if they can overcome the initial investment hurdle

Source: Industry interviews

5 | Cooking – biogas: Biogas is cost-competitive against purchased fuels when evaluated on an annualised capital expenditure basis

AS OF SEPTEMBER 2025[2]



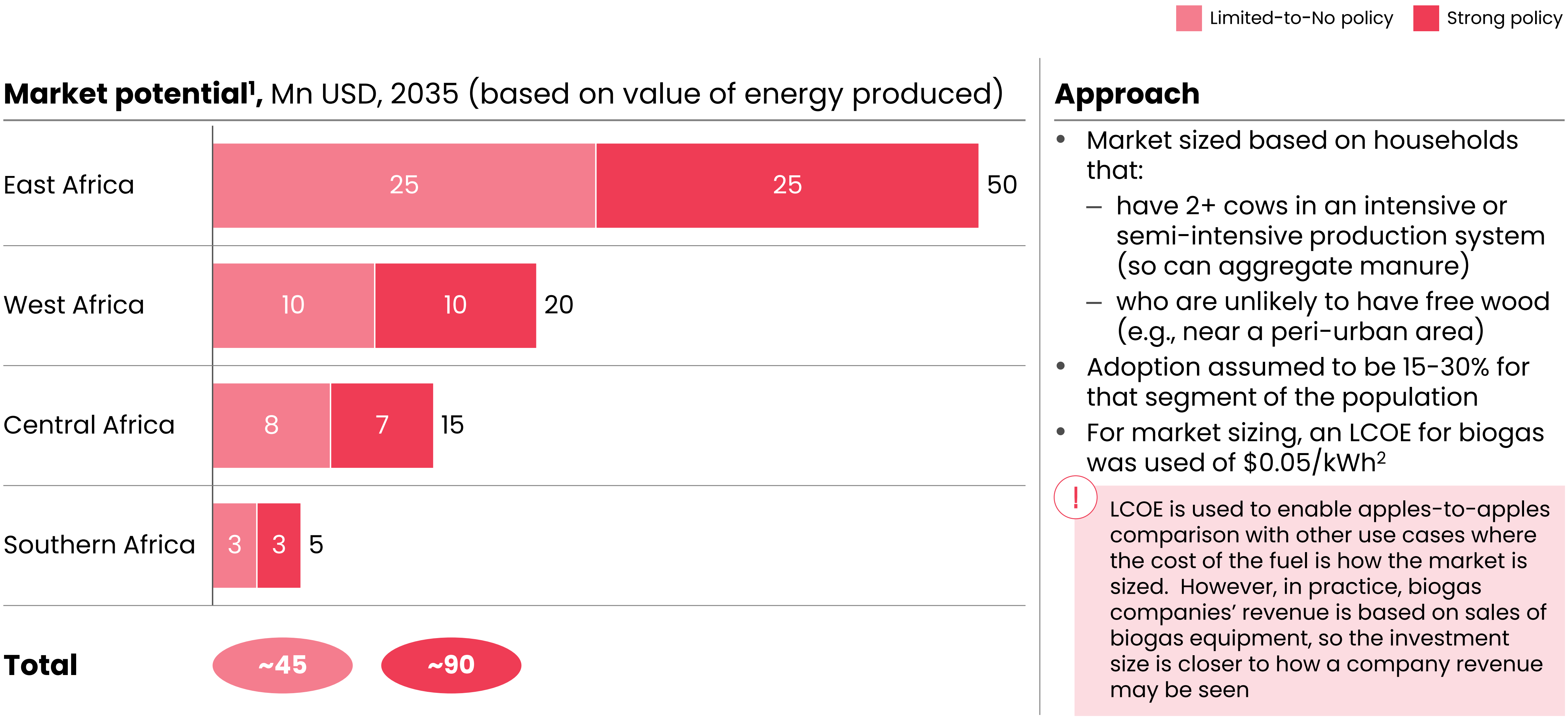
While biogas is cost competitive on an annualised basis, the upfront cost (~$700) may potentially be prohibitive. Some providers offer payment plants with repayment of ~$25 monthly making it more accessible while having marginal impact on cost competitiveness

---

1. Price includes the fuel cost, stove efficiency and fuel efficiency
2. No cost for gathered wood, upper bound reflects purchased wood
3. Sistema Bio price as of September 2025 (Sistema 8) of $685, assuming a 10 year lifespan and 3.3MJ of output per year
4. Assuming biogas competes against fuels widely available in rural and peri-urban areas shown here and is not competing against LPG and electricity

Source: Sistema Bio, MECS, Clean Cooking Alliance, Government Reports, Statista

5 | Cooking – biogas: The biogas market has up to ~$90Mn annual value potential across African countries



Approach

- Market sized based on households that:
  - have 2+ cows in an intensive or semi-intensive production system (so can aggregate manure)
  - who are unlikely to have free wood (e.g., near a peri-urban area)
- Adoption assumed to be 15-30% for that segment of the population
- For market sizing, an LCOE for biogas was used of \$0.05/kWh[2]

! LCOE is used to enable apples-to-apples comparison with other use cases where the cost of the fuel is how the market is sized. However, in practice, biogas companies' revenue is based on sales of biogas equipment, so the investment size is closer to how a company revenue may be seen

---

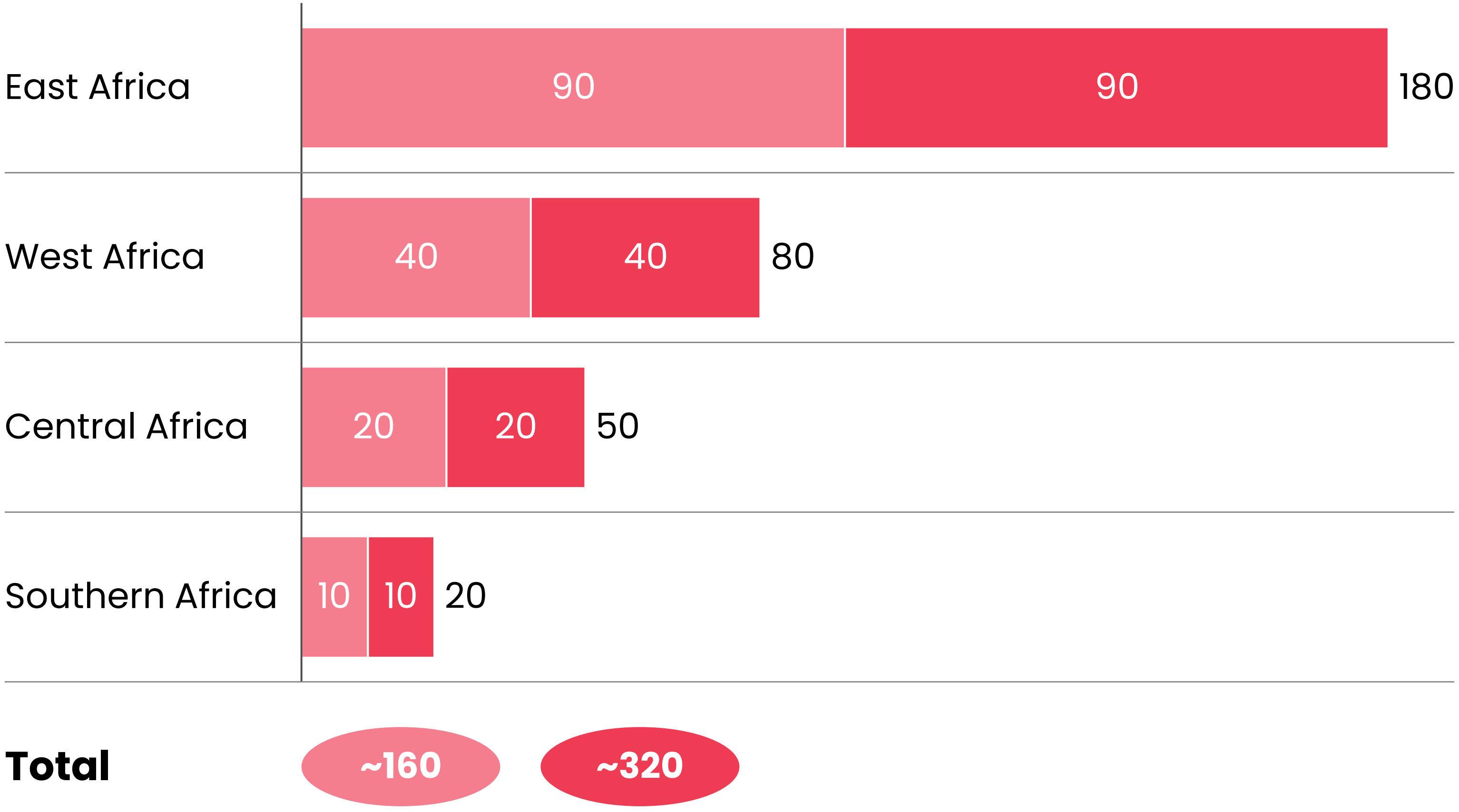
1. Calculated by dividing the discounted 10-year investment cost of the biogas digester by the total energy used for household cooking over its lifetime
2. LCOE calculated for a $700 cooking biogas system generating ~4,000MJ per year with a discount rate of 25%

Source: Manufacturing Africa team analysis

5 | Cooking – biogas: The biogas market requires up to ~$0.3Mn in distributed CAPEX to realise the full potential

🟥 Limited-to-No policy 🟥 Strong policy

Investment size[1], Mn USD, 2035



Approach and considerations

- Each household-level system costs approximately $700 which represents a carbon credit-subsidised price point. This cost accounts for the digester unit, installation materials, labour, user training, and periodic maintenance support
- No financing cost assumed – some biogas providers do provide a PAYGO option with a financing cost

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1. Based on $700 decentralised investment requirement, based on current price points in the market

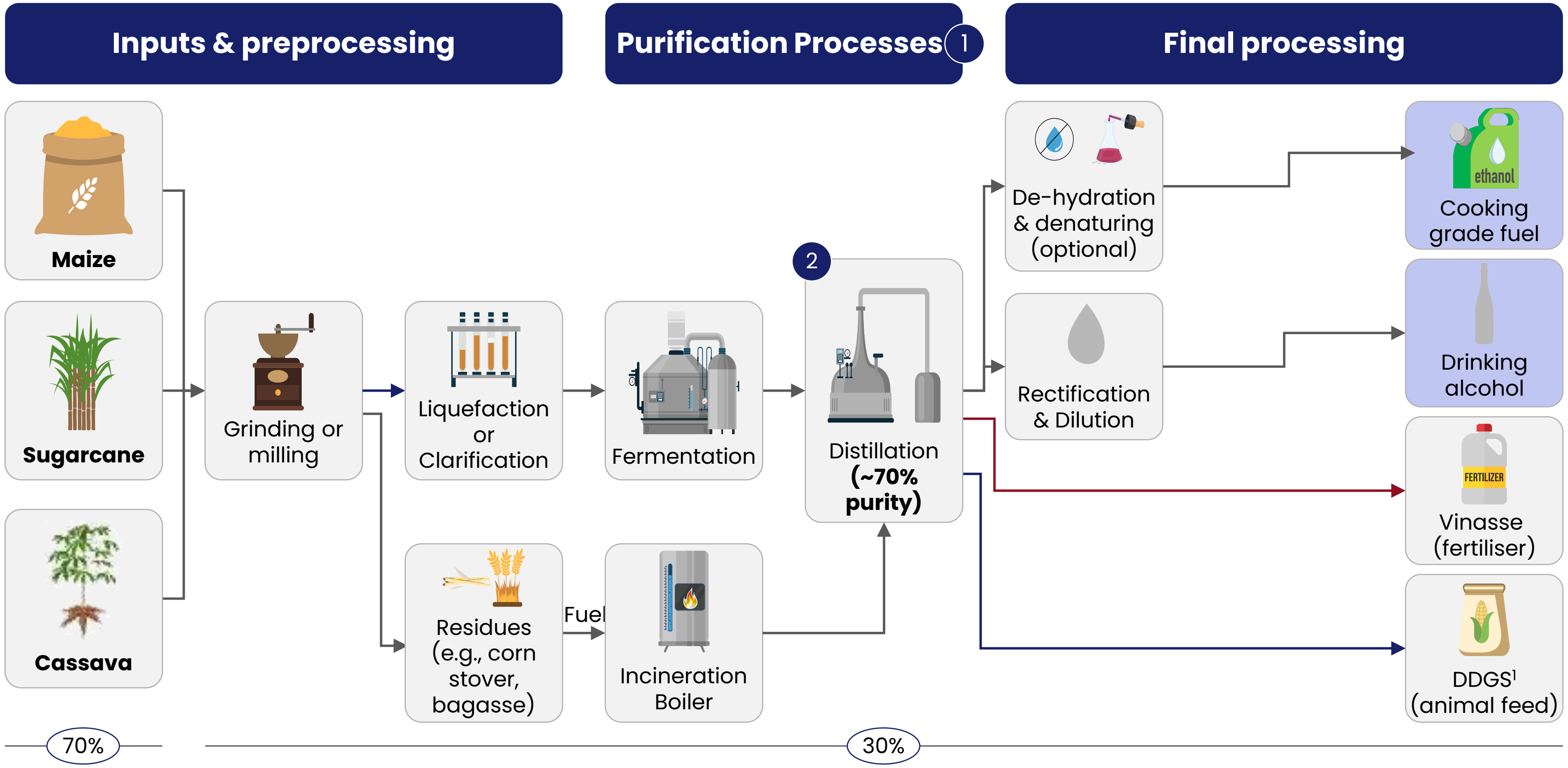
Source: Manufacturing Africa team analysis

Contents

Executive summary
Biofuels overview, scope, and context in Africa
Details on approach for sizing the opportunity for biofuels in Africa
Appendix 1: Africa biofuel feedstock availability assessment
Appendix 2: Use case deep-dives
  1, 2 Road – Ethanol, FAME diesel
  4, 5, 6 Cooking – bio-pellets, biogas, ethanol
  – Context
  – 4 Bio-pellets
  – 5 Biogas
  6 Ethanol
  7, 9 Industrial Heat and Power – biogas, bio-briquettes
  10 Aviation - 2G oil-based feedstock export
  11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

6 | Cooking – ethanol: Production for clean cooking can be done at a smaller and more cost-effective scale than ethanol for road

● % of total production cost



Inputs & preprocessing

Maize

Sugarcane

Cassava

Grinding or milling

Residues (e.g., corn stover, bagasse)

Purification Processes ①

Liquefaction or Clarification

Fermentation

Fuel

Incineration Boiler

② Distillation **(~70% purity)**

Final processing

De-hydration & denaturing (optional)

Rectification & Dilution

Cooking grade fuel

Drinking alcohol

Vinasse (fertiliser)

DDGS[1] (animal feed)

70%

30%

① Cooking ethanol plants can operate at small scale (<15Mn litres/year)

② Cooking ethanol is low purity (~70%) vs. road ethanol (>99%)

---

1. DDGS - Dried Distillers Grains with Solubles

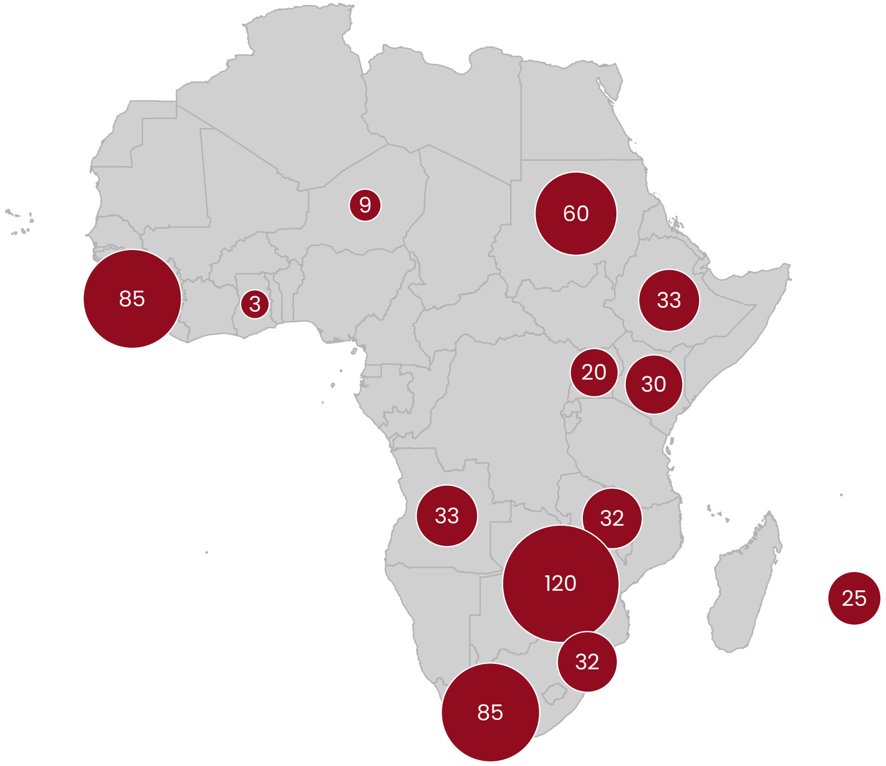
Source: Team analysis, Expert discussions, Ministry of petroleum and natural gas

6 | Cooking – ethanol: 20 (non-fuel grade) ethanol plants with >700Mn litres total capacity are in operation or planned in Africa

AS OF OCTOBER 2025 – BASED ON PUBLICLY AVAILABLE DATA

xx Liters of annual production capacity (Mn litres)

>700 million litres annual production capacity in Africa



Current and planned ethanol facilities

Country	Facility Name	Start-Up	Capacity
Zambia	Sunbird Cassava Ethanol	2023	120
Zimbabwe	Green Fuel Chisumbanje Plant	2013	120
Sierra Leone	Sunbird (Addax) Bioenergy Plant	2014	85
South Africa	AlcoNCP Distillery	1868	85
Sudan	Kenana Sugar Ethanol Plant	2009	60
Angola	Biocom Bioethanol Plant	2015	33
Eswatini	RSSC Ethanol Distillery (Simunye)	1995	32
Mauritius	Omnicane Ethanol Production Ltd.	2014	25
Ethiopia	Wonji-Shoa Ethanol Project	2024	22
Mozambique	Tongaat Hulett Xinavane Plant	2024	20
Ghana	Finchaa Sugar Ethanol Plant	2011	20
Uganda	Kakira Sugar Ethanol Plant	2017	20
Malawi	PressCane Ethanol Ltd.	2004	18
Kenya	Spectre International Distillery	2006	18
Ghana	Sinostone Bioethanol Project	2021	15
Other[1]			51

Key takeaway

Non-fuel grade ethanol is produced in Africa, typically for the alcohol, food, and cosmetics industry

Conversion of this ethanol to cooking grade requires one additional step, which is denaturisation

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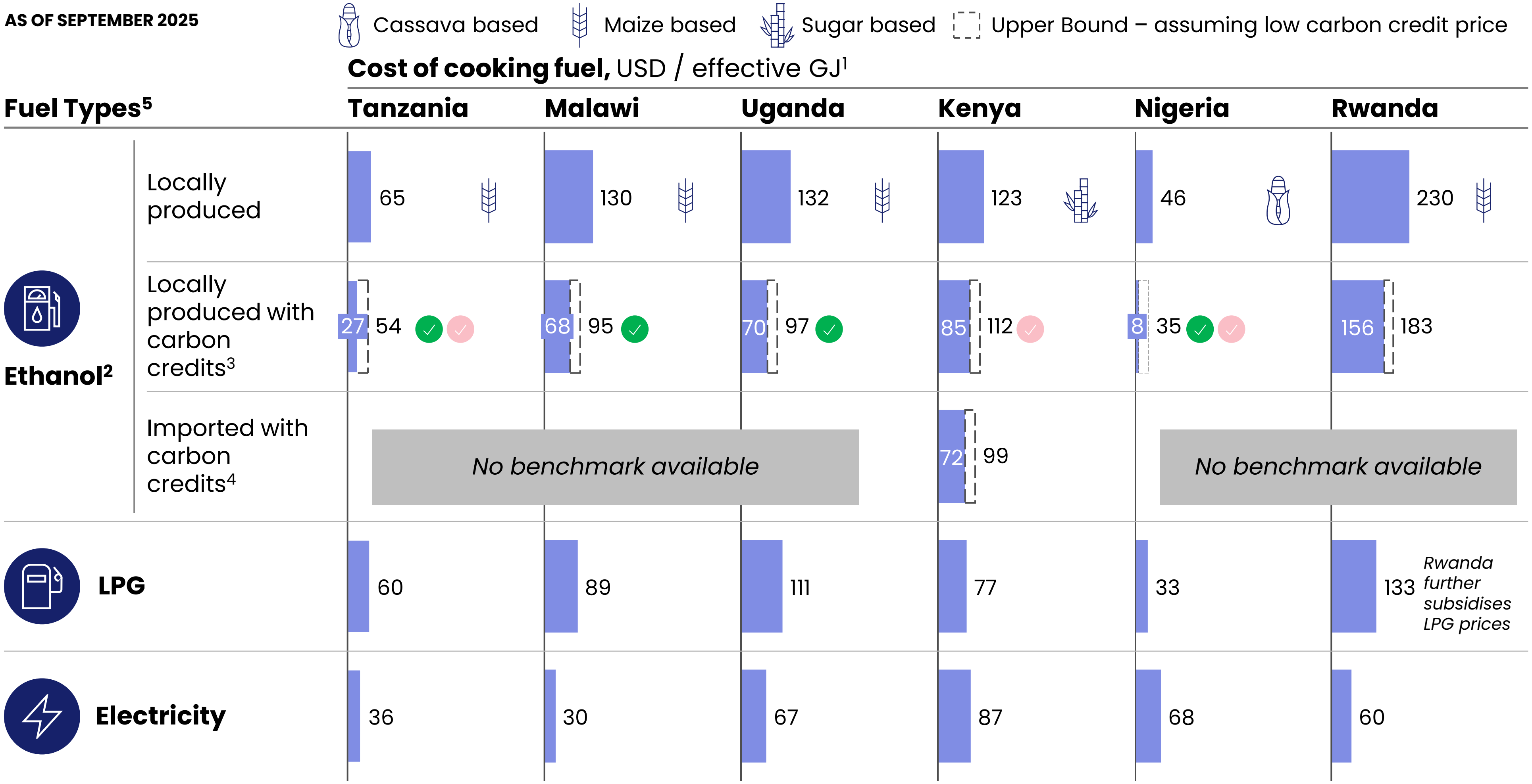
1. Combined capacity of 5 small scale plants

Source: IEA Universal Access to Clean Cooking Africa, Press Search

6 | Cooking – ethanol: Ethanol can be cost competitive in some countries, but with carbon credits

AS OF SEPTEMBER 2025



Key insights

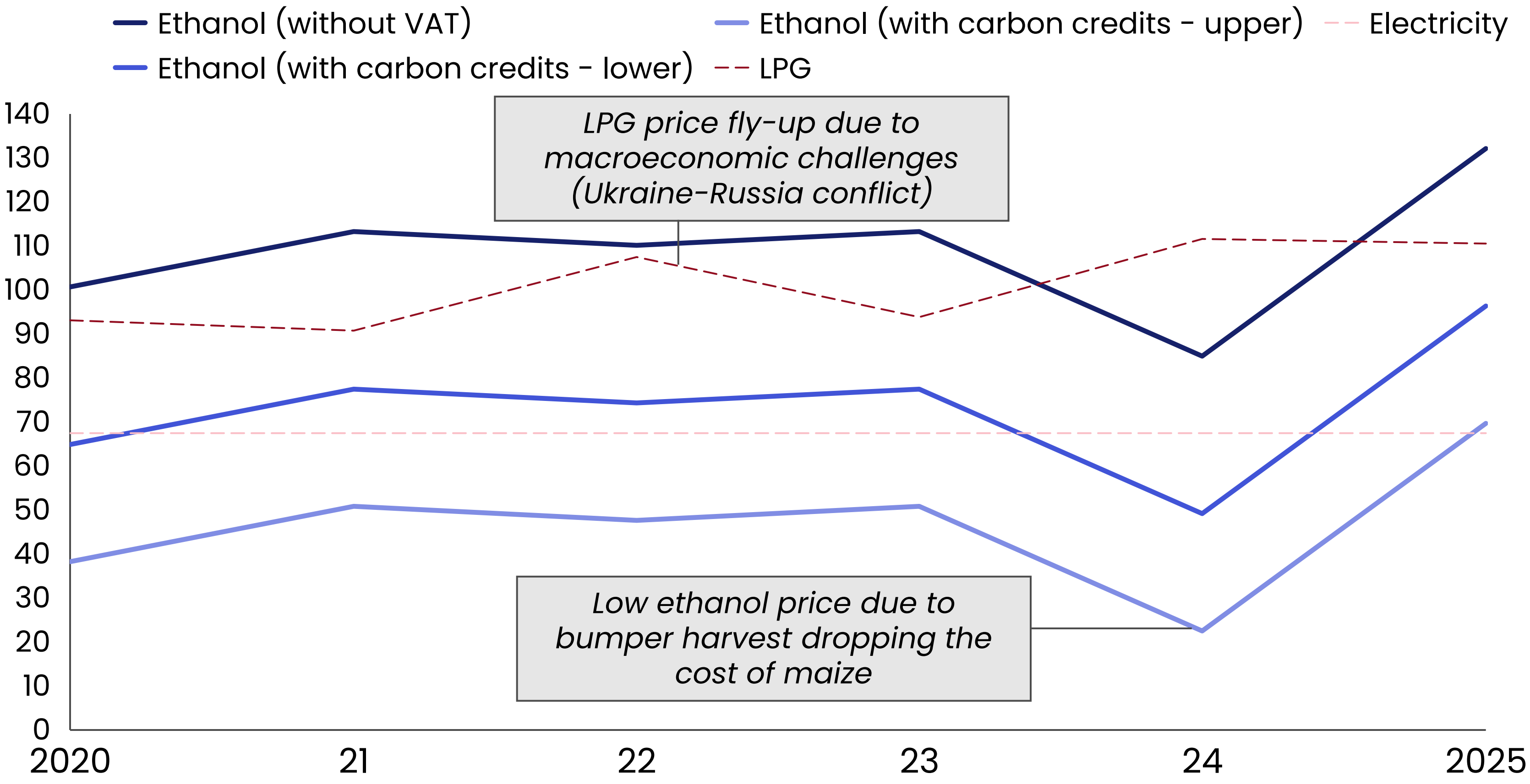
- Ethanol **may not be competitive against alternatives**, except with carbon credits. Even then, in countries with low electricity tariffs, it is not cost-competitive
- Cost competitiveness can fluctuate over time given carbon credit and LPG prices fluctuate; however, electricity prices are relatively stable
- Looking back over 5 years where data is available, in most years, the finding is consistent; there are 1-2 years where ethanol can be cheaper than LPG

1. All prices are excluding VAT and incorporate stove efficiencies. For LPG, all selected countries apply duty exemptions for LPG. Considers the cost of effective energy used for heating taking into account fuel and stove efficiency
2. Ethanol feedstock price is average of feedstock prices between 2020 and 2025 for Maize and 2020 and 2023 for Cassava, except for Rwanda (3 years)
3. Carbon credits applied at $11-25 per tCO2e
4. Imported ethanol only available for Kenya as benchmark, prices assume zero-rated VAT and 35% duty, 20% logistics costs and margins
5. Assuming ethanol competes against fuels available in urban areas shown here and is not competing against wood, charcoal, and kerosene (where it is not competitive)

Source: Press Search, Country Statistics Offices for prices

6 | Cooking – ethanol: Ethanol competitiveness may vary driven by fluctuations in feedstock price

Cost competitiveness of fuels over time – Uganda, $ / effective GJ (derived)[1]



LPG price fly-up due to macroeconomic challenges (Ukraine-Russia conflict)

Low ethanol price due to bumper harvest dropping the cost of maize

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1. Based on available LPG pricing data for Uganda (2020 and 2025) with trend derived based on Kenya costs as LPG is imported to Uganda via Kenya; Ethanol price also derived based on local maize prices and expected cost of production; carbon credits assumed to be constant

Source: KNBS Cost of Living Report, Trading Price – Ethanol USA, M-Kopa Labs Uganda LPG Market Assessment, Total Energies

Key Insights

Cost competitiveness of ethanol may fluctuate due to changing price dynamics of LPG, different prices of feedstock, and carbon credit price changes

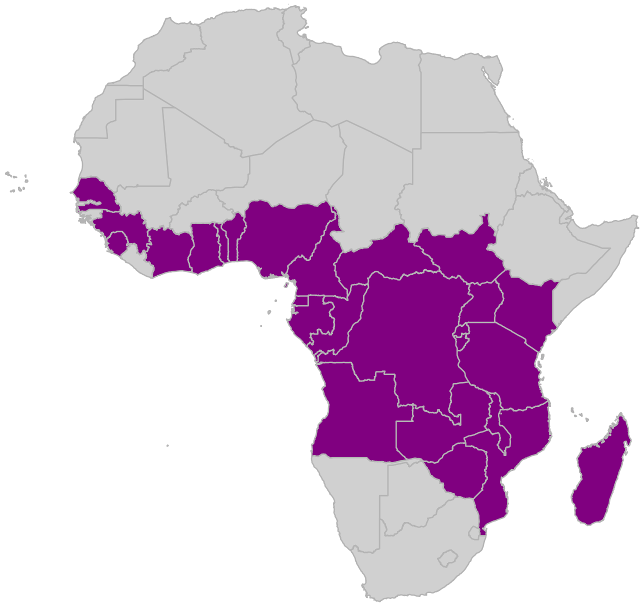
However, given investment requirements for local production of ethanol, **countries cannot easily switch between clean cooking solutions based on short-term cost competitiveness** due to different pricing dynamics; they will need to commit to a long-term strategy and focus on scaling the chosen solution

6 | Cooking – ethanol: 36 countries could have surplus of maize, cassava, and sugarcane for cooking ethanol production for by 2035

Medium feedstock projection[1]: countries highlighted with sufficient surplus for >15Mn litres production of cooking-grade ethanol

Maize

Cassava



Sugarcane

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1. Medium agriculture projection assumes crop yields forecasted to match peer countries (Maize – India; Cassava – Brazil; Sugarcane – Africa best-of-best benchmarks) with focus on smallholder-farmer yields and where Africa is actually close to benchmark already in some regions (e.g., some countries in Africa each 12 tonnes/ha for cassava; Brazil benchmark is 15 tonnes/ha), plus conservative land growth (1% p.a. assumed; historical has been 2% p.a. for maize and 3% p.a. for cassava)

Source: Manufacturing Africa team analysis

6 | Cooking – ethanol: The ethanol clean cooking market in Africa could grow to $0.7-0.8Bn by 2035

Estimated market potential for cooking ethanol, Mn USD, 2035

Limited-to-No policy Strong policy

Sizing approach:

Countries archetyped based on the competitiveness of ethanol (based on feedstock prices) and the availability of alternatives such as LPG and electricity, assuming use of ethanol is highest where ethanol is low cost (due to low cost feedstock) and there is low availability of alternatives

Note that future evolution may change – for example, Uganda may have access to low-cost LPG if oil projects fully come online

Opportunity description – based on country archetypes	**Top 3 countries in archetype**	**Market potential** Mn USD, 2035		**Investment size,** Mn USD, 2035		**# of plants,** 2035	
		Limited-to-No policy	Strong policy	Limited-to-No policy	Strong policy	Limited-to-No policy	Strong policy
Total Africa		690	790	870	990	70	78
Archetype 1: Low relative ethanol price and low availability of alternatives – 70% of CC households could adopt	Uganda, Benin, Democratic Republic of the Congo	400	400	495	495	40	40
Archetype 2: High relative ethanol price and low availability of alternatives – 20-30% of CC households could adopt[1]	Ethiopia, Tanzania, Zambia	190	290	240	360	20	28
Archetype 3: Low relative ethanol price and high availability of alternatives - 5% of CC households could adopt	Nigeria, Angola, Ivory coast	70	70	90	90	7	7
Archetype 4: High relative ethanol price and high availability of alternatives - 2% of CC households could adopt	Kenya	30	30	40	40	3	3

---

1. No change in adoption rates across scenarios for all archetypes except Archetype 3. Archetypes 1, 2, and 4, it is assumed government does not implement any strong policies given either the economics already make sense or there are already alternatives. For Archetype 3, government could implement some actions to reduce the cost of ethanol in the strong policy scenario given there are no alternatives available (e.g., subsidies to plant equipment)

Source: Manufacturing Africa team analysis

6 | Cooking – ethanol: Ethanol for clean cooking can be accelerated by strategic prioritisation, or considered as an opportunistic play

Archetype 1 countries: Ethanol can be strategic, but path selection is needed

For countries with **low availability of alternatives and competitive feedstock costs, ethanol can be a primary cooking fuel**

Countries that prioritise ethanol for road fuel can also see synergies with cooking-grade ethanol

However, given the high investments required for local ethanol production, **countries must choose this as a path and consider supporting local production through policy mechanisms** (e.g., prevent competition with low-cost imports or alternates, create supportive carbon policies)

Archetype 2 countries: Ethanol can be a potential interim solution

For countries with **low availability of alternatives and high feedstock prices**, there may be a short-medium term opportunity as infrastructure of more cost competitive fuels is developed, e.g., electricity access and reliability is expanded

There may be longer term potential to compete in peri-urban/tier 2 cities which may not achieve infrastructure development. Given the high investment, government support may be required to ensure these markets remain available for ethanol until investment is recovered

Archetype 3 & 4 countries: Ethanol opportunity is more niche

For countries with **high availability of alternatives**, ethanol will likely be a niche play, in competition with other fuels (e.g., government unlikely to provide strategic support to ethanol over other clean fuels)

While local production can be more cost-effective, because of competition with other fuels, **importation of ethanol may be a pragmatic approach as the market is built**

Source: Manufacturing Africa team analysis

Contents

Executive summary
Biofuels overview, scope, and context in Africa
Details on approach for sizing the opportunity for biofuels in Africa
Appendix 1: Africa biofuel feedstock availability assessment
Appendix 2: Use case deep-dives
    1, 2 Road – Ethanol, FAME diesel
    4, 5, 6 Cooking – bio-pellets, biogas, ethanol
    – Context
    – 4 Bio-pellets
    – 5 Biogas
    – 6 Ethanol
    7, 9 Industrial Heat and Power – biogas, bio-briquettes
    10 Aviation - 2G oil-based feedstock export
    11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

7, 9 | Industrial heat and power: Market opportunity likely ~$0.4Bn for biogas and ~$1.6Bn for bio-briquettes by 2035

		Market potential, Bn USD, 2035		**Potential investment size,** Bn USD, 2035	
⑦ **Biogas**	**Onsite heat and power –** mainly for food and beverage processing industries and wastewater treatment plants that use biogas for own use due to availability of feedstock supply	**0.1**	**0.4**	**0.4**	**1.4**
		Adoption rates of 5-80% depending on industry and policy scenario *LCOE of $0.065/kWh for CHP*		*0.5-2MW plants at $1-4Mn each*	
	Mini grids – use of farm waste to produce power for communities	**0.01**	**0.03**	**0.4**	**0.8**
		3-5% of government targets achieved with biogas mini-grids *LCOE or $0.05-0.08/kWh*		*60kW mini-grids at $120,000 each*	
⑨ **Bio-briquettes**	**Offsite heat and power** – mostly used by industrial players who use biomass in heating and power generation and do not have access to alternatives	**0.1**	**1.6**	**0.1**	**1.7**
		5-80% of current biomass for industrial use converted to bio-briquettes at $115/tonne		*$3Mn for a 24kpta plant*	

! Bio-briquettes are produced in the same facility as bio-pellets (for clean cooking); difference is the size of the product (bio-pellets are smaller to fit into cookstoves)

---

1. In reality, this is an avoided cost for companies as they invest the capex in the biogas digester to avoid purchasing electricity

Source: Manufacturing Africa team analysis

7, 9 | Industrial heat and power: Biofuels can be used for a range of industry heat and power requirements

Use	Relevant biofuel	Feedstock	Production process
Onsite heat and power generation **Back-up power in mini-grids (replaces battery)**	Biogas Syngas	Wet bio waste - manure, urban waste / sewage sludge, brewery waste Forest or agriculture biomass (e.g., sawdust, woodchips)	Anaerobic digestion or pyrolysis (woody feedstock)
Offsite heat and power generation	Syngas	Biogas	Reforming
	Methane	Biogas	Bio-methane Upgrading
	Bio-briquettes	Forest or agriculture biomass (e.g., bagasse, sawdust)	Compaction
	FAME HVO	Waste Oils (E.g., Used Cooking Oil, Tallow), 2G oils (e.g., castor), or 1G oils (e.g., palm oil)	Transesterification

Onsite dry waste more likely to be incinerated than used for biofuels

Due to low energy density, biogas is not economical for transport so must be upgraded for offsite use

Bio-briquettes would not be used for onsite heat and power as industries that have available dry feedstock would typically instead use incineration (e.g., bagasse in sugar mills)

While commonly used for industrial heat and power, direct incineration (e.g., sugar mills burning bagasse) not in scope given this is not considered a biofuel (biofuels require additional upgrading over biomass to be considered biofuels)

Source: Expert input

7, 9 | Industrial heat and power: Biogas and bio-briquettes are prioritised for industrial energy use given feedstock availability, cost, and technology maturity

🟩 High 🟨 Medium 🟥 Low ✓ Yes ✗ No

Fuel	Use case	Feedstock availability	Cost ranking among biofuels	Cost of transport (relative to energy density)[1]	Technology maturity	Shortlisted
Biogas	Onsite heat & power Mini-grid	🟩	🟨	N/A - Only onsite (low energy density makes transport costly)	🟩	✓ **For industries with wet waste** (e.g., breweries, sewage treatment); industries with dry waste likely to incinerate
Syngas	Onsite heat & power Mini-grid Offsite heat & power	🟩	🟥 20%+ premium over biogas	🟥 Compressed gas can go short distances but must be liquified to go longer distances	🟥	✗ Emerging technology
Methane	Offsite heat and power	🟩	🟥 20%+ premium over biogas	🟥 Same as syngas	🟩	✗ Not cost competitive against alternatives
Bio-briquettes	Offsite heat and power	🟩	🟩	🟨 Truck, but relatively bulky so transport costs can be high over long distances	🟩	✓ **For industrial players already using biomass for heat and power** (requires limited to no additional CAPEX) **and close to bio-briquette production (near a feedstock source) to avoid long trucking distances**
HVO	Offsite heat and power	🟥	🟥	🟩 Trucked but similar to diesel	🟨	✗ Prohibitively expensive driven by high production costs
FAME diesel	Offsite heat and power	🟥	🟥	🟩 Trucked but similar to diesel	🟩	✗ Not compatible in most gensets

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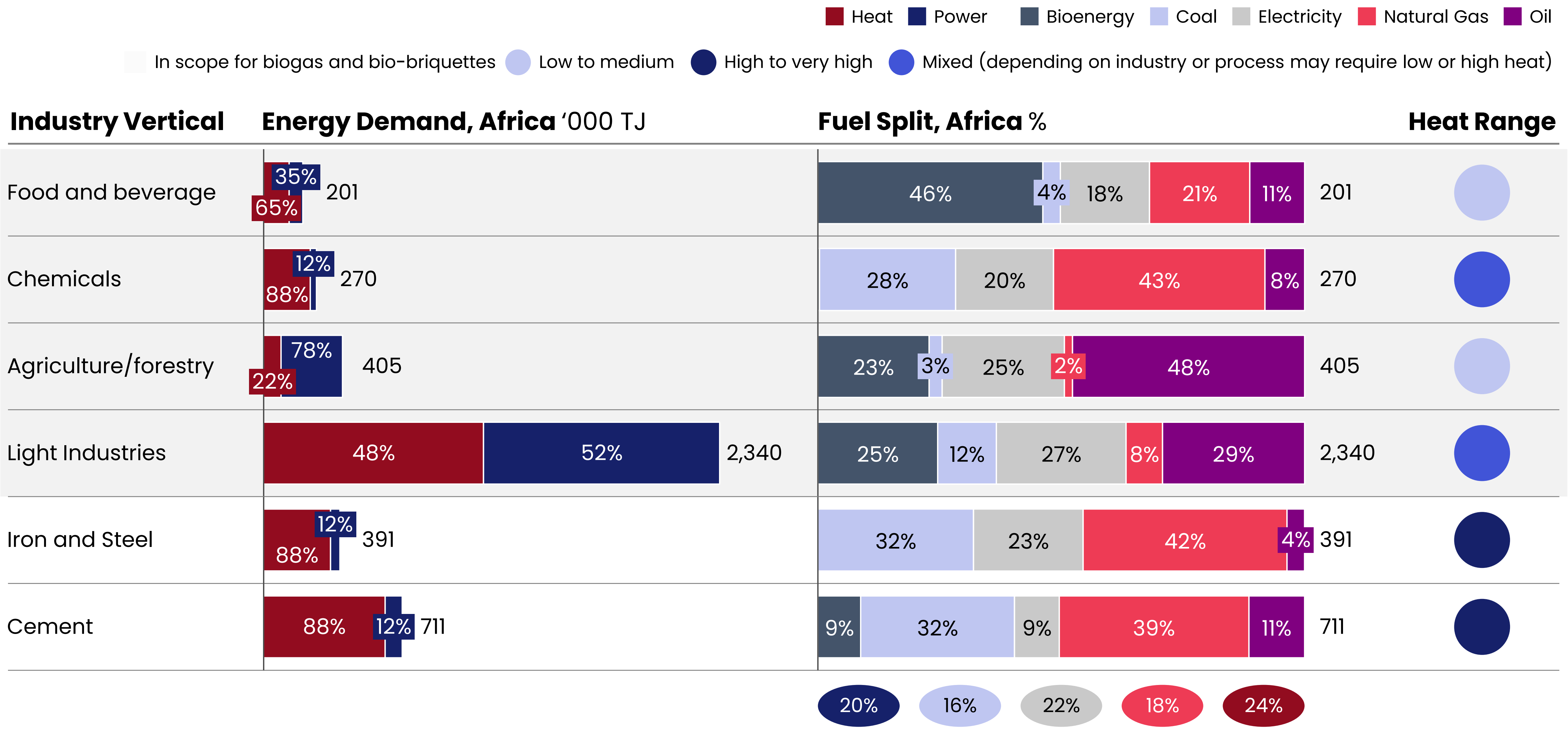
1. While all biofuels can be trucked, lower energy density (e.g., for biogas or bio-briquettes) can make this costly over long distances versus alternatives. Syngas and methane would need to be compressed or liquified to go long distances which adds additional cost.

Source: Expert input

7, 9 | Industrial heat and power: Biogas and bio-briquettes are only suitable for industries with low-to-medium heat requirements



1. Low: <200, Medium: 200-500, High: 500-1000, Very High: >1000 Degrees Celsius

Manufacturing Africa

Source: IEA Fuel Mix 2025, McKinsey Global Energy Perspective

7, 9 | Industrial heat and power: Bio-briquettes and biogas are already used in Africa across the three prioritised used cases, but only at limited scale

NOT-EXHAUSTIVE

Industrial

Bio-briquettes

Mostly used by industrial players who use biomass in heating and power generation and do not have access to alternatives

Limited use of bio-briquettes driven mostly **insufficient feedstock** due to **lack of scaled production**

Key Players

TAMUWA, eco Charge

Industrial use biogas

35MW of capacity installed for biogas for industrial use

Mainly **food and beverage processing industries and waste-water treatment plants** use biogas for own use due to availability of feedstock supply

Key Players

bio-watt Energy Holdings, HEINEKEN, Tropical POWER, safisana, WATERLEAU, Cummins

Community

Mini-grids

3% of global mini-grids use biogas

815 mini-grids have been installed in Africa across **16 countries** providing **75MW** of energy

Solar and hybrid mini-grids are the most popular with the share of biogas mini-grids unspecified

Key Players/ Projects

BePeARL[1], HUSK Power Systems

Africa EU-Energy Partnership

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1. Bio-energy Powering Agriculture & Rural Livelihoods

Source: Press search

7, 9 | Industrial heat and power: Biogas is only relevant for industries generating wet waste; bio-briquettes are relevant for a wider set of industries

■ High ▩ Medium □ Low 🛒 Bio-briquettes H_2 Biogas

NON-EXHAUSTIVE

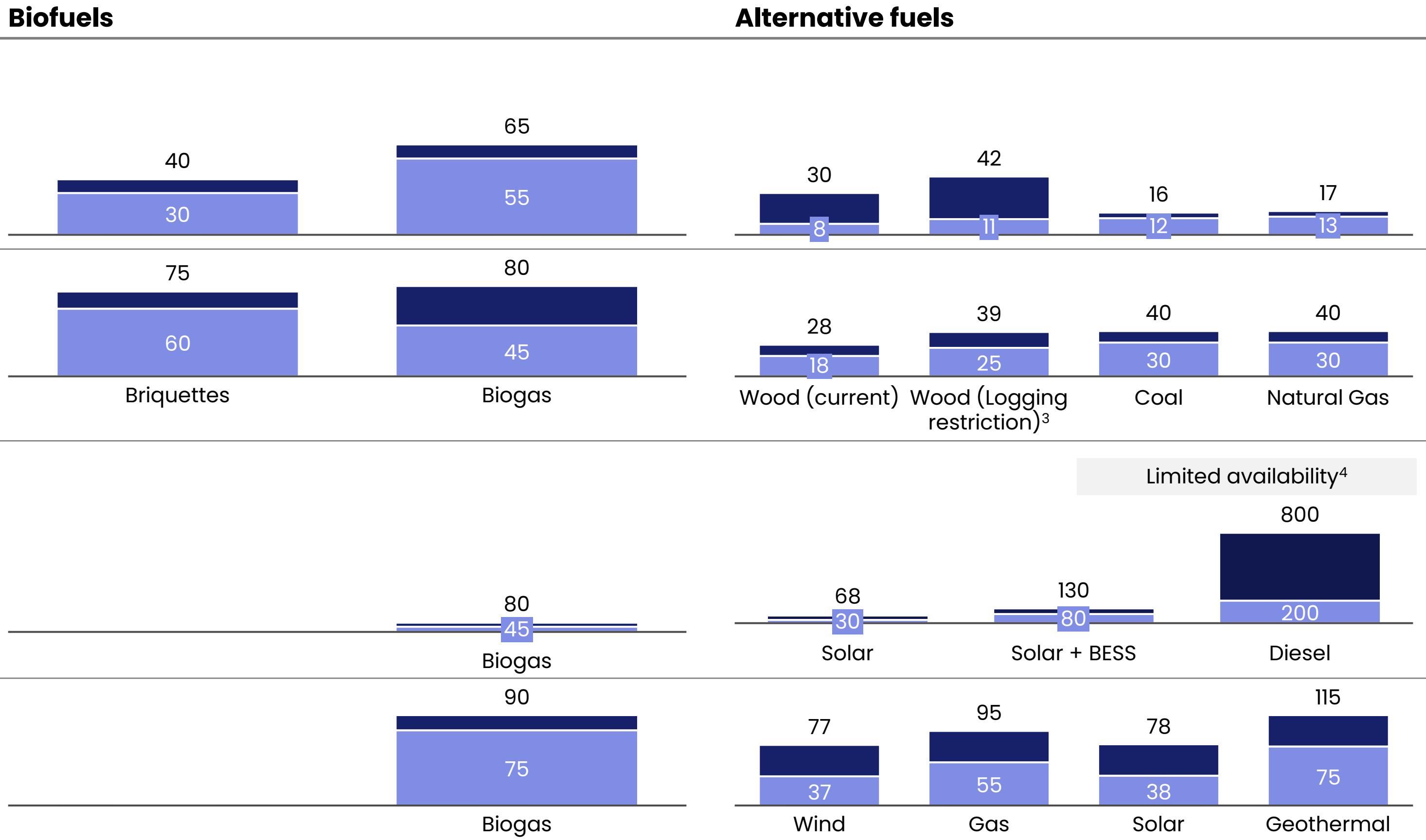
Sector	Industry	**Source of own feedstock** (required for biogas)	**Difficulty using alternate process**	**Own heat demand**	**Biofuel potential**	**Biofuel type**
Agro-processors, Agriculture/ Forestry	Sugar	■ Bagasse (dry)	□ Incinerate dry waste	■	□ More likely to incinerate bagasse	N/A
	Livestock farms	■ Manure (wet)	■	□	□ Low heat demand	N/A
	Fruit & Vegetable processing	▩ Peels, off-cuts (wet)	■	■	■	🛒 H_2
	Flower, tea and coffee farms	▩ Cuttings, leaves (wet, dry)	■	▩	▩	🛒 H_2
Food & Beverage	Breweries	■ Brewery waste (wet)	■	■	■	H_2
	Processed food and drinks (juice, tomato products, etc)	▩ Agro waste (wet/dry)	■	■	■	🛒 H_2
	Dairy processing	□ Assuming few integrated dairy processors so access to manure low	■	■	■	🛒
Waste water mgt	Waste water management	■ Sludge (wet)	■	■	■	H_2
Light industries	Leather tanneries	□	■	■	■	🛒
	Textiles and apparel	□	■	■	■	🛒
	Soap and detergent	□	■	■	■	🛒
	Pulp and paper	▩ Sawdust (dry) – if integrated with mill	□ Incinerate dry waste	■	□ More likely to incinerate sawdust	N/A

Source: Manufacturing Africa team analysis

7, 9 | Industrial heat and power: Bio-briquettes and biogas can be viable for CHP and power, but under specific conditions

Comparison of effective cost of energy, USD/MWh[1,2]

🟦 Low ■ High



Use Case	Implications
Onsite ***Combined Heat and Power (CHP)***	Bio-briquettes can be attractive against wood for CHP, but **only where transport costs are low** (e.g., near feedstock source) or **alternatives are not available** (e.g., many countries in Africa have no natural gas infrastructure; coal availability low in inland areas) Biogas can be attractive for CHP in niche cases with **low availability of alternatives**
Power only	Biofuels are not a cost-competitive solution for industrial players for power
Mini-grid (Local use)	Biogas is a viable fuel for **night-time power generation, offering a more cost competitive alternative versus solar + BESS**
Grid feed-in (Utility)	Biofuels are unlikely to be a cost-competitive solution for grid (utility scale) power generation

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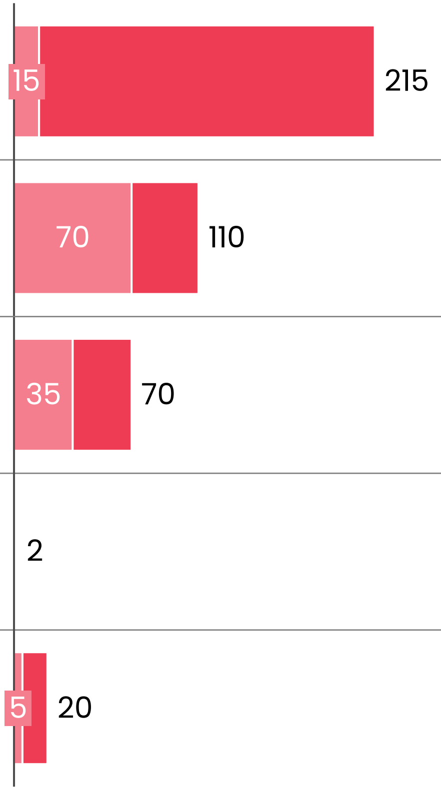
1. Based on 88% energy conversion efficiency (44% heat, 44% power). Does not factor in boiler efficiency;
2. Retail price used for bio-briquettes, wood, and diesel; LCOE calculated for all other fuels shown; prices based on benchmarks from a range of companies and countries in Africa where available, acknowledging that local price dynamics may be different;
3. Based on the increase in wood price seen in Kenya when logging ban was implemented in early 2020s;
4. Major coal reserves are found mainly in South Africa, Zimbabwe, and Mozambique, while significant natural gas reserves exist primarily in Nigeria, Mozambique, Algeria, Egypt, and Tanzania. Infrastructure, however, still remains underdeveloped in several of these markets

Source: Lazard LCOE June 2025, Expert interviews, Source: McKinsey Analysis, World Bank Pink Sheet 2025, IRENA Renewable Power Generation Costs 2024

7 | Industrial heat and power – biogas: The biogas market for onsite heat and power has potential to generate up to $0.4Bn in annual value

🟥 Limited-to-No policy 🟥 Strong policy



Industry	Market potential, Mn USD, 2035 (value of energy produced)	Adoption rates, %	Leading markets	Key Considerations
Wastewater Mgmt.	15 215	5 80	🇿🇦 🇲🇦	**Limited policy scenario:** Adoption rates are likely to remain low as plants depend on public grid and may focus on expansion rather than cost optimisation **Strong policy scenario:** Renewable energy mandates and incentives, could accelerate adoption, particularly as wastewater's high organic content waste puts it at the lowest end of the cost curve
Breweries	70 110	50 80	🇿🇦 🇪🇬	**Limited policy scenario:** Breweries are likely to adopt biogas even without policy mandates, driven by sustainability targets and the ease of using high organic content wastewater (e.g., Heineken) **Strong policy scenario:** Breweries could significantly transition to biogas with sustainability incentives, following examples from markets like Europe where this is common practice
Food Processing	35 70	5 10	🇳🇬 🇿🇦	Limited biogas adoption without Incentives: food processors are likely to prioritise cost-competitive fuels (e.g., coal, natural gas, wood), with biogas adoption limited to those lacking alternative options
Flower Farms	2	5 10	🇰🇪 🇪🇹	Low waste volumes and modest energy demand limit potential, but small-scale biogas systems could still fit specific off-grid needs
Other	5 20			Represent roughly ~5% additional potential from niche sectors (e.g., small agro-processors, livestock units) where localised waste and energy needs align
Total	125 400			

! **Market potential is based on energy usage at LCOE of $0.065/kWh to enable apples-to-apples comparison with other fuels; however, in reality, this is an avoided cost for these industries as the capex they invest in biogas allows them to avoid purchasing electricity.**

1. Kenya, Tanzania, Senegal and Morocco

Source: FAOSTAT Brewery Production 2022, World Bank Population Data, Global and regional potential of wastewater, Expert interviews, Press search

7 | Industrial heat and power – biogas: Investment required of up to $1.4Bn for biogas onsite heat and power

Investment requirement

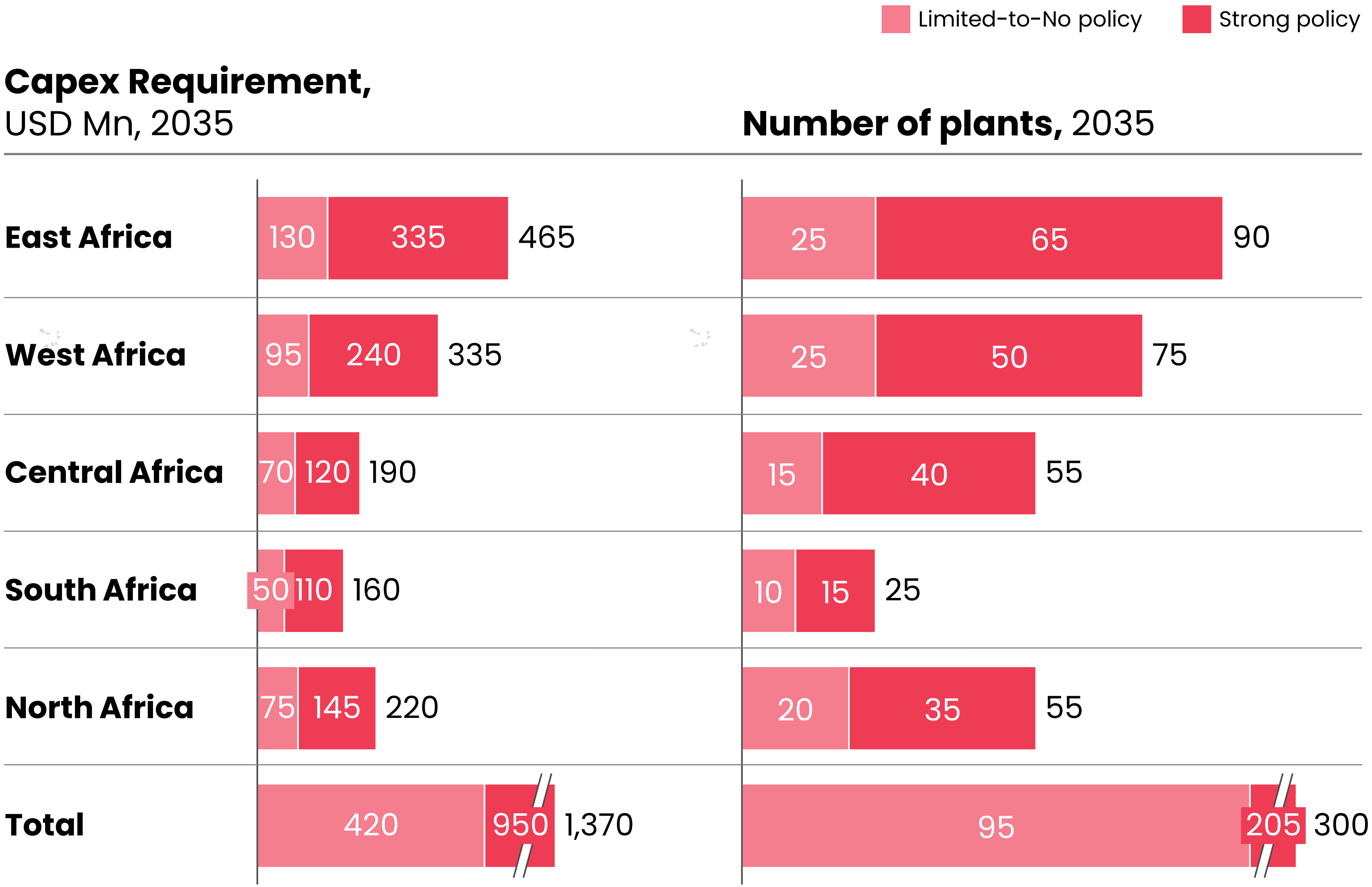
$2M Average investment per MW

×

0.5-2MW Average plant size for industrial use

=

$1-4Mn Average CAPEX investment per plant



Capex Requirement, USD Mn, 2035

Number of plants, 2035

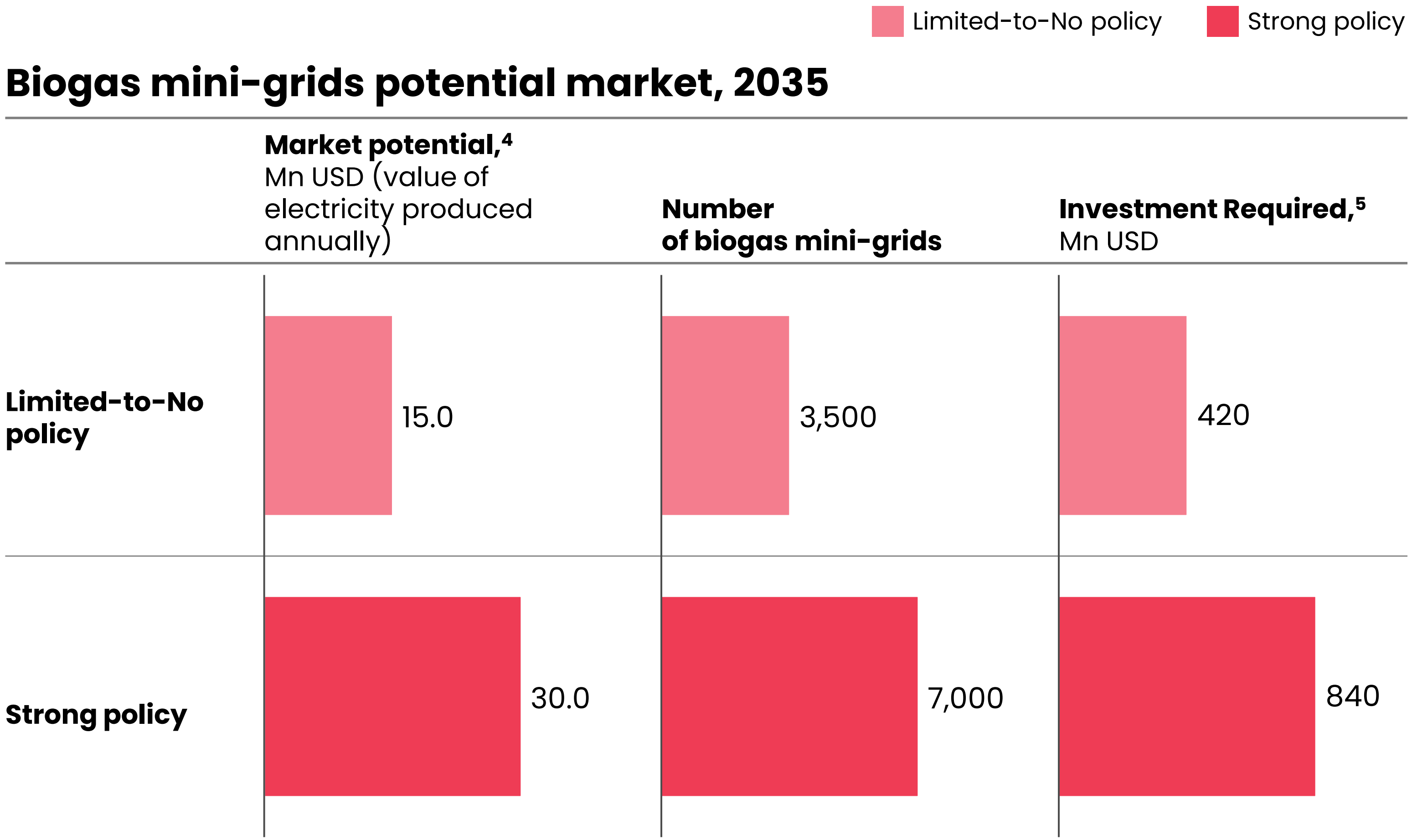
Source: Expert inputs, McKinsey Sustainability Practice

7 | Industrial heat and power – biogas: Biogas for use in mini-grids could require up to $0.9Bn in investment for $30Mn in annual electricity revenue

Maximum potential market

Country electrification strategies, % of non-electrified population to be covered by minigrids[1]	23%
Total population to be covered by mini-grids under country electrification strategies	245Mn
Population covered by each minigrid[2]	1,750
Maximum potential mini-grids	140,000
Adoption rates[3]	3% 5%

Biogas mini-grids potential market, 2035



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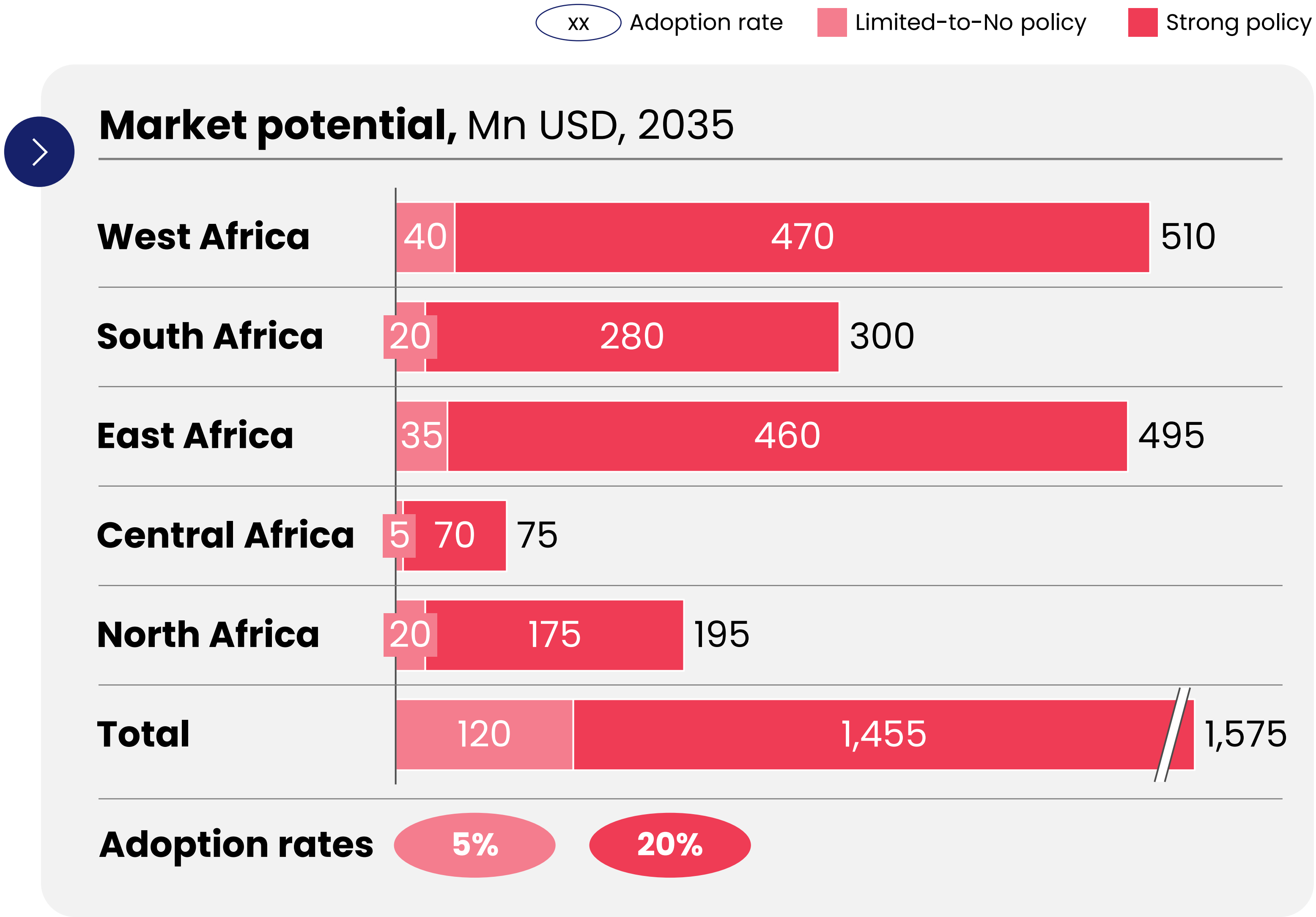
1. Based on average commitments in energy compacts for mini-grid connectivity by 2035 by Chad, Cote d'Ivoire, DRC, Liberia, Madagascar, Malawi, Mauritania, Niger, Senegal, Zambia, Nigeria, Ethiopia, Tanzania and Uganda
2. Based on rural mini-grid archetype in Africa
3. Adoption rates take into account likelihood of government and private sector achieving committed rates of electrification in energy compacts
4. Value of energy generated based on an LCOE of $0.05-0.08/kWh
5. Assuming 60kW mini-grids at $120,000 investment each

Source: Expert inputs, Press search, Country Energy Compacts

9 | Industrial heat and power – bio-briquettes: Bio-briquettes for industrial use could have a market of $1.6Bn by 2035

Approach

- Took as baseline IEA's biomass for industrial energy by region
- Constrained demand by feedstock availability in each country (bagasse)
- Assumed adoption rate of 5-80%, with 5% driven by industries with sustainability objectives (e.g., export-oriented industries such as tea processors) and 80% occurring in the strong policy scenario with logging restrictions
- High transport costs limit competitiveness, making rural and peri-urban industries near feedstock sources the most viable users
- Assumed price of $115/tonne with an energy conversion factor of 22.5 MJ/kg of bio-briquettes



Market potential, Mn USD, 2035

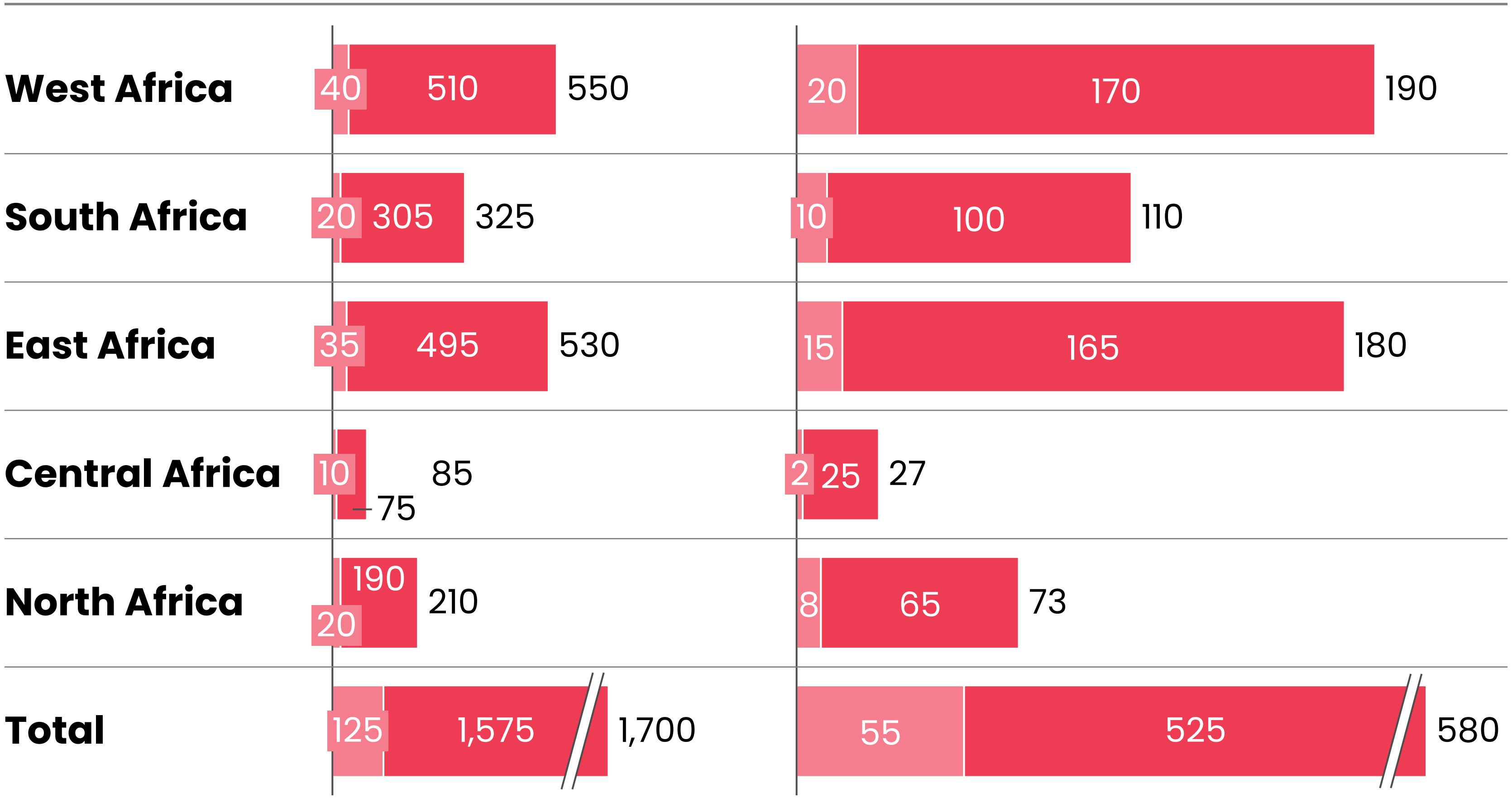
Source: IEA, Expert inputs

9 | Industrial heat and power - bio-briquettes: Realising the potential for bio-briquettes requires investment of $1.7Bn

🟥 Limited-to-No policy 🟥 Strong policy

Investment size for bio-briquette market, Mn USD, 2035

Number of plants, 2035



Sizing approach

Market potential: Assume average plant size of ~24,000 tonnes per year and $2-3Mn investment size per plant (same plant as producing bio-pellets for clean cooking)

Constraints

Only be produced in countries with scaled availability of feedstock, particularly bagasse, sawdust and rice husk

Source: Expert inputs

7, 9 | Industrial heat and power: Enablers to support implementation

Feasibility[1] ○ Low ● High

Category	Enablers for consideration	Details	Stakeholders				Feasi-bility
			Government	Development partners	Research institu-tions	Private sector	
Improve commercial attractiveness	**Improve cost competitiveness**	Financial incentives like capital subsidies or tax incentives for digesters, VAT exemptions on equipment, or reduced tariffs which can lower barriers to entry	✓				◕
	Encourage voluntary sustainability targets	Renewable energy targets, potentially through incentives, that recognise bioenergy as a contributor encouraging investment	✓			✓	◑
	Avail patient capital for bio-briquette production	$2–3 million in upfront investment for each plant as markets and offtake contracts develop. Patient capital is needed to finance plant construction so industrial buyers can commit to long-term supply agreements		✓		✓	◕
Increase demand	**Logging restrictions**	Logging restrictions / limitations on wood burning for industrial use to shift demand	✓				◔
	Enforcement of biogas for public industries	State-owned enterprises or institutions use biomass fuels, in particular wastewater treatment facilities and mini-grids	✓			✓	◑

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1. Feasibility based on: High - proven enabler demonstrated in multiple African countries (even if in other industries); Medium (1/2 moon) - proven enabler demonstrated in peer countries (e.g., India); Low - high complexity intervention, unproven in any developing economy

Source: Manufacturing Africa team analysis

7, 9 | Industrial heat and power: Implementation roadmap

	Phase 1: Create supportive enabling environment (Year 1-2)	**Phase 2: Scale investment** (Year 3-10)	**Phase 3: Continued scale** (Year 10+)
Drive demand	Consider requiring wastewater treatment facilities to use biogas (common in other regions globally) given strong use case		
	Consider logging restrictions to encourage industrial use of biofuels versus traditional biomass; embed industrial biomass into country energy development plans		
	Consider incentives for biofuel use for industrial (e.g., VAT exemptions for digesters)		
Set up industrial EPC businesses	Set up / scale up EPC businesses to implement C&I biogas (for mini-grids as well as onsite industrial use)	Scale up, targeting wastewater treatment, breweries, agro-processors and rural mini-grids	
	Set up patient capital financing for bio-briquettes (linked to clean cooking bio-pellets as these are the same companies, typically)	Scale-up targeting industries using biomass and within 150km of production (to reduce transport costs)	

1. Includes South Africa, Angola, Mozambique, and Zambia
2. Power-to-liquid

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

Appendix 2: Use case deep-dives

- 1, 2 Road – Ethanol, FAME diesel
- 4, 5, 6 Cooking – bio-pellets, biogas, ethanol
  - Context
  - 4 Bio-pellets
  - 5 Biogas
  - 6 Ethanol
- 7, 9 Industrial Heat and Power – biogas, bio-briquettes
- 10 Aviation - 2G oil-based feedstock export
- 11 Aviation - SAF refining

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

10 | Aviation – 2G oil-based feedstock export: Africa could export 2G oil-based feedstocks for use in SAF production globally

▨ Limited-to-No policy ■ Strong policy

Opportunity	**2025-30**	**2030-35**	**Market potential,** Bn USD, 2035[1]	**Potential investment size,** Bn USD, 2035[1]
Purposefully grown 2G oil export	Continue **testing and growing** 2G oil crops (e.g., castor, carinata)	Ramp-up castor oil production to potential of **~1.2Mn** tonnes by using **2Mn ha**	▨ 0.1[2] ■ 1.4 *Market potential based on castor oil exports* *Limited-to-no policy scenario assume current export levels continue, led by companies like Eni; strong policy assumes full estimated potential is reached due to higher global demand*	▨ - ■ 0.4 *Based on average of CAPEX benchmark for oil seed refining in Sub-Saharan Africa (e.g., Nigeria, Zambia, South Africa, Ethiopia, Uganda, Zimbabwe) ranging from $110-440 per tonne/year – used average of $330 per tonne/year* *This only applies to 1.2Mn tonnes of castor oil potential*
2G waste oils export	Improve UCO & tallow collection for export		▨ 0.4 ■ 1.1 *Assumes different urban collection rates 5% current average for Africa in no and limited policy and 25% in strong policy*	▨ - ■ -

1. Assumed global cost UCO - 1000$/tonne and 2G oil crops (Castor)
2. Market based on Eni benchmark - <100,000 tonnes of castor oil exports

Source: McKinsey Global Energy Perspective 2025, Press Search, Expert interviews

10 | Aviation – 2G oil-based feedstock export: 1G oil crops, 2G waste oils and fats, and 2G non-edible oil crops are key oil-based feedstock for biofuels available for export

🟦 1G 🟥 2G **Favourability:** 🟩 High 🟨 Medium 🟥 Low

	Oil crops (edible)	Waste oils and fats	Non-edible oil plants1
Examples	Palm oil, sunflower seeds, soybeans	Old cooking oil, industrial waste oils, animal fats (i.e., tallow)	Castor, Camelina, Jatropha, Ethiopian Mustard, Macauba
Key considera-tions	Palm oil predominant source for oil, but associated with deforestation	Key challenge for waste oils is the aggregation (e.g., collection of cooking oils from households, restaurants, etc.)	Current supply is limited, and viability needs to be tested at scale; but companies are actively exploring options due to feedstock scarcity
2035 global demand supply balance	🟥 Undersupply expected, driven by growing demand from USA, China, India and Brazil	🟨 Potential undersupply expected; if policy commitments are met, waste feedstocks could only meet 85% of the global feedstock demand	🟨 Supply highly uncertain – oversupply could be created if production is scaled-up. 2G oil-based feedstock supply gap could be closed. If cost parity can be achieved, additional potential to meet 1G demand.

Source: Expert interviews

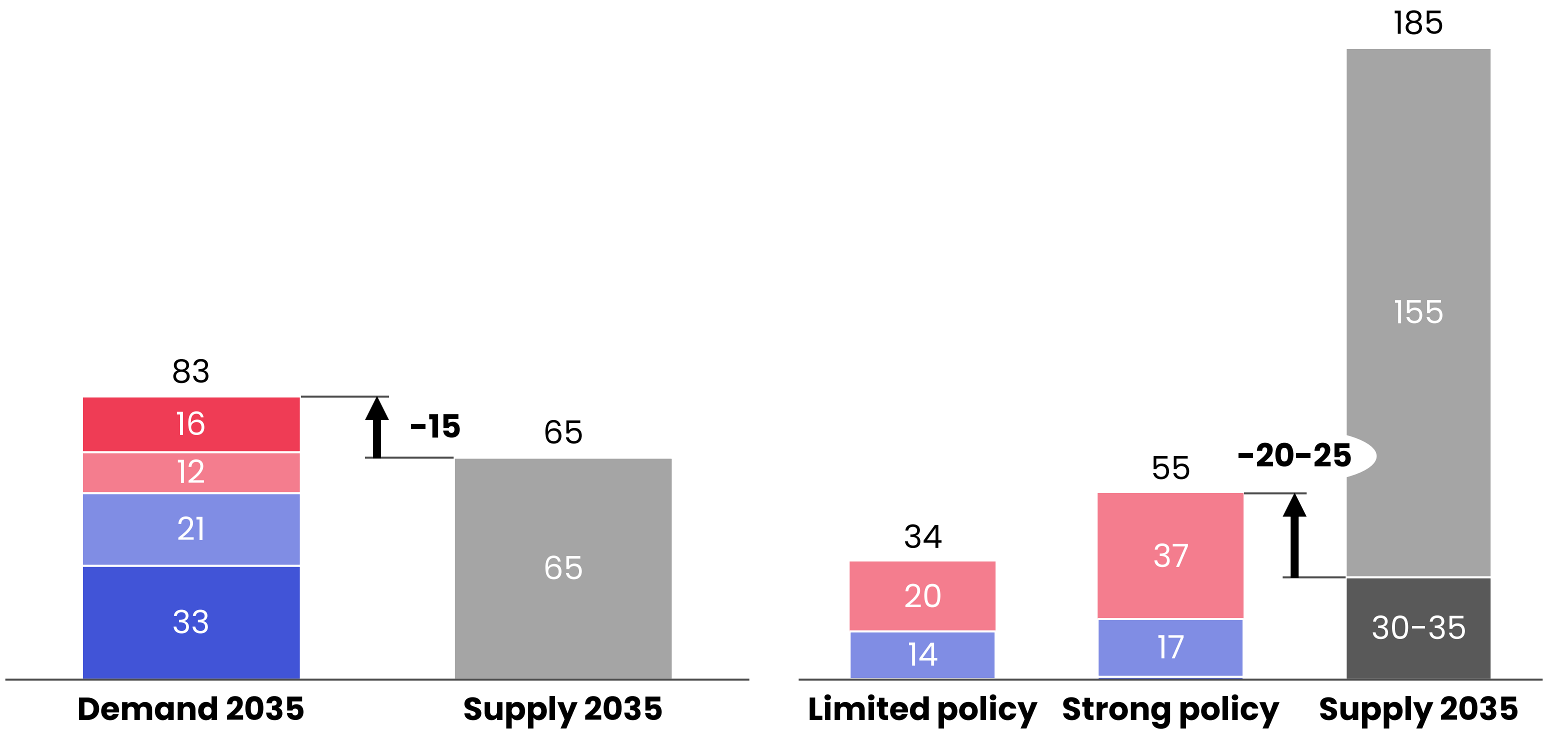
10 | Aviation – 2G oil-based feedstock export: In 2035, there may an opportunity for 2G waste oils export, with demand for 2G non-edible oils likely in high demand scenario

🟥 ASEAN 🟥 EU27 + UK 🟦 North America 🟦 Others ⬜ Plant oils ⬛ Waste oils

Global feedstock demand and availability, 2035, Mn tonnes of fuel equivalent[1,2]

1G feedstocks for biofuels,
e.g., palm oil, sunflower seeds, soybeans

2G oil-based feedstocks for biofuels,
e.g., waste oils and non-edible oil plants



While a **~15Mn tonnes global supply gap** for 1G oil crops is expected, **opportunity is likely limited for Africa to export** – existing local production in Asia (e.g., palm oil), US push to support local 1G feedstock production (e.g., soybeans), and EU restrictions limit potential

For 2G oil-based feedstock, key **opportunity lies in waste oils**, with 2G oil crops potential likely only to grow from **stronger policy[3]**

- With limited policy (particularly in Europe), **waste oils** expected to be **sufficient to cover 2G oil-based feedstock demand**
- With stronger policy (particularly in Europe), **20-25Mn tonnes supply gap of 2G oil-based feedstocks** expected creating demand for 2G oil crops

1. Oil equivalent in case of lipids and oil plants
2. Not all commitments by governments are met
3. Policies mentioned are those that drive more use of biofuels requiring oil-based feedstocks (e.g., SAF, HVO, FAME diesel)

Source: Proprietary sustainable fuels solution, Expert input

10 | Aviation – 2G oil-based feedstock export: Rotational crops and perennial trees can be used for biofuel production

Selected purposely grown oil crops for fuel production (not exhaustive)

🟨 Shows promise in Africa but remains unproven ⬜ Proven globally but has limited potential in Africa 🟩 Potential proven at scale in Africa ⬚ High-level potential assessment follows

	Annual (rotational)			**Perennial (not rotational)**			
Crop	🟨 **Carinata**	⬜ **Camelina**	⬜ **Pennycress**	⬜ **Macauba**	⬜ **Pongamia**	⬜ **Jatropha**	🟩 ⬚ **Castor**
Description	Currently most promising rotational crop type, can adapt to semi-arid climates and has high oil content	Camelina is mostly produced in Europe and Asia and its a short-season crop that takes 85 to 100 days to mature	Flowering plant native to Eurasia and common in North America - primarily a temperate seed crop used as a winter cover crop	Palm tree found in arid and semiarid regions in South America; yields like palm oil but less restrictions on temperature & precipitation	Leguminous tree crop, native to South-East Asia and targeted at subtropical land and degraded soils	A perennial woody shrub/tree, originally from Central America, grows in arid and semi arid areas	Indigenous to tropical Africa, commercially grown for pharmaceutical or industrial use, or biofuels (e.g., Eni)
Cultivation period	~6 months	~3-4 months	~ 3 months				
Yield, t oil/ ha	1-1.3	0.4-0.6	0.4-0.6	5-6	2-4	1.5	1
Suitability to growing in Africa	◕ Well adapted to semi-arid conditions; traditionally cultivated in Ethiopia	◔ Grown mostly in Europe and North America	◔ Temperate climates	◕ Palm oil native to Africa, Macauba more flexible	◑ Well adapted to tropical climate	◑ Grows in arid/semi arid areas	◕ Drought resistant Cultivated in Ethiopia, Mozambique and Zambia
Other consideration	Non usable by-product			Yields of macauba and pongamia not proven at scale		Initial trials suggest no economic viability	Relatively high price

1. Detailed regional potential dependent on local boundary conditions (e.g., climate, infrastructure, technology)

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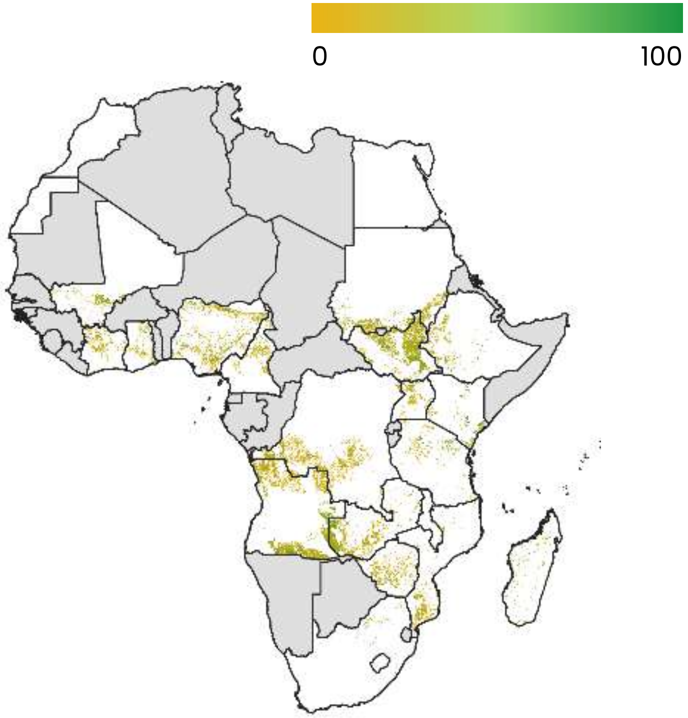
Source: USDA; Science Direct, McKinsey analysis

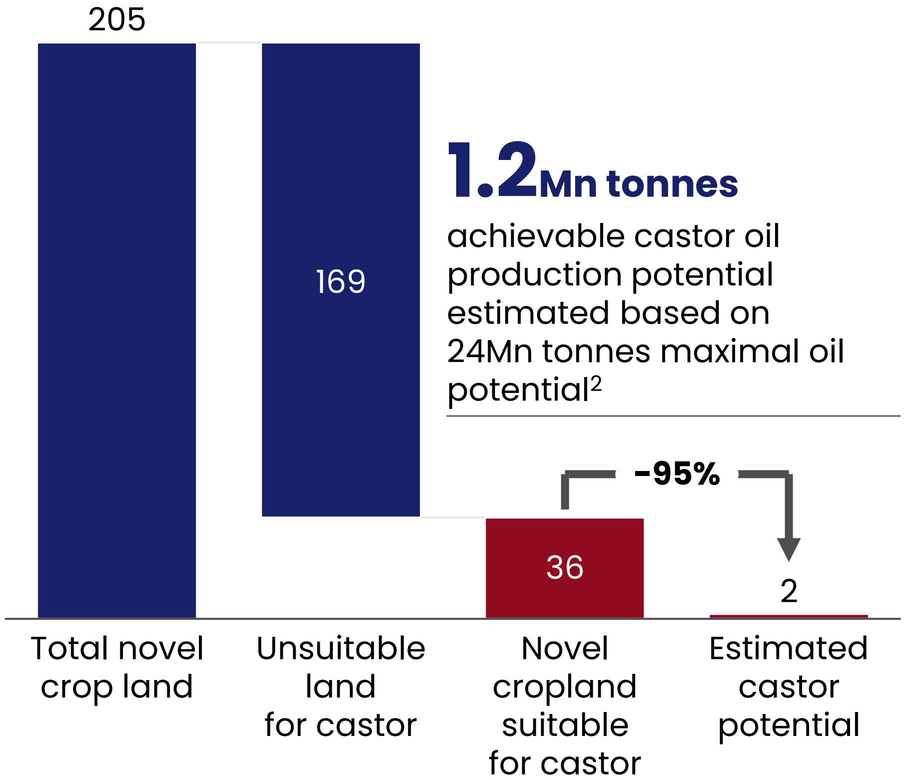
10 | Aviation – 2G oil-based feedstock export: ~1.2Mn tonnes potential for castor oil identified across 20+ African countries

Illustration: Novel crop land suitable for castor cultivation[5]

Novel suitable cropland concentration, %



Novel crop land suitable for castor and estimated potential, Mn ha



1.2Mn tonnes achievable castor oil production potential estimated based on 24Mn tonnes maximal oil potential[2]

Methodology

First, **novel crop land was identified** at 1km granularity by excluding unsuitable land, protected or environmentally critical land (e.g., forest land, critical habitats, protected areas), current crop land and areas unsuitable for mechanised farming (i.e., land with >15% slope)[3]

Among the novel crop land, **suitable land was identified** based on **climate, soil pH level and soil depth**

Only 5% of novel crop land is assumed to be available for non-food crop production in line with global benchmark of today's crop land split

1. Forest land, critical habitats, protected areas
2. Assuming 0.7 tonnes of oil per hectare on average across Africa and only 20% of crop land is used for non-food crops (based on global benchmark)
3. Unsuitable land includes, e.g., urban land, water bodies; protected or environmentally critical land includes, e.g., forest land, critical habitats, protected areas; areas unsuitable for mechanised farming are defined as areas with >15% slope
4. including land with barriers to farming
5. Countries in grey not assessed due to already expected low potential for castor oil suitability

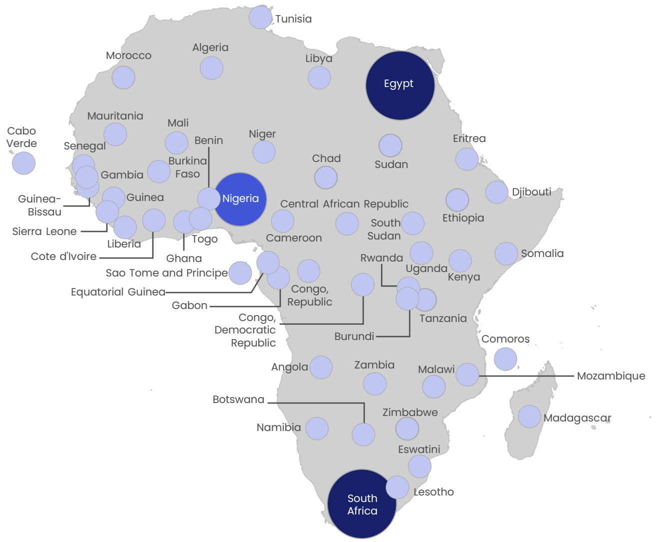
Source: UNEP WCMC, EarthEnv, CHELSA, HUMERIS, ISRIC, Ianda et. al (2020) Optimising the Cooperated "Multi-Countries" Biodiesel Production and Consumption in Sub-Saharan Africa, Our World in Data

10 | Aviation – 2G oil-based feedstock export: Africa could have 0.5–1.6Mn tonnes of UCO/tallow by 2035, depending on collection rate

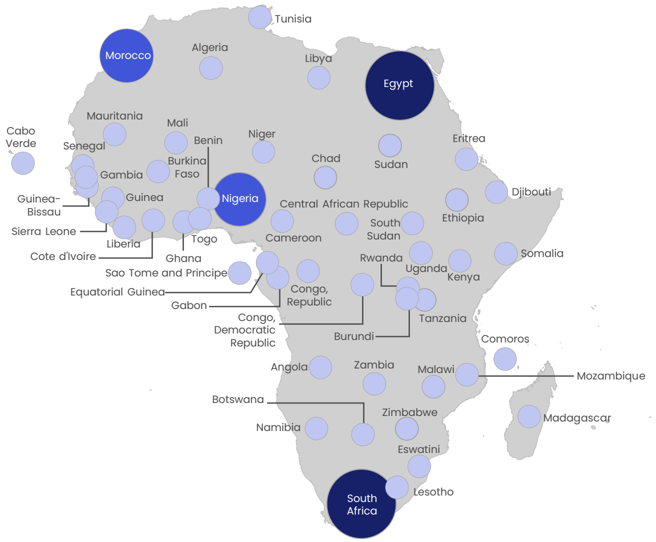
Countries projected surplus for waste oils (UCO, and Tallow[1]), tonnes, 2035

⬚ Projection used for market sizing ● <50,000 ● 50,000-99,999 ● 100,000+

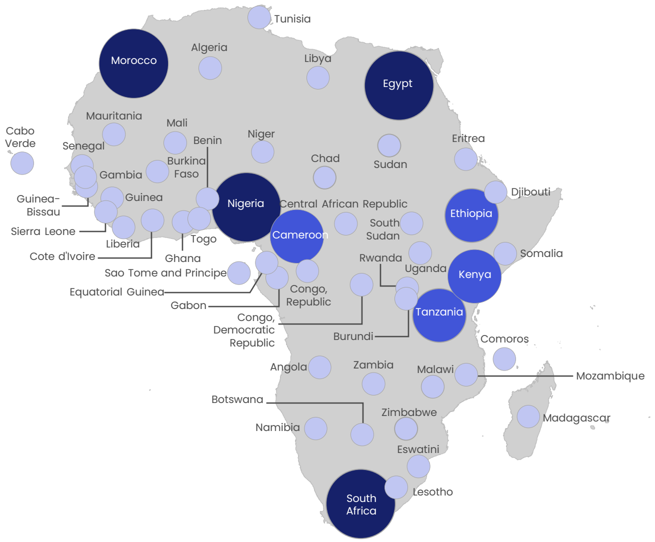
Low – 5% UCO urban collection rate, based on current Africa average



Medium – 10% UCO urban collection rate, midpoint (India benchmark)



High – 25% urban collection are based on peer country (Indonesia) assuming regulation[2]



Total potential usable surplus, Mn tonnes, 2035	0.5	0.8	1.6

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1. UCO - Used Cooking Oil; Tallow - animal fat waste
2. Introduction of ban on reusing used cooking oil

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Source: ACRE Analysis, Gatsby Report, Press search, OECD-FAO Agricultural Outlook 2025-2034

10 | Aviation – 2G oil-based feedstock export: Enablers to support implementation

Feasibility[1] ● Low ● High ▨ Deep-dives next

			Stakeholders				
Category	**Enablers for consideration**	**Details**	**Government**	**Development partners**	**Research institutions**	**Private sector**	**Feasibility**
2G waste oils and fats	**Health regulations**	Cooking oil use regulations to limit re-use (e.g., setting of cooking oil standards, ban on re-use)	✓				◑
	Set up of UCO collection centres	Aggregation centres for UCO to support collection from households and businesses	✓			✓	◑
	Adoption of technology in UCO collection	Tech and payment company partnerships to develop solutions for support UCO collection from households				✓	◕
	Implement a traceability system	Traceability system to track use of edible oils (i.e., from the source to disposal)				✓	◕
2G non-edible oil crops	**Investment in piloting of 2G crops**	Testing and scaling 2G oil crops (e.g., castor, carinata, jatropha, moringa)		✓	✓	✓	◔
	Out-grower schemes	Organise smallholder farmers via contracts, training, and services to expand reliable feedstock supply	✓	✓		✓	◕
	Inputs & technical assistance	Improve access to seeds, fertilisers, and agronomy support to lift yields and consistency	✓	✓		✓	◕

1. Feasibility based on: High - proven enabler demonstrated in multiple African countries (even if in other industries); Medium (1/2 moon) - proven enabler demonstrated in peer countries (e.g., India); Low - high complexity intervention, unproven in any developing economy

Source: Manufacturing Africa team analysis

10 | Aviation – 2G oil-based feedstock export: Improved UCO collection could be driven by health regulations and tech initiatives

UCO collection – case examples of India and Indonesia

	India	Indonesia
Context	Policy-led increase in UCO collection, driven by regulations and government incentives	Initially city-level rules (Jakarta) and export-driven market; shifting to national policies and incentives
Collection system	National network of authorised aggregators (RUCO program)[2] pick up UCO from restaurants and food businesses	Mix of local rules, export-driven collection, and new retail take-back schemes (e.g., collection boxes at fuel stations)
Government support	Food Safety and Standards Authority of India (FSSAI) capped reuse (25% TPC[1]) and mandated disposal	City regulations (e.g., Jakarta Governor Regulation 167/2016) Export restrictions to retain UCO for domestic biodiesel/SAF Mandated palm oil blend in diesel fuel (B40)
Economic/ technological enablers	Guaranteed price for UCO-based biodiesel (0.58-0.62 USD/L) Digital portals for traceability and collection optimisation Focus on industrial producers for easier regulation	Export incentives (EU RED II) historically drove collection Digital platforms connect collectors and originators; Agent-based and smart tank models E-wallet payments and MyPertamina[3] points for households Private sector innovation (FatHopes)
Partners/ organisations	Food Safety and Standards Authority of India (FSSAI) Biodiesel Association of India (BDAI) State oil companies	Pertamina (Indonesia's state-owned oil and gas company) FatHopes Local governments Private sector depots/warehouses
Results	Steady UCO pickups reported Structured demand for biodiesel Improved traceability and compliance	23% of UCO collected (households account for 52% of potential supply) Accelerating with new incentives and export restrictions Centralised aggregation and export system

[1] Total Polar Compounds - lab metric of oil degradation formed when edible oils are repeatedly heated

[2] Repurpose Used Cooking Oil - Network of licensed UCO aggregators & biodiesel plants, traceability, and awareness for households/restaurants

[3] Official digital platform and mobile app — developed by PT Pertamina, Indonesia's state-owned oil and gas company

Source: Press Search

10 | Aviation – 2G oil-based feedstock export: Eni set up castor production and processing capacity in Kenya

Context

- Eni is a **global energy company** targeting net-zero by 2050
- In Kenya, it is building an advanced biofuels supply chain to decarbonise transport and create rural income
- Backed by **IFC and the Italian Climate Fund**, Eni aims to scale **oilseed production and processing** and integrate Kenya into its biofuel value chain

Approach

- Eni has established **agri-hubs** that press non-food oilseeds (e.g., castor) grown on **degraded/rotation land**
- Farmers receive **inputs, mechanisation, logistics, training and ISCC certification** support
- Oil is shipped to Eni's biorefineries in **Gela and Venice**
- Operational hubs: **Wote–Makueni** (15k tonnes/year); second hub in **Kwale**; plans to expand include **Nakuru**

Key stats

$210Mn	Investment size
500k	Targeted annual production of oil seeds
200k	Smallholder farmers targeted
80k	Hectares targeted for feedstock production
70k	Targeted annual production of oil

Source: Eni, IFC, Press releases

10 | Aviation – 2G oil-based feedstock export I Implementation roadmap

	Phase 1: Ramp up collection and production (Year 1-5)	**Phase 2: Scale production; pilot new 2G crops** (Year 5-10)	**Phase 3: scale new 2G crops if business case is viable** (Year 10+)
2G waste oils and fats	Institute heath regulation to improve standards of cooking oils to prevent re-use		Expand regulations to incentivise higher UCO collection and export (e.g., tax credits)
	Develop tech-based solutions to support collection of UCO from households and businesses	Build a digital traceability system for cooking oil to limit leakages of oil during disposal (e.g., to black market)	Expand use of innovative tech-based solutions to drive more collection of UCO from households
2G non-edible oil crops	Continue **testing and growing** of 2G oil crops (focus on castor)	Ramp-up castor oil production by driving farmer adoption Continue **testing and growing** of 2G oil crops (focus on less proven crops such as carinata)	Explore potential to **scale additional 2G oil crops** (e.g., brassica carinata)

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Source: Manufacturing Africa team analysis

Contents

Executive summary
Biofuels overview, scope, and context in Africa
Details on approach for sizing the opportunity for biofuels in Africa
Appendix 1: Africa biofuel feedstock availability assessment
Appendix 2: Use case deep-dives
  1, 2 Road – Ethanol, FAME diesel
  4, 5, 6 Cooking – bio-pellets, biogas, ethanol
  – Context
  – 4 Bio-pellets
  – 5 Biogas
  – 6 Ethanol
  7, 9 Industrial Heat and Power – biogas, bio-briquettes
  10 Aviation - 2G oil-based feedstock export
  11 Aviation - SAF refining
Appendix 3: Lessons learned on biofuels adoption from other countries
Appendix 4: Methodology

11 | Aviation – SAF: SAF market potential in Africa may be driven by SAF HEFA production in Nigeria and South Africa for export

▫ Limited-to-No policy ■ Strong policy

	2025-30	**2030-35**	**Market potential,** Bn USD, 2035[1]	**Potential investment size,** Bn USD, 2035[1]
SAF based on 1G for export	Grow palm oil production by **tripling yields** and adding an additional **0.8Mn** ha of land	Set up **SAF plant in Nigeria** – will require offtake deals in APAC countries (e.g., S. Korea, Japan).	▫ - ■ 0.8	▫ - ■ 1 *Typical 0.5Mn tonnes annual capacity SAF facility is ~1Bn USD*
SAF based on 2G for export		Set up a **SAF plant in South Africa** — depends on demand in Europe and feasibility of aggregating of UCO, and 2G oil crops from neighbours (Angola, Mozambique, Zimbabwe)	▫ - ■ 0.3 *Assumes additional value captured addition from 2G oil-based feedstock with a 0.5Mn tonnes SAF in South Africa (nets out 2G feedstocks exported from those countries that count in the 2G export opportunity)*	▫ - ■ 1 *Typical 0.5Mn tonnes annual capacity SAF facility is ~1Bn USD*
SAF for local demand	**No opportunity** – limited likelihood of local SAF mandates in Africa; voluntary commitments unlikely without mandates			

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1. Assumed global production cost for 1G SAF/HVO– 1700 USD/tonne; 2G SAF/HVO production cost - USD1500/tonne; Revenues from SAF plants include sale of HVO by-product (potentially to Europe)

Source: McKinsey Global Energy Perspective 2025, Press Search, Expert interviews

11 | Aviation – SAF: There are four main certified pathways to produce SAF, with HEFA the most mature and cost-competitive

! *Certified by ASTM International (formerly American Society for Testing and Materials)*

🟥 Focus of this effort

	HEFA	**Alcohol-to-Jet[4]**	**Gasification/ FT**	**Power-to-liquid (eSAF)**
Opportunity description	Safe, proven, and scalable technology	Potential in the mid-term, however significant techno-economical uncertainty		Proof of concept 2025+, primarily with cheap high-volume electricity
Feedstock & availability	Waste and residue oils, purposely grown oil plants[2]	Agricultural and forestry residues, municipal solid waste, industrial waste gas, purposely grown cellulosic energy crops[5]		CO2 and renewable electricity Unlimited potential via direct air capture
Technology maturity	● Mature	← ◐ Commercial pilot →		○ In development
Net CO_2 emission re-duction vs. fossil jet, %	70-85%[3]	← 82-94%[6] →		85-100%[7]
Share of planned supply, 2030[1]	~72%	~8%	~10%	~11%
Average global production cost, 2025, USD / tonne	1,500-1,800	2,600-2,800	3,500-4,000	3,500-4,000

1. Based on planned announcements
2. Oilseed bearing trees on low-indirect land use change (degraded land or as rotational oil cover crops)
3. Excluding all 1st generation feedstock (edible oils)
4. Ethanol route
5. As rotational cover crops
6. Excluding all 1st generation feedstock (edible sugars); high share of plastic in MSW may result in lower GHG savings
7. Emission reduction of 100% only with a fully decarbonised supply chain

! *SAF is expected to remain **2-5x costlier than fossil jet fuel** by 2030 despite technology improvements; cost likely to be borne by airlines*

Source: CORSIA, RED II, De Jong et al. 2017, GLOBIUM 2015, ICCT 2017, ICCT 2019, E4tech 2020, Hayward et al. 2014, ENERGINET renewables catalogue, Van Dyk et al., 2019, NRL 2010, Umweltbundesamt 2016, ASTM International, Expert interviews

11 | Aviation – SAF refining: Global SAF demand is largely driven by blending mandates in EU & UK, and ambitions in the US

Current momentum scenario

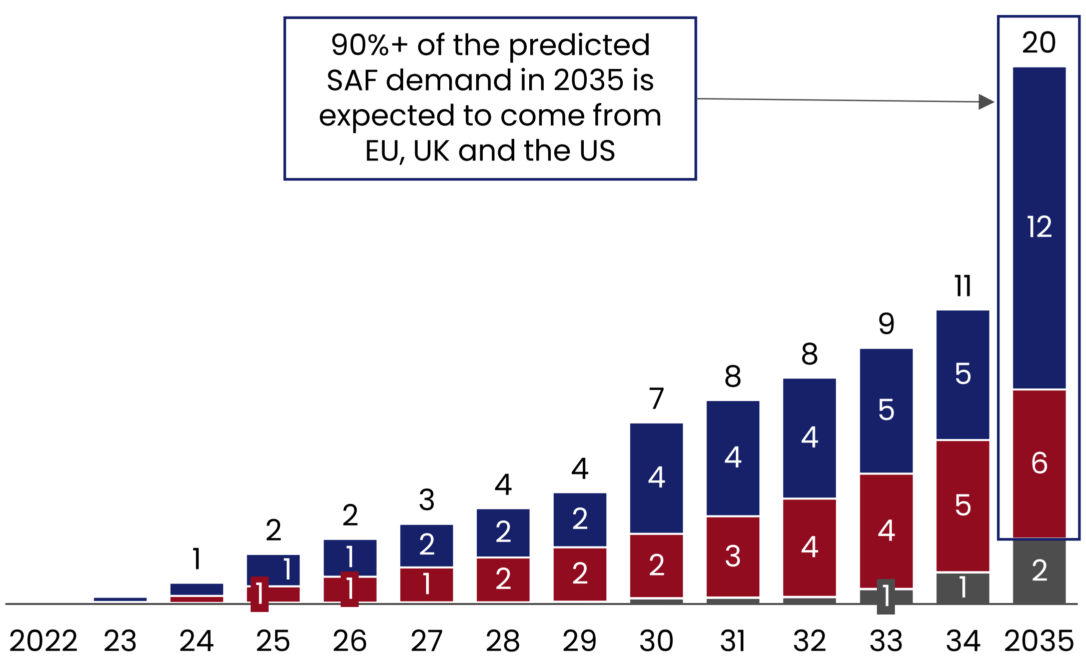
NON EXHAUSTIVE

⬚ Mandated by law 🟦 EU27+UK 🟥 USA ⬜ China ⬛ Rest of the World

SAF targets and mandates

🇪🇺	EU	6% SAF blends by 2030[1]
🇬🇧	UK	10% SAF blends by 2030
🇺🇸	USA	10% SAF blends by 2030[2]
🇯🇵	Japan	10% SAF blends by 2030
🇮🇩	Indonesia	5% SAF blends by 2025
🌍	Other	Growth in other countries is driven by net-zero ambitions

SAF demand by region, Mn tonnes p.a. (2022-2035[4])



90%+ of the predicted SAF demand in 2035 is expected to come from EU, UK and the US

Forecast assumes mandates / targets are not fully met

Key takeaways

~90%+ of SAF demand by 2035 could be driven by mandates in EU and supply-side incentives in US (e.g., ReFuelEU, SAF Credit in US) – assuming a continued momentum scenario where nations strive to balance affordability, security of supply, and sustainability

Voluntary industry commitments (e.g., CORSIA[3]) and **demand by companies or passengers** are expected to have **limited impact** on the demand

! Projections are medium (continued momentum) scenario. However, demand could be 10-40Mn tonnes in lower and higher scenarios by 2035

1. 2% by 2025, 6% by 2030, 70% by 2050 from ReFuelEU proposal
2. 3Bn gallons of SAF by 2030 out of an expected demand of ~30Bn gallons of jet fuel (kerosene)
3. CORSIA - Carbon Offsetting and Reduction Scheme for International Aviation; majority of airlines could potentially opt to buy CORSIA credits to offset emissions instead of voluntarily adopting SAFs |
4. 2022 actuals based on latest IEA data; 2023-2035 is forecasted

Source: Proprietary Energy Perspective 2025, Proprietary demand model

11 | Aviation – SAF refining: SAF demand in Africa is likely to remain limited until 2035

AS OF MAY 2025

Limited SAF demand outlook for Africa is based on:

Mandates

Africa has no SAF mandates announced/planned as of May 2025

Current mandates are **largely in Europe** (RefuelEU and Jet Zero UK)

Some other regions (e.g., Turkey, Japan) have **announced potential mandates** likely to come into action soon

Industry ambitions

Airlines likely buy cheaper carbon credits instead of using SAF in the short-to-medium term to reduce CORSIA offset requirements

CORSIA ambitions to reduce international aviation emissions can be met using **SAF or carbon credits**

However, **SAF's higher carbon abatement costs** compared to CORSIA offset credits (~300 vs. 14-16 /tCO2e) may **deter SAF demand from airlines**

Global regulation

RefuelEU and Jet Zero UK mandates currently **not creating incentives for SAF uptake** by African airlines **outside Europe**

RefuelEU and Jet Zero UK mandates only impact flights **refuelling at European airports** – unlikely to drive SAF uplift at African airlines

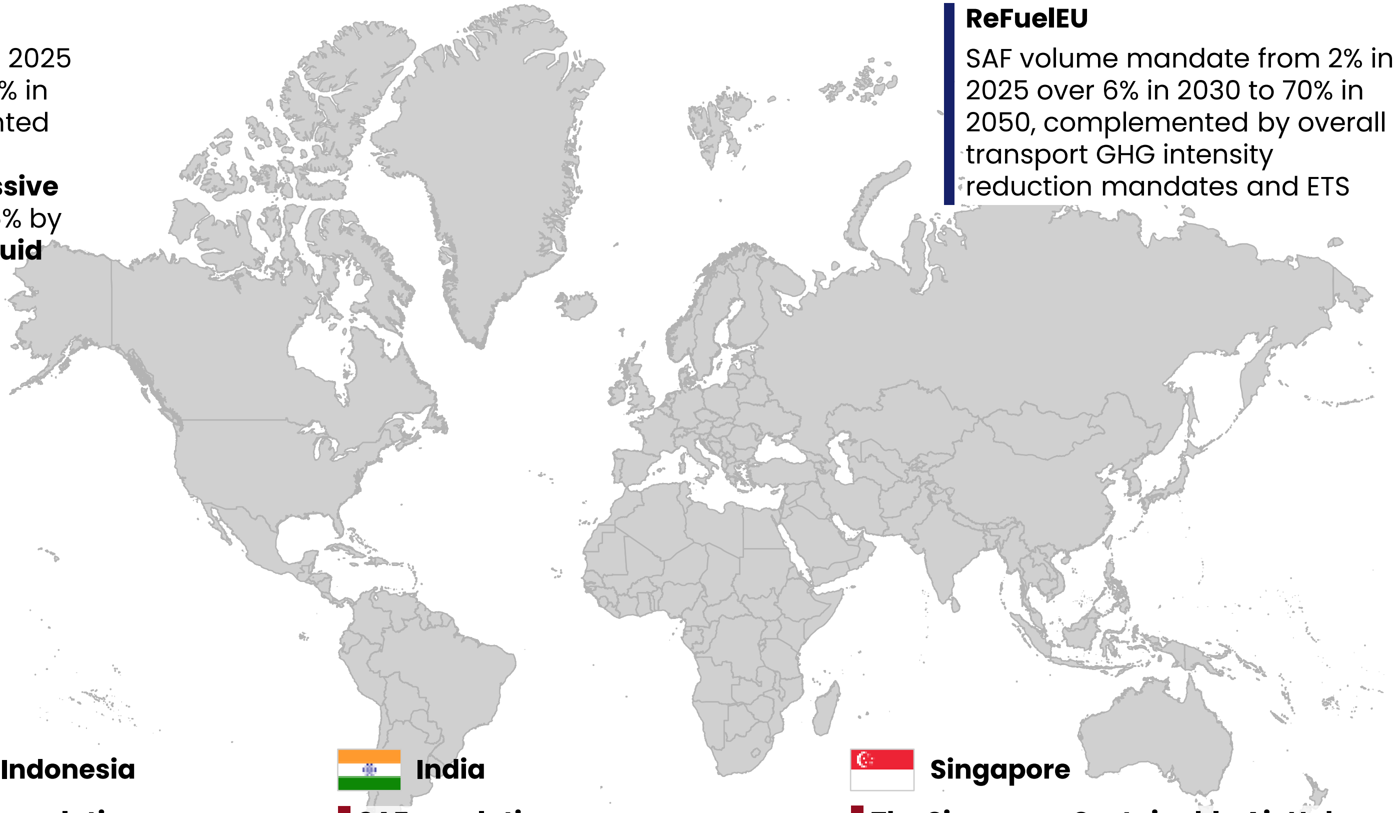
Other global mandates likely to operate in a similar way

Source: RefuelEU, Jet Zero UK, press search, CORSIA, SAF benchmarks

11 | Aviation – SAF: Mandates largely in Europe; some other regions have announced potential mandates; Africa has none

AS OF MAY 2025 **NOT EXHAUSTIVE**

🟦 Mandate implemented 🟥 Mandate planned



UK

Jet Zero

SAF volume mandate from 2% in 2025 increased on a linear basis to 10% in 2030 to 22% in 2040, complemented by ETS and renewable fuel certificates (RTFC), **with progressive HEFA cap** from 71% by 2030 to 35% by 2040 and **specific Power-to-Liquid mandates** (3.5% in 2040)

Canada

British Columbia LCFS

SAF volume mandate from 1% in 2028 to 3% in 2030, complemented by increasingly stringent jet fuel carbon intensity reduction targets as of 2026

EU

ReFuelEU

SAF volume mandate from 2% in 2025 over 6% in 2030 to 70% in 2050, complemented by overall transport GHG intensity reduction mandates and ETS

Turkey

SAF regulation

Planned SAF mandate of 1% in 2025 and 5% in 2030

Japan

SAF regulation

Announced SAF mandate of 10% in 2030 and GHG emissions reduction mandate for SAF producers

Indonesia

SAF regulation

Announced SAF mandates on international flights by 2027 (1% and 2.5% by 2030)

India

SAF regulation

Announced mandate for international flights of 1% blending of SAF by 2027, 2% by 2028

Singapore

The Singapore Sustainable Air Hub Blueprint

Suggested mandate of 1% SAF uplift in 2026, with plans to raise this to 3-5% by 2030, complemented by a SAF levy

Malaysia

National Energy Transition Roadmap

Planned SAF mandate of 1% in 2027 and 47% in 2050

Source: US IRA; US RINs; US states LCFS; British Columbia LCFS; UK Jet Zero; UK RTFC; Japan mandate; Japan SAF GHG emission reduction; India; Indonesia; UAE; Singapore; SkyNRG SAF market outlook 2024; Eurocontrol SAF map; ICAO; Press search

11 | Aviation – SAF refining: Some African airlines have SAF commitments suggesting potential future voluntary SAF demand

Overview of ambitions by top African airlines – based on public announcements

✓ Planned / exists
⊗ Not announced

AS OF AUGUST 2025

Airline	SAF target	Net zero target	Offtake agreements
Ethiopian ኢትዮጵያ	✓ **10%** SAF mix by 2028/29 according to Ethiopia's 2021 SAF Roadmap – *Ethiopia currently reviewing its biofuel roadmap, which may change SAF plan*	✓ **2050** net zero target; 25% reduction by 2030 (2021 baseline)	✓ Signed MoU with **Satarem America** for 100k tonnes of locally produced SAF – *plan currently delayed*
Kenya Airways	✓ **10%** SAF blend by 2030	✓ Net zero goal by **2050**	✓ Signed agreement with **Enilive** for future offtake *(quantity unclear)*
الخطوط الملكية المغربية royal air maroc	✓ **10%** SAF incorporation by 2030	✓ Net-zero by **2050**	⊗ In partnership with **Vivo Energy Maroc**
South African Airways	⊗ No recent specific SAF target found	⊗ **50%** reduction by 2030 (2005 baseline)	⊗ Partnered with **Sunchem SA** on trial flight, no offtake agreement announced
EGYPTAIR	✓ **6%** by 2030	✓ Net-zero by 2050	⊗ Partnered with **NESTE** on trial flight, no offtake agreement announced

Targets are **publicly announced**, but **not validated** (e.g., by SBTi[1])

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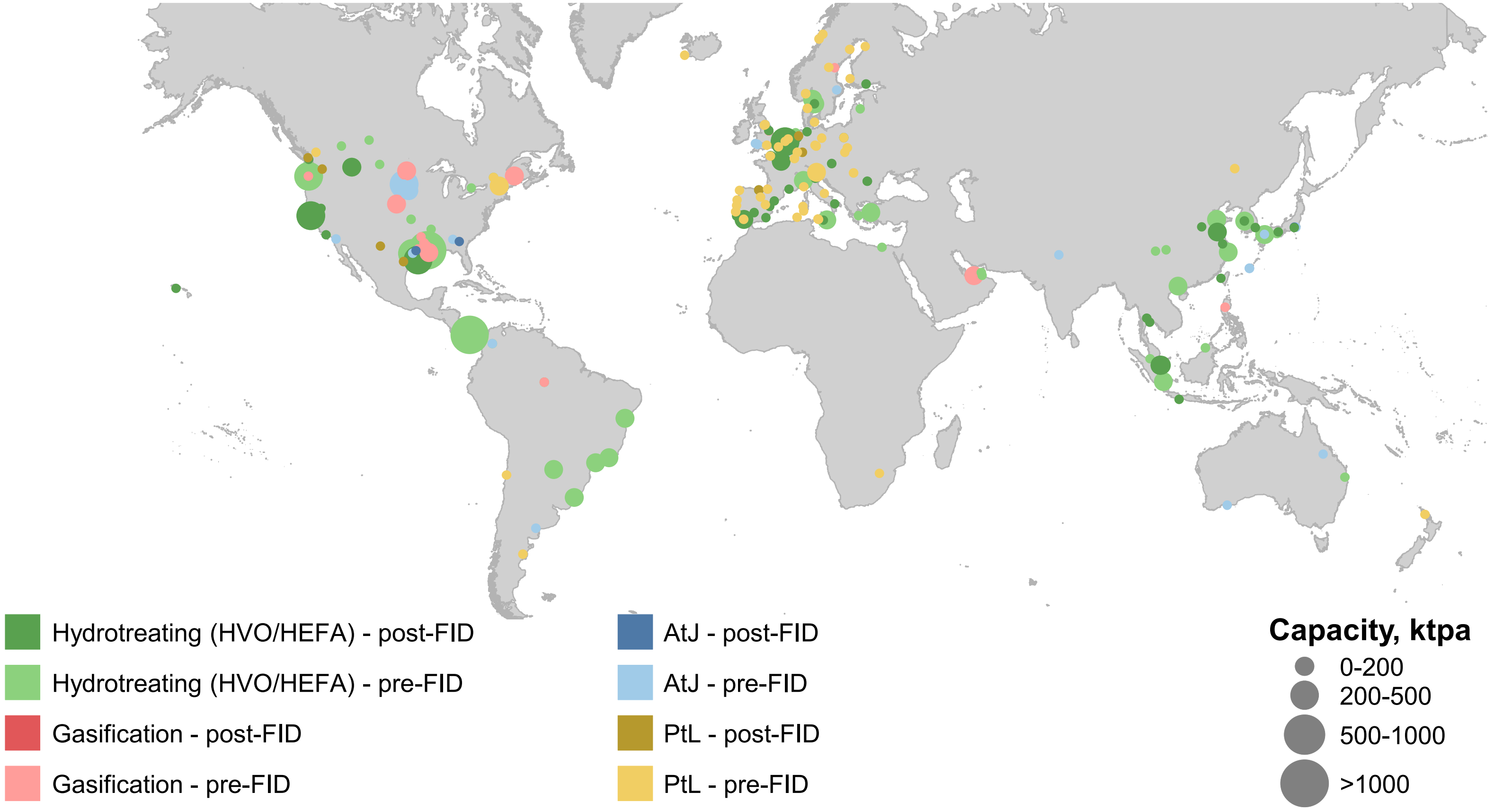
1. Science Based Targets initiative

Source: Airlines websites, Press search

11 | Aviation – SAF refining: SAF supply is expected to accelerate with 29Mn tonne capacity announced by 2030, with one project in Africa

AS OF MAY 2025

Sustainable fuels production facilities around the world with option for SAF[1]



214 projects
with SAF production flexibility, with majority of the investments focused on HVO/HEFA

29Mn tonnes
total SAF production capacity planned for 2030, but projects post-FID only account for 7Mn tonnes

USD 0.75-1Bn
average CAPEX for typical facility with 0.5Mn tonnes annual capacity (HEFA)

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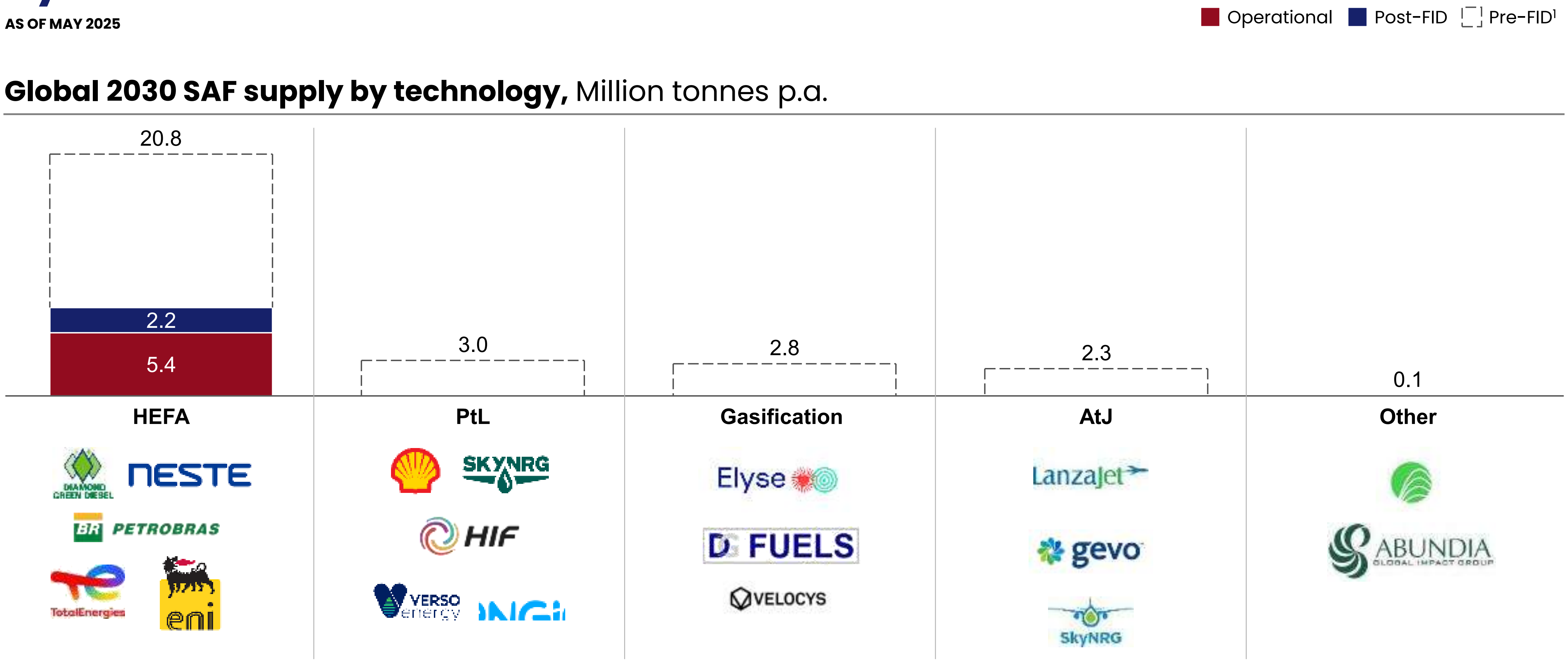
1. Based of announcement as of May 2025; 2. Financial Investment Decision

Source: Proprietary Sustainable Fuel Supply Tracker

11 | Aviation – SAF refining: HEFA projects dominate the SAF landscape, accounting for +70% of announced SAF supply globally by 2030

AS OF MAY 2025

Global 2030 SAF supply by technology, Million tonnes p.a.



1. Publicly announced with no final investment decision taken

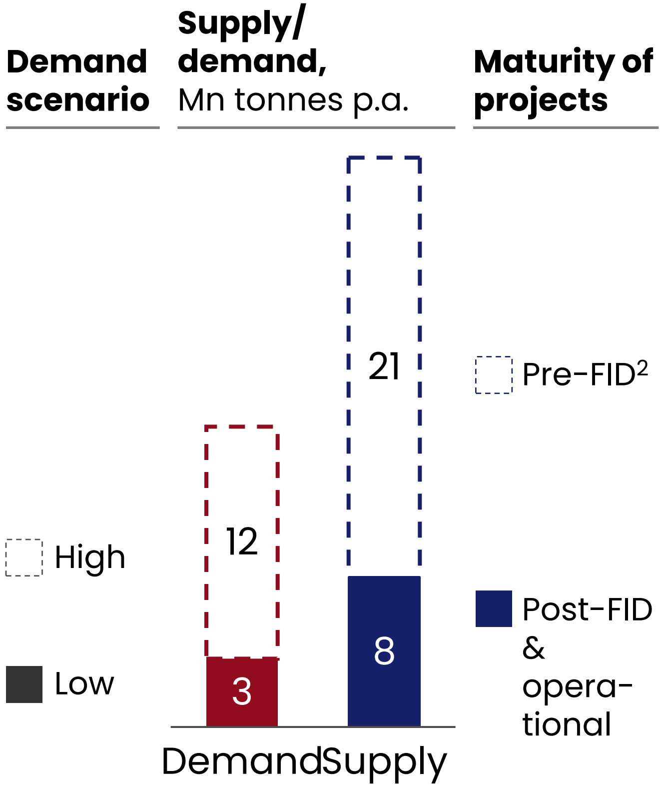
Source: Proprietary Sustainable Fuels Supply Database

11 | Aviation – SAF refining: Future SAF demand-supply balance suggest surplus until 2030, with potential supply gap expected post-2030 if demand continues to grow

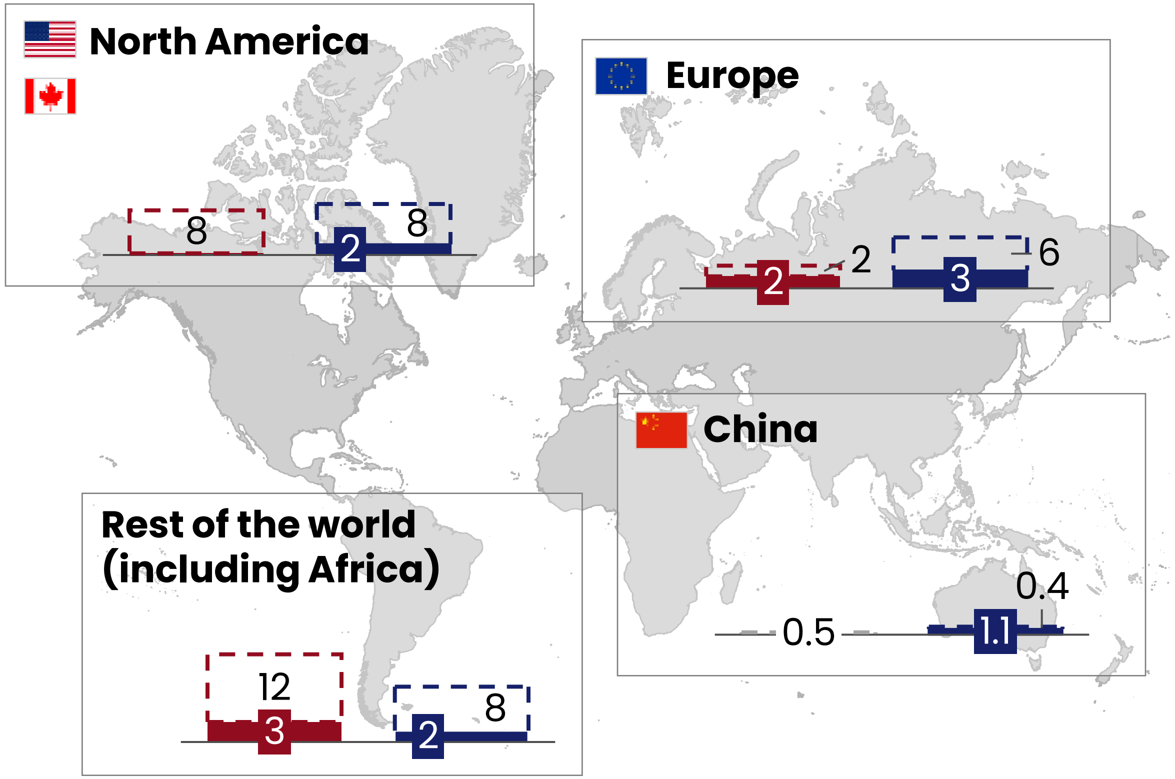
🟥 Demand 🟦 Supply

AS OF MAY 2025

Global SAF supply-demand balance by 2030



SAF supply-demand balances in 2030 across regions, Mn tonnes p.a.



Up to 2030, SAF supply is **expected to outstrip demand** if all planned projects are executed

HEFA¹ makes up 70%+ of planned SAF projects by 2030

Post-2030, there may be a **possible undersupply of SAF** if demand continues to grow (i.e., announced mandates and targets persist)

---

1. HEFA: Hydroprocessed Esters and Fatty Acids
2. FID: Final Investment Decision

Manufacturing Africa

Source: Proprietary Sustainable Fuel Solution

11 | Aviation – SAF refining: SAF export opportunity in Africa is based on oil-based feedstock availability and cost-competitiveness

Opportunity assumed to be under strong policy scenario

Select countries with potential feedstock availability

Identify countries with feedstock potential of at least 600ktpa (feedstock required for a 500ktpa SAF HEFA plant[1])

Smaller plants are possible but have lower economies of scale (i.e., produce more expensive SAF). Estimated SAF (HEFA) production costs might increase by ~25% when a scale of 250ktpa is assumed[2]

Evaluate cost-competitiveness of SAF produced in selected countries

Given SAF opportunity is considered for export, cost-competitiveness vs. global benchmarks is assessed

Production cost for SAF from palm oil is compared to other 1G oils (e.g., soybeans) in the US and China

Alternatively, 2G SAF (castor and UCO mix) cost is compared to benchmarks in the US and Europe

Estimated market potential …

HEFA/HVO[3] value assumed to be based on estimated global production costs (i.e., 1G: $1700/tonne and 2G: $1500/tonne)

HEFA vs. HVO production per plant is not specified, as various combinations of SAF output can be obtained alongside other by-products such as HVO (naphtha assumed to be negligible)

… and investment required

$1Bn benchmark CAPEX for 500ktpa SAF plants used

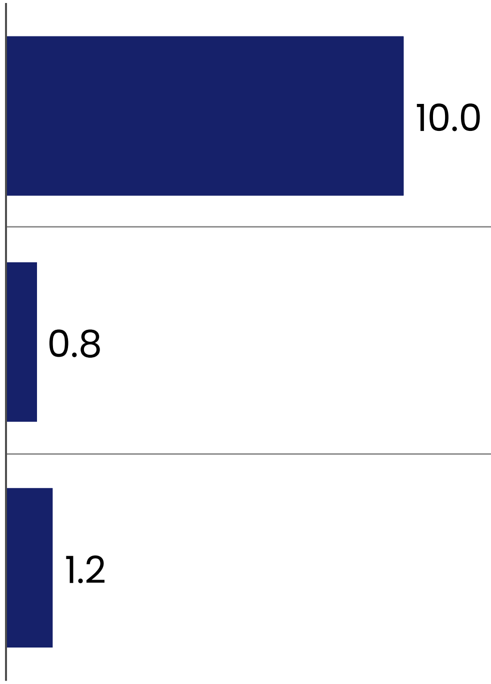
---

1. Feedstock required estimated by assuming a 1.2x factor based on planned scale
2. Production cost assumed to scale by a factor of 0.7 (in line with oil refining)
3. HVO – Hydrotreated Vegetable Oil (Renewable diesel/biodiesel)

Source: Expert input

11 | Aviation – SAF refining: In Africa, South Africa and Nigeria appear to have feedstock potential for a 500ktpa scale SAF HEFA plant

600ktpa oil-based feedstock required for a 500ktpa scale SAF HEFA plant[3]



Type of feedstock		**Projected availability in Africa**, Mn tonnes, 2035 (medium projection)[1]	**Countries with sufficient feedstock to meet 500ktpa plant scale**, 2035	**Considerations**
First generation (1G)	**Edible oil crops** – palm oil	10.0	Nigeria	Only 600ktpa of the 10Mn estimated surplus may need to be used – higher scale not assumed given sustainability concerns of 1G production limit export market
Second generation (2G)	**Waste oils and fats** – UCO/tallow	0.8	South Africa	South Africa alone has potential for 300ktpa oil-based feedstock (primarily UCO/tallow) To meet minimum scale requirements, South Africa will need to aggregate castor oil and UCO from Angola, Mozambique, Zimbabwe
	Non-edible oil crops – castor oil[2]	1.2		

---

1. Assumes palm oil crop yields match peer country yields (i.e., Indonesia, Malaysia) and conservative land expansion (1% p.a.); Assumes UCO/tallow collection matches India benchmark (10% urban collection rate); castor oil production estimate assumes adoption rate of 5% by farmers on land suitable for castor oil production in Africa and yield of 0.675 tonnes of oil per hectare
2. Other non-edible oil crops (e.g., carinata, jatropha) de-prioritised as their economic viability is still unproven at scale in Africa
3. Feedstock required estimated by assuming a 1.2x factor based on planned scale

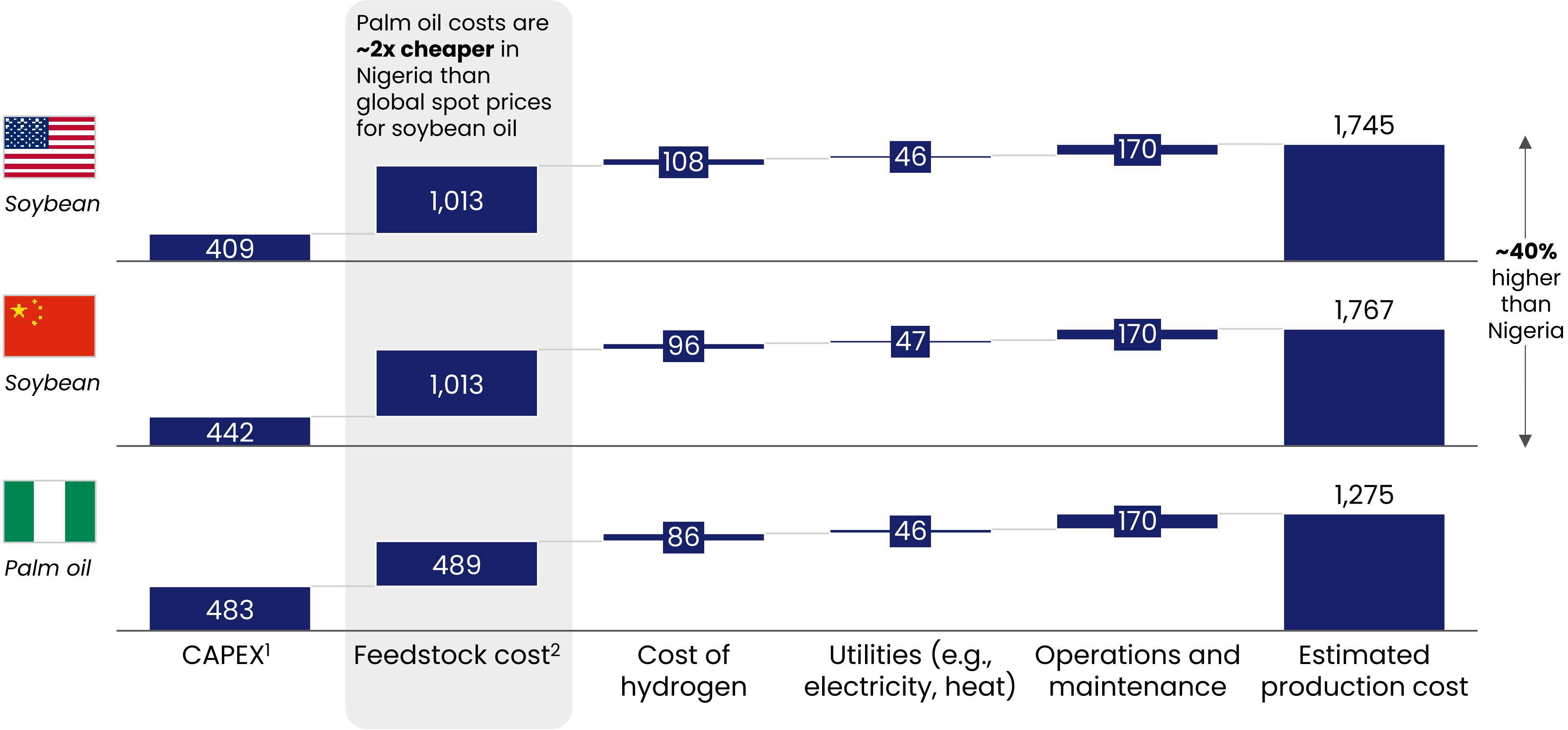
Source: ACRE analysis, FAOSTAT, Press Search, Expert input

11 | Aviation – SAF refining: Nigeria 1G HEFA may compete globally; however, use of 1G feedstock limits offtake markets

Estimated 1G HEFA production cost (USA/China vs. Nigeria), USD/tonne

AS OF 2025 OR LATEST AVAILABLE

EXCLUDES MARGINS AND ANY POTENTIAL TARIFFS AND TRANSPORT COSTS



If Nigeria maintains low palm oil prices, it can be cost-competitive in SAF

However, given use of 1G feedstock, exports to some regions are restricted (e.g., Europe restricts 1G feedstock use)

Likely only market is **Asia; however, any investment is depending on mandates scaling there**

---

1. Assumes a 500,000 tonnes SAF annual capacity; Nigeria estimated to have higher equipment/materials cost
2. Soybean oil – assumed global prices based on Argus data; Palm oil – FAOSTAT producer prices average 2018-2023

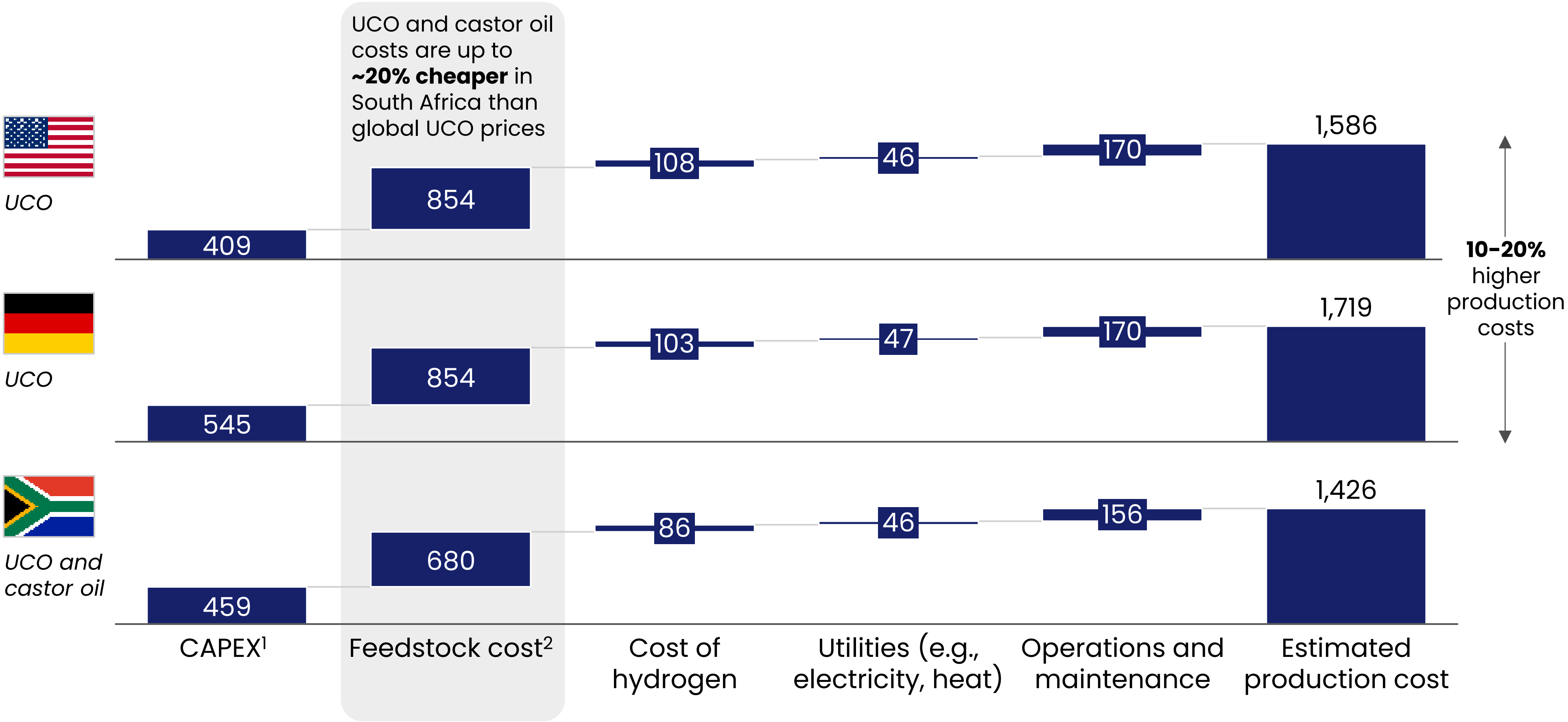
Source: McKinsey Global Energy Perspective 2025, FAOSTAT, Argus Media, Expert interviews, Press Search

11 | Aviation – SAF refining: South Africa 2G HEFA may compete globally because of competitive castor oil and UCO prices

Estimated 2G HEFA production cost (USA/China vs. South Africa), USD/tonne

AS OF 2025 OR LATEST AVAILABLE

EXCLUDES MARGINS AND ANY POTENTIAL TARIFFS AND TRANSPORT COSTS



UCO and castor oil costs are up to **~20% cheaper** in South Africa than global UCO prices

10-20% higher production costs

If South Africa maintains low UCO prices and castor oil prices, it can be competitive in SAF to the **Europe**, **US, and Asia; however, given oversupply of SAF until 2030, decision needs to be made to invest based on whether mandates scale in those regions**

Also, given likely need to aggregate castor regionally, there must proper mechanisms in place to **ensure competitive sourcing from neighbouring countries**

---

1. Assumes a 500,000 tonnes SAF annual capacity; South Africa estimated to have higher equipment/materials cost
2. UCO – assumed global prices based on Argus data; Castor oil price ($650-800/tonne) – FAOSTAT producer prices average 2018-2023 (indicative conversion from castor oil seeds prices); UCO price from Kenya benchmark ($0.4-1/L); Feedstock mix is 80% UCO and 20% castor oil

Source: McKinsey Global Energy Perspective 2025, FAOSTAT, Argus Media, Expert interviews, Press Search

11 | Aviation – SAF refining: Enablers to support implementation

Feasibility[1] ○ Low ● High 🟪 Deep-dives next

			Stakeholders				
Category	**Enablers for consideration**	**Details**	**Government**	**Development partners**	**Research institu-tions**	**Private sector**	**Feasi-bility**
investment strategy	**Make investment decision based on mandates in other regions**	Given over-supply of SAF until 2030, make investment decision in SAF production for export based on expectation on global mandates (PPP or JV for global producers mitigates risk)	✓			✓	◔
Feedstock availability	**Control on oil feedstock export**	Limit oil feedstock export for countries with SAF potential to ensure availability	✓				◐
	Regional feedstock aggregation network	Network in Southern Africa[2] to support oil feedstock aggregation for SAF refining in South Africa	✓	✓		✓	◐
SAF refining	**Offtake agreements**	SAF offtake agreements with fuel suppliers and/or airlines in Asia and Europe				✓	◔
	JVs with global producers	Financing arrangements with global producers to reduce investment risk				✓	◐
	Patient financing	Concessional financing to allow for scaling given expected slow-ramp for feedstock	✓	✓		✓	◐

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1. Feasibility based on: High - proven enabler demonstrated in multiple African countries (even if in other industries); Medium (1/2 moon) - proven enabler demonstrated in peer countries (e.g., India); Low - high complexity intervention, unproven in any developing economy. 12 Includes South Africa, Angola, Mozambique, and Zambia

Source: Manufacturing Africa team analysis

11 | Aviation – SAF refining: Implementation roadmap

	Phase 1: Scale feedstock and make investment decision (Year 1-2)	**Phase 2: Invest in SAF refining** (Year 3-7)	**Phase 3: Scale production** (Year 8-10)	**Phase 4: Explore new technologies and crops** (Year 10+)
Feedstock availability	Institute heath regulation to improve standards of cooking oils to prevent re-use			Expand regulations to incentivise higher UCO collection and export (e.g., tax credits)
	Develop tech-based solutions to support collection of UCO from households and businesses	Build a digital traceability system for cooking oil to limit leakages of oil during disposal (e.g., to black market)		Expand use of innovative tech-based solutions to drive more collection of UCO from households
	Continue testing and growing of 2G oil crops (e.g., castor, carinata, jatropha)	Ramp-up castor oil production by driving farmer adoption		Explore potential to scale additional 2G oil crops (e.g., brassica carinata)
		Set up controls for oil feedstock export from Nigeria and South Africa; Develop a network in Southern Africa[1] to support oil feedstock aggregation for SAF refining in South Africa		
SAF refining	Based on demand outlook for SAF in export markets, make investment decision to build SAF plants in Nigeria and South Africa	Raise financing for setting up a SAF plant; Explore JVs and offtake agreements in Europe (2G SAF) and Asia (1G SAF)		Consider offtake agreements with other regions (e.g., US) Explore SAF plants in other countries and/or different pathways (e.g., PtL)

1. Includes South Africa, Angola, Mozambique, and Zambia

Manufacturing Africa

Source: Manufacturing Africa team analysis

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

Appendix 2: Use case deep-dives

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

Case study on biofuels in Brazil

Context

In the 1970s, Brazil's **reliance on imported oil** was exposed by the global oil shock

This prompted the launch of the ***"Proálcool"*** program in 1975 to replace gasoline with ethanol, leveraging abundant sugarcane to **enhance energy security and support agriculture**

Approach

India operationalised biofuel blending through:

Policy Framework

- Proálcool mandated 20% ethanol blending by 1980
- From 2011, ANP[1] regulated ethanol chain from production to distribution
- 2017 RenovaBio program set decarbonisation targets and introduced CBIO credits[2] to promote biofuels

Incentives: The government offered low-interest loans, tax exemptions, and BNDES[3] financing to boost sugarcane cultivation and ethanol production

Operations:

- Car manufacturers modified engines for ethanol (e.g., development of "fuel flex" cars in the 2000s)
- Infrastructure for ethanol production, storage, and distribution was expanded to ensure a steady supply
- ~50% of sugarcane is used for ethanol, with ~120,000 smallholder farmers contributing to the supply chain

1.33Mn

m^3 reduction in gasoline demand by moving from 27% to 30% blending rate reduction, improving its energy self-sufficiency

In 2024, Brazil had an external gasoline deficit of 872,000m^3

71.1Mn

Tonnes of carbon dioxide emissions cut in 2022

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1. National Agency of Petroleum, Natural Gas, and Biofuels
2. Decarbonization Credit
3. Brazilian Development Bank

Source: IEA Bioenergy Country Report-Brazil, IEA Country Brief on Brazil-2023, The Story of Brazil's Ethanol Programme, Biofuels International, Press search, Expert interviews, USDA – Report Name: Biofuels Annual (Brazil), Brazil raises biofuel levels, sees gasoline self-sufficiency

Case study on biofuels in India

Context

India faced challenges with its **heavy reliance on imported fossil fuels**, straining its FX reserves

Also, push from sugar industry to **create a market for surplus crops**

To address this, India introduced the **EBP[1], mandating a 5% ethanol blend in petrol** in 2003

In 2022, the **target was updated to 20% 2025-26,** plus an indicative target of 5% biodiesel blending by 2030

Approach

India operationalised biofuel blending through:

Policy Framework: The National Policy on Biofuels set blending targets and promote biofuels

Incentives: Reduction of GST[3] on ethanol from 18% to 5% to make it more cost-competitive

Operations: Oil marketing companies were required to procure ethanol for blending, and the program was expanded to more States and Union Territories by 2006

Impact[2]

$15.5Bn

Foreign exchange savings

~70Mn

Tonnes of carbon dioxide emissions cut

---

1. Ethanol Blended Programme
2. Since 2014
3. Goods and Services Tax

Manufacturing Africa

Source: Ethanol Blending in India: Enhancing Energy Security, India's biofuel drive is saving billions but also sparking worries, Ethanol Blending Boosts Farmers' Income and Rural Economy, Press search, expert interviews

Case studies show that biofuels can boost crop production, provide crop price floors, improve external balances, but can inflate food prices…

Potential impacts of ethanol adoption based on case studies for US, Brazil, and India

Impact supports biofuels adoption

↘ Headwind ↗ Tailwind

Impact			Insights
I Increase local agriculture production	↗	🇺🇸	Since the introduction of the blending mandate in 2005, corn production has risen by an **average of 20%**, while corn acreage has expanded by **14% on average**
		🇧🇷	In the **first 10 years** of the programme, sugarcane production **grew 10% p.a.** as the mandate increased from **E11 to E20; 5% p.a.** ramp up from **2004 to 2015** when the mandate grew from **E20 to E27** also noted
		🇮🇳	While still inconclusive due to nascency of the programme, sugarcane production has increased on **average 2%** since the **revision of the blending mandate in 2018**
II Reduce crop price volatility	➡	🇺🇸 🇧🇷	**Literature and data inconclusive** on ethanol's potential to create a price "floor" for feedstock. As a second market, ethanol can **absorb oversupply and reduce price drops** (e.g., processors in Brazil/ US can shift 40–60% of output between sugar/corn and ethanol). But, in shortage years (e.g., 2007/08), mandates have **amplified price increases.** **Brazil has often flexed** to stabilise its sugarcane market (critical export crop) to counter ethanol market volatility.
III Inflate food prices	↘	🇺🇸	**Increased fuel demand** from emerging markets (e.g., India, China) in 2008 led to **higher ethanol demand driving up corn prices** in the short term. In the long-term, US real corn prices **increased by +10% since 2005. 2013 EPA paper** concluded that each billion-gallon ethanol expansion can yield **2-3% increase in long-run corn prices**
		🇮🇳	India's recent ramp up of corn ethanol from 2021 led to **62% p.a. higher prices** on average by 2023
IV Improve trade and FX balance	↗	🇮🇳	Since 2014, India has **saved 15.5Bn+ on FX** by reducing oil imports with gasoline blending
		🇧🇷	In August 2025, Brazil expanded their mandate **from E27 to E30** which could cut annual gasoline consumption by up to **1.36Bn litres**, enabling Brazil to **cease being a net importer** of gasoline

UKaid **Manufacturing Africa**

Source: Expert interviews, OECD-FAO Agricultural Outlook 2022-2031, FAOSTAT, Reuters, EIA, EIA, University of Illinois, OPIS, CGIAR, Advanced Biofuels USA, Grainsorg, EPA-NCEE

…while also improving fuel quality, reducing air pollution and GHG emissions, without significantly impacting fuel cost

Potential impacts of ethanol adoption based on case studies for US, Brazil, and India

Impact supports biofuels adoption

↘ Headwind ↗ Tailwind

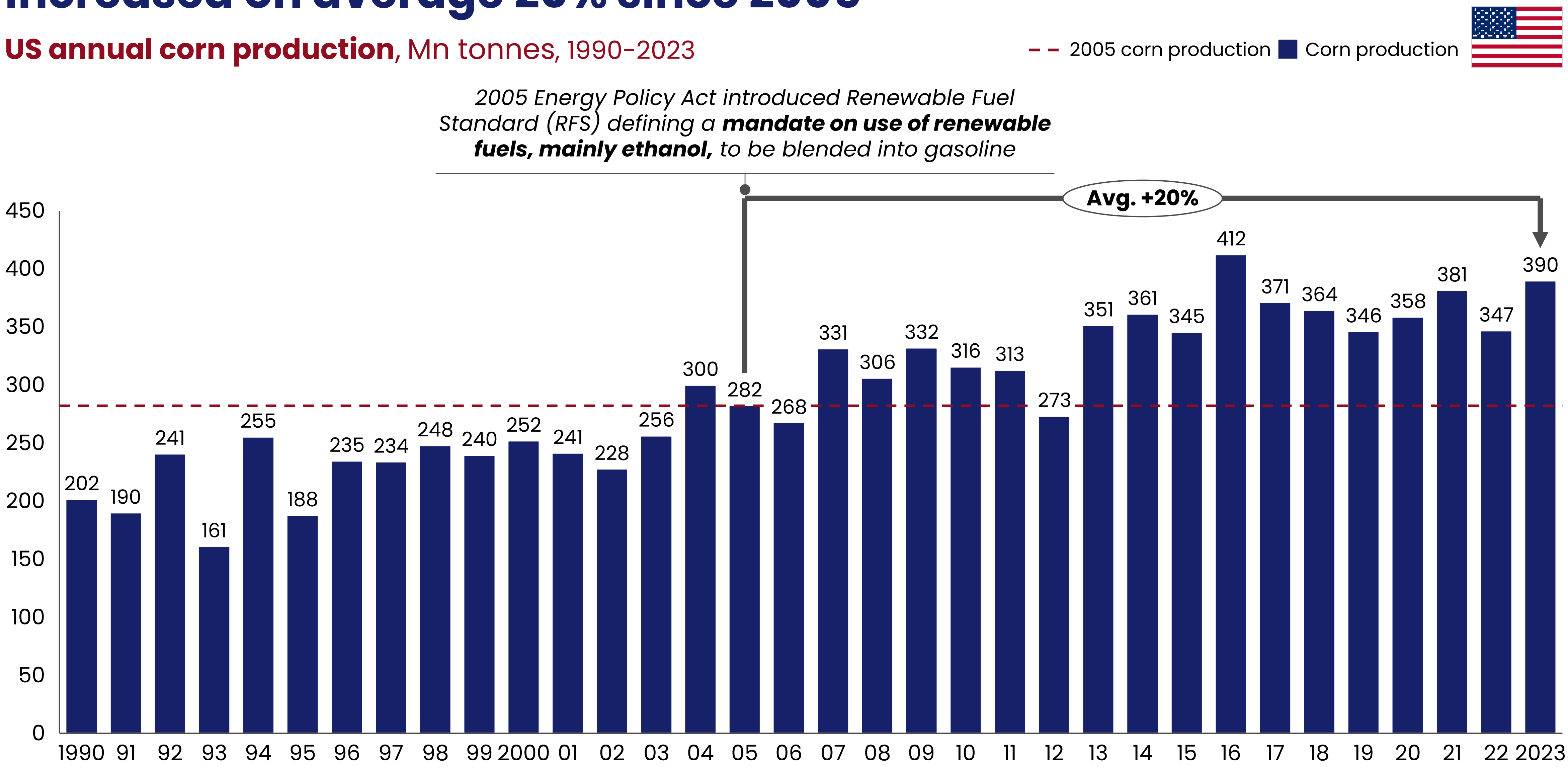
Impact		Insights
V Change in fuel cost	→	**While ethanol is cheaper than gasoline on a per litre basis, range differences make it more expensive.** Data shows that global ethanol spot price on **average 7% been lower than gasoline over the last 10 years**. While fuel range impact on E5 blends can considered **negligible,** E10 blends have a **1-2% range disadvantage** due to lower energy content of ethanol implying up to **1% cost increase per kilometre.** Range impact can be higher on E20 blends **(3-6%)** implying up to **3%+ cost increase per kilometre.**
VI Cost effectively improve fuel quality	↗	Ethanol could be a **cost-effective, cleaner octane enhancer for gasoline**. At 500–600 USD/tonne, it is cheaper than most alternatives (biobutanol 900+, MTBE/ETBE[1] 700+, reformate[2] 800+, alkylate[2] 600+, aromatics 1200+) and less toxic/corrosive than methanol (< 400)
VII Reduce GHG emissions	↗	Ethanol blends can support GHG emission reduction. Ethanol from corn and sugar have on average **25% and 61% lower emission content** than gasoline. At 5% or 10% blending rate this suggests a **1,25-3% or 0.5-4% emission reduction per km** after adjusting for the fuel efficiency impact. Significantly higher emission reductions could be achieved with ethanol from 2G feedstocks (90-110% emission reduction), but at significantly higher costs.
VIII Improve air quality & health outcomes	↗	Higher ethanol volume fuel (E85) can contain **85%+ less sulphur, aromatics, and benzene** compared to gasoline

1. Methyl Tertiary Butyl Ether (MTBE); Ethyl Tertiary Butyl Ether (ETBE)
2. Purposefully produced at oil refineries

Source: Expert interviews, OECD-FAO Agricultural Outlook 2022-2031, FAOSTAT, Reuters, EIA, EIA, University of Illinois, OPIS, CGIAR, Advanced Biofuels USA, Grains.org

I. US corn production data shows that annual production levels increased on average 20% since 2005

US annual corn production, Mn tonnes, 1990-2023



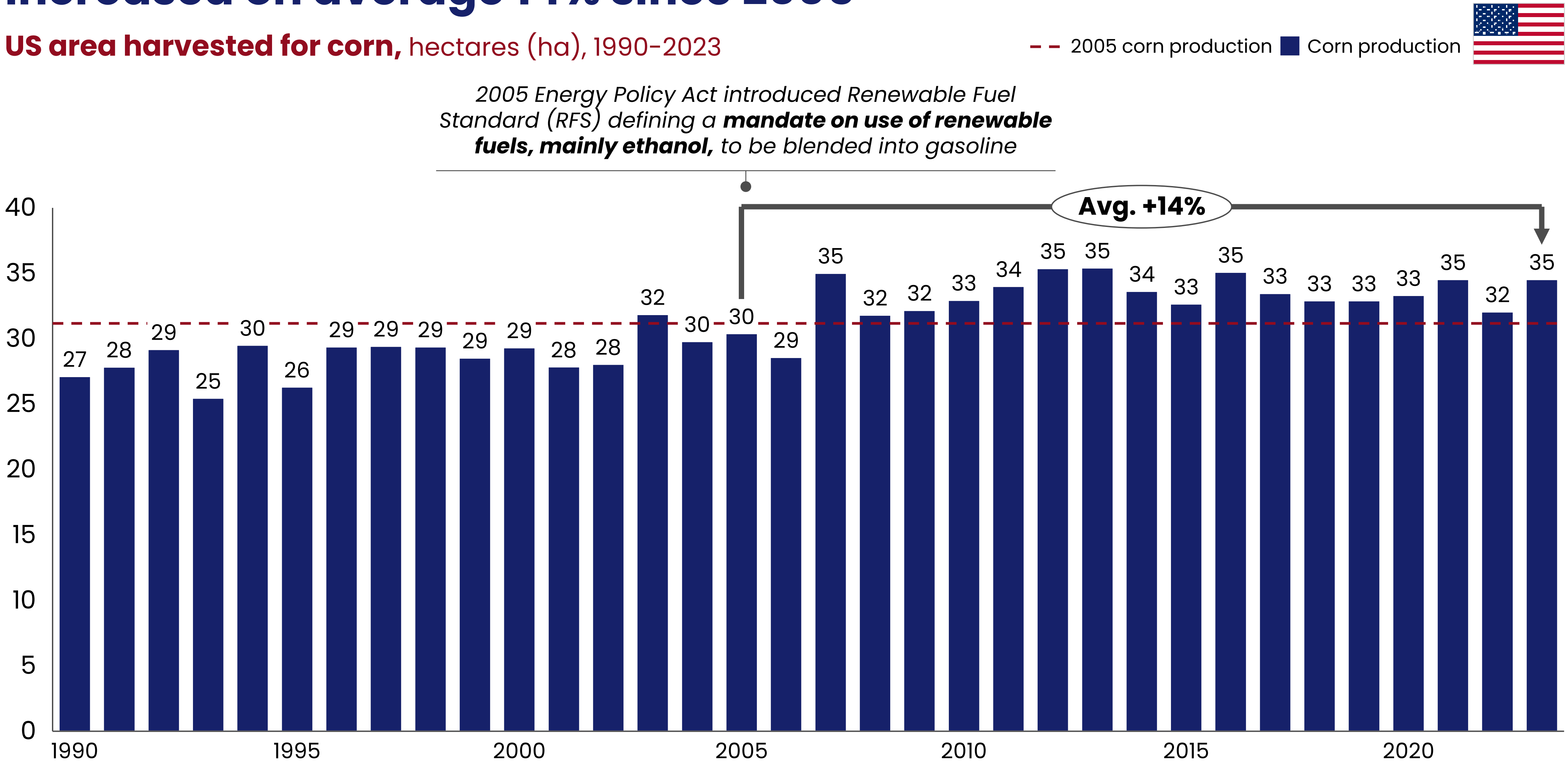
2005 Energy Policy Act introduced Renewable Fuel Standard (RFS) defining a ***mandate on use of renewable fuels, mainly ethanol,*** *to be blended into gasoline*

Manufacturing Africa

Source: OECD-FAO Agricultural Outlook 2022-2031

I. US harvest data shows that annual area harvested for corn has increased on average 14% since 2005

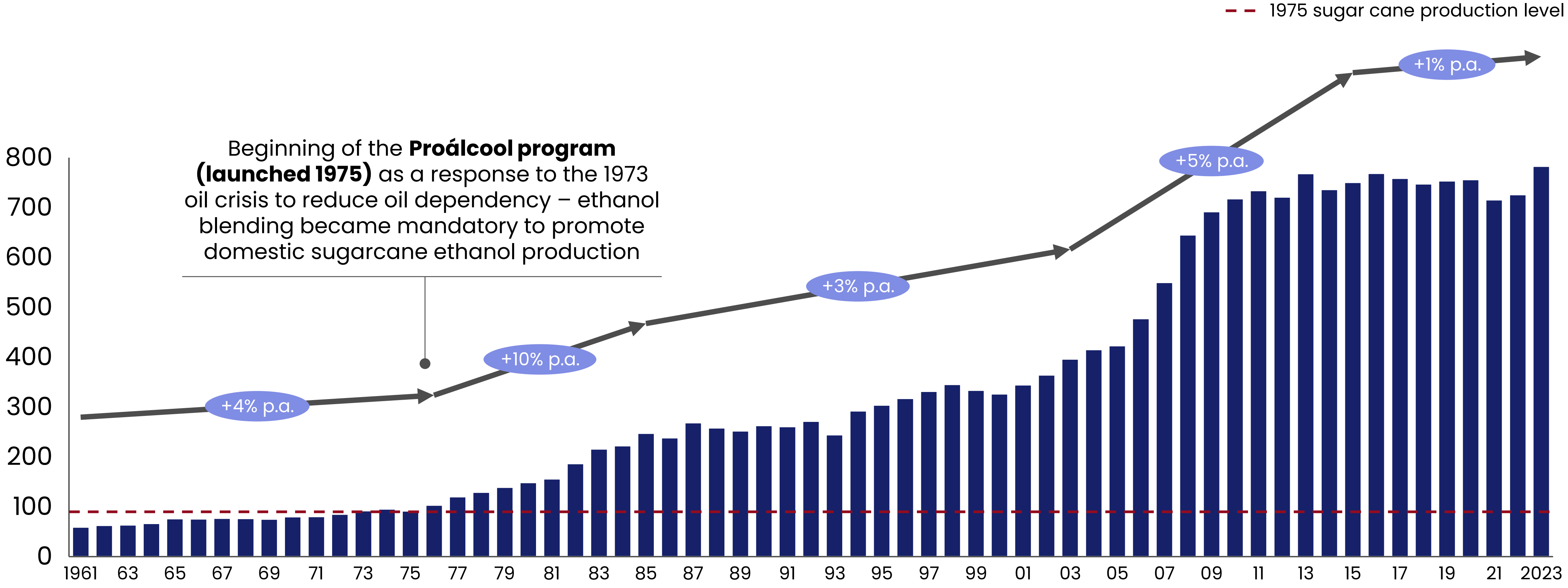
US area harvested for corn, hectares (ha), 1990-2023



Source: OECD-FAO Agricultural Outlook 2022-2031

I. Brazil sugar cane production data shows that annual production levels have increased since 1975

Brazil annual sugar cane production, Mn tonnes, **1961-2023**



Beginning of the **Proálcool program (launched 1975)** as a response to the 1973 oil crisis to reduce oil dependency – ethanol blending became mandatory to promote domestic sugarcane ethanol production

***1961-1975:** period before ethanol blending mandates*

***1976-1985:** aggressive mandate ramp up from E11 to E20*

***1986-2003:** mandate growth from E20 to E22 by 1988, and up to E25 by 2003*

***2004-2015:** mandate dropped to E20 by 2006 but grew to E27 by 2015*

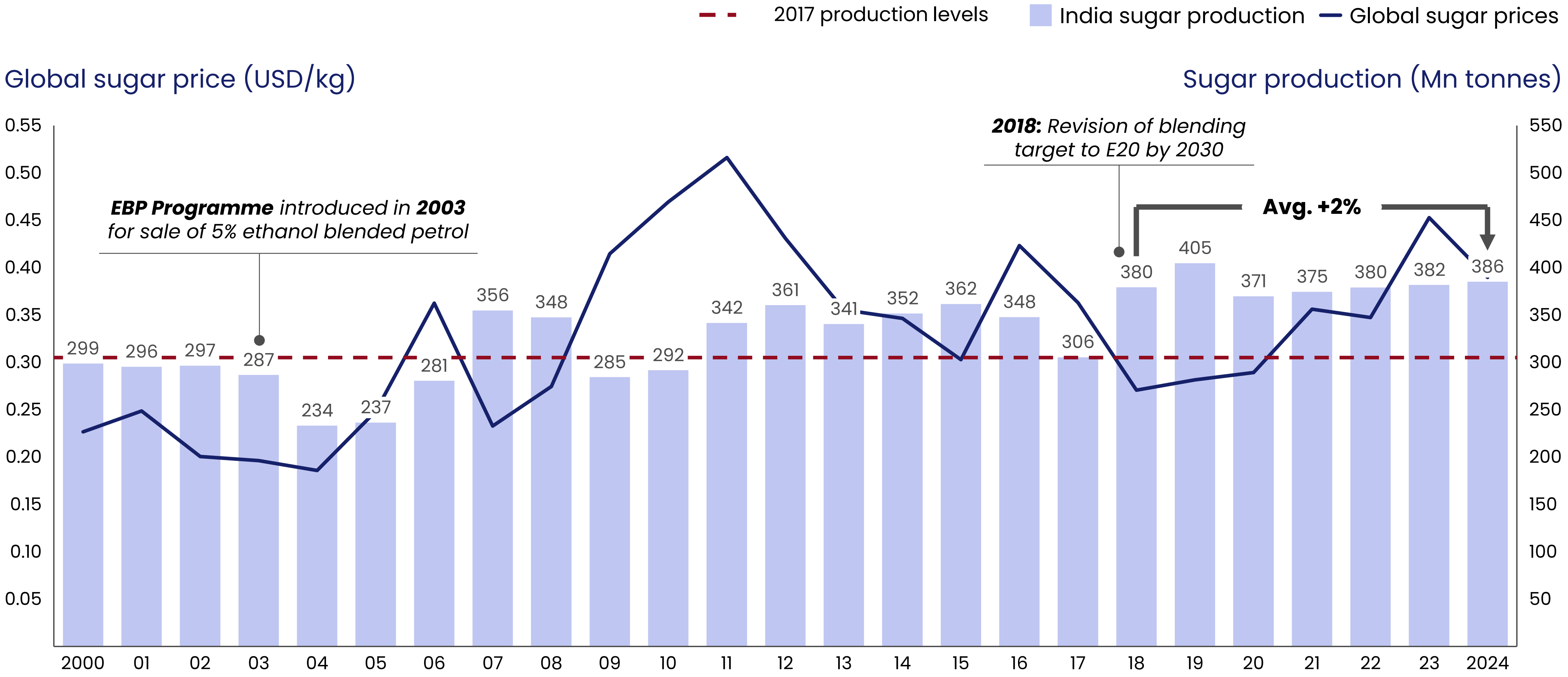
***2015-2025:** mandate now at E30 in August 2025*

Manufacturing Africa

Source: FAOSTAT

I. India sugar cane production data shows an average growth of 2% since the revision of the blending mandate in 2018

India annual sugar cane production (Mn tonnes) **and real global sugar prices** (USD/kg), 2000-24



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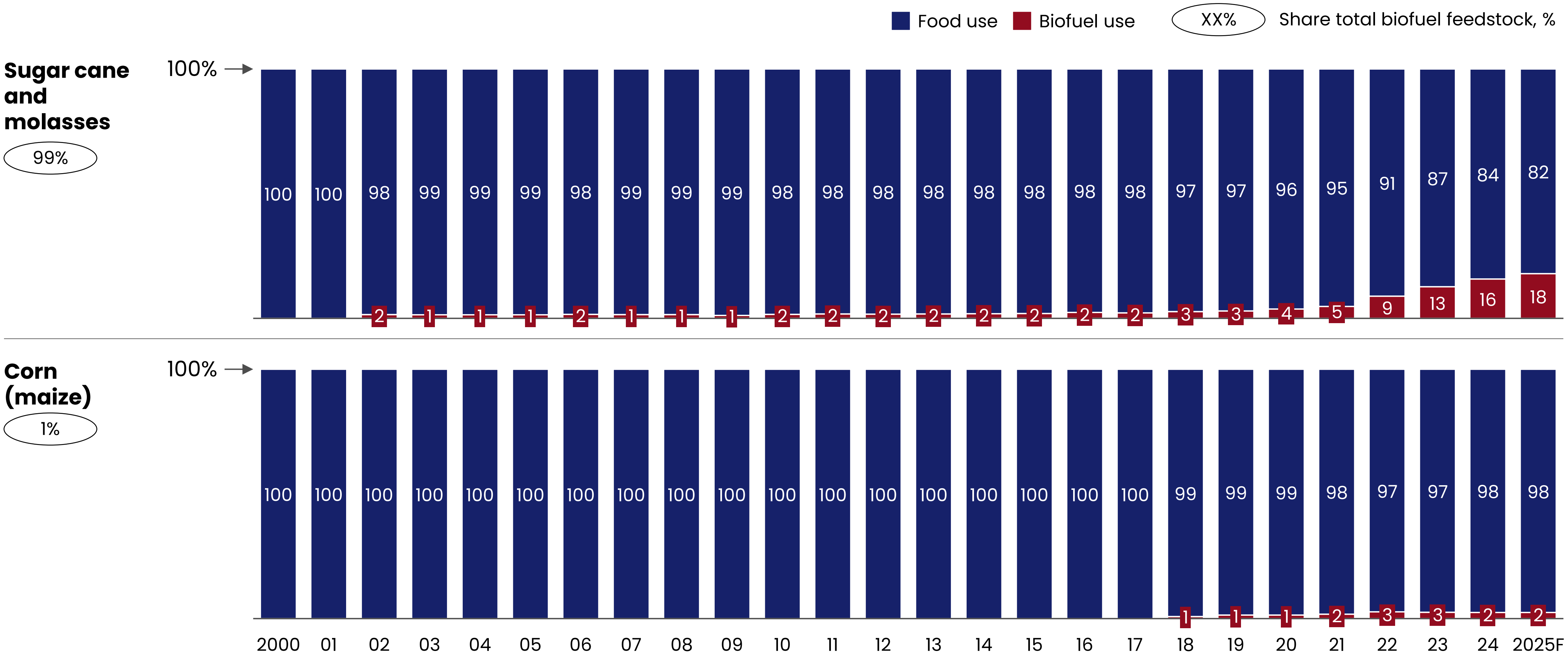
Source: OECD-FAO Agricultural Outlook 2022-2031

I. Sugar and molasses use for ethanol in India has grown steadily since 2018 due to increased mandates

Annual end market use for sugar cane and molasses, and corn in India, 2000-25F[1]



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UKaid

Source: OECD-FAO Agricultural Outlook 2022-2031

II. Impact of ethanol demand of feedstock prices is variable, with farmers potentially the biggest beneficiaries

🟢 Positive 🟡 Medium 🔴 Negative ↑ Increase = Stabilise ↓ Lower

	Feedstock (corn, sugar)		**Gasoline**[1]	
Scenarios	**Oversupply**	**Undersupply**	**Price hikes**	**Price drops**
Potential ethanol impact on feedstock prices	= Ethanol can provide **an alternative market for excess feedstock**, preventing sharp decline in prices	↑ Ethanol **competing with food demand** can drive feedstock prices up in the short-term	↑ Increased gasoline prices drive ethanol demand, which can **increase competition with food** in the short-term if supply is not sufficient	↓ Lower gasoline prices can impact demand for ethanol, **reducing competition with food** potentially lowering feedstock prices if no shocks to food demand
Potential impact on farmers	🟢 Stable prices for produce	🟢 Higher prices for their produce	🟢 Higher prices for their produce	🔴 Lower prices for their produce
Potential impact on ethanol producers	🟢 Availability of cheaper feedstock stock	🔴 Lower and more expensive feedstock stock	🟢 Increased market for ethanol	🟢 Availability of cheaper feedstock
Potential impact on consumers	🟡 Lower fuel cost; could prevent lower food prices	🔴 Higher fuel and food costs	🔴 Higher fuel and commodity costs	🟢 Lower fuel and commodity costs
Examples (US)	In 2024, higher **ethanol demand in the US (domestic and export) absorbed excess production of corn** potentially preventing further drop of corn prices	In 2012, the drought-induced **corn undersupply, coupled with strong ethanol demand from mandates** temporarily drove up corn prices; this also led to ethanol production cuts	In 2021-2022, surging crude oil and gasoline prices **boosted ethanol demand, intensifying competition for U.S. corn feedstock** and driving corn prices to their highest levels in years	The sharp drop in oil prices in 2014-2015 reduced **decreased the competitiveness and demand for ethanol** leading to lower ethanol and corn prices as a result

1. Impact potentially limited in the US given lower correlation between gasoline and ethanol compared to other regions (e.g., Brazil)

Source: Reuters – Oversized US corn crop responsible for swell in global supplies, EIA – U.S. fuel ethanol exports rise on strong international demand and low U.S. prices, EIA – Drought has significant effect on corn crop condition, projected ethanol production, FAO, NCEE - Impacts of Ethanol Policy on Corn Prices: A Review, University of Illinois - The New Upside-Down Relationship of Ethanol and Gasoline Prices, OPIS – US Ethanol Industry Explores Avenues for Expanding its Markets, Press search, Expert Interviews

II. Literature review: Various publications are inconclusive about the primary impact ethanol demand on feedstock prices (1/2)

NON-EXHAUSTIVE

			Highlighted scenario			
			Feedstock		Gasoline	
Source	**Focus period**	**Key takeaways**	**Oversupply**	**Undersupply**	**Hike**	**Drop**
University of Illinois: "The New Upside-Down Relationship of Ethanol and Gasoline Prices"	2014-2015	Highlights that **falling gasoline prices can lead to ethanol becoming less competitive, reducing its demand**. This can reduce feedstock price pressure in the short term, despite mandates. The price dynamic emphasizes **ethanol vulnerabilities to gasoline price fluctuations, leading to corn feedstock price volatility**.				✓
U.S. EIA: "U.S. fuel ethanol exports rise on strong international demand"	2023-2024	**Rising ethanol demand** from both domestic policies and export markets increases **pressure on feedstock supplies, pushing prices higher**. The linkage between gasoline pricing and ethanol drives demand impacting feedstock prices. **Supply constraints can lead to volatility in corn prices** and expanding ethanol markets intensify this feedstock competition.		✓	✓	
U.S. EIA: "Drought has significant effect on corn crop condition, projected …"	2012	Drought **limiting corn supply**, combined with **steady ethanol demand driven by mandates, exacerbate corn price spikes**. Such interactions highlight the **regulatory rigidity around ethanol blending contributing to heightened price responses** during adverse agricultural conditions.		✓		
CGIAR: "Food Versus Fuel v2.0: Biofuel Policies and the Current Food Crisis"	2020-2023	Biofuel mandates have **increased demand for feedstock commodities, intensifying food versus fuel competition**. This has contributed to **short-term food price spikes and volatility**, with negative impacts on global food security, especially in developing countries.		✓		

Source: Links on page

II. Literature review: Various publications are inconclusive about the primary impact ethanol demand on feedstock prices (2/2)

NON-EXHAUSTIVE

			Highlighted scenario			
			Feedstock		Gasoline	
Source	Focus period	Key takeaways	Oversupply	Undersupply	Hike	Drop
FAO: "The rise in crude oil prices stimulates ethanol-related demand for feedstocks"	2001-2006	Rising crude oil prices increase ethanol demand, driving up demand and prices for feedstocks. This increases **competition between fuel and food markets, generally pushing food prices higher**.			✓	
EPA report: "Impacts of Ethanol Policy on Corn Prices"	2008-2013	Ethanol mandates are estimated to **increase corn prices by 20-30% above what they would otherwise be**.		✓		
Reuters: "Oversised US corn crop responsible for swell in global supplies"	2023-2024	An oversized US corn production crop in 2023-24 **demonstrated ethanol's role as an alternative market** that can absorb excess supply. Ethanol helped stabilise or lower corn prices short-term. However, this balance is **delicate and can reverse quickly with demand or supply shocks**.	✓			
USDA Foreign Agricultural Service: "Biofuels Annual India 2025"	2020-2023	India's expanding **ethanol program is increasing demand for feedstocks, raising feedstock prices**.		✓		
ScienceDirect: "The impact of energy prices on the…"	2020-2025	The study finds a significant link between energy prices (crude oil/gasoline) and ethanol demand, which in turn affects feedstock prices. **Volatility in energy prices transmits to agricultural markets through ethanol demand**.			✓	✓

Source: Links on page

II. US Mandates: EPA blending mandate waivers primarily impact energy security, with limited focus on stabilising agricultural prices

Examples federal mandate waivers by the EPA[1]

Period	Mandate adjustment	Rational
2010 - 2011	E15 Waiver (15% ethanol blend for +2007 models)	**Energy security:** Regulatory adjustment to allow for higher ethanol adoption in line with Energy Independence and Security Act of 2007
2012	Multistate fuel waiver during Hurricane Sandy	**Energy security:** Pipeline and fuel **distribution disruptions** in Northeast US
2016 - 2025	Small refinery exemptions (SREs) granted	**Support of small refiners:** SREs argued **biofuel mandates imposed financial burdens** and received exemptions to ensure economic viability
May - Sept 2023; 2024 – 2025	Multiple short-term waivers allowing E15 sales during summer months	**Fuel price reduction:** Reduce customers pump price during time of gasoline price hikes

Over the past two decades, EPA waivers have aimed to boost ethanol use to **ease pressure on gasoline demand, address supply disruptions,** and **support local refineries**

There appears to be **limited focus on stabilising agricultural prices** using flex mandates

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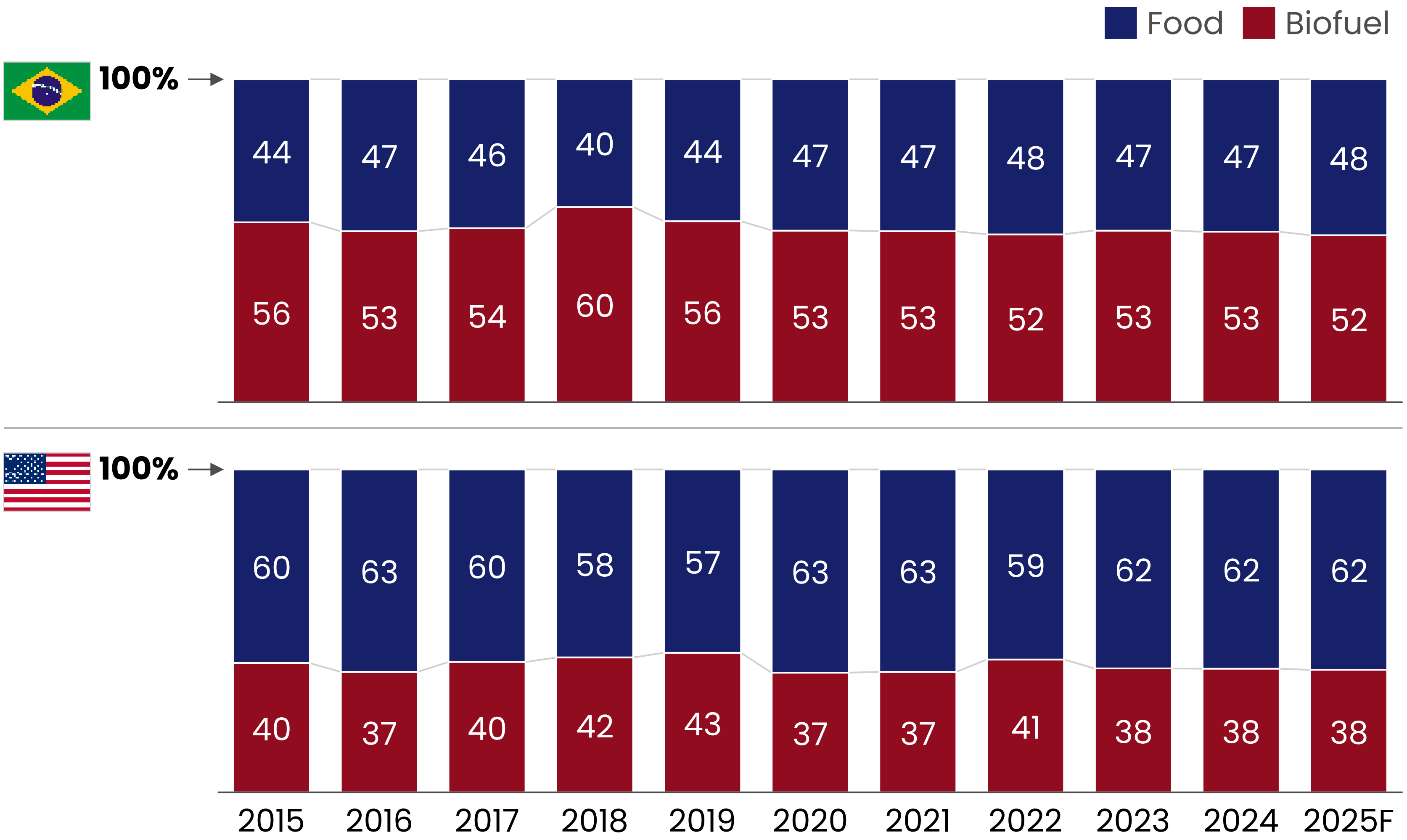
1. Environmental Protection Agency
2. A measure of the volatility of gasoline and other petroleum products

Source: Press search, EPA

II. Biofuel production enables farmers in Brazil and the US to hedge and secure demand

Annual end market use of sugarcane in Brazil and corn in the US, 2015-25F[1]



Key takeaways

Biofuel production has **flexed between 52-60%** of sugarcane use in Brazil and **37-43%** of corn use in the US since 2015 – producers **switch based on profitability of the end market** (i.e., sugar & ethanol) at any given time

Biofuel production provides farmers with a baseload domestic demand enabling them to **hedge against volatile global prices** (e.g., sugar is an export product in Brazil whose prices can be driven by demand in the US and China)

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1. Forecasted

Source: OECD-FAO Agricultural Outlook 2022-2031, Expert interviews

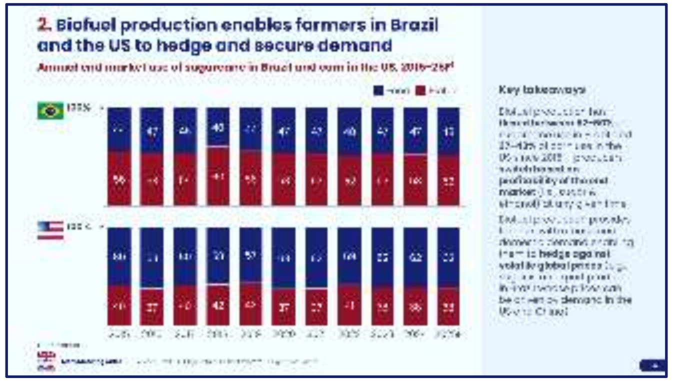
II. Sugarcane producers in Brazil are highly integrated, allow flexing

Sugarcane producers in Brazil are highly integrated…

Sugarcane producers, such as Consecana[1] in São Paulo, are **highly integrated**, with many producing both sugar and ethanol; approximately **50% of sugarcane** is grown on plantations owned by mills or distilleries

Producers typically operate their plants at **5-10% below optimal capacity** to maintain flexibility, enabling them to switch between sugar and ethanol production based on prevailing profit margins

… allowing them to easily flex between ethanol and sugar production…



2. Biofuel production enables farmers in Brazil and the US to hedge and secure demand

Key takeaways

Ethanol production has **flexed between 52-60%** of sugarcane use in Brazil since 2015 – producers switch based on profitability of the end market (i.e., sugar & ethanol) at any given time

… while setting sugar cane prices to ensure relative market stability

Consecana[1] sets sugar cane prices monthly based on the:

Monthly TRS (total recoverable sugars) prices – weighted average of each of the 9 index prices with their production share/mix

TRS content (kgs of TRS per tonne of cane)

Cane price = TRS price per kg * TRS content in kg per tonne of cane

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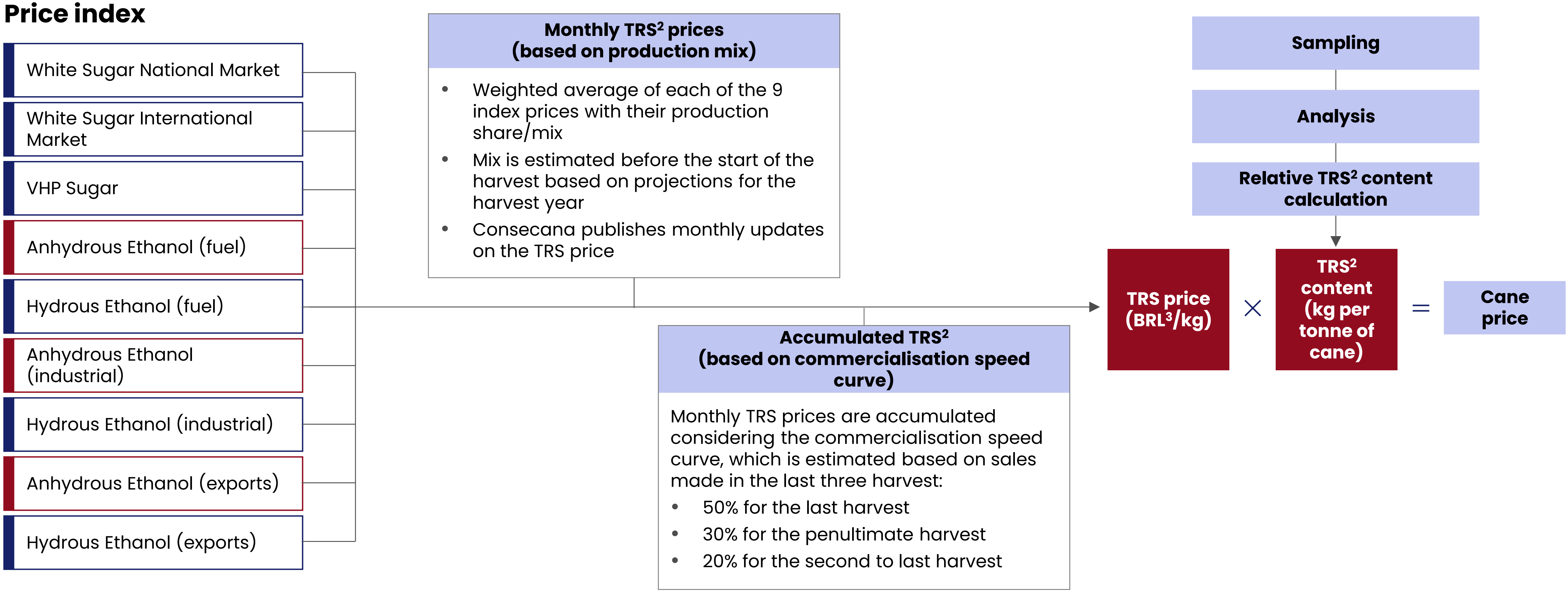
1. Conselho dos Produtores de Cana-de-açúcar, Açúcar e Álcool do Estado de São Paulo (São Paulo State Council of Sugarcane, Sugar, and Ethanol Producers)

Source: Expert interviews

II. In Brazil, Consecana calculates cane prices limiting adverse impacts from any one commodity

Calculation overview for Consecana[1] using production mix and commercialisation speed curve



Price index

- White Sugar National Market
- White Sugar International Market
- VHP Sugar
- Anhydrous Ethanol (fuel)
- Hydrous Ethanol (fuel)
- Anhydrous Ethanol (industrial)
- Hydrous Ethanol (industrial)
- Anhydrous Ethanol (exports)
- Hydrous Ethanol (exports)

Monthly TRS[2] prices (based on production mix)

- Weighted average of each of the 9 index prices with their production share/mix
- Mix is estimated before the start of the harvest based on projections for the harvest year
- Consecana publishes monthly updates on the TRS price

Accumulated TRS[2] (based on commercialisation speed curve)

Monthly TRS prices are accumulated considering the commercialisation speed curve, which is estimated based on sales made in the last three harvest:

- 50% for the last harvest
- 30% for the penultimate harvest
- 20% for the second to last harvest

Sampling

Analysis

Relative TRS[2] content calculation

TRS price (BRL[3]/kg) × **TRS[2] content (kg per tonne of cane)** = **Cane price**

---

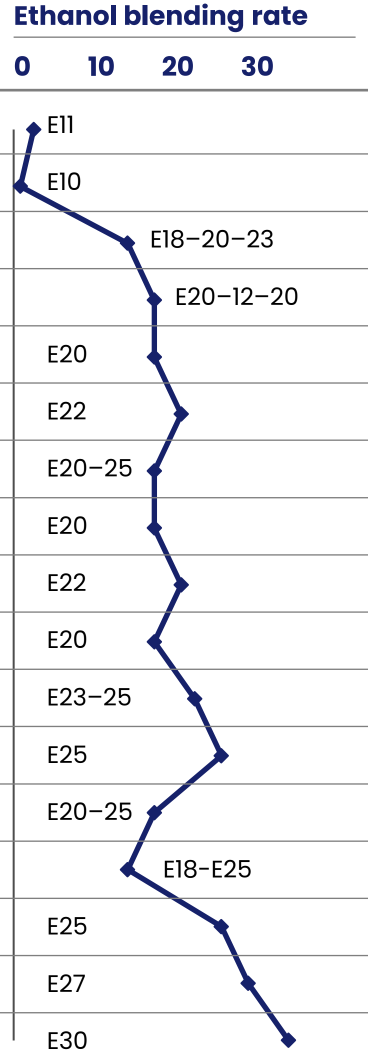
1. Conselho dos Produtores de Cana-de-açúcar, Açúcar e Álcool do Estado de São Paulo (São Paulo State Council of Sugarcane, Sugar, and Ethanol Producers)
2. Total recoverable sugars (TRS) - measure of the total amount of sugars available in sugarcane
3. Brazilian Real

Source: Consecana, AgroAdvance

II. Brazil steadily raised its ethanol blending mandate since the 1970s, temporarily lowering it during shortages or price spikes

Evolution of Brazil's ethanol blending rate

! Illustrated rate is the regulated minimum for blending anhydrous ethanol (contains ~1% water); Brazil has flex fuel cars that can use up to 100% hydrous ethanol (contains ~4-5% water) ***– both options typically at the pump***



Period	Ethanol blending rate	Reason for mandate change: Stabilisation of fuel costs	Reason for mandate change: Support for sugar market	Explanation
1976	E11	✓		Beginning of the Proálcool program (launched 1975) as a response to the 1973 oil crisis to reduce oil dependency – ethanol blending became mandatory to promote domestic sugarcane ethanol production
1977	E10		✓	Blend adjusted slightly within early stages of Proálcool, reflecting the initial ramp up of ethanol use
1978	E18–20–23	✓		Gradual increase in mandate blending to support expanding ethanol production capacity and increasing gasoline substitution
1981	E20–12–20		✓	Blend fluctuated due to sugarcane harvest variability and supply-demand dynamics
1984–86	E20	✓		Stabilisation of blending mandates as ethanol industry matured and flex-fuel technologies slowly developed
1987–88	E22	✓		Ethanol blending mandated at 22% by volume as government policy to maintain ethanol market share
2003	E20–25	✓	✓	Legal limits established for ethanol blending at minimum 20% and maximum 25% - allowed adaptation to harvest yields, stabilisation of prices, and market conditions
2004	E20		✓	Adjusted to manage ethanol supply fluctuations amid growing flex fuel vehicle adoption
2005	E22	✓		Increase back towards upper limits due to improved ethanol availability
2006	E20		✓	Slight decrease responding to ethanol supply constraints and price variability
2007	E23–25	✓		Mandate raised to 25% (E25) reflecting stabilised supply and policy focus on reducing fossil fuel use
2008–09	E25	✓		Maintained high blend level coinciding with peak flex-fuel car market penetration reducing gasoline use
2010	E20–25	✓	✓	Temporary reduction to 20% early 2010 due to ethanol supply shortages and high prices, then readjusted
2011	E18-E25		✓	Blend floor reduced to 18% to manage recurring ethanol supply shortfalls
2013	E25	✓		Increased back to 25% as ethanol supply and production rebounded supporting higher blending
2015	E27	✓		Temporarily raised to 27% as incentive to consume ethanol surplus and support the ethanol industry
2025	E30	✓	✓	Raised to 30% due to increased ethanol production

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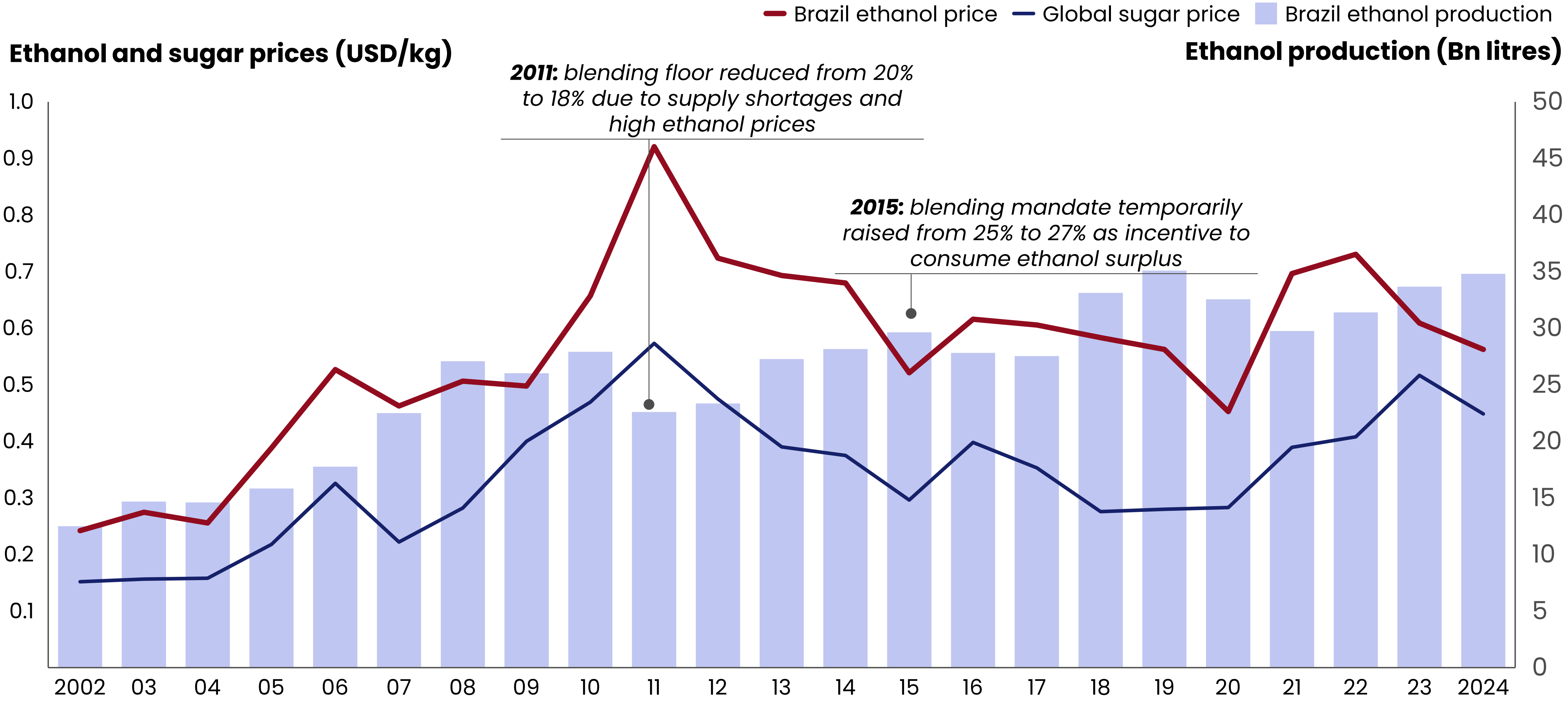
Source: Expert interviews, Press search

II. Since 2002, global sugar prices have mirrored Brazil’s domestic ethanol price

Brazil ethanol and global sugar prices (USD/kg), and ethanol production (Bn litres), 2000-24



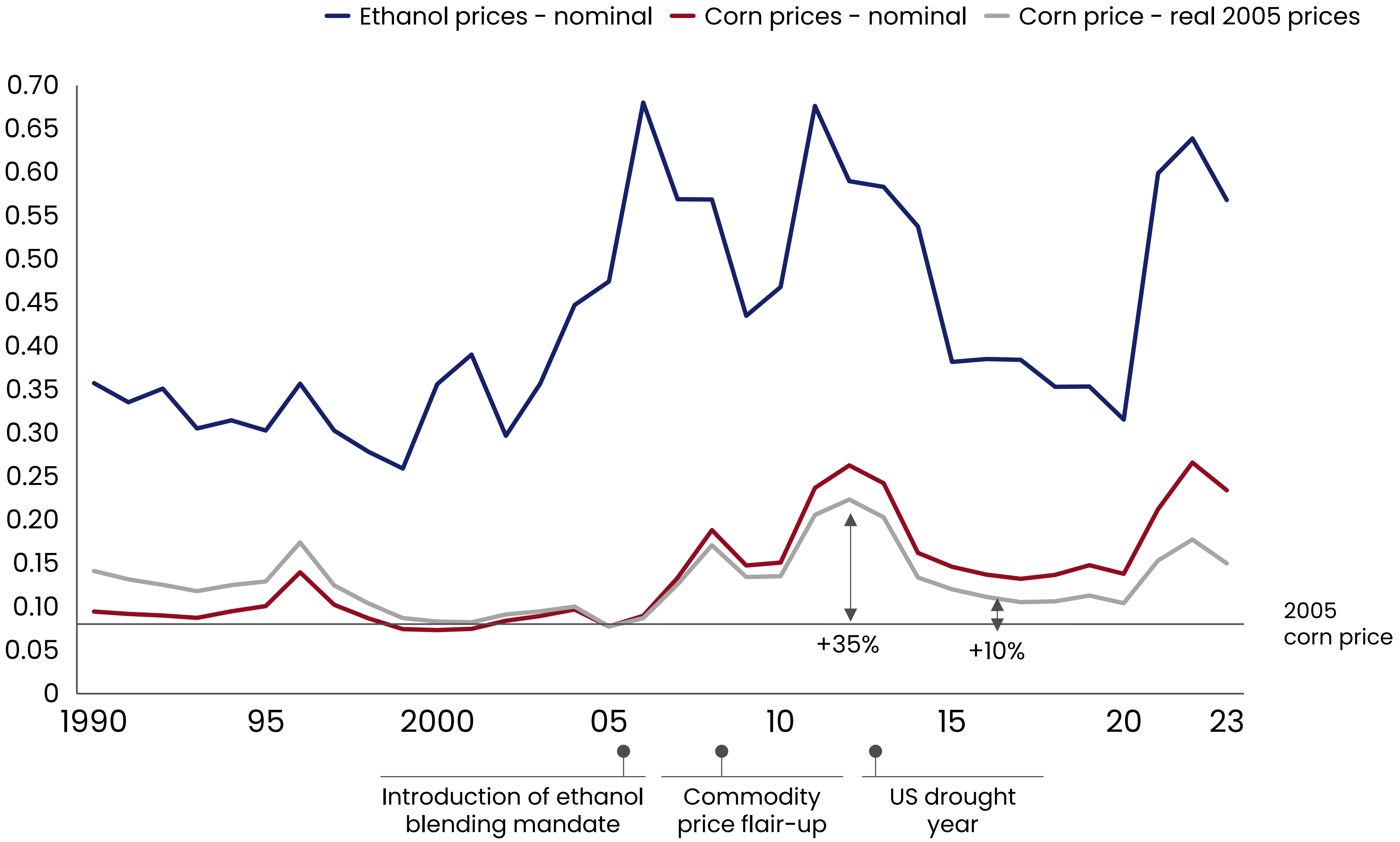
***2011:** blending floor reduced from 20% to 18% due to supply shortages and high ethanol prices*

***2015:** blending mandate temporarily raised from 25% to 27% as incentive to consume ethanol surplus*

Source: CEPEA - Center for Advanced Studies of Applied Economic University of Sao Paolo, Conab, World Bank Group

III. Since introduction of blend mandates, corn prices have mirrored ethanol price and increased by +10%

US ethanol and corn prices (USD/kg), 1990-2023



In 2005, the Energy Policy Act introduced the Renewable Fuel Standard (RFS) defining a **mandate on use of renewable fuels**, mainly ethanol, to be blended into gasoline

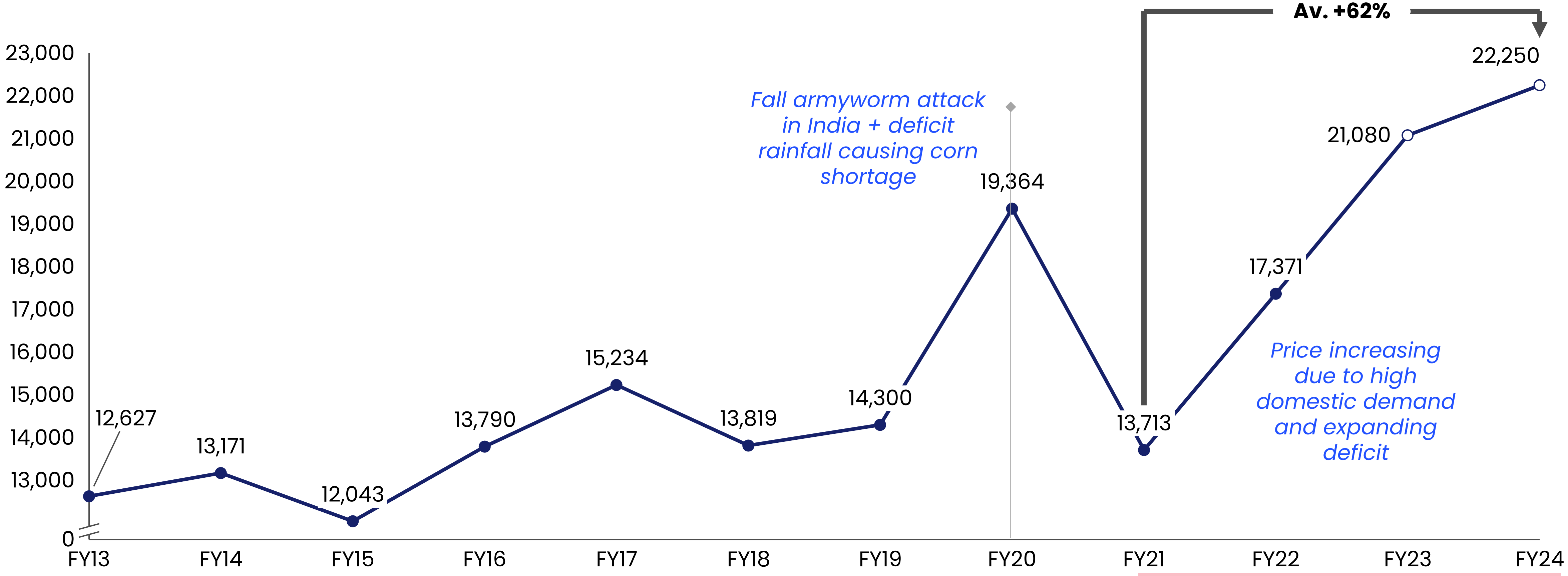
Since then, the **ethanol and corn price** have been **strongly correlated** with the ethanol reacting to corn price shocks (e.g., 2012 drought) and the corn price reacting to commodity prices (e.g., 2008 commodity price flair up due to high fuel demand in emerging markets)

Real corn prices have gone up by **+10%** since the introduction of the ethanol mandate. Yet, definitive conclusion on causal relationship cannot be made.

Source: USDA, FAOSTAT

III. Diversion of corn to ethanol has put pressure leading to led to on average 62% higher prices since 2021

Corn prices[1], INR/tonne



Fall armyworm attack in India + deficit rainfall causing corn shortage

Price increasing due to high domestic demand and expanding deficit

***2021:** Revision of E20 mandate target achievement from 2030 to 2025-26 accelerating the need for alternative feedstock (e.g., corn)*

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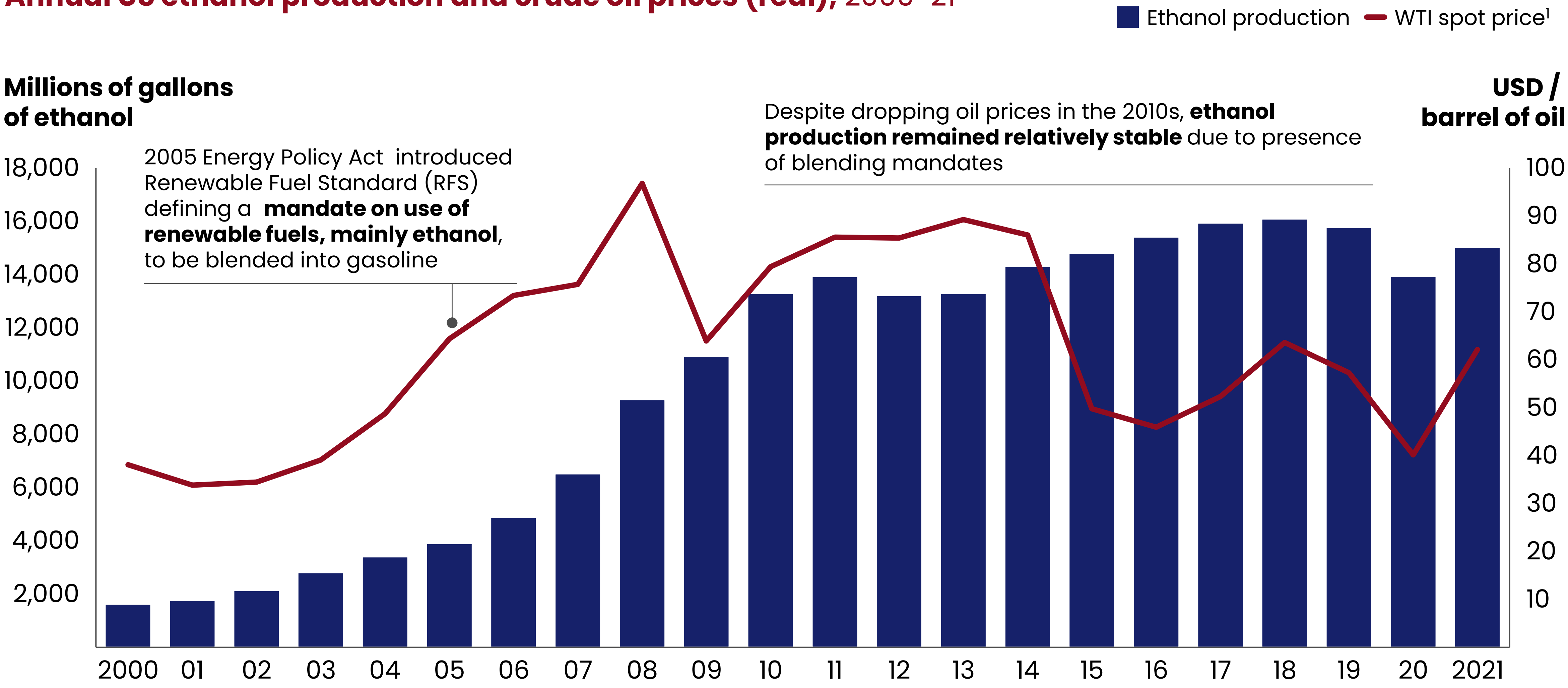
1. Annual average of corn prices for markets across Karnataka, Maharashtra

Source: Expert interviews, Press Search

IV. Fuel prices have historically driven uptake of ethanol as a fuel substitute

Annual US ethanol production and crude oil prices (real), 2000-21



2005 Energy Policy Act introduced Renewable Fuel Standard (RFS) defining a **mandate on use of renewable fuels, mainly ethanol**, to be blended into gasoline

Despite dropping oil prices in the 2010s, **ethanol production remained relatively stable** due to presence of blending mandates

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1. WTI - West Texas Intermediate

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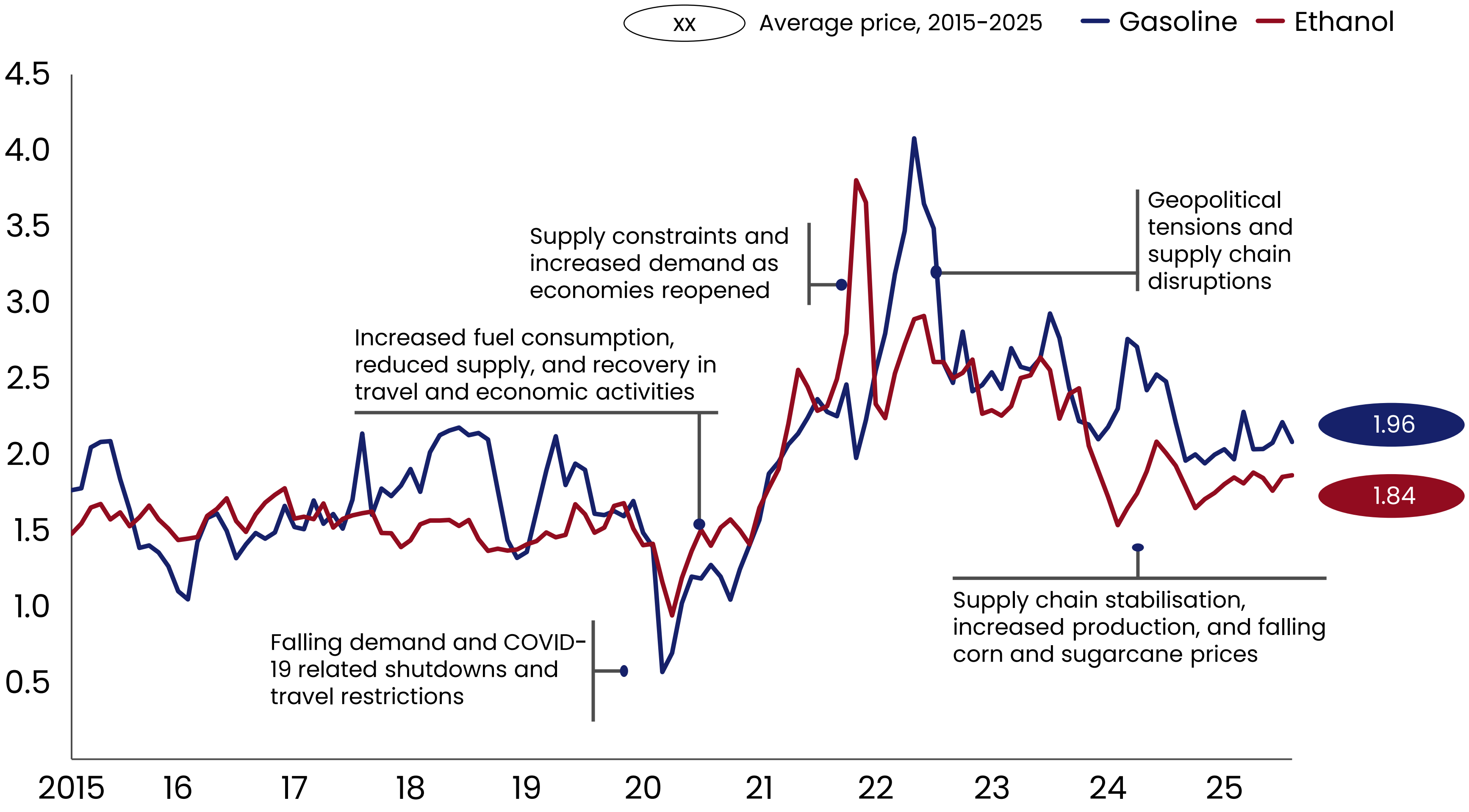
Source: Renewable Fuels Association and Federal Reserve Bank of St. Louis, NREL – History of Ethanol Fuel Adoption in the United States: Policy, Economics, and Logistics, World Bank Commodity Price Data (The Pink Sheet) – May 2025 update, US Energy Information Administration, Press search

V. Ethanol price tends to trend below the gasoline price, while volatility is driven by shocks to the gasoline and feedstock price

Global month on month gasoline and ethanol prices, USD per gallon, 2015-2025



Supply constraints and increased demand as economies reopened

Geopolitical tensions and supply chain disruptions

Increased fuel consumption, reduced supply, and recovery in travel and economic activities

Falling demand and COVID-19 related shutdowns and travel restrictions

Supply chain stabilisation, increased production, and falling corn and sugarcane prices

Gasoline and ethanol prices are correlated due to their **interconnected role in the energy market**

Ethanol prices can differ from gasoline due to **feedstock costs and availability**, which are seasonal and weather-dependent

Since 2015-25, ethanol spot price has been **7% lower on average** (1.84 vs. 1.96 USD/gallon)

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Source: Investing.com (CME), Trade economics, Expert market research – Ethanol Price Trends and Forecast Report 2025 Edition, S&P Global, Oil Price Information Service, Center for Agricultural and Rural Development (CARD), Expert interviews

V. While ethanol may be cheaper than gasoline per unit, fuel economy losses can drive higher adjusted fuel costs at higher blends

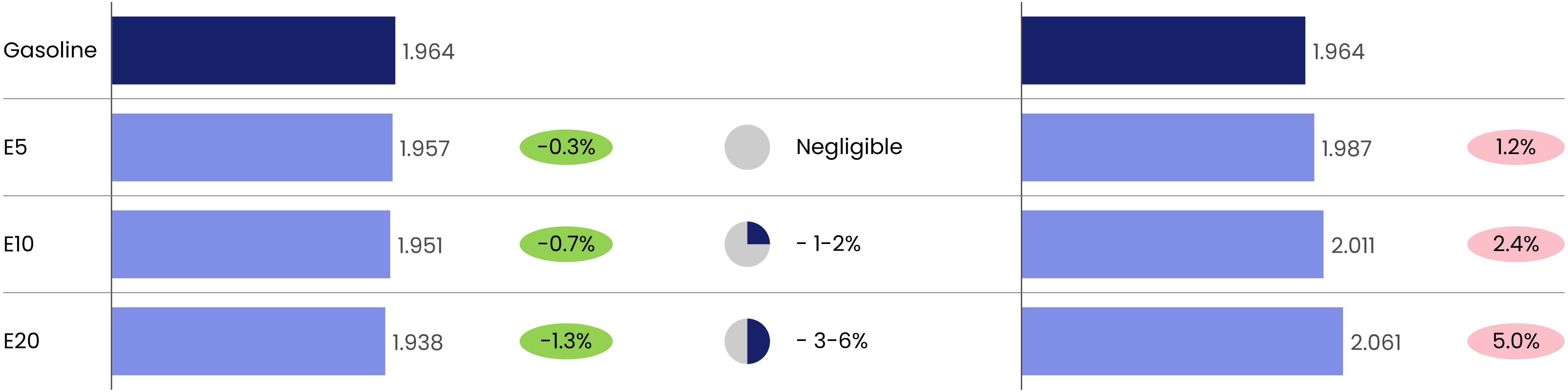
XX Percentage difference between price of ethanol blends and gasoline ● High ○ Low

Standard car[2]

Gasoline vs. implied prices for blends[1], USD/gallon

Range impact[3]

Fuel economy adjusted price comparison, USD/gallon



Gasoline	1.964				1.964	
E5	1.957	-0.3%	○	Negligible	1.987	1.2%
E10	1.951	-0.7%	◔	- 1-2%	2.011	2.4%
E20	1.938	-1.3%	◑	- 3-6%	2.061	5.0%

Standard cars are typically produced in **Asia** (e.g., Japan) **and Europe**

1. Implied blend price – reflects the weighted average price based on fuel mix percentages; 2015-205 average spot price for gasoline used; Estimated average (2015-2025) spot price for ethanol used – 1.835 USD/gallon
2. Most standard cars use E10 blend without requiring modifications (built post-2000). Alternatively, flex fuel cars operate on any mixture of ethanol, usually up to 85% ethanol (E85), with the fuel blend automatically detected by sensors, allowing the engine to adjust fuel injection and combustion for optimal performance. These can be found in Brazil, US, Canada, and parts of Europe (e.g., Sweden). Flex fuel cars do not experience fuel economy losses when using ethanol blends
3. Accounts for the 30% less energy content in ethanol compared to gasoline and potential advantages from higher octane content for ethanol

Source: Investing.com (CME), Trade economics, American Coalition for Ethanol – Optimal Ethanol Blend-Level Investigation, Expert interviews, ACEA – Vehicle Compatibility List 2022 update, Foray Motor Group

VI. Ethanol could be a cost-effective and cleaner gasoline octane enhancer than alternatives

Comparison of key gasoline octane enhancers

AS OF OCT 2025

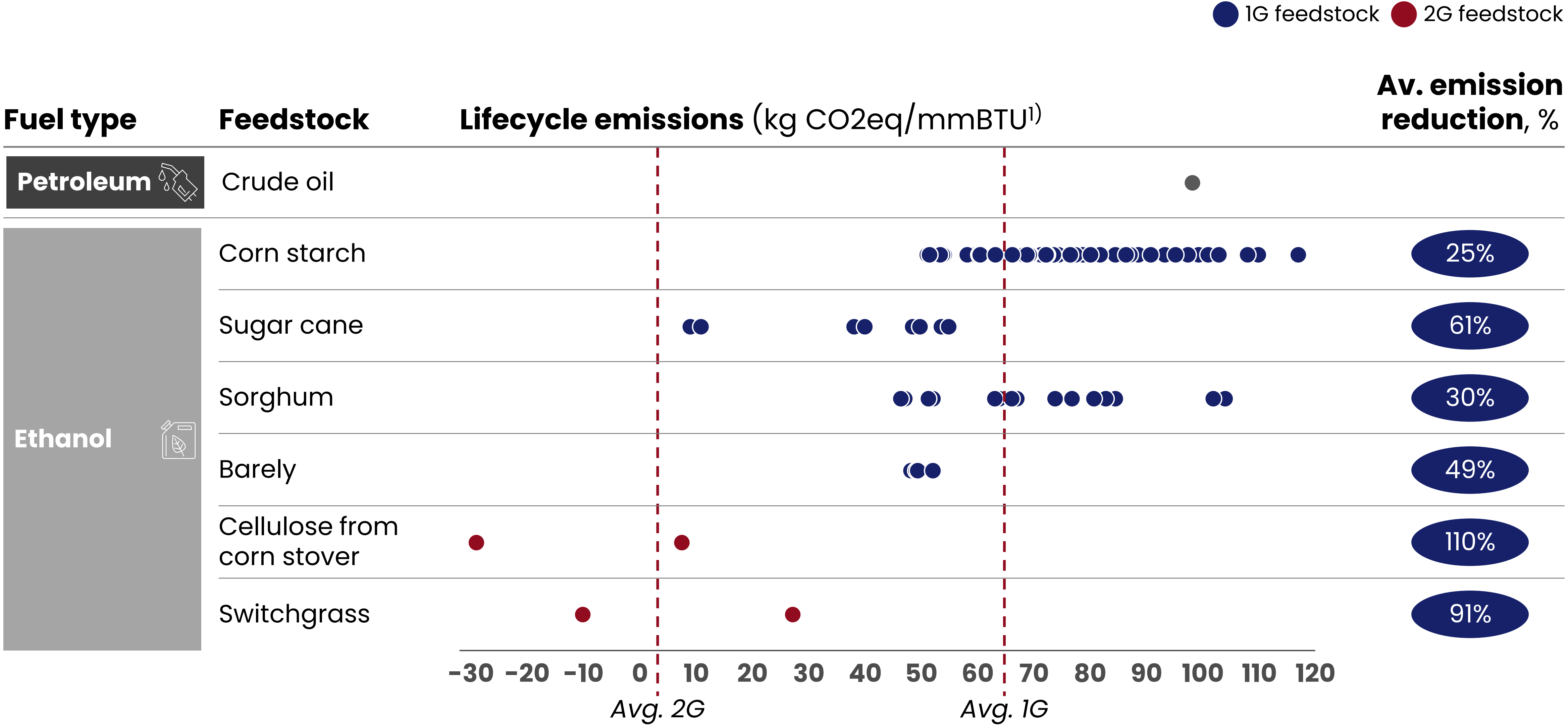
▍ Purposefully produced at oil refineries 🌿 Bio-based 🛢 Petrochemical ⚗ Chemical specialty - - Estimated ethanol price

Octane Enhancer	**Source**	**Example regions used**	**Estimated global spot price**, USD/tonne	**Additional considerations**
Ethanol	🌿	🇺🇸 🇨🇦 🇮🇩 🇨🇳 🇮🇳 🇧🇷	500-600	Clean burning, renewable, miscibility with gasoline, moderate octane improvement
Biobutanol[1]	🌿	🇺🇸	960-990	Higher energy density than ethanol, better blending properties, less water absorption
MTBE (Methyl Tertiary Butyl Ether)	🛢	🇨🇳 🇲🇽 🇮🇩	740-880	High octane boost, environmental concerns (groundwater contamination), use restricted in many regions
Methanol	🛢 🌿	🇨🇳 🇮🇳	260-360	Low cost, corrosive, toxic, often used in blends, moderate octane enhancement
ETBE (Ethyl Tertiary Butyl Ether)	🛢	🇯🇵 🇪🇺	700-900	Derived from ethanol, good octane enhancer, similar toxic groundwater risk as MTBE
Aromatic amines	⚗	🇺🇸 🇨🇦	1200-3000	High cost, specialty chemical, not a primary enhancer but additive for specific gasoline properties
▍ **Petroleum reformate**	🛢	🇯🇵 🇪🇺	800-1100	Derived from ethanol, good octane enhancer, similar toxic groundwater risk as MTBE
▍ **Petroleum alkylate**	🛢	🇺🇸 🇨🇦	600-900	High cost, specialty chemical, not a primary enhancer but additive for specific gasoline properties

1. While it is allowed in some regions, it has limited uptake due to higher costs

Source: S&P Global, Stratas Advisors, Research Nester Octane Improver Fuel Additives Market, Fortune Business Insights Gasoline Octane Improvers Market, Verified Market Reports Octane Boosters Market, Global Octane Number Enhancer Market Analysis, Data Intelo Octane Boosters Market, Expert interviews

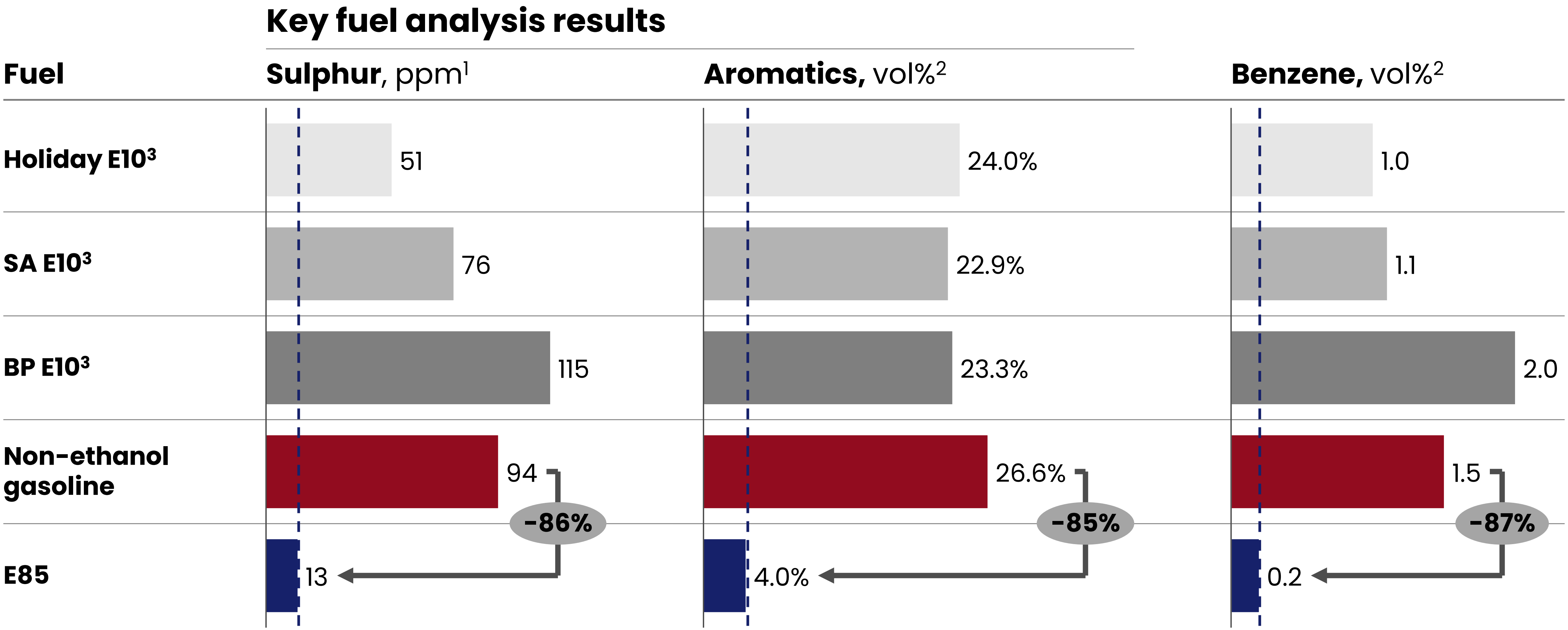
VII. Ethanol lifecycle GHG emissions are on average 30% lower than baseline gasoline



1. Kilograms of CO2 equivalent per million British thermal units (kg CO2e/mmBTU)

Source: United States Environmental Protection Agency

VIII. Higher ethanol volume fuel (E85) can contain 85%+ less sulphur, aromatics, and benzene compared to gasoline



Tailpipe emissions study was performed on a 2004 Ford Explorer Sport Trac flexible fuel vehicle equipped with a 4.0-litre engine

1. ppm –Parts per million, weight basis
2. Volume percent
3. Study used 3 brands of E10 fuel

Source: University of North Dakota Energy & Environmental Research Center – Comparison of Carbon Dioxide Emissions from Gasoline and E85

Contents

Executive summary

Biofuels overview, scope, and context in Africa

Details on approach for sizing the opportunity for biofuels in Africa

Appendix 1: Africa biofuel feedstock availability assessment

Appendix 2: Use case deep-dives

Appendix 3: Lessons learned on biofuels adoption from other countries

Appendix 4: Methodology

We excluded use cases that are technologically immature or too expensive to be viable, even with strong policy support (1/2)

🔵 1G ◐ 1G/ 2G 🔴 2G

Use case	Traditional fuel	Biofuel	Feedstock	Rationale for exclusion
Road	Gasoline	Ethanol	🔴 Agriculture waste	• Ethanol from agricultural waste costs 0.8-1.3 USD/tonne, compared to 0.5-0.95 USD/tonne for domestic ethanol production. Wood residue-based ethanol is costlier due to immature technology • Ethanol production from waste remains small-scale, capped at 30Mn litres annually • Scaling waste aggregation is difficult. Only major forestry and bagasse producers meet large-scale ethanol plant needs. Rice husk and corn stalks face aggregation challenges due to smallholder farming and low mechanisation
		Renewable gasoline	🔴 Agriculture or municipal waste, purposefully grown dry matter	• Cost 3-6x higher than gasoline in the short-term due to immature technology
	Diesel	Renewable diesel (HVO)	◐ Oil crops and waste oils	• HVO production cost (2020–2024): 1.30–2.5 USD/L vs diesel pump price: 0.2–0.8 USD/L (<60% from crude oil and refining). By 2035, HVO cost may drop to 0.9 USD/L, remaining more expensive than diesel but being most cost effective against other drop-in fuels
			🔴 Agriculture or municipal waste, purposefully grown dry matter	• HVO from dry biomass via Fischer Tropsch Gasification costs 2-2.5x more than 1G production, with the gap expected to remain as both technologies advance
			🔵 starch and sugar-based crops	• HVO from sugar crops uses the Power-to-liquid process, which is less mature and currently costs 3x more to produce in Europe. By 2035, the cost gap is projected to narrow but will remain higher than 1G. These crops will likely continued to be used for more cost-effective ethanol production
Cooking		Bio-methane	🔴 Manure, agriculture or municipal waste	• Not commonly used for cooking; biomethane has higher gas content and is used to replace natural gas in industrial processes. Production of biomethane, however, is more CAPEX intensive (+25%).
		Ethanol	🔴 Agriculture waste	• High cost (see ethanol for road); cooking applications are even more cost-sensitive given the availability of competitive alternatives and the limited purchasing power of households.

Source: Expert interviews

We excluded use cases that are technologically immature or too expensive to be viable, even with strong policy support (2/2)

🔵 1G ◐ 1G/ 2G 🔴 2G

Use case	Traditional fuel	Biofuel	Feedstock	Rationale for exclusion
Maritime	Natural Gas	Bio-methane	🔴 Manure, agriculture or municipal waste	- By 2030, methanol fuelled vessels likely to maintain <30% TCO gap with conventional ships. Demand (<0.1%) will come from firms prioritising sustainability or operating in regions with strict regulations (e.g., Maersk)
	Diesel	FAME diesel	◐ Oil crops and waste oils	- Currently not widely used for maritime applications
		Renewable diesel (HVO)	🔴 Municipal waste or purposefully grown dry matter	- HVO from dry biomass via Fischer Tropsch Gasification costs 15% more than oil crop based production, with the gap likely to remain as both technologies evolve
			🔵 starch and sugar-based crops	- Economics for HVO from non-oil feedstocks will similarly be higher
Aviation	Kerosene	SAF refining	🔵 starch and sugar-based crops	- High cost (see HVO for road)
			🔴 Agriculture or municipal waste, purposefully grown dry matter	
Power & Heat Generation	Any non-green fuel for power or heat generation	Renewable diesel (HVO)	◐ Oil crops and waste oils	
			🔴 Municipal waste or purposefully grown dry matter	
		FAME diesel	◐ Oil crops and waste oils	- Production cost more than + 70% expensive than diesel pump price - Additionally, diesel generators often not designed for use of blended fuels

Source: Expert interviews

Market and investment size | We used specific approaches and assumptions for market and investment sizing per use case (1/3)

Use cases	Biofuels	Market sizing	Investment size
Road	① **Ethanol**	• Baseline = forecast 2035 gasoline demand by country • Limited-to-No policy scenario: Ethanol volumes (5-10%) on premium gasoline share (assumed 1% of gasoline); Focus only on medium-to-high income countries • Strong policy scenario : Focus only on countries with high gasoline consumption, sufficient feedstock surplus, and cost-competitive local ethanol production (based on high gasoline prices); Mandates ranged from 5-10% depending on country (higher mandates in countries with more feedstock and higher gasoline prices) × retail price assumption • Retail price assumed to be $0.85/L	• Derive required number of large fuel-grade plants and apply benchmark CAPEX per plant • 100-200Mn L plants at $35-70Mn each
	② **FAME diesel**	• Baseline = forecast 2035 diesel demand by country • No market in limited-to-no policy scenario - mandates required to unlock demand; some small industrial use expected but fragmented and not sized • Strong policy scenario: Focus only on Nigeria with sufficient oil-based feedstock; Market value = FAME volumes under the mandated blend (5%) × assumed retail price assumption; • Retail price assumed to be $0.85/L	• Assume a single commercial FAME facility in Nigeria of 300Mn L, applying large-plant biodiesel CAPEX benchmarks (Indonesia) of $200Mn
Clean cooking	④ **Bio-pellets**	• Identified countries with sufficient dry residues (bagasse, sawdust, rice/wheat husk) and low clean-cooking penetration • Within these, target peri-urban and near-rural households with enough income that currently buy wood/kerosene and live ≤10km from towns (exclude remote rural and households mainly collecting wood) • Assumed 70-80% adoption rates depending on scenario • Assume 490 kgs of consumption per HH annually at $0.12/kg (market price of current players)	• Sized number of plants required based on demand • $3Mn for a 24kpta plan

Source: Manufacturing Africa team analysis

Market and investment size | We used specific approaches and assumptions for market and investment sizing per use case (2/3)

Use cases	Biofuels	Market sizing	Investment size
Clean cooking	⑤ **Biogas**	• Use livestock and household data to find rural, non-pastoralist households (e.g., households with an intensive or semi-intensive production system) with ≥2 cows as the only addressable segment • Identified those HHs within 10km of town (therefore, more likely to be buying fuels versus harvesting wood) • Assumed 15-30% adoption rates for those HHs • Assumed LCOE of household biogas digester of $0.05/kWh	• $700 per household biogas digester based on current market price benchmarks
	⑥ **Ethanol**	• Classified countries into four archetypes based on ethanol competitiveness and availability of other clean-cooking options • For each archetype, apply scenario-specific adoption bands to the additional urban clean cooking households projected by IEA between 2025-2035 (assumed that current urban cooking households largely do not switch as likely using LPG and/or electricity): – 70% adoption in countries where ethanol is cheap and alternates are scarce – 20-30% adoption where ethanol is expensive but alternates are scarce – 2-5% adoption where ethanol is cheap but alternatives are available – 1-2% adoption where ethanol is expensive and alternatives are available • Focus only on countries with sufficient feedstock surplus	• Assume 15Mn L per plant at $12Mn per plant • Derive the number of cooking-ethanol plants needed to meet demand
Industrial power and heat	⑦ **Biogas**	For onsite use: • Consider industrial heat/power demand by sector and temperature band, then restrict to low-/medium-heat industries producing wet waste (mainly wastewater treatment, breweries, and some food & beverage plants) that can host onsite anaerobic digestion • Assume 5-80% adoption range based on individual sectors (e.g., wastewater and breweries have higher adoption rates given better waste availability) and scenarios (higher range of adoption assuming logging restrictions) • LCOE of $0.065/kWh assumed for market sizing For mini-grids: • Assume governments reach some share of mini-grid targets in stated compacts with biogas mini-grids (3-5% of aims) • LCOE of $0.05-0.08/kWh assumed for market sizing	• Assume industrial onsite biogas plants sized at 0.5–2MW with $1-4Mn capex • Mini-grids assumed to be 60KW at $120,000 each

Source: Manufacturing Africa team analysis

Market and investment size | We used specific approaches and assumptions for market and investment sizing per use case (2/3)

Use cases	Biofuels	Market sizing	Investment size
Industrial power and hear	⑨ **Bio-briquettes**	• Used IEA baseline biomass for industry use energy demand by region and assume adoption rate of 5-80% of bio-briquettes, with high-end of range assuming logging restrictions • Assumed $115/tonne of bio-briquettes and energy conversion factor of 22.5MJ/kg	• Average plant of 24ktpa at $3Mn capex
Feedstock export	⑩ **2G oil-based feed-stock export**	• Estimate volumes of collectable 2G oil-based feedstocks by 2035: – UCO from cooking-oil demand (assuming ~80% of veg-oil use is cooking oil, then applying benchmark urban-collection rates adjusted for urbanisation; assume 5-25% collection with 25% being Indonesia benchmark) – tallow from processed-meat shares (e.g., 80% processed meat in South Africa, 4% in rest of SSA) with 50% of tallow from processed meat available for biofuels • UCO price of $1,000/tonne (global benchmark, given UCO would be exported) • For castor, assume Africa only achieves 5% of total maximum potential given restrictions on land availability (with some semi-degraded land being used for castor)	• Castor oil production capex benchmarked at $330 / tonne / year • UCO/tallow collection – no capex
Aviation	⑪ **SAF refining**	• Focus exclusively on export markets (no domestic SAF mandates expected) • Assessed regions with minimum required feedstock for a 500Mn tonne capacity plant – the minimum viable scale for a SAF plant (note – smaller plants do exist but typically brownfield co-located with a refinery to reduce costs). Only Nigeria and southern Africa have sufficient feedstock • Assume SAF HEFA plants in Nigeria (1G palm-oil-based) and South Africa (2G UCO/castor-based) • Price of 1G SAF at $1,700/tonne and of 2G SAF at $1,500/tonne	• Benchmarked HEFA facility capex of $1Bn for 500Mn tonne capacity

Source: Manufacturing Africa team analysis

Demand | Demand for starch and sugar crops is forecasted based on population, income and meat demand growth

Food demand growth

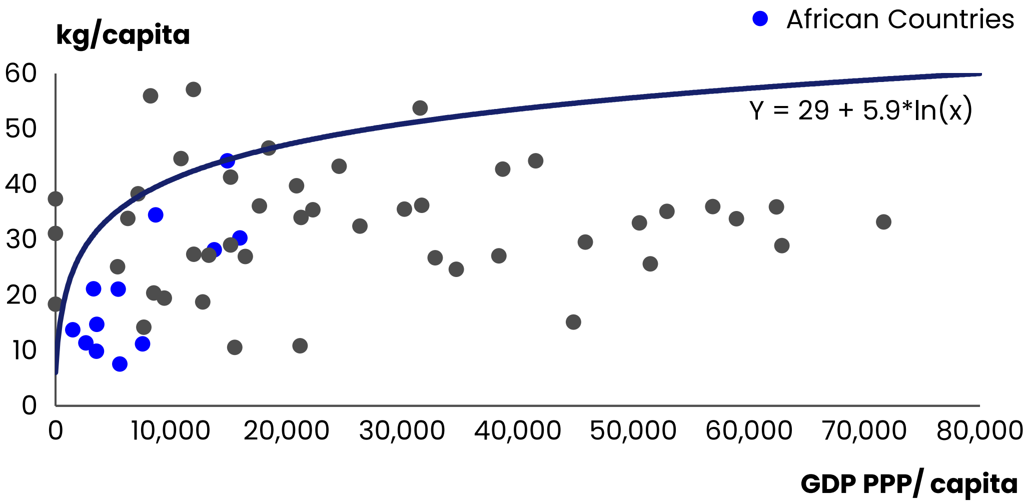
1 Per capita demand growth

- Consumption per capita of non-staple starch crops and sugar is grown based on expected income growth
- Non-staple crops are: Rice, except in Western Africa, and wheat, expect in Northern Africa
- Income growth is measured by the average annual growth of GPD per capita measure at constant purchasing power parity between 2022-24[1]
- For countries with negative growth rates, long-term growth projections were leveraged[2]
- For starch crops, 1 pp of income growth is assumed to create 1.5 pp consumption growth
- For sugar crops, income-based growth was determined based on global relationship between per capita consumption and income

2 Population growth

- Total future consumption is calculated by multiplying future per capita demand growth with projected population[3]

Illustration: Relationship income and per capita sugar consumption



Feed demand growth

- Feed demand is determined based on current and future consumption of dairy, chicken meat and eggs
- Use of animal feed is only assumed in intensive and semi-intensive production
- Animal feed is assumed to range from 0.2-0.5kg per litre milk and 2-2.5 kg per kg poultry product
- 75% of animal feed is assumed to be cereals out of which 90% is maize

Illustration: Production intensity diary by region, % of total production

	Intensive		Semi-intensive	
Region	2025	2035	2025	2035
SSA	10%	11%	13%	29%
North Africa	65%	100%	13%	0%
South Africa	100%	100%	0%	0%

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1. GDP per capita data retrieved from World Bank
2. Retrieved from Oxford Economics
3. Using UN population projections

Manufacturing Africa

Source: BMI data, World Bank

Demand | Demand for 1G oil and waste oils is forecasted based on population, income and meat demand growth

1G Oil demand growth

① Per capita demand growth

Per capita consumption is grown based on expected income growth which is measured by the average annual growth of GPD per capita measure at constant purchasing power parity between 2022-24[3]

Countries with negative growth rates, long-term growth projections leveraged[4]

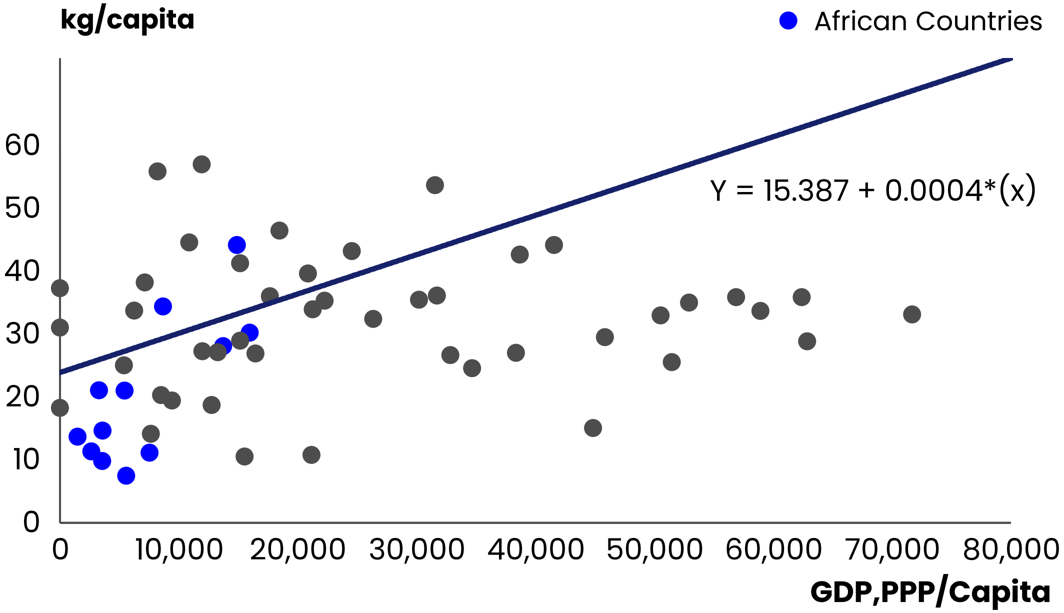
An income-based growth was determined based on global relationship between per capita consumption and income

② Population growth

Total future consumption is calculated by multiplying future per capita demand growth with projected population

Palm oil derived based on total plant oil demand, takeaway oil from soy from animal production, and taking out sunflower oil based on share of demand-remains constant over time

Illustration:
Relationship income and per capita oil consumption



Waste oil (Tallow & Used Cooking Oil) growth

Waste oils potential is projected based on growing plant oil and meat(beef& poultry) demand for UCO and tallow respectively

Assumed the collection rates for **tallow** will be constant over the years

The demand for tallow for other uses than biofuels is expected to remain a constant share of the demand

The amount of **collectable waste oils** is projected to increase for UCO based on increase in urban collection rates based on scenarios; Scenario 1- 5% collection rate (implies no improvement), Scenario 2- 10% collection rate (moderate improvement) e.g., Kenya with 30% urbanisation rate would reach India levels (3% collection rate), Scenario 3- 25% collection rate (assumes collection rate for leading Asian peers e.g., Indonesia can be reached

Demand for UCO and tallow for other use cases beyond biofuels is expected to remain a constant share of total demand

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1. GDP per capita data retrieved from World Bank
2. Retrieved from Oxford Economics
3. Using UN population projections

Source: BMI data, World Bank

End of report