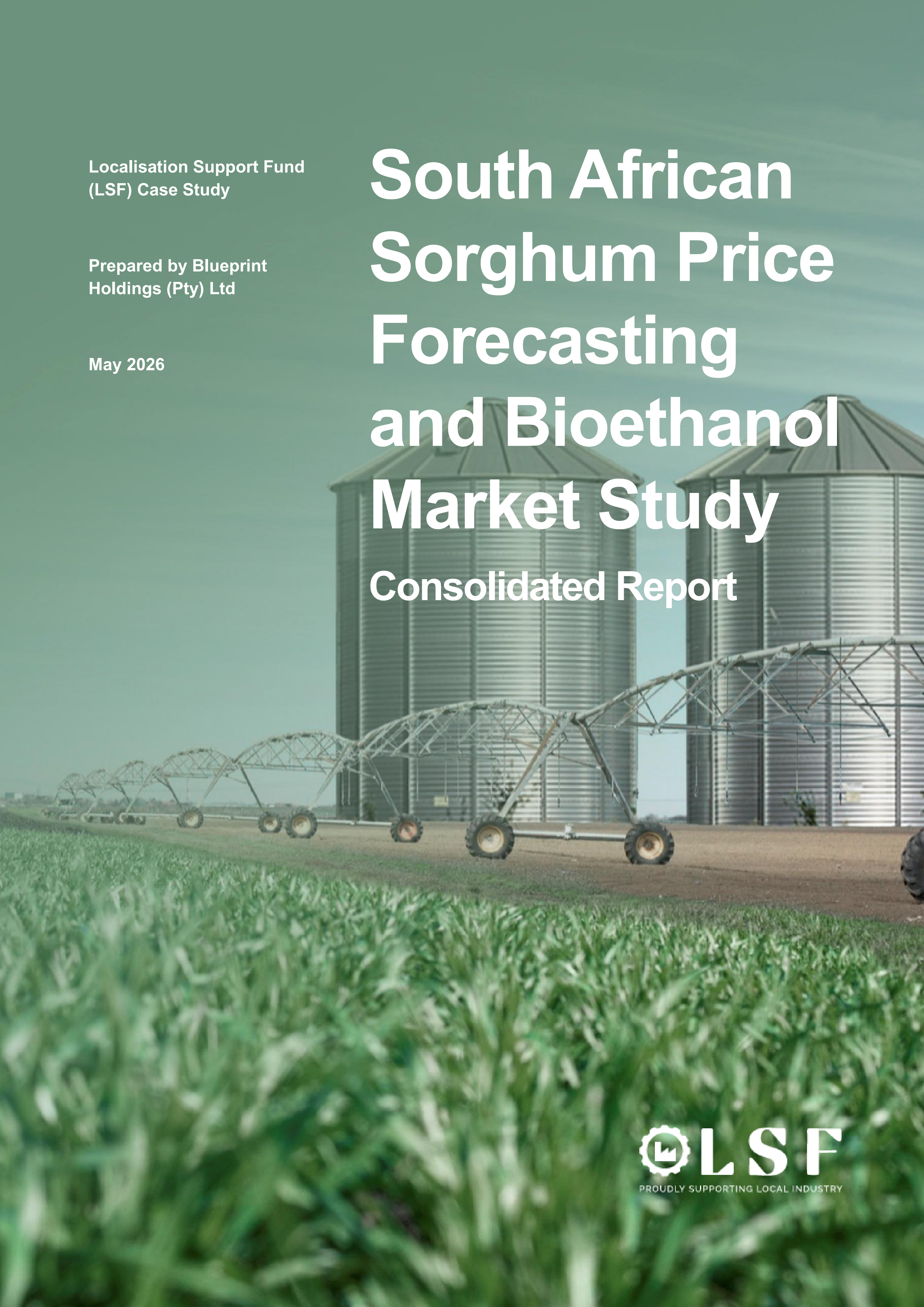
Localisation Support Fund (LSF) Case Study

Prepared by Blueprint Holdings (Pty) Ltd

May 2026

South African Sorghum Price Forecasting and Bioethanol Market Study

Consolidated Report



LSF
PROUDLY SUPPORTING LOCAL INDUSTRY

ABOUT THIS STUDY

This is the final report of five in the overall delivery of the Sorghum Price Forecasting and Bio Ethanol Study. It establishes a defensible, end-to-end pricing framework for South African sorghum by explicitly anchoring domestic price formation to upstream dynamics in US corn futures. The objective is to ensure that local sorghum price forecasts are grounded in the dominant global mechanisms governing Corn price formation, while preserving sensitivity to South African market structure, import-parity transmission, substitution with yellow maize, and exchange-rate pass-through. The framework is designed for investor-facing and policy-relevant use, prioritising transparency, empirical discipline and scenario capability over black-box forecasting.

ABOUT LSF

The Localisation Support Fund NPC ("LSF") was established as a non-profit company in 2021, funded by private sector contributors committed to localising manufacturing in South Africa. The LSF is a network orchestrator within the localisation ecosystem facilitating the connection between supply and demand participants, enhancing the value of the interactions by funding industry research and the deployment of technical expert resources to accelerate or unblock opportunities for localisation and growth in the manufacturing sector.

ABOUT SERVICE PROVIDER

Blueprint Holdings (Pty) Ltd is a bespoke specialist consulting firm focused on industrial development, strategy, policy, planning and implementation. It was founded in 2004 and has been working successfully in industrial development for over 20 years. It has delivered over 400 accepted assignments since then, with none rejected. It undertakes work with International Agencies, Universities, Governments, and the private sector in the industrial development arena. It has been appointed to various Government and industry association based South African panels to provide research and strategy development and planning services. Skills and competencies include all those required to deliver on assignments and range from policy analysis to detailed modelling and scenario planning. It is 100% black owned and 100% female managed.

DISCLAIMER

To the fullest extent permitted by law, in no circumstances will the LSF and/or Representatives be responsible or liable for any direct, indirect or consequential loss or loss of profit arising from the use of this report, its contents, its omissions, reliance on the information contained within it or on opinions communicated in relation thereto or otherwise arising in connection therewith.

The report has not been independently verified by LSF and/or its Representatives. LSF and/or its Representatives does not undertake or expect to update or otherwise revise this report and expressly disclaim any obligation to disseminate any updates or revisions, including to any financial data or forward-looking statements, that may result from any change expectations, conditions or any other events or circumstances arising after the date of this report.

The information includes forward-looking statements which include, without limitation, any statements preceded by, followed by or including words such as “target”, “objective”, “believe”, “expect”, “aim”, “intend”, “may”, “anticipate”, “estimate”, “plan”, “project”, “will”, “can have”, “likely”, “should”, “would”, “could” and other words and terms of similar meaning or the negative thereof.

The forward-looking statements in the report are based on beliefs and projections and on information currently available to them; however, these forward-looking statements are subject to risks, uncertainties and assumptions. Should risks or uncertainties materialise, or should any underlying assumptions prove to be incorrect, the actual financial conditions or results of operations could differ materially from those described herein as anticipated, believed, estimated or expected. No representation or warranty is made that any forward-looking statement will come to pass. No one undertakes to update or revise any such forward-looking statement.

DISCLOSURE

This research was commissioned by the LSF and was conducted independently by Blueprint Holdings (Pty) Ltd. The lead consultant responsible for this report as well as the overall project was Blueprint Holdings (Pty) Ltd). The opinions or recommendations contained in this report represent the views of the authors and do not necessarily reflect the views and opinions of the LSF.

This report is addressed to the LSF solely for its use and benefit for purposes of the Sorghum Price Forecasting and Bio Ethanol Study, and may not be transmitted to any other person, nor quoted or referred to in any public document, nor filed with any governmental agency or person without the LSF’s prior written consent.

Unless otherwise agreed to by the LSF in writing, no person, other than the LSF, is entitled to rely on this report and LSF shall have no responsibility or liability to any party who has access to this report, whether in contract, delict (including gross negligence) or otherwise.

COPYRIGHT

Contents

Table of Figures

List of Tables

List of Abbreviations, Acronyms and Definitions

Acronym/Term	Definition/Expansion
1G	First-generation bioethanol produced from sugar or starch-rich food crops e.g., sugarcane, maize, wheat, or sorghum.
2G	Second-generation bioethanol from lignocellulosic biomass.
3G	Third Generation
ACCI	Agricultural Council of South Africa
AD	Anaerobic Digestion
AFD	Agence Française de Développement
ANP	Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (Brazilian National Petroleum Agency)
ANP	National Agency of Petroleum, Natural Gas and Biofuels
APAP	Agricultural Policy Action Plan
ARC	Agricultural Research Council
ARC/PLC	Agricultural Risk Coverage / Price Loss Coverage (U.S. farm programs)
ATR	Açúcar Total Recuperável (Total Recoverable Sugar - Brazil pricing metric)
BACF	Black Agriculture Commodities Federation
BEE	Black Economic Empowerment
BESS	Battery Energy Storage System
BFAP	Bureau for Food and Agricultural Policy
BFIP	Biofuels Infrastructure Partnership
BMP	Best Management Practice
BNDS	Brazilian Development Bank
BPCL	Bharat Petroleum Corporation Limited
BRICS	Brazil, Russia, India, China, South Africa
CAGR	Compound Annual Growth Rate
CBAM	Carbon Border Adjustment Mechanism
CBIO	Carbon Intensity Credits
CBIOs	Decarbonization Credits under RenovaBio
CCUS	Carbon Capture, Utilisation, and Storage.
CDS	Condensed Distillers Solubles
CEC	Crop Estimates Committee
CEC	Cation Exchange Capacity
CEC	Cation Exchange Capacity
CHP	Combined Heat and Power
CI	Carbon Intensity
CIF	Cost, Insurance, and Freight

CMF	Chloromethyl furfural
CMS	Condensed Molasses Solubles
CO^2	Carbon Dioxide
COD	Chemical Oxygen Demand
CONSECANA	São Paulo State sugarcane council pricing system
CPI	Consumer Price Index
CSIR	Council for Scientific and Industrial Research
CTL	Coal to Liquid
DAFF	Department of Agriculture, Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform and Rural Development
DBSA	Development Bank of Southern Africa
DDGS	Distillers Dried Grain with Solubles
DFFE	Department of Forestry, Fisheries and the Environment
DFI	Development Finance Institution
DG	Distillers Grains
DM	Dry Matter
DMRE	Department of Mineral Resources and Energy
DoE	Department of Energy
DSI	Department of Science and Innovation
DTIC	Department of Trade, Industry and Competition
E10	Gasoline blend containing 10% ethanol
E15	Gasoline blend containing 15% ethanol
E85	Fuel blend containing up to 85% ethanol for FFVs
EABL	East African Breweries Ltd
EAF	Energy Availability Factor
EBP	Ethanol Blended Petrol Programme (India)
EIA	Environmental Impact Assessment
EP3	Efficient Producer Petition (EPA program for lifecycle pathway updates)
EPA	Environmental Protection Agency
EPC	Engineering, Procurement, and Construction
ESG	Environmental, Social, and Governance
ETS	Emissions Trading System
EU	European Union
FAOSTAT	Food and Agriculture Organization Statistical Database
FFV	Flexible Fuel Vehicles
FOB	Free on Board
FPO	Farmer Producer Organisation
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GG	Government Gazette
GHG	Greenhouse Gas
GM	Genetically Modified

GREET	Greenhouse gases, Regulated Emissions, and Energy use in Technologies model (Argonne National Laboratory)
GSA	Grain South Africa
HBIIP	Higher Blends Infrastructure Incentive Program (USDA)
HDSA	Historically Disadvantaged South Africans
HPE	High Purity Ethanol
ICAR-IIMR	Indian Council of Agricultural Research - Indian Institute of Millets Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDC	Industrial Development Corporation (South Africa)
IEA	International Energy Agency
ILUC	Indirect Land Use Change
IOCL	Indian Oil Corporation Limited
IPM	Integrated Pest Management
IPP	Independent Power Producer
IRP	Integrated Resource Planning
IRR	Internal Rate of Return
ISCC	International Sustainability and Carbon Certification
JET	Just Energy Transition
KL	Kilolitre
KLPD	Kilolitres Per Day
KZN	KwaZulu Natal
LCA	Life Cycle Assessment
LCFS	Low-carbon Fuel Standard (state clean-fuels programs, e.g., California)
LCOE	Levelised Cost of Energy
LCOF	Levelised Cost of Fuel
LLC	Limited Liability Company
Low -CI	Low Carbon Intensity
LPG	Liquid Petroleum Gas
LSF	Localisation Support Fund
LUC	Land Use Change
MSP	Minimum Support Price
NGO	Non-Governmental Organisation
NPV	Net Present Value
NSI	National Sugar Institute (India)
NTCSA	National Transmission Company South Africa
OMC	Oil Marketing Companies (India)
OPV	Open-Pollinated Varieties
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PPPP	Public-private-people partnerships
R&D	Research and Development
RED	Renewable Energy Directive

REFIT	Renewable Energy Feed-in Tariff
RenovaBio	Brazil’s national biofuels policy and carbon credit scheme
RFS	Renewable Fuel Standard (US)
RIN	Renewable Identification Number
RMA	Risk Management Agency (USDA)

Executive Summary

With the August 2025 gazetting of the national ethanol pricing framework, the last regulatory barrier to a domestic bioethanol market has been removed, creating a concrete basis for blending mandates and for investment decisions that have been deferred for more than a decade. A two percent ethanol blend (E2) will require about 180 million litres of bioethanol a year, and meeting this domestically implies capital expenditure in the order of ZAR 3-5 billion for first-generation plants (at current rates), depending on technology choice and configuration. In this context, the central question for policymakers and investors is no longer whether sorghum-based ethanol is technically feasible, but under what conditions it becomes commercially investable, strategically valuable, and socially defensible at scale (justifiable to society, government, and oversight bodies without generating material political, social, or ethical backlash).

This report speaks to why sorghum is an appropriate feedstock choice for bioethanol under South African conditions; why bioethanol profitability hinges on the spread between fuel pricing (Brent-linked) and feedstock pricing (domestically determined); and why targeted policy intervention is justified, predictable in impact, and does not distort markets. The methodology employed in this analysis is designed to reduce model risk, which is often the primary concern of investors and senior officials. It demonstrates that conclusions are not derived from a single statistical model or limited dataset, but from converging evidence across import and export price dynamics, demand responsiveness, cost transmission, and international comparators.

The evidence presented in this study shows that a sorghum to bioethanol industry is strategically attractive for South Africa, but not yet self-sustaining under current price, yield, and cost conditions. Sorghum offers a credible feedstock pathway that can complement a stressed sugarcane sector, de-risk national fuel supply, and open a new axis of agro-industrial investment into semi-arid regions that are otherwise structurally disadvantaged. Sorghum can be grown at scale on substantial areas of moderate and marginal land that are not suitable for sugarcane or high-input maize, with approximately 29 million hectares of such land identified across key provinces, of which a portion has sufficient infrastructure to be brought into production. As climate risks intensify, this ability to anchor industrial investment in water-constrained areas is not peripheral, it is central to a resilient fuel and food system.

At the same time, the integrated LSF (Localisation Support Fund) model, which combines a mass balance framework with scenario and sensitivity analysis, demonstrates that under current policy and market parameters, none of the six tested feedstock and technology configurations produces a sustainable positive margin at refinery level without some form of policy, pricing, incentive, or subsidy support. This applies across configurations at current scale and yield levels, and in the presence of certain disabling policy factors. The analyses were run for grain sorghum, grain sorghum with maize blending, sweet sorghum, new and converted sugar plants, and maize plants running off-specification downgraded stocks. Across all configurations, primary feedstock cost, conversion efficiency, and by-product revenues are the dominant determinants of viability at this time.

The sorghum value chain is underdeveloped relative to its commercial potential. Upstream fragmentation, poor post-harvest handling, inconsistent quality, and thin markets (where few buyers and sellers exist, limiting price stability and liquidity) create supply risks for processors and deter private investment. A critical but often underemphasised constraint in the commercialisation of sorghum is the limited investment in seed research and the near absence of local hybrid seed production systems. Unlike maize, which has benefited from decades of sustained breeding programmes, advanced hybrid development, and private-sector-led seed distribution networks, sorghum remains heavily reliant on outdated varieties with limited yield potential and weak climate resilience. This technological lag, coupled with poor access to certified seed, undermines productivity and discourages commercial cultivation. For farmers, this technological lag translates into both lower expected returns and higher production risk relative to maize. The absence of locally adapted, market-oriented seed systems erodes farmer confidence in sorghum as a reliable cash crop, dampening adoption even when offtake agreements exist. Thus, strengthening upstream seed innovation and distribution, through public-private partnerships and targeted R&D incentives, is essential for unlocking farmer motivation and attracting sustained investment across the sorghum value chain.

Downstream, processing capacity exists but is concentrated in a small number of firms, particularly in brewing and industrial milling, resulting in asymmetric bargaining power and limited competition. In the grain sorghum pathways, income from by-products such as distillers' grains and carbon dioxide significantly reduces losses and, in some cases, approaches breakeven, whereas sweet sorghum and sugar variants are more exposed, particularly where bagasse (the fibrous residue from crushing) and vinasse (the liquid residue from distillation) use is not optimised. Modelling also confirms that the economics are shaped by stable, system-wide price relationships between raw material costs, product prices, and by-product revenues, which constrain profitability and therefore define the parameters for any support or investment decision.

From a value chain perspective, the analysis unequivocally shows that the largest structural cost and risk centre is primary production. Farm-level operations account for roughly 50 to 85 percent of total sorghum-based ethanol value chain costs, and yield levels, input use efficiency, and seasonal climate variability drive the feedstock cost curve. Without a systematic programme to lift average dryland yields towards global benchmarks through better seed systems, agronomy, and mechanisation, the country will not be able to supply an ethanol industry at the volumes, prices, and quality required. This is not a marginal technical point; it is the difference between a value chain that can mobilise commercial and development finance at scale, and one that remains permanently dependent on ad hoc subsidies or restrictive mandates that are vulnerable to political reversal.

After primary production, aggregation, storage, logistics, and plant siting emerge as the next set of binding determinants of competitiveness. The analysis shows that current logistics and storage infrastructure are not sufficient to support a large-scale, geographically distributed sorghum to ethanol industry at the lowest possible cost. While existing maize grain infrastructure may offer partial leverage opportunities, particularly in high-production regions, its suitability for sorghum remains conditional on varietal compatibility (closeness to feedstock, transport linkages), drying and storage requirements, and geographic alignment. Nonetheless, selective integration with maize logistics could reduce duplication and improve early-stage cost efficiencies where feasible.

Aggregation hubs, drying and storage capacity, and improved road and rail connections into refinery nodes are needed to reduce post-harvest losses, stabilise quality, and minimise long farm-to-plant haulage costs. The location of bioethanol plants relative to high-potential sorghum zones and existing fuel blending and distribution infrastructure is therefore a strategic decision, not a purely commercial one. Poor siting choices will hardwire uncompetitive logistics into the value chain.

On the technology and processing side, the report confirms that first-generation starch-based plants using grain sorghum are the realistic near-term option, given cost, risk, and global technology readiness. Integrated first and second-generation plants remain at demonstration scale internationally and are unlikely to be investable in South Africa over the short to medium term without exceptional support.

Sweet sorghum juice to ethanol offers a high potential but higher risk opportunity that would require disciplined, time sensitive harvesting and crushing systems, or the development of decentralised syrup production to manage perishability and distance to plant. Biomass and forage sorghums, although attractive for second generation ethanol and power, depend on clear low-carbon intensity credit regimes and are therefore more appropriately treated as a later stage option once first-generation infrastructure and policy frameworks are fully established.

The international benchmarking undertaken in the report underlines that South Africa is not starting from a blank slate, but from a position that combines latent strengths and visible weaknesses; nonetheless, there are important transferable lessons. In the United States, sorghum is used mainly as a flexible adjunct feedstock in maize-based ethanol plants, with operators switching feedstocks in response to relative prices. In Brazil, the success of the sugarcane ethanol model has rested on stable, long-term blending mandates, a credible low-carbon fuel credit scheme, and integrated infrastructure from field to flex-fuel vehicle. In India, sweet sorghum and other non-traditional feedstocks have been tested in smallholder compatible models using decentralised syrup and mini-mill arrangements. The Kenyan experience highlights the power of anchor buyers and contract farming in transforming sorghum into a reliable cash crop for brewing. Zimbabwe provides a cautionary example of how monopoly control and abrupt policy shifts can undermine sector credibility. These benchmarks converge on three messages for South Africa: policy certainty on blending (and potentially carbon credits) is non-negotiable, anchor demand is essential, and farmer integration will need to be designed, not assumed.

Against this comparative backdrop, the South African sorghum-to-ethanol value chain displays a clear SWOT profile. Strengths include a sophisticated commercial grain sector, established agro-processing capabilities, large areas of suitable land, and a mature fuel distribution system that can integrate bioethanol blends. Weaknesses centre on the long-term contraction of the sorghum industry, low smallholder participation, sporadic research and development investment, and a legacy of delayed, uncoordinated and uncertain biofuels policy. Opportunities arise from the newly gazetted pricing framework, the potential to substitute imported ethanol with domestic production, the alignment with climate and *Just Energy Transition (JET)* agendas, and the scope for rural industrialisation in semi-arid regions. Threats include feedstock price volatility, climate variability, infrastructure bottlenecks, and the risk of policy reversal or weak implementation.

Demand growth for sorghum is not uniform; it is concentrated in specific, high-impact segments. Feed and food markets remain important, but bioethanol represents the most strategically significant demand anchor; however, international experience shows that ethanol-driven grain demand stabilises prices only after scale thresholds are reached. In the United States, ethanol absorbs more than one-third of maize output, and econometric studies attribute substantial long-run price effects to this demand. South Africa is not at this scale, and the report does not assume immediate price uplift. Instead, it demonstrates that ethanol demand, when combined with productivity gains and aggregation infrastructure, can transform sorghum from a thin, volatile market into a predictable industrial input over time. This phased, evidence-based interpretation directly addresses the risk of overstatement and reinforces the credibility of the demand projections.

The current policy environment does not provide sufficient signal clarity to investors. Sorghum remains weakly integrated into agricultural support frameworks, climate strategies, industrial policy, and energy planning. This fragmentation increases risk premiums and delays capital deployment. The analysis shows that closing the commercial viability gap does not require open-ended subsidies. Instead, it points to targeted, fiscally disciplined instruments, including viability-gap funding at plant level, blended finance structures, contract farming models with offtake guarantees, and carbon credit mechanisms that reward low-carbon-intensity liquid fuels.

Because these interventions are targeted at structural inefficiencies rather than price manipulation, they are defensible from a fiscal and competition perspective and consistent with international best practice.

The study’s policy alignment and investment analysis identifies a detailed and structured set of instruments that could bridge the gap between strategic attractiveness and financial viability. These include viability gap funding for bioethanol plants, blended finance facilities combining concessional and commercial capital, contract farming schemes with offtake guarantees that link farmers to refineries, and output-based carbon credit models that reward producers and blenders. Alongside these, credit guarantees, green bonds, innovation challenge funds, and lease finance for mechanisation and planting equipment can be implemented largely within existing regulatory frameworks. The analysis stresses that these instruments must be sequenced and targeted along the value chain at farmer, producer, and blender or retailer level, rather than applied in a diffuse or fragmented manner.

Scenario analysis and the price forecasting model are presented not as academic exercises but as decision tools. By stress testing the value chain under different assumptions regarding exchange rates, maize and sorghum price paths, Brent linked basic fuel price trajectories, and other priority factors and risk, the models identify which combinations of yield improvement, by-product valorisation, support instruments, and mandate settings move projects from negative to positive returns. This provides a quantitative basis for designing policy packages and investment structures, rather than relying on generic subsidy calls or untested optimism. For investors, the models define the range of conditions under which equity and debt can be prudently deployed. For policymakers, they indicate where relatively modest but well-targeted interventions are sufficient, and where more substantive reforms or concessional support will be required. The sorghum price forecast model findings (a separate model from the integrated scenario model) integrate global parity pricing logic, local exchange rate effects, transport and freight cost dynamics, import/export price corridors, and structural substitutions between maize and sorghum.

The strategic value of a sorghum-to-ethanol industry extends beyond fuel substitution. By developing grain and sweet sorghum value chains that may integrate smallholder farmers through contract farming, aggregation hubs, mechanisation services, and bundled input and insurance packages, this creates an opportunity to align bioethanol investment with inclusive rural transformation. In the earlier phases, rural development associated with the value chain will create employment and other economic spin-offs. Sorghum's resilience and suitability for semi-arid zones mean that the same hectares supplying ethanol feedstock can stabilise local livelihoods, support livestock through stover and distillers' grains, and improve degraded soils, including on certain mining rehabilitation sites, where sorghum-based systems have already demonstrated positive impacts on soil quality and biomass yields.

International experience demonstrates that once a bioethanol blending mandate is adopted, the critical policy task shifts immediately from announcing demand to actively building supply in a controlled and predictable manner. In the United States, Brazil, and Kenya, this was achieved through a common sequence of actions rather than through price intervention alone. Governments first stabilised demand through legally enforceable mandates and clear pricing rules, then rapidly aligned agricultural supply by anchoring ethanol demand to existing grain and sugar value chains via contract farming, aggregation infrastructure and guaranteed offtake. In the United States, ethanol plants were deliberately clustered within defined feedstock catchments, minimising logistics risk and allowing flexible switching between maize and alternative grains as relative prices shifted. Brazil paired its mandate with long-term policy continuity, investment in logistics and storage, and a low-carbon fuel credit system that rewarded efficient producers rather than inflating feedstock prices. Kenya illustrates the smallholder pathway, where anchor buyers created assured markets that justified farmer adoption of improved seed and practices. Across all cases, governments avoided attempting to push supply through subsidies alone; instead, they translated mandate certainty into structured demand signals, supported aggregation, de-risked first movers, and allowed productivity gains to follow market integration.

The clear lesson for South Africa is that even a modest two percent (E2) blending mandate will only be credible and durable if it is accompanied by early, deliberate action to organise feedstock supply through contract farming, aggregation and logistics planning, and refinery siting linked explicitly to production zones. Without this parallel supply-building phase, mandates risk relying on imports, overloading thin markets, or generating price volatility that undermines both food security and investor confidence.

The study's recommendations span the full sorghum-to-bioethanol value chain. However, the analysis also makes clear that not all instruments carry equal strategic weight, nor can they be implemented simultaneously without diluting impact. For policymakers and investors, the central requirement is sequenced credibility, the early establishment of mechanisms that anchor demand, stabilise risk, and change behaviour at scale, before more diffuse support instruments are layered in. The key priorities are outlined below.[1] The prioritisation reflects three core findings of the study:

i. Demand certainty must precede supply response.
ii. First-mover risk must be neutralised before scale can emerge.
iii. Farm-level productivity follows market certainty, not the reverse.

For policymakers, this sequencing ensures fiscal discipline, avoids duplication, and aligns interventions with measurable outcomes. For investors, it signals that the state understands where risk actually lies and is willing to intervene only where markets cannot self-correct in early phases. Taken together, this prioritised package will convert the sorghum-to-bioethanol value chain from a collection of promising components into a coherent, investable system.

Priority 1: Policy certainty mechanisms that anchor demand and revenue

The single most critical enabling condition for the sorghum-to-bioethanol value chain is credible, durable demand certainty at blender and refinery level. Without this, no combination of farm-level incentives or concessional finance will catalyse private investment. Accordingly, the highest-priority instruments recommended are those that lock in revenue visibility.

i. **Blending mandates under the gazetted biofuels pricing framework**, supported by transparent administration and enforcement.
ii. **Output-based bioethanol pricing linked to the Basic Fuel Price**, providing a predictable revenue ceiling.
iii. **Carbon accounting and credit recognition frameworks** where low-carbon-intensity ethanol demonstrably qualifies.

These instruments are prioritised because they establish the end-market, without which upstream interventions will fail to scale. International benchmarking consistently shows that ethanol industries emerge where demand is mandated credibly, and revenue rules are known in advance. From an investor perspective, this reduces regulatory risk, allows project finance structuring, and lowers the cost of capital. From a National Treasury perspective, these instruments are fiscally contained and do not require upfront budget expenditure. The study demonstrates that this demand-side certainty does not distort prices artificially. Rather, it creates a market where existing inefficiencies can be addressed systematically.

Priority 2: Viability gap funding for first-mover bioethanol plants

Once demand certainty is established, the next binding constraint is initial refinery-level viability under current yield, scale, and logistics conditions. The scenario modelling shows that first-generation grain sorghum ethanol plants approach break-even only once scale thresholds are reached and by-products are fully valorised. Early movers therefore face a structural disadvantage that will not correct itself

[1] Refer to detail in this report

without intervention. Viability Gap Funding (VGF) for bioethanol plants is therefore prioritised as the second essential instrument. VGF is preferred over blanket subsidies because it is:

i. **Targeted** to quantifiable gaps identified through modelling.
ii. **Time-bound** and can be tapered as yields, volumes, and efficiency improve.
iii. **Compatible with PPPs (Public-Private Partnerships) and blended-finance structures**, limiting fiscal exposure.

This instrument is prioritised because it directly addresses the transition from strategically attractive to financially investable without locking the sector into permanent support. From an investor perspective, VGF converts marginal projects into financeable ones. From a policy perspective, it ensures that public funds are leveraged rather than substituted for private capital.

Priority 3: Blended finance facilities with concessional risk-sharing

Parallel to VGF, the study identifies capital structuring risk as a major barrier for both refineries and upstream aggregation infrastructure. High initial capital outlays, long payback periods, and policy legacy risk inflate the cost of debt and limit commercial lender participation. For this reason, blended finance facilities combining concessional capital, guarantees, and commercial finance are prioritised as the third essential intervention. Their primary function is not to subsidise returns, but to:

i. Absorb early-stage policy and execution risk.
ii. Crowd in private lenders by improving debt tenors (the length of loan agreements) and coverage ratios.
iii. Enable system-level investments in aggregation, storage, and logistics that individual actors cannot finance alone.

This prioritisation reflects international best practice in energy transition and agro-industrial development. It also aligns with National Treasury’s preference for *risk-sharing over direct expenditure* and provides DFIs (Development Finance Institutions) with a clear catalytic role rather than a permanent financing function.

Priority 4: Feedstock-linked contract farming with offtake guarantees

Once downstream investment is mobilised, the binding risk shifts decisively to feedstock supply stability. The study shows that primary production accounts for majority of the value chain costs and that sorghum supply is structurally inelastic (unable to respond quickly to price signals under current conditions). For this reason, contract farming schemes explicitly linked to bioethanol refinery offtake are prioritised ahead of stand-alone farmer subsidies or support programmes. These schemes are essential because they:

i. Translate downstream demand certainty into farm-level behavioural change.
ii. Enable yield-enhancing investments by providing price and offtake certainty.
iii. Allow input provision, mechanisation services, and extension to be bundled coherently.

The Kenyan brewing case study and international ethanol benchmarking both show that anchor-buyer models, not spot markets, drive sustained farmer participation. From an investor perspective, contract farming reduces feedstock risk. From a policy perspective, it ensures that public support at farm level is market-integrated rather than welfare-oriented.

Priority 5: Output-based carbon credit models for ethanol and blending

Carbon credit mechanisms are prioritised not as primary revenue drivers but as margin stabilisers that improve long-term competitiveness and align the value chain with climate commitments. Where implemented effectively, carbon credits:

i. Reward operational efficiency rather than scale alone.
ii. Improve resilience during periods of feedstock price volatility.
iii. Strengthen the case for financing by increasing revenue diversity.

The study emphasises output-based models rather than blanket offsets, ensuring alignment with international verification standards and avoiding reputational risk. This sequencing reflects the reality that carbon revenue strengthens mature operations but rarely catalyses initial investment on its own.

The remaining instruments identified in the study retain importance but are supportive rather than catalytic and should be deployed once the core architecture is in place. Processes of removing VAT from sorghum, in line with the VAT treatment of other grains, and permitting the use of maize unfit for human or animal consumption as bioethanol feedstock, could begin immediately. However, the following processes can also be initiated in parallel to improve the enabling environment.

i. **Credit guarantees** to expand working capital access for SMEs (Small and Medium Enterprises) and aggregator networks.
ii. **Green bonds** to refinance infrastructure once operating cash flows stabilise.
iii. **Innovation challenge funds** to support technology transfer, by-product optimisation, and efficiency gains.
iv. **Lease finance and equipment-sharing models** to accelerate mechanisation uptake among smallholders.

These instruments are not deprioritised due to lack of value, but because their effectiveness depends on the success of the higher-order interventions above. Implemented prematurely, they risk fragmentation and low impact.

In summary, the critical findings of the sorghum-to-bioethanol value chain analysis are that South Africa now has a credible regulatory platform and clear policy window to act; that sorghum can be a central feedstock in a diversified, climate-smart bioethanol strategy; that the economic case will not close without targeted instruments to support primary production efficiency, infrastructure and logistics, and refinery profitability; and that, if designed around inclusive value chain principles and international best practice, a sorghum to ethanol industry can deliver not only fuel and emissions benefits, but also tangible dividends in rural employment, land rehabilitation, and industrial localisation. The work presented here does not guarantee success, but it defines the conditions under which success is attainable. For senior policymakers, investors, and public finance institutions, it provides a robust analytical foundation from which to investigate specific projects, negotiate risk sharing arrangements, and design an integrated national roadmap for sorghum-based bioethanol over the next decade.

1. Introduction

1.1 Context and Background

The last regulatory barrier to the creation of a bioethanol market in South Africa has been removed with the August 2025 gazetting of the South African ethanol pricing framework. The regulated biofuels price published under the Petroleum Products Act (Government Gazette No. 53146 of 12 August 2025) has been approved by cabinet and will unlock blending mandates in South Africa, a critical precursor for the development of the sorghum to bioethanol value chain, which is currently nascent. Initially, a 2% ethanol blend (E2) for South Africa will require approximately 180 million litres per year of bioethanol based on the current vehicle fleet and annual petrol consumption. Meeting this with domestic capacity is likely to require a capital investment of ZAR3-5 billion depending on the technology choice. While several bioethanol technologies exist at this stage of market development, commercial ethanol plants that integrate first-generation (1G) [2] and second-generation (2G) [3] technologies remain largely at demonstration stage internationally, with high capital and operating costs. 2G integrated plants are unlikely to be feasible in South Africa in the near term.

Demand, even at 2%, is significant enough to accommodate sorghum and potentially South Africa's well-established but financially stressed sugarcane sector. If both the sorghum and sugarcane pathways grow, or sorghum grows rapidly, it may be possible to implement a mandate that would de-risk the entire sorghum to bioethanol value chain, from farm gate to pump. Ethanol yields per unit of input with natural factors, starch content, and processing costs, as the scenario analysis and modelling demonstrate. With domestic ethanol consumption poised to pick up as a blending mandate is implemented, and as the demand for grain sorghum grows, sorghum can provide a significant feedstock for bioethanol production, diversifying supply, creating jobs, and making productive use of marginal land.

Sorghum can be used as a high potential feedstock for bioethanol. Sweet sorghum for bioethanol presents a high-potential but higher-risk opportunity than grain sorghum due to challenges of rapid post-harvest juice deterioration and seasonal supply constraints. Additionally, the use of downgraded maize unfit for human or animal consumption, could significantly reduce feedstock risk for local producers without compromising food security.

While feedstock source is critical, other factors also determine the success of the sorghum-to-bioethanol value chain. Globally, the two biggest producers of grain sorghum bioethanol, the United States (US) and China, currently use sorghum as an alternative or adjunct feedstock in ethanol plants that are primarily designed to process maize and rotate feedstocks based on varying factors including price. Brazil's bioethanol success story was characterised by public-private partnerships (PPPs) and the development of supporting infrastructure including dedicated pipelines, storage depots, and flex-fuel vehicle technology, ensuring ethanol could be produced, transported, and consumed nationwide. The majority state-owned Petrobras invested heavily in distribution and blending, while in some cases

[2] A first-generation ethanol plant produces ethanol (bioethanol) from food crops that are high in sugars or starches such as Sugarcane, sugar beet, maize (corn), wheat, sorghum, and other grains

[3] A second-generation ethanol plant uses non-food plant materials rich in cellulose and hemicellulose such as Agricultural residues (e.g., corn stover, wheat straw, sugarcane bagasse); Forestry residues (wood chips, sawdust). Dedicated energy crops (e.g., switchgrass, miscanthus).

private sugar mills diversified into ethanol production, often supported by subsidised credit lines from development banks.

1.2 Inclusive Value Chains

Inclusive value chains for sorghum can combine anchor-buyer contracts with guaranteed pricing formulas, equipment financing, mechanisation services on a pay-as-you-go basis, aggregation hubs for bulking and drying, and weather-index insurance to reduce risk. Sweet sorghum syrup has potential to grow in two complementary market segments. First, there are local rural and township markets where smallholder cooperatives can supply low-cost syrup for household cooking, brewing, and sweetening applications. Second, an urban niche market exists among health-conscious consumers in Johannesburg, Cape Town, and Durban, who are increasingly seeking natural" and "heritage" foods. Syrup can be positioned in urban supermarkets and health food stores, where natural, unrefined sweeteners command a premium, competing with honey, molasses, and imported agave or maple syrups.

Sorghum brewing has potential to support small scale commercial brewing involving local micro-breweries or cooperatives producing sorghum beer for local retail, taverns, tourism or niche markets, using standardised recipes and basic quality controls. With appropriate support this can formalise traditional recipes into branded local products to capture emerging markets for heritage, craft, and nutritional products.

Sorghum is generally classified into four main types, each serving distinct purposes. Grain sorghum (Sorghum bicolor var. bicolor) is the most widely grown, producing starchy grains used for human food (such as porridge, couscous, and flour), animal feed, and brewing; it can also be used for ethanol production from starch. Within grain sorghum, varieties differ in tannin content: low- or no-tannin sorghum is more palatable and digestible, making it better suited for food and feed, whereas high-tannin sorghum has lower digestibility but offers advantages in pest resistance and certain industrial uses. Sweet sorghum has tall stalks rich in fermentable sugars, making it valuable for bioethanol production, syrup, and as animal fodder via its bagasse (the fibrous residue remaining after juice extraction). Forage sorghum is bred for high biomass yields and digestibility, used primarily as silage or green fodder for livestock. Each type thus contributes differently to food, feed, and energy markets, reflecting sorghum's versatility as both a staple crop and an industrial input.

1.3 Sorghum Grain

For the purposes of this study, the critical value chain of interest is the industrial sorghum to bioethanol chain (including by-products) covering grain starch to ethanol, and sweet sorghum juice to ethanol. Food and beverage chains including grain for human consumption, sorghum syrup and traditional beer are covered for completeness and to highlight commercial opportunities. Both core chains also generate valuable by-products: sorghum bran and distillers' grains can feed livestock; carbon dioxide from fermentation can be captured; and bagasse can provide process heat, electricity, or advanced biorefinery feedstocks.[4] The technology and financial risks of second-generation biofuels outweigh the benefits at this stage leaving space for simpler and less investment-intensive opportunities.

Sorghum (Sorghum bicolor) is one of the world's oldest domesticated cereals, with origins in northeast Africa dating back more than 5,000 years. It spread through trade and migration across Asia and the

[4] Punia, P. "Sweet Sorghum for Bioethanol: Prospects and Challenges." *Biofuels* 15, no. 3 (2024): 233–246.

Middle East, and later the Americas, and today is the fifth most produced cereal crop globally[5]. Sorghum's resilience is central to its appeal as it tolerates high temperatures and drought stress through traits such as efficient root systems, waxy cuticles, and "stay-green" physiology. As climate change places pressure on water and heat-stressed ecosystems, these features have made sorghum a serious candidate in climate-smart agriculture portfolios.[6] [7]

From a nutritional perspective, grain sorghum is naturally gluten-free, high in dietary fibre, antioxidants, and micronutrients such as iron and zinc, and increasingly used in gluten-free bakery, pasta, and blended food products.[8] It underpins many different cultural diets and the traditional/opaque beer industry in southern Africa, where sorghum malt is a core input.[9] These food and beverage value chains are critical to livelihoods and food security. However, the commercial footprint of sorghum in South Africa has shrunk dramatically. The cultivated area fell to about 41,150 hectares in 2024/25, with output near 138,000 tonnes, a 75% decline since the early 1990s, as producers shifted to more profitable crops such as maize and oilseeds.[10] [11]

1.4 Sorghum to Bioethanol

For bioethanol, sorghum offers two distinct pathways: grain sorghum, processed in conventional first-generation (1G) starch-to-ethanol plants, and sweet sorghum, where sugar-rich stalk juice can be fermented directly, with bagasse converted to second generation (2G) ethanol or power. Grain sorghum carries known and familiar technology risks (similar to maize), while sweet sorghum faces challenges of rapid post-harvest juice deterioration, seasonal supply, and lower global technology maturity.[12] [13] Compared with sugarcane, sorghum's advantage is its adaptability to semi-arid and marginal lands unsuited to sugarcane; sugarcane's advantage is entrenched large-scale processing capacity and higher steady yields where water is abundant.[14]

In the South African context, sorghum and sugarcane can serve as complementary feedstocks for bioethanol production, rather than competing alternatives. While sugarcane remains the primary source of fermentable sugars, sorghum offers a valuable supplementary feedstock that can diversify supply, enhance resilience against seasonal fluctuations, and expand the production base. The ability of sorghum to be cultivated on marginal and semi-arid land less suited to sugarcane broadens geographic participation, generating additional rural employment, and making more efficient use of underutilised agricultural land. This complementarity strengthens the overall sustainability and inclusiveness of South Africa's bioethanol industry.

---

[5] Li, X., et al. "Unravelling Sorghum Domestication." Journal of Integrative Agriculture 21, no. 6 (2022): 1502–1514.

[6] Hossain, M. S., et al. "Sorghum: A Prospective Crop for Climatic Vulnerability." *Current Research in Environmental Sustainability* 4 (2022): 100201.

[7] Mwamahonje, A., et al. "Advances in Sorghum Improvement for Climate Resilience." *Agronomy* 14, no. 2 (2024): 321.

[8] Healthline. "Sorghum: Nutrition, Benefits, Risks." Healthline, 2023.

[9] Hlangwani, E., et al. "Processing and Quality of Traditional African Sorghum Beers." *Processes* 8, no. 6 (2020): 716.

[10] Agbiz. The Troubling Decline of the South African Sorghum Industry. Johannesburg: Agbiz, 2025

[11] USDA Foreign Agricultural Service (FAS). *South Africa's Declining Trend in Sorghum Production.* Washington, D.C.: USDA, 2020.

[12] ibid

[13] Gnansounou, Edgard, et al. "Bioethanol Production from Sweet Sorghum: Status and Perspectives in India." *Bioresource Technology* 92, no. 1 (2004): 85–89.

[14] Hossain, M. S., et al. "Sorghum: A Prospective Crop for Climatic Vulnerability." *Current Research in Environmental Sustainability* 4 (2022): 100201.

South Africa's policy trajectory on biofuels has been characterised by repeated delays. Blending mandates have been repeatedly delayed, undermining investor confidence and delaying plant construction, and this remains the biggest barrier to the development of the sector.[15] Yet import-parity analysis shows that domestic production could be competitive: local sugarcane or molasses ethanol costs in 2025 are estimated at ZAR12.5-14.3/L, below current import-parity landed costs of ZAR14-20/L for US and Brazilian ethanol.[16] [17] Sorghum-based ethanol could fit into this band and be integrated into existing agro-industrial hubs.

Critical infrastructure requirements for a sorghum-to-bioethanol value chain include modern distilleries, fermentation and distillation equipment, feedstock aggregation logistics, storage and blending facilities, and grid and pipeline connections for co-products. Costs for bioethanol plants vary depending on the source. Recent industry evidence indicates that first-generation (1G) bioethanol plants typically require capital expenditure in the range of approximately USD 1.5–2.5 per litre of annual capacity, reflecting current construction costs, scale efficiencies, and integration requirements[18]. 2G plants are smaller (30-100 million L/yr) and more expensive, often costing more than USD1.00/L capacity[18]. A report published by the Department of Mineral Resources and Energy (DMRE) in 2010 presents a 150ML grain sorghum plant at ZAR 4 billion (bn) in 2025 Rands[19], while discussions conducted in 2025 with stakeholders suggest that the price of the proposed 162ML Mabele Plant will cost in the region of ZAR 3bn.[20]

The scale of bioethanol needed for a blending mandate is substantial. South Africa's petrol consumption in 2024 was almost 9 billion litres. A 2% ethanol blend (E2) will therefore require about 180 million litres per year of bioethanol. Meeting this with domestic capacity will require a capital investment of between ZAR3-5 bn (2025) depending on the technology choice. In the meantime, imports would be essential. This illustrates both the opportunity for new industrial development and the investment challenge.[21]

Table 1 below offers a useful overview of sorghum across a number of variables and the key bottlenecks for each pathway. It provides a summary of the two fundamentally different routes to ethanol, their process readiness, technology pathways, and key differences. For example, a sorghum grain that is bitter (high tannin) has relatively low sorghum to ethanol prospects unless there is an investment in tannin management but is an excellent brewing/feed crop. For low tannin grain sorghum, the constraint is price and scale as opposed to technology, while for sweet sorghum, the binding constraint is speed and proximity. For high tannin grain, the constraint is chemistry (fermentation inhibition). Forage and biomass sorghums are more constrained by policy and offtake as without a clear low-carbon intensity credit (low-CI) or mandate, 2G ethanol and power/biogas are less attractive than cheaper 1G routes. From a South African sorghum portfolio sequencing perspective, the table shows that in the nearer Insight term, sorghum grain (low tannin) is operationally better de-risked as it allows for arbitrage (if desired) between maize and sorghum, and co-products can be sold into feed markets as not all sorghum is equal for bioethanol.

[15] International Energy Agency (IEA). *Renewables 2023: Analysis and forecast to 2028.* Paris: IEA, 2023

[16] Mvelase, L., and S. Ferrer. "Comparative Feasibility of Bioethanol from Sugar"

[17] Engineering News. "EU Regulations Can Benefit Bioethanol Production in South Africa." June 9, 2021.

[18] Irwin, S. H. (2025). *2024 ethanol production profits: Regression to the mean*. farmdoc daily (15 March 2025), Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign.

[19] Biofuels pricing and manufacturing economics n.d. https://www.dmre.gov.za/Portals/0/Energy_Website/files/esources/renewables/BiofuelsPricingAndManufacturingEconomics.pdf.

[20] Stakeholder interviews

[21] Biofuels pricing and manufacturing economics n.d. https://www.dmre.gov.za/Portals/0/Energy_Website/files/esources/renewables/BiofuelsPricingAndManufacturingEconomics.pdf. Prices adjusted for inflation.

Table 1: Sorghum varieties

Variety	Characteristics	Primary Uses	Bioethanol Relevance	Secondary Products & Opportunities
Grain Sorghum (Low/No Tannin)	White/light-colored grains, low tannin. Moderate biomass (20-40 tonnes/ha fresh weight). 10-20% fermentable sugars in grains/stalks. Grown in Free State, Mpumalanga, North-West, Limpopo (400-800 mm rainfall).	Primarily grown for its seeds (grain), which are starchy and used for food, feed, or brewing. Human consumption (porridge, flour, couscous, rice, grits). Animal feed.	Ethanol can be produced from the starch in the grain, much like maize.	Bagasse: Animal feed, biogas, electricity, paper pulp. Grain: Food products. Opportunities: Food processing, marginal land cultivation, ethanol co-production.
Grain Sorghum Bitter (High Tannin)	Red/brown grains, high tannin for bird resistance. Moderate biomass (20-40 tonnes/ha). Growing in Free State, Mpumalanga, North-West, Limpopo.	Brew traditional sorghum beer (umqombothi). Animal feed (less digestible due to tannins).	Limited to 1G ethanol due to tannins complicating fermentation. Lignocellulosic bagasse for 2G ethanol after tannin removal.	Bagasse: Feed, biogas, electricity. Opportunities: Beer industry growth, bioenergy from by-products.
Sweet Sorghum	High juice content (70-80% stalk), 10-20% fermentable sugars (sucrose, glucose, fructose). Moderate biomass (20-40 tonnes/ha). Lignocellulosic bagasse (30-40% cellulose, 20-25% hemicellulose). Experimental in Free State, Mpumalanga.	First-generation bioethanol from stalk juice. Food/pharma (syrup, grain). Limited commercial use in SA, mainly research (e.g., ARC Potchefstroom).	Primary for 1G ethanol via juice fermentation. Lignocellulosic bagasse for second-generation ethanol. High potential but limited by infrastructure in SA.	Bagasse: Feed, biogas, electricity, paper pulp. Vinasse: Fertilizer. Specialized: Nutraceuticals, waxes. Opportunities: Ethanol plant integration, marginal land use, high-value by-products.
Forage Sorghum	Tall (6-12 feet), high biomass (50-100 tonnes/ha). Lignocellulosic (40-50% cellulose, 25-30% hemicellulose, 15-20% lignin). Grown in Free	Livestock feed (silage, hay, green chop, grazing) for cattle, sheep, goats, horses.	Secondary use as lignocellulosic feedstock for 2G ethanol, but less optimized than biomass sorghum.	Biomass: Biogas, electricity, second-generation ethanol. Opportunities: Livestock industry, marginal land use, bioenergy potential.

Variety	Characteristics	Primary Uses	Bioethanol Relevance	Secondary Products & Opportunities
	State, North-West (350-400 mm rainfall).		Limited bioethanol uses in South Africa due to feed focus.	
Biomass Sorghum	Very tall (3-5 m), high biomass (50-100 tonnes/ha, sometimes higher). Lignocellulosic (40-50% cellulose, 25-30% hemicellulose, 15-20% lignin). Low sugar content, minimal grain yield. Experimental in SA (e.g., ARC trials).	Bioenergy (second-generation ethanol, biogas, electricity). Limited commercial use in SA.	Primary lignocellulosic feedstock for 2G ethanol or sustainable aviation fuel. Not widely adopted in SA due to market constraints.	Biomass: Bioethanol, biogas, electricity, lignin for chemicals. Opportunities: Bioenergy research, marginal land cultivation, policy-driven ethanol demand.

Finally, South Africa's broader context of high unemployment and sluggish growth underscores the importance of agro-industrial projects that can be inclusive. Sorghum is well suited to integration with smallholder farmers, especially in semi-arid provinces like Limpopo, North West, and the Free State. Inclusion could be enabled via contract farming models, aggregation hubs, provision of seed and mechanisation services, and guaranteed offtake into food, brewing, and ethanol value chains.[22] If well-designed and effectively supported, such integration could strengthen rural livelihoods, diversify the energy mix, and support a more resilient agricultural economy.

[22] International Energy Agency (IEA). *Renewables 2023: Analysis and forecast to 2028.* Paris: IEA, 2023

2. Global and Domestic Sorghum

Global sorghum sits at a nexus. It is a staple crop still central to food security for millions, an adaptable feed grain in competitive markets, and a crop with growing relevance for biofuels and climate resilience. Its future will be shaped by how it competes with dominant cereals, how policies support or neglect it, and how global trade channels continue to evolve.

Sorghum is the fifth most important cereal crop worldwide, cultivated in over a hundred countries across nearly 40 million hectares each year. Its versatility has long underpinned both food security in semi-arid regions and feed supply in more industrialised systems. Roughly half of global production is consumed as food, particularly in Sub-Saharan Africa and South Asia, where it remains a staple for porridges, flatbreads and traditional beverages. In contrast, in the Americas and Australia, sorghum is primarily grown as animal feed, reflecting structural differences in diets and markets.[23] [24]

Despite its resilience as a grain crop, sorghum faces structural competition from maize, wheat and rice. Rising incomes and dietary transitions often lead consumers away from coarse cereals toward subsidised or more refined grains. Policy choices, particularly input subsidies and procurement systems, have reinforced this trend.[25] Nonetheless, trade dynamics offer new opportunities. China, the world's largest sorghum importer, sources millions of tonnes annually from the US and Australia, and in 2025, China cleared Brazil to ship sorghum for the first time. This reflects sorghum's role as a strategic substitute for maize in feed rations whenever maize supplies tighten or prices surge.[26]

Globally, production patterns are uneven. Yields in much of Africa and South Asia hover below 1 tonne per hectare, compared to the 3-4 t/ha achieved in the US, Brazil or Australia with fully mechanised systems. The global area under sorghum has declined slightly over the past decade, from 42 to 39 million hectares, but improvements in productivity have kept production relatively stable.[27] Table 2 offers a picture of the top global producers.

Table 2: Top 10 global producers of sorghum, area cultivated and yield, and role

Rank	Country	Area (ha) under sorghum	Yield (t/ha)	Production (tonnes)	Trade role	Notes
1	US	2,268,000	3.85	8,734,000	Major exporter	4.4 million tonnes exports in 2023 (USD1.39Bn), 85% to China
2	Nigeria	6,100,000	1.07	6,500,000	Domestic use	Local food, feed, beer

[23] Khalifa, Muhammad, and Elfatih A. B. Eltahir. 2023. "Assessment of Global Sorghum Production, Tolerance, and Climate Risk" 7 (June). https://doi.org/10.3389/fsufs.2023.1184373

[24] D. Kumara Charyulu, Victor Afari-Sefa, and Murali Krishna Gumma. 2024. "Trends in Global Sorghum Production: Perspectives and Limitations," January 1–19. https://doi.org/10.1007/978-981-97-4347-6_1.

[25] Mundia, Clara W., Silvia Secchi, Kofi Akamani, and Guangxing Wang. 2019. "A Regional Comparison of Factors Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel." Sustainability 11 (7): 2135. https://doi.org/10.3390/su11072135.

[26] Griffin, Oliver. 2025. "China Clears Imports of Brazil Sorghum, Official Says, in Blow to US." Reuters, September 10, 2025. https://www.reuters.com/markets/commodities/china-clears-imports-brazil-sorghum-official-says-blow-us-2025-09-10/.

[27] Khalifa, Muhammad, and Elfatih A. B. Eltahir. 2023. "Assessment of Global Sorghum Production, Tolerance, and Climate Risk" 7 (June). https://doi.org/10.3389/fsufs.2023.1184373

Rank	Country	Area (ha) under sorghum	Yield (t/ha)	Production (tonnes)	Trade role	Notes
3	India	4,800,000	1.25	6,000,000	Domestic use	Domestic consumption (Jowa)
4	Brazil	1,600,000	3.75	5,000,000	Emerging exporter	Feed use, First shipments to China 2025
5	Mexico	1,200,000	3.50	4,200,000	Producer and Importer	Produces 4.2 million tonnes but imports from US to cover feed
6	Ethiopia	1,650,000	2.48	4,100,000	Domestic use	Domestic food
7	Argentina	850,000	4.12	3,500,000	Exporter	0.22 million tonnes experts in 2022, Middle East and Asia
8	Sudan	6,000,000	0.55	3,300,000	Domestic use	Consumes locally
9	China	630,000	4.76	3,000,000	Major importer	Produces 3 million tonnes but imports 5 million mostly from US
10	Australia	540,000	4.31	2,325,000	Exporter	2.5 million tonnes exports 2022 mostly Asia Pacific

Sources: Calculations by Blueprint Holdings (Pty) Ltd with data derived from FAOSTAT (2024); USDA Foreign Agricultural Service – Production, Supply and Distribution (PSD) database (2024/25); UN Comtrade (2023–2024); International Grains Council (IGC) Grain Market Reports; supplemented by national agricultural statistics and industry sources. Note: Figures represent latest available estimates (2022–2024) and have been harmonised across sources for comparability.

The US dominates in production, but Argentina, China and Australia have better yields. Those countries with low yields produce almost entirely for domestic consumption.

2.1 Sorghum types and processing

Processing begins with the four main types: grain sorghum, sweet sorghum, forage sorghum, and biomass sorghum. This report focuses on grain sorghum as the beginning of the dominant value chain but with comparison and reference to the other sorghum types.
Grain sorghum dominates the market, accounting for over 70% of production and use, reflecting its role in food, feed and ethanol value chains.[28] It is harvested for kernels that are milled into flour, porridge, couscous, and gluten-free baked goods, or malted for traditional beers and spirits. A significant share also enters animal feed, particularly poultry and cattle rations, and bioethanol.

Sweet sorghum contributes around 15%, largely in Asia for bioethanol pilot programs.[29] Its high-sugar stalks are crushed for juice used in syrups, jaggery, and bioethanol, while the grain can be used for food and feed co-products. Bagasse from the stalk supports second-generation ethanol and biomass energy. Forage sorghum, processed primarily as silage or hay, serves livestock systems in arid regions and covers another 10%, especially in livestock-intensive economies.[30] Biomass sorghum bred for tall,

[28] Food and Agriculture Organization (FAO). FAOSTAT Crops and Livestock Data. Rome: FAO, 2023. https://www.fao.org/faostat/en/#data

[29] National Center for Biotechnology Information (NCBI). "Sweet Sorghum for Biofuel Production." *Frontiers in Energy Research*, 2023. https://pmc.ncbi.nlm.nih.gov/articles/PMC10213934/

[30] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Sorghum for Food, Feed and Fuel. Hyderabad: ICRISAT, 2022. https://www.icrisat.org

fibrous stalks, enters bioenergy and bioproduct markets, including bioplastics and pellets for heat and power generation. It remains a niche but rapidly developing sector, accounting for less than 5% of global production, driven by renewable energy mandates.[31]

In South Africa, "sweet sorghum" can refer to low-tannin grain sorghum (for food) or specialised bioethanol varieties (high stalk sugar). In this report, sweet sorghum only refers to the bioethanol variety with a high sugar stalk. Grain sorghum varieties with varying levels of sweetness and tannin are referred to as grain sorghum or grain sorghum bitter variety.

In South Africa, grain sorghum production dominates (e.g., 56,305 tonnes bitter variety, 10,600 tonnes sweet variety in 2021/22). Forage sorghum is common for livestock, while biomass and sweet sorghum for bioethanol are mostly experimental due to market and infrastructure limits. The South African Grain Information Service (SAGIS) and the Crop Estimates Committee (CEC) primarily track commercial grain production, with data largely reflecting grain sorghum volumes. Sweet sorghum is limited to experimental trials (e.g., by Agricultural Research Council (ARC) and Agricultural Council of South Africa (ACCI) for biofuel and syrup) and is not included in these commercial estimates.[32]

2.2 Land in South Africa for Sorghum[33]

There is sufficient land available for sorghum production. Table 3from the Bureau for Food and Agricultural Policy (BFAP) illustrates land available by province.[34] According to the BFAP report (2023), only 9.3% of South Africa's land can be classified as having high agricultural potential, and 65% of the high-potential agricultural land is found in Mpumalanga, KwaZulu-Natal and Limpopo Provinces. Across these provinces, 29 million hectares of moderate and marginal land remain uncultivated and available for potential sorghum cultivation.

Table 3: Sorghum land availability by province

Land capability (LC) class		High	Moderate	Marginal	Non-Arable	Total
Mpumalanga	Total Hectares	2,246,547	2,309,327	2,059,958	750,178	7,366,010
	Hectares cultivated	629,097	504,977	149,611	6,714	1,290,399
	% Hectares cultivated	46%	42%	12%	0%	
Free State	Total Hectares	1,040,681	2,710,414	6,853,371	2,374,450	12,978,916
	Hectares cultivated	750,827	1,314,830	1,583,915	206,487	3,856,059
	% Hectares cultivated	19%	34%	43%	7%	
North West	Total Hectares	1,347,721	1,638,746	5,004,238	2,492,112	10,481,817
	Hectares cultivated	479,859	680,559	990,660	158,172	2,309,250
	% Hectares cultivated	21%	29%	43%	7%	
Limpopo	Total Hectares	2,095,211	2,618,803	5,580,407	2,255,438	12,549,859

[31] Sciencedirect. "Advances in Biomass Sorghum for Bioenergy." Industrial Crops & Products 145 (2020): 111984. https://doi.org/10.1016/j.indcrop.2020.111984

[32] sagrainmag.co.za. 2024. "Data on Producer Deliveries Compared to Crop Estimates - SA Grain." SA Grain -. September 3, 2024. https://sagrainmag.co.za/2024/09/03/data-on-producer-deliveries-compared-to-crop-estimates/

[33] "South Africa's Land Resource in the Water-Energy-Food (WEF) Nexus Context." 2022. https://www.bfap.co.za/wp-content/uploads/2023/03/Land-resource-in-the-Water-Energy-Food-nexus-context.pdf.

[34] South Africa's Land Resource in the Water-Energy-Food (WEF) Nexus Context 30 June 2022 (https://www.bfap.co.za/wp-content/uploads/2023/03/Land-resource-in-the-Water-Energy-Food-nexus-context.pdf)

Land capability (LC) class		High	Moderate	Marginal	Non-Arable	Total
	Hectares cultivated	432,609	421,662	483,493	27,828	1,365,592
	% Hectares cultivated	32%	31%	35%	2%	
Gauteng	Total Hectares	596,535	493,248	437,916	117,910	1,645,629
	Hectares cultivated	223,183	119,474	43,491	2,389	388,358
	% Hectares cultivated	57%	31%	11%	1%	
KwaZulu-Natal	Total Hectares	2,522,663	2,185,723	2,754,571	1,428,974	8,891,931
	Hectares cultivated	388,229	222,478	174,731	31,961	817,399
	% Hectares cultivated	47%	27%	21%	4%	
Eastern Cape	Total Hectares	1,086,153	1,776,631	6,805,093	7,221,222	16,889,099
	Hectares cultivated	340,388	371.519	473,219	106,924	1,292,050
	% Hectares cultivated	26%	29%	37%	8%	
Northern Cape	Total Hectares	118	38,255	9,094,512	28,115,580	37,247,465
	Hectares cultivated	15	9,350	163,004	95,810	268,180
	% Hectares cultivated	0%	3%	61%	36%	
Western Cape	Total Hectares	230,039	748,215	3,127,355	8,454,170	12,559.779
	Hectares cultivated	73,726	285,734	1,109,391	432,540	1,901,391
	% Hectares cultivated	4%	15%	58%	23%	

Source: Calculations by Blueprint Holdings (Pty) Ltd with data derived from Department of Agriculture, Forestry and Fisheries (DAFF); Statistics SA; Department of Agriculture, Land Reform and Rural Development (DALRRD).

These 29 million hectares are characterised by lower rainfall (350-600 mm annually) and poorer soils, making them less suitable for maize but viable for drought-tolerant crops like sorghum. However, estimates suggest only 20-40% of this moderate and marginal land has adequate infrastructure such as roads, electricity, and available water for irrigation.[35]

Land classified as high-potential but degraded through poor management should also be considered. Planting sorghum on high potential but degraded land can aid in soil restoration by improving nutrient stocks, enhancing microbial activity, and reducing erosion in appropriate systems. For instance, integrating sorghum with tied-ridging tillage has been shown to increase soil carbon, nitrogen, and phosphorus while boosting yields by up to 271% in semi-arid zones.[36] [37]

Table 4 provides a high-level indication of the extent of land potentially available for expanded sorghum cultivation, focusing specifically on moderate and marginal land that is currently not utilised. Drawing on BFAP-aligned analysis, the table highlights the scale and geographic distribution of underutilised agricultural land across key provinces, illustrating that a substantial land base exists that could support increased sorghum production without displacing existing high-value or staple crop systems. This is particularly important in the context of developing a sorghum-to-bioethanol value chain, as it demonstrates that feedstock expansion can be achieved through better utilisation of existing land resources rather than through competition with established food production areas.

---

35 ibid

36 L.G. Njiru, J.R. Yegon, G. Mwithiga, A. Micheni, N.J. Gitari, and F.S. Mairura. 2023. “Restoring Soil Nutrient Stocks Using Local Inputs, Tillage and Sorghum-Green Gram Intercropping Strategies for Drylands in Eastern Kenya.” Heliyon 9 (10): e20926–26. https://doi.org/10.1016/j.heliyon.2023.e20926.

37 Tied-ridging tillage is an agricultural technique used to conserve soil moisture and reduce erosion, particularly in semi-arid regions, which traps rainwater, allowing it to infiltrate into the soil rather than running off.

Table 4: High-level view of land availability for sorghum cultivation (BFAP)

Selected Provinces *(based on highest potential for sorghum expansion)*	**Moderate unused (ha)**	**Marginal unused (ha)**	**Moderate + Marginal (ha)**
Mpumalanga	1,804,350	1,910,347	3,714,697
Limpopo	2,197,141	5,096,914	7,294,055
KwaZulu-Natal	1,963,245	2,579,840	4,543,085
Gauteng	373,774	394,445	768,219
Eastern Cape (whole province)	1,405,112	6,331,874	7,736,986
Northern Cape (whole province)	958,187	4,013,578	4,971,765
Total **(six provinces, whole province-numbers)**	**8,701,809**	**20,326,998**	**29,028,807**

Sources: Calculations by Blueprint Holdings (Pty) Ltd with data derived from Bureau for Food and Agricultural Policy (BFAP) analysis; Department of Agriculture, Land Reform and Rural Development (DALRRD) Land Capability Classification dataset; Statistics South Africa (Census of Commercial Agriculture and land-use statistics)

Several studies have explored the use of sorghum for phytoremediation and rehabilitation on degraded mining land, particularly due to its tolerance for heavy metals and drought. A 2017 study in China demonstrated that sorghum effectively reduced cadmium and lead contamination in mine tailings, with biomass production of 20-30 t/ha while accumulating metals in roots, aiding soil stabilization.[38] In South Africa, a 2021 study by the University of Limpopo found that sweet sorghum on coal mine waste improved soil pH and organic matter, yielding 15-25 t/ha of biomass suitable for biofuel.[39] Further research is needed on unused land of various qualities owned by mining companies in Limpopo and Mpumalanga, and the ability to tap into mining rehabilitation funds may provide a source of funding as well as strong links with employment opportunities in the Just Energy Transition (JET).[40]

2.3 Status of the South African sorghum industry

South Africa's sorghum industry has undergone a long-term contraction, with planted area falling to 41,150 ha in 2024/25, down 75% from the early 1990s. Five-year rolling averages confirm the decline: production has averaged 146,000 tonnes in 2020-2024, compared to ~260,000 tonnes in the early 2000s.[41]

This was mainly due to weak consumer demand as traditional uses such as beer declined, and consumers preferred maize; sorghum farming became less profitable than crops such as maize, and sorghum attracts VAT at the standard rate, whereas key competing grains such as maize are zero-rated for basic food products. Production was also affected by drought (especially in 2015/16) and pest issues created more uncertainty. There has been very little investment in sorghum research or seed development, which has held back productivity improvements. There is also weak alignment between

[38] Liu, Zhiquan, Hongli Liu, Xiaoqun Zeng, Leping Cheng, Jingying Fu, Lijun Guo, Wilson Kimani, et al. 2020. "Coupling Phytoremediation of Cadmium-Contaminated Soil with Safe Crop Production Based on a Sorghum Farming System." Journal of Cleaner Production 275 (December): 123002–2. https://doi.org/10.1016/j.jclepro.2020.123002.

[39] Thuthukani Mkhize, Elias T. van der Merwe. 2021. "Sweet Sorghum (Sorghum bicolor (L.) Moench.) Growth and Soil Physico-Chemical Properties on Coal Mine Waste." Journal of South African Forestry Societies.

[40] "JET SEP - National Business Initiative." 2024. National Business Initiative -. October 28, 2024. https://www.nbi.org.za/jet-sep/.

[41] Agbiz. "The Troubling Decline of the South African Sorghum Industry." May 5, 2025.

government, industry, and market stakeholders, limiting access to opportunities. Without a clear and sustained strategy addressing these factors including stimulating domestic demand, supporting biofuel markets, improving competitiveness, and building value chains the sorghum sector is likely to remain marginalised.

The decline of the sorghum sector reflects a combination of demand-side, supply-side, and policy-related constraints:

Demand-side factors

- Weak consumer demand, including declining consumption of traditional products such as sorghum beer
- Substitution towards maize-based products, which are more widely consumed and competitively priced
- VAT treatment disadvantages sorghum, which is taxed at the standard rate, while maize-based staple foods are zero-rated

Supply-side factors

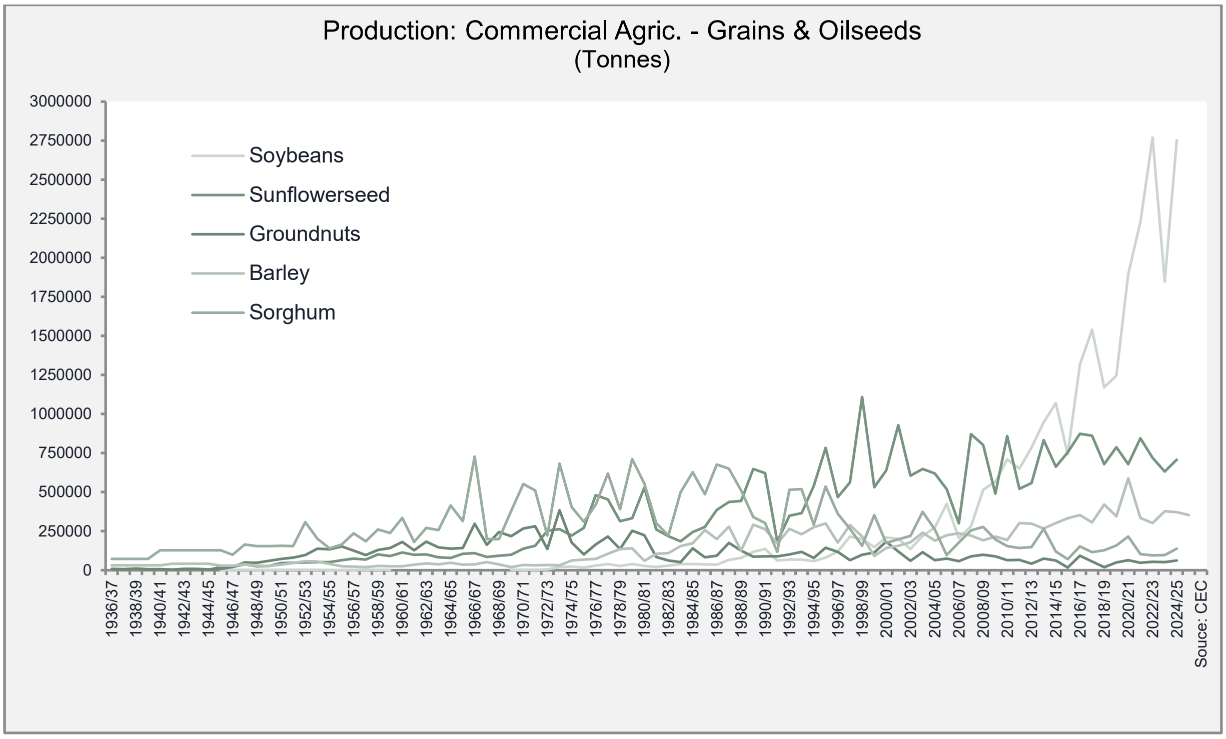
- Reduced profitability relative to competing crops, particularly maize
- Climate shocks, notably the 2015/16 drought, increasing production risk
- Pest pressures contributing to yield uncertainty
- Limited investment in research, seed development, and productivity-enhancing technologies

Policy and market structure factors

- Weak coordination between government, industry, and market stakeholders
- Limited development of integrated value chains and market access opportunities

Without a clear and sustained strategy addressing these constraints including stimulating domestic demand, supporting biofuel market development, improving competitiveness, and strengthening value chain coordination, the sorghum sector is likely to remain marginalised.

Figure 1: Production of grains and oilseeds in South Africa.[42]



Source: CEC (2025)

Processing volumes have also softened. In 2023/24, 147,283 tonnes of sorghum were milled, down from 160,241 tonnes in 2022/23 and below the five-year average of 156,000 tonnes. Of this, 55% went to meal/porridge, 36% to malting, and the remaining 9% to animal feed.[43] The opaque beer market has been the weakest link, with demand falling as consumer preferences shift, competition from other beverages has grown, and Botswana, once a major export destination, has become self-sufficient and now exports back into South Africa[44]. By contrast, food demand (meal/porridges) has been comparatively stable, with the US Department of Agriculture (USDA) estimates indicating only a ~5% decline in sorghum meal consumption since 2008, highlighting that malting, not food use, is driving the sector's contraction.[45] Imports remain a feature of the market. In years of short local supply, South Africa brings in sorghum from countries such as the United States and Botswana, underlining both the tightness of domestic supply and the exposure of processors to international prices.[46]

Sorghum farmers in South Africa face significant challenges due to fluctuating prices, which hinder effective planning and investment, often prompting shifts to alternative crops such as maize and

[42] Downloaded from https://www.sagis.org.za/non-sagis-historic-info/. Data from Crop Estimates Committee (CEC), an official body under the Department of Agriculture, Land Reform and Rural Development (DALRRD).

[43] South African Grain Laboratory (SAGL). "Supply and Demand (2022/23–2023/24): Sorghum Processing by End Use." PDF, 2024.

[44] Harvest SA. "Back to the Future: Reviving Sorghum in South Africa." November 26, 2024.

[45] United States Department of Agriculture, Foreign Agricultural Service (USDA FAS). *The South African Sorghum Market*. May 28, 2019.

[46] National Agricultural Marketing Council (NAMC). *SASDE Report-April 2025 (143rd Meeting, 6 May 2025): Sorghum Supply–Demand Estimates*. 2025.

oilseeds when sorghum returns are uncompetitive.[47][48] The vast majority of sorghum produced in South Africa is produced by large-scale commercial farmers, with limited sorghum cultivation being produced by smallholder farmers in the former homelands. Sorghum cultivation has declined over the past few decades, driven largely by competition from maize which offers higher yields and better-developed markets, as well as reduced demand for traditional sorghum foods and beverages. However, there has been a renewed surge of interest in recent years.

Sorghum markets

Stakeholders from Grain South Africa (Grain SA) acknowledge that the industry is currently not in a healthy state, though a turnaround strategy is underway. Historically, demand for sorghum has come from the food sector, primarily traditional beer and porridge, but Grain SA is now working to stimulate new demand by highlighting sorghum's nutritional benefits. Farmers note that sorghum, with its strong drought resistance, fits well into crop rotation systems with maize, sunflower, or soybean. However, fluctuating prices and unstable supply-and-demand dynamics mean that one year there may be surplus and depressed prices, followed by shortages and imports the next. A stable offtake market would give farmers greater confidence, and the implementation of blending mandates, together with a functioning bioethanol market, could provide this. According to Grain SA, a grain sorghum price set at 18-20% above the white maize price would make cultivation sustainable.[49]

Growing concerns about climate change and water scarcity have highlighted sorghum's resilience as a drought- and heat-tolerant crop. Climate change is expected to make South Africa's summer rainfall regions hotter and more erratic, with more droughts, more intense rainfall events, and shorter growing seasons. Mpumalanga and KwaZulu-Natal may see rainfall totals maintained or even slightly increase, but concentrated into fewer, heavier events.[50] Maize yields are projected to decline in marginal western areas, making drought-tolerant crops such as sorghum increasingly important for both food security and bioethanol feedstock. For biofuel strategies, this reinforces the rationale for diversification away from cane-only models and the inclusion of sorghum as a climate-resilient option.

The increasing recognition of sorghum's nutritional value has significantly boosted its relevance. Recent studies from Zimbabwe, Zambia, and Tanzania emphasise sorghum's continuing role in traditional agriculture, while research from Namibia reveals that 70% of sorghum farmers are women, with the majority over the age of 60, underlining its importance in rural livelihoods and food security.[51]

[47] Mabele, T., et al. "Feasibility Analysis of Sorghum Farming in South Africa." *Agriculture* 14, no. 12 (2024): 2348. https://doi.org/10.3390/agriculture14122348.

[48] South Africa. Department of Agriculture, Forestry and Fisheries. *Grain Market Early Warning Report No. 1 of 2015*. Pretoria: DAFF, 2015.

[49] Information from stakeholder interviews.

[50] Engelbrecht, Francois A., et al. "Projections of Future Climate Change over Southern Africa." Climate Dynamics 52, no. 9–10 (2019): 3993–4012.
Schulze, R.E. "South African Atlas of Agrohydrology and Climatology." University of KwaZulu-Natal, 2016.
IPCC. Sixth Assessment Report (AR6), Regional Fact Sheet – Africa. Geneva: IPCC, 2021.

[51] "A World-Class Regulator of a Vibrant, Diversified and Sustainable Crop Industry Agronomy and Horticulture market development divisions sorghum value chain analysis in Namibia (2023). https://www.nab.com.na/wp-content/uploads/2024/01/SORGHUM-VALUE-CHAIN-ANALYSIS-IN-NAMIBIA-STUDY-NAB-2023.pdf.

2.4 Integrating smallholders into sorghum value chains

The integration of smallholders into commercial value chains has been a challenge in South Africa. This applies particularly for crops such as sorghum where yields remain low and market linkages weak. Studies show that the vast majority of South African sorghum is produced by large-scale commercial farmers, with only limited participation from smallholders in the former homelands. Where pilot projects have been attempted, results underline both the opportunities and the constraints.[52] Recent research highlighted barriers such as lack of improved seed, limited extension, and weak buyer commitments, and found that without bundled input provision and guaranteed offtake, smallholder sorghum cultivation remains financially marginal.[53] More promising has been the AgriFoSe2030 project in KwaZulu-Natal[54], where cooperative farmers were supported with crop rotations, training, and direct buyer interest, enabling improved product quality and modest income gains.
Beyond sorghum, several South African commodity sectors illustrate what effective smallholder inclusion can look like. In the sugarcane sector, Illovo Sugar has integrated thousands of outgrowers by supplying seed cane, fertiliser credit, and extension services, with smallholders contributing up to 30% of cane to certain mills.[55] In horticulture, Woolworths "Farming for the Future" program demonstrates how supermarket-led initiatives can support smallholder compliance with Global Good Agricultural Practice (GAP) standards, provided intensive training and monitoring are available. For dryland grains, Grain SA's Farmer Development Programme has delivered significant yield increases, raising maize yields from 1.5 t/ha to 3-4 t/ha through mechanisation access, field schools, and extension support.

Comparable international experiences reinforce these lessons. In East and Southern Africa, cotton out grower schemes bundled seed, pesticides, and guaranteed purchase, integrating tens of thousands of farmers into export markets. Rwanda's coffee cooperatives and washing stations demonstrated how certification and aggregation can improve farmer prices and quality, while Kenya's dairy cooperatives illustrate the role of shared chilling infrastructure in enabling smallholder participation in formal milk markets. These models show that successful integration depends on three pillars: (1) bundled services (inputs, credit, insurance, extension), (2) guaranteed and transparent market access via anchor buyers or cooperatives, and (3) shared infrastructure to reduce transaction costs and meet quality standards.

Applied to sorghum, inclusive value chain design would combine anchor-buyer contracts with guaranteed pricing formulas, financial loans for equipment, mechanisation services on a pay-as-you-go basis, aggregation hubs for bulking and drying, and weather-index insurance to reduce risk. South Africa's precedent in other crops, together with international lessons, makes clear that integration is not only possible but replicable, provided that policy frameworks, anchor investors, and farmer support systems are aligned.

[52] Nkosi, Zamaswazi; Nyankomo Marwa; and Olawale Olufemi Akinrinde. *"Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique." Agriculture* 14, no. 12 (2024): 2348.

[53] Dunjana, Nothando, et al. *"Sorghum as a Household Food and Livelihood Security Crop under Climate Change in South Africa: A Review." South African Journal of Science* 118, no. 6 (2022): Article #13340.

[54] "AgriFoSe2030'S Sorghum Project Contributes to Climate Smart Agriculture | Slu.se." 2019. Www.slu.se. 2019. https://www.slu.se/en/news/2024/01/agrifose2030s-sorghum-project-contributes-to-climate-smart-agriculture/.

[55] Illovo Sugar Africa. Sustainability Report 2021. Durban: Illovo, 2021.

2.5 Competitive grains

Sorghum competes most directly with maize, wheat, and rice, the world's dominant cereals in both production and consumption. Maize, in particular, is its closest competitor, supplying both food and feed markets at higher yields, often exceeding 6-10 t/ha in the U.S. and Brazil compared with sorghum's average five year yield in South Africa of 3.1 t/ha.[56] Government subsidies, input support, and well-established markets further reinforce maize's dominance.[57] Wheat and rice, while less adapted to semi-arid conditions, benefit from entrenched consumer preferences and procurement policies, especially in Asia where rice is culturally central and heavily subsidised.[58]

This dynamic places sorghum at a disadvantage in terms of consumer demand, where rising incomes often drive shifts away from "coarse cereals" toward "finer" grains. Yet sorghum retains a competitive edge in marginal, water-stressed lands, where its drought and heat tolerance outperform maize or wheat, positioning it as a climate-smart alternative.[59] International trade also reflects these dynamics: maize dominates feed markets globally, while sorghum acts as a substitute during periods of high maize prices or restricted access, as seen in China's import surges when US maize was scarce.[60] Thus, the competition is less about agronomic potential alone, and more about policies, consumer preferences, and trade patterns that shape cereal markets.

From a biofuel's perspective, soybean oil is extracted from the beans and chemically converted into biodiesel, which can be used in diesel engines, often blended with petroleum diesel. The Rainbow Nation Renewable Fuels (RNRF) soybean plant in Coega was delayed by the 2008 global financial crisis, and although the project has a production and manufacturing license and was in advanced stages of funding and design, regulatory uncertainty has halted further progress. In South Africa, biodiesel production, primarily utilizing soybeans, canola, and waste cooking oil as feedstocks, operates at a limited scale, with output at approximately 2.7 thousand barrels per day. Small-scale initiatives, including cooperative models in KwaZulu-Natal and pilot projects by Sasol, face challenges from high feedstock costs and import reliance, though the recent blending mandate is expected to stimulate growth.[61]

Supportive policy and infrastructure that has led to the growth of the soybean food value chains include i) the implementation of the Genetically Modified (GM) Organisms Act of 1997, which facilitated the approval and widespread use of GM soybeans (reaching 94% adoption by 2019), boosting yields through pest resistance and herbicide tolerance; ii) agricultural policies promoting biotechnologies and crop diversification, enabled area expansion from 150,000 ha in the early 1990s to over 750,000 ha by 2013; growth of local soybean processing capacity, driven by rising demand from the poultry sector for oilcake; and reduced reliance on imports and encouraged domestic production. Regional initiatives,

[56] Food and Agriculture Organization (FAO). FAOSTAT Crops and Livestock Data. Rome: FAO, 2023. https://www.fao.org/faostat/en/#data

[57] OECD-FAO. OECD-FAO Agricultural Outlook 2023–2032. Paris: OECD Publishing, 2023. https://doi.org/10.1787/08801ab9-en

[58] Pingali, Prabhu. "Green Revolution: Impacts, Limits, and the Path Ahead." Proceedings of the National Academy of Sciences 109, no. 31 (2012): 12302–08. https://doi.org/10.1073/pnas.0912953109

[59] Food and Agriculture Organization (FAO). The Future of Food and Agriculture: Alternative Pathways to 2050. Rome: FAO, 2018. https://www.fao.org/documents/card/en/c/CA1553EN

[60] United States Department of Agriculture (USDA). Grain: World Markets and Trade. Washington, D.C.: USDA FAS, 2024. https://apps.fas.usda.gov/psdonline/circulars/grain.pdf

[61] "International - U.S. Energy Information Administration (EIA)." 2025. Eia.gov. 2025. https://www.eia.gov/international/data/country/ZAF.

such as the Southern Africa Soybean Roadmap, advocated for national policy reforms to promote soy cultivation and consumption, further accelerating growth.

MAIZE

Maize poses significant competition to sorghum in South Africa, with 4.5-5 million hectares planted annually and yields of 5-6 t/ha, far exceeding sorghum's 2-4 t/ha. Its versatility for food, feed, and industrial uses, coupled with a zero-rated VAT status on maize products since 1991 under the Value-Added Tax Act, enhances its market appeal and affordability, outpacing sorghum's non-zero-rated status. [62]

The Maize Trust and the Department of Agriculture, Land Reform and Rural Development (DALRRD's) Crop Estimates Committee provide research funding and data support, while the Agricultural Policy Action Plan (APAP) promotes maize through extension services and input subsidies, reinforcing its position. Additionally, tariff protections against imports and irrigation support in water-scarce regions further bolster maize's dominance, challenging sorghum's viability despite its drought tolerance.

Maize is generally easier and more profitable to cultivate than sorghum in regions with reliable rainfall and good soils, as it benefits from extensive breeding, high yields, and well-established markets for food, feed, and bioethanol. Sorghum, by contrast, is more resilient under drought and heat stress, making it suitable for marginal lands where maize struggles, but average yields and prices are lower, and markets are less developed outside of specific niches (e.g., brewing, biofuels, and animal feed). In terms of supply and demand, maize enjoys strong global demand with predictable off-take and price support, while sorghum markets are more variable, offering opportunities in bioenergy and climate-resilient agriculture but carrying greater market risk. [63]

Table 5: Global sorghum cultivation compared to maize, wheat and rice. [64] [65] [66]

Crop	Global Harvested area (m/ha)	Average yield (t/ha)	Global production (m/t)	Main uses	Key Notes
Sorghum	40	1,5-2.0	60	Food (50%) feed, biofuel, beverages	Drought/heat tolerant; staple food in Africa/India
Maize	200	6.0	1,200	Feed (60%) food, ethanol	World largest cereal, heavy subsidies, US, Brazil and China
Wheat	220	3,5	785	Food (70%), feed, industrial	Staple for bread/pasta. Key in Europe, Russia, North America; highly traded
Rice (paddy)	165	4,7	780	Food (85%+)	Asian staple, highly subsidised

Sources: Sources: FAOSTAT (2024); Food and Agriculture Organization (FAO) – Crop production and yield statistics; International Grains Council (IGC) Grain Market Reports (2023–2024); United States Department of Agriculture (USDA) Production, Supply and Distribution (PSD) database; own synthesis.

[62] "South African Grain Market | 2022 - 27 | Industry Share, Size, Growth - Mordor Intelligence." n.d. Www.mordorintelligence.com. https://www.mordorintelligence.com/industry-reports/south-african-grain-market.

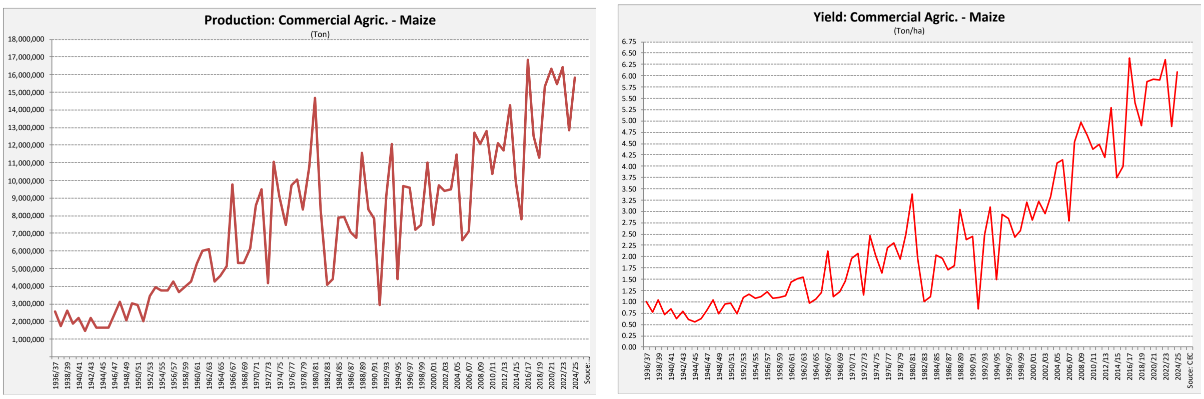
[63] Abu-Ria, Mohamed E, Wafaa M Shukry, Samy A Abo-Hamed, Farag Ibraheem, and Eman M Elghareeb. 2025. "Differential Physiological Responses of Zea Mays and Sorghum Bicolor to Drought Stress: Insights into the Ameliorative Role of Humic Acid at the Reproductive and Yield Stages." Journal of Plant Growth Regulation, July. https://doi.org/10.1007/s00344-025-11813-5.

Soyabeans

Starting around 2000, soybean production in South Africa has outstripped competing grains and oilseeds due to policy changes that supported commercialization, biotechnology adoption, and market demand.[67] Rising yields supported by a favourable agricultural policy environment backing the commercialisation and use of agricultural biotechnologies, has supported commercial farmers to shift from traditional grains to soybean production and to be able to rotate soybeans with other grain crops to maximise profits. Soybeans are a major biofuel feedstock, primarily used for biodiesel production.

From a biofuels perspective, South Africa's Biofuels Strategy Paper of 2007, adopted by cabinet, banned the use of maize for biofuel production, primarily to address concerns about its impact on food security and escalating food prices.[68]

Figure 2: Increasing commercial production of maize in millions of tonnes and yields



Source: Grain SA (2025)

However, over the past few years, studies have shown that rotating sorghum with maize generally improves yields for both crops. Practically, this rotation typically follows a two-year cycle where maize is planted in the first year and sorghum in the second year, allowing soil nutrients to recover and breaking pest and disease cycles. These studies, including a five-year Kansas State University trial, demonstrated that maize yields increased by about 8.4% when following sorghum compared to continuous maize cropping. This improvement partly results from better soil health, nutrient cycling, and reduced pest pressure. Crop residues from sorghum also help retain moisture and improve soil organic matter, benefiting the subsequent maize crop. The rotation is flexible but often follows a maize year followed by sorghum year pattern to optimize land use and yield stability.[69] [70]

68 https://www.dmre.gov.za/Portals/0/Energy_Website/files/media/explained/strategy_biofuels_2007.pdf

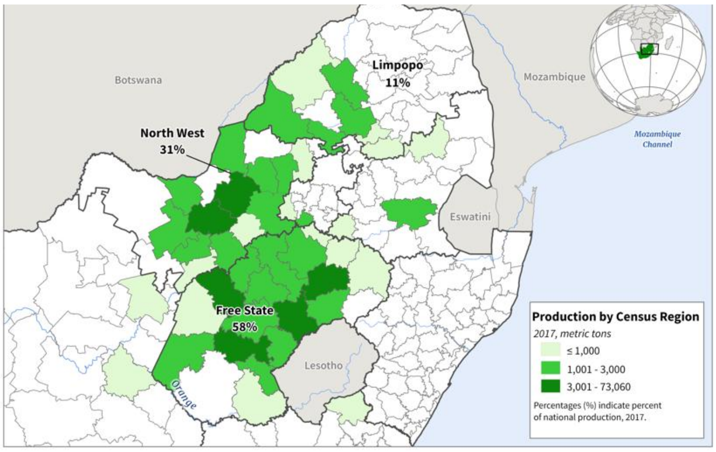
69 Kady. 2024. “Sorghum in 2025: Low Seed Costs, Resilience and Crop Rotation Benefits - Sorghum Checkoff.” Sorghum Checkoff. October 25, 2024. https://www.sorghumcheckoff.com/agronomy-insights/sorghum-in-2025-low-seed-costs-resilience-and-crop-rotation-benefits/.

70 Li, Guang, Aixia Ren, Sumera Anwar, Lijuan Shi, Wenbin Bai, Yali Zhang, and Zhiqiang Gao. 2024. “Optimizing Soil Health and Sorghum Productivity through Crop Rotation with Quinoa.” *Life* 14 (6): 745. https://doi.org/10.3390/life14060745.

Sunflowers

Sunflower cultivation presents a competing business case for farmers, especially in semi-arid or marginal environments, offering a profitable and resilient alternative to sorghum. In South Africa, sunflowers thrive on dryland, requiring minimal irrigation and fewer inputs, while offering a fast-growing crop (around 120-day maturity) that supports crop rotation or double-cropping strategies. Compared to sorghum, both crops are suited to summer rainfall areas of South Africa (North West, Free State, Mpumalanga, Limpopo), but sorghum is more resilient to variable rainfall and poor soils. Input costs for sunflowers generally exceed that of sorghum.

As one of the country's most important oilseed crops, sunflower contributes significantly to the local edible-oil market. Its seeds are crushed for oil, and the valuable high-protein oilcake feeds livestock, especially poultry. In recent seasons, South African sunflower yields averaged ~1.2 t/ha, with national delivery values translating to a gross return of approximately ZAR 11,900/ha at prevailing futures prices. Pilot programs have demonstrated higher return for farmers using high oil-content hybrids (46-48%) which earned premiums of 12-15% per tonne delivered, alongside impressive yields of approximately 2 t/ha. Sunflowers are a concentrated, easily stored commodity (seed), and an established crush market, where harvested sunflower seeds are "crushed" (mechanically pressed and/or solvent-extracted) to separate their two main products namely, sunflower oil used in cooking, food processing, and industrial applications and sunflower meal which is a high-protein by-product used as animal feed.[71]



USDA

Source: South Africa Crop Estimates Committee, Department of Agriculture, Land Reform, and Rural Development. South Africa 2017 Census of Commercial Agriculture.

Input costs for sunflower (seed, fertiliser, herbicide and crop protection, and harvest) are moderate but fixed, break-even prices are sensitive to yield, and fertiliser and fuel price volatility affects margins. Market demand is driven by domestic edible-oil crushing and cooking-oil markets as well as export flows; South Africa produced approximately 600-700 kt of sunflower seed in recent seasons and domestic oil demand is projected to grow slowly, supporting a stable crush industry. Policy and value-chain support exist in the form of advisory work (BFAP, Oilseeds Advisory Committee) and occasional incentives or recommendations to bolster oilseed throughput and smallholder participation, though explicit long-term subsidy programs are limited.

Current trends show area and production volatility (seasonal, price-and-input-driven), modest consolidation of hybrid technology that can raise yields, and price sensitivity to global vegetable-oil markets, meaning sunflower is a viable competitor to sorghum where farmers prefer a storable cash crop and have reliable access to crushing markets. But it is less well suited where low rainfall, marginal soils or the desire for integrated juice/bagasse uses (i.e., sorghum for biofuel or syrup) dominate.

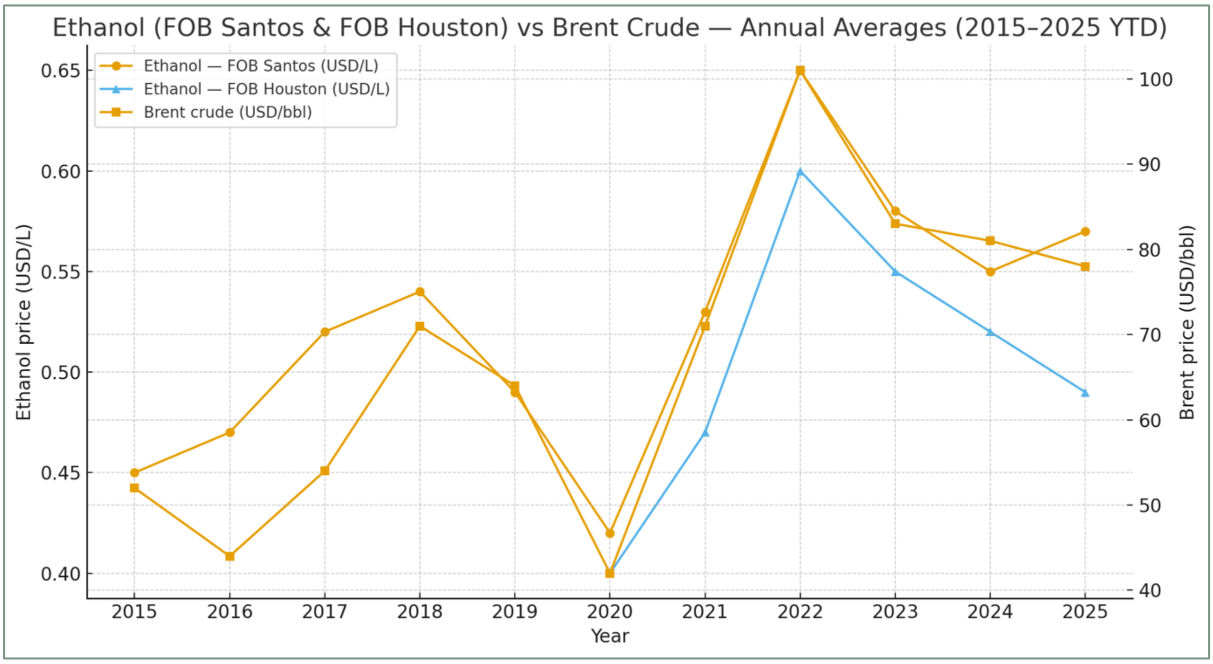
[71] https://ipad.fas.usda.gov/countrysummary/Default.aspx

3. Bioethanol

3.1 Global context

The global market for bioethanol is expanding due to a combination of climate policy, energy security, and agricultural economics. Many countries are mandating higher biofuel blending levels to cut transport emissions and reduce reliance on fossil fuels. As Figure 4 shows, ethanol has grown substantially in its role as a transport fuel substitute.

Figure 4: Ethanol price trends at FOB Santos (Brazil) and FOB Houston (U.S. Gulf).[72]



Sources: World Bank - Commodity Price Data (Pink Sheet): ethanol (Brazil, anhydrous, FOB Santos) and Brent crude monthly series (used for the decade context). Grains.org. https://grains.org/wp-content/uploads/2025/08/Ethanol-Market-and-Pricing-Report-08132025.pdf

The ethanol market was valued at USD116.47 billion in 2024, and total ethanol revenue is expected to grow at a CAGR of 5.5% from 2025 to 2032, reaching nearly USD 178.74 billion.[73]

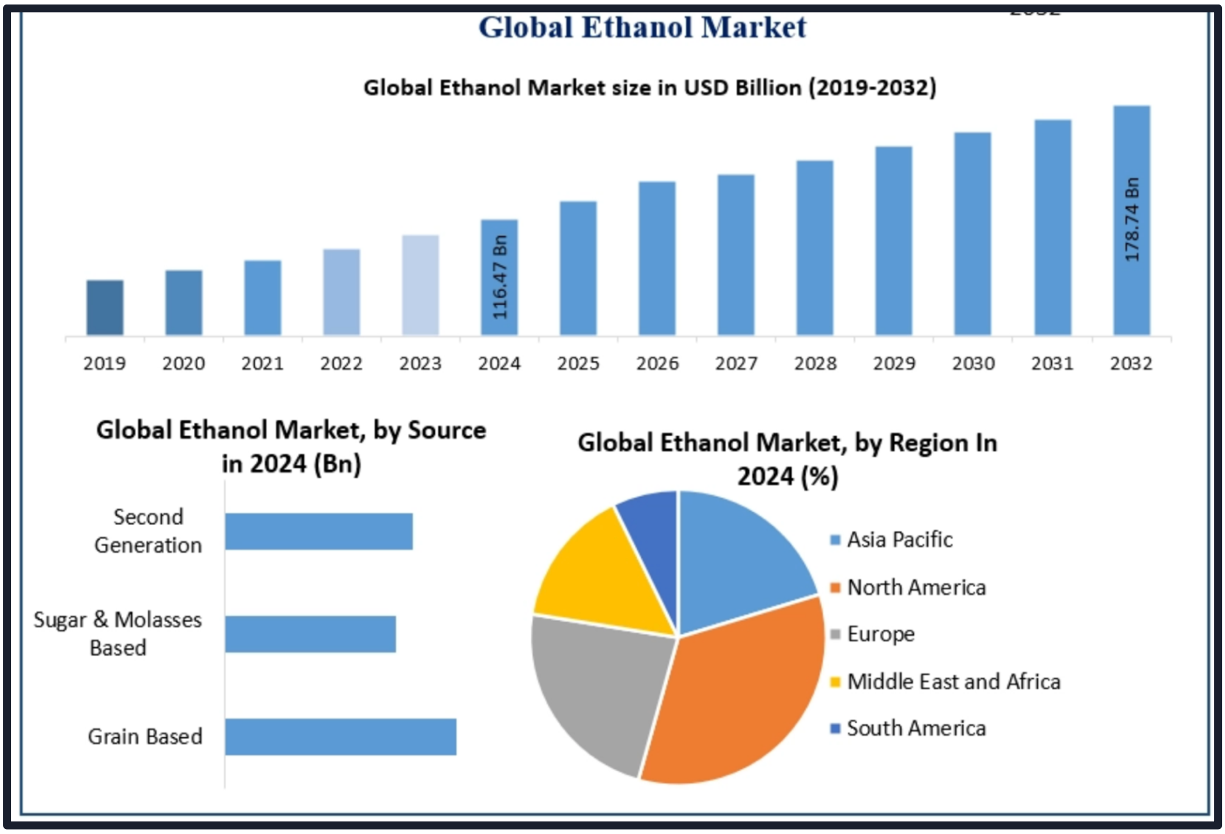
Global ethanol prices broadly track Brent crude because ethanol competes directly with gasoline as a transport fuel. When oil prices rise, ethanol becomes more competitive, pulling its price upward; when oil falls, ethanol prices also soften. There are some divergences; ethanol can be influenced by sugar markets (since mills switch between sugar and ethanol depending on relative prices) and by domestic policy in Brazil. The price relationship between global ethanol and Brent crude evolves with supply-

[72] World Bank - Commodity Price Data (Pink Sheet): ethanol (Brazil, anhydrous, FOB Santos) and Brent crude monthly series (used for the decade context). Grains.org. https://grains.org/wp-content/uploads/2025/08/Ethanol-Market-and-Pricing-Report-08132025.pdf

[73] "Global Ethanol Market – Industry Analysis and Forecast (2020-2027)." n.d. https://www.maximizemarketresearch.com/market-report/global-ethanol-market/25241/.

demand dynamics, energy policies, and feedstock costs, but follows Brent crude as the fundamental price reference for liquid transport fuels.[74] The North American market held the largest share in the global ethanol market in 2024.

Figure 5: Global ethanol market growth 5% CAGR for the next eight years.[75]



Source: World Bank (2025)

The US is the world's largest producer. The dominant feedstock is maize, which accounts for about 94-95% of total ethanol output, while grain sorghum contributes a smaller share, and sugarcane-based ethanol is produced in very limited volumes in Hawaii and Florida.[76] Ethanol demand is underpinned by the RFS, first enacted in 2005 and expanded in 2007, which mandated up to 136 billion litres of renewable fuels by 2022, with sub-targets for advanced and cellulosic fuels[77].

The US market relies on blending mandates. E10 (10% ethanol in gasoline) is universal, while E15 and E85 (high ethanol blends for flex-fuel vehicles) are available regionally. Despite constraints such as the *blend wall* and limited penetration of advanced biofuels, ethanol remains critical as a clean-burning

[74] "Pricing of Ethanol Blends at the Pump Differs in the Short Term Compared with the Long Term | Economic Research Service." 2024. Usda.gov. 2024. https://www.ers.usda.gov/amber-waves/2024/december/pricing-of-ethanol-blends-at-the-pump-differs-in-the-short-term-compared-with-the-long-term.

[75] "Global Ethanol Market – Industry Analysis and Forecast (2020-2027)." n.d. MAXIMIZE MARKET RESEARCH. https://www.maximizemarketresearch.com/market-report/global-ethanol-market/25241/.

[76] U.S. Department of Agriculture (USDA). *Grain: World Markets and Trade*. Washington, DC: USDA Foreign Agricultural Service, 2024. https://apps.fas.usda.gov/psdonline/circulars/grain.pdf

[77] U.S. Environmental Protection Agency (EPA). *Renewable Fuel Standard (RFS)*. Washington, DC: EPA, 2007. https://www.epa.gov/renewable-fuel-standard-program

additive and as a mechanism to support farm incomes and rural economies.[78] The blend wall refers to the maximum limit on the amount of ethanol that can be blended into gasoline for use in vehicles, typically capped at about 10% ethanol by volume (known as E10). This limit exists because most existing fuel infrastructure, vehicle engines, and regulatory certifications are designed to accommodate gasoline with no more than 10% ethanol. When ethanol use hits this blend wall, it restricts the expansion of ethanol consumption despite policy mandates to increase renewable fuel usage.

The blend wall creates a bottleneck in increasing ethanol market penetration since going beyond the 10% limit requires vehicle modifications, upgraded fuelling infrastructure, or approval of higher-level ethanol blends like E15 or E85, which face technical, regulatory, and consumer acceptance challenges. The term is often used in the biofuels and energy policy space to describe the practical upper limit for ethanol blending in the current vehicle and fuel system environment. In short, the blend wall is a regulatory and technical cap on ethanol blending, limiting growth in ethanol consumption in transportation fuel unless infrastructure and vehicle compatibility evolve to handle higher blends.

Table 6: Top 5 global bioethanol producers

Rank	Region	Latest Annual production (L)	Main feedstocks	Domestic vs Export
1	US	61,5 Bn L in 2024	Corn (94-95%)	7,2 Bn exports
2	Brazil	37,4L in 2024/5	Sugarcane; corn ethanol at 8,2Bn L	Mainly domestic (E27/E30 blends) Exports 1,9-2,4 Bn L in 2024
3	India	10,5 Bn L (fuel 9,7Bn L)	Sugar cane; expanding in grain	Entirely domestic
4	EU	6,4 Bn L in 2023, fuel share 86%	Corn 485; wheat 25%; sugars, 10%	Net importer 2,08 Bn L in 2023
5	China	3,9 Bn L in 2023	Corn (some cassava)	Primarily domestic; trade tightly managed.

Sources: U.S. Energy Information Administration (EIA) (2024); Renewable Fuels Association (RFA) (2024); International Energy Agency (IEA) Renewables (2023–2024); USDA Foreign Agricultural Service (FAS) Biofuels Annual Reports (2023–2025); European Commission (2024); UNICA (Brazilian Sugarcane Industry Association) (2024); Government of India (Ministry of Petroleum & Natural Gas) (2024); own synthesis.

The first EU's Renewable Energy Directive (RED), adopted in 2009 set a binding target of 10% renewable energy in transport by 2020, which drove bioethanol demand as a blending component.[79] It was revised in 2018 (RED II, Directive (EU) 2018/2001), raising the overall renewable energy target to 32% by 2030 and capping food-based biofuels at 7% of transport energy.[80] A further revision (RED III, 2023) increased the EU renewable share target to 42.5% by 2030, with advanced biofuels receiving more policy support.[81] Ethanol blending into petrol in the EU is generally limited to 10% by volume under existing EU standards and fuel quality rules.

Brazil produces about 37 billion litres of ethanol annually, derived mainly from sugarcane with a fast-growing maize ethanol segment, and consumes most domestically through its high-blend E27-E30

[78] U.S. Energy Information Administration (EIA). *U.S. Fuel Ethanol Overview.* Washington, DC: EIA, 2023. https://www.eia.gov/energyexplained/ethanol/

[79] European Commission. *Directive 2009/28/EC of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources*. Brussels : EU, 2009. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028

[80] European Commission. *Directive (EU) 2018/2001 on the Promotion of the Use of Energy from Renewable Sources (Recast)*. Brussels : EU, 2018. https://eur-lex.europa.eu/eli/dir/2018/2001/oj

[81] European Union. Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 Amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as Regards the Promotion of Energy from Renewable Sources and Repealing Council Directive (EU) 2015/652. Official Journal of the European Union L, no. 2023/2413 (20 November 2023): 1–131. https://eur-lex.europa.eu/eli/dir/2023/2413/oj/eng

mandate, while exporting 2-3 billion litres to markets such as the US, EU, and Asia.[82] Brazil's ethanol industry is integrated with its sugar industry, allowing flexible allocation of sugarcane between sugar and ethanol based on market prices. The government supports ethanol exports through policies, blending mandates, and investments in infrastructure and innovation.[83]

India's ethanol programme relies largely on sugarcane molasses and juice, supplemented by surplus food grains, producing around 10 billion litres annually to supply the government's E20 blending target by 2025, with almost all production consumed domestically.[84] China has 21 first generation plants and produces close to 4 billion litres of ethanol per year, primarily from maize, and while it has piloted E10 mandates in some provinces, the market remains policy-sensitive with tight trade controls and almost entirely domestically consumed.[85]

3.2 South African bioethanol

The regulated biofuels price published under the Petroleum Products Act (Government Gazette No. 53146 of 12 August 2025) has begun the process of unlocking blending mandates in South Africa.[86] The price of bioethanol is equivalent to the basic fuel price plus a zone differential to cover the cost of transport from refineries or ports to inland distribution nodes, so that blended fuel will cost the same as regular non-blended petrol at the pump.

South Africa has long recognised the potential of biofuels as part of its energy transition, yet implementation has lagged. The path to regulated bioethanol pricing has unfolded over nearly two decades of slow policy development. The starting point was the Biofuels Industrial Strategy (2007), which identified biofuels as a diversification tool but excluded maize and jatropha as feedstocks on food security grounds. This was followed by the Biofuels Regulatory Framework (2019/20), gazetted in 2020, which set out licensing conditions, feedstock protocols, and sustainability requirements for producers but stopped short of mandating blending due to the absence of a pricing mechanism. The Petroleum Products Amendment Regulations (2021-2023) gradually aligned the sector with South Africa's fuel pricing system, paving the way for implementation. Finally, in August 2025, Government gazetted a regulated transfer price for biodiesel and bioethanol, linked to the Basic Fuel Price. (BFP) This pricing regulation closes a last major policy gap, enabling the rollout of biofuel blending mandates and unlocking market opportunities for the private sector to innovate and invest. [87]

In this context, sorghum is significant because maize is explicitly excluded as a feedstock for biofuels, leaving sugarcane, molasses, and sorghum as the principal options under the Biofuels Industrial Strategy. Cassava is another crop used for bioethanol production primarily in tropical and subtropical regions where it is a major staple crop, but this is not the case in South Africa. Nigeria is the world's largest producer of cassava, with extensive use of the crop for bioethanol as a renewable energy source

[82] U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS). Brazil Biofuels Annual 2024. GAIN Report No. BR2024-0034. Brasília: USDA FAS, 2024.

[83] Vidyesh Swar. 2025. "Brazil Ethanol Market Share, Share & Opportunities 2025-2032." Coherent Market Insights. March 4, 2025. https://www.coherentmarketinsights.com/industry-reports/brazil-ethanol-market.

[84] U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS). *India Biofuels Annual 2024.* GAIN Report No. IN2024-0078. New Delhi: USDA FAS, 2024. https://apps.fas.usda.gov/gainfiles/2024/IN2024-0078.pdf

[85] U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS). *China Biofuels Annual 2023.* GAIN Report No. CH2023-0095. Beijing: USDA FAS, 2023. https://apps.fas.usda.gov/gainfiles/2023/CH2023-0095.pdf

[86] "Government Notices Goewerments kennis GewinGs DMRE." 2025. https://www.gov.za/sites/default/files/gcis_document/202508/5314gon6499.pdf.

[87] IEA Bioenergy. *Emerging Markets Policy Brief: Biofuels in Emerging Economies.* Paris: IEA Bioenergy, 2024.

amid efforts to diversify energy supplies.[88] The potential for significant expansion of sugar cane cultivation is limited and its high-water requirements are a constraint in a water-scarce country like South Africa.[89]

South Africa's operational non-fuel ethanol industry combines fermentation-based bioethanol from sugar and starch with Sasol's synthetic production. AlcoNCP (Merebank, Durban) produces about 85 million litres per year of neutral alcohol from maize starch for beverage, cosmetics, and pharmaceutical markets, serving primarily coastal demand.[90] Illovo Sugar SA, through its KwaZulu-Natal mills, generates more than 50 million litres annually from cane molasses as a co-product of sugar milling.[91] By contrast, Sasol's High Purity Ethanol (HPE) unit at Secunda produces roughly 108 million litres equivalent per year not from biomass, but as a by-product of coal-to-liquids (CTL) synthetic fuel chemistry.[92] Thus, while Illovo and AlcoNCP represent fermentation-based bioethanol plants integrated with the sugar and starch sectors, Sasol's HPE is a fossil-based synthetic ethanol stream, differentiated in both feedstock and infrastructure role.

There are no commercial fuel-ethanol plants operating at full scale using sorghum as feedstock, however the policy support under the Biofuels Industrial Strategy has acknowledged sorghum as an eligible feedstock and sorghum offers South Africa important advantages because of its climate resilience. Although yields and conversion efficiencies are lower than sugarcane, the relative GHG savings from sorghum ethanol are still substantial given South Africa's reliance on carbon-intensive CTL fuels (Sasol). Ethanol from local feedstocks can deliver up to 87% GHG reductions compared to fossil fuels.[93]

Sugarcane vs. sorghum for bioethanol in South Africa

According to the DMRE (2010), grain sorghum and sugarcane are the leading contenders for bioethanol in South Africa. The report quotes minimum recommended plant capacities as 158,000 m3/a in the case of sorghum and 95,000 m3/a for sugar cane.[94] The capital investments for these plants are ZAR2,131 million and ZAR1,973 million[95],respectively. A sugar cane to ethanol plant is about 25% more expensive than a sorghum plant of the same size. These are the reference plant configurations used for the cost and financial modelling in this report.

South Africa's well-established but financially stressed sugarcane sector represents a possibly strong driver as well as a competitor to the emergence of a sorghum-to-bioethanol industry. Currently, there is insufficient demand to allow for a blending mandate, and supply, even at 2%, is significantly lower than demand. A firm blending mandate will de-risk the sector and encourage new investment. There are clear reasons why Brazil, South Africa's fellow Brazil, Russia, India, China, South Africa (BRICS)

88 Nuwamanya, Ephraim, Linley Chiwona-Karltun, Robert S. Kawuki, and Yona Baguma. 2011. "Bio-Ethanol Production from Non-Food Parts of Cassava (Manihot Esculenta Crantz)." *AMBIO* 41 (3): 262–70. https://doi.org/10.1007/s13280-011-0183-z.

89 DMRE (2010) "Biofuels pricing and Manufacturing economics." n.d. Accessed September 29, 2025. https://www.dmre.gov.za/Portals/0/Energy_Website/files/esources/renewables/BiofuelsPricingAndManufacturingEconomics.pdf.

90 AlcoNCP. "Company Profile." Accessed October 1, 2025. https://www.alconcp.co.za/.

91 Illovo Sugar Africa. "Ethanol Production." Illovo Sugar Africa, 2023. https://www.illovosugarafrica.com/Products/Ethanol.

92 Sasol South Africa. Environmental Audit Report: High Purity Ethanol Plant, Secunda. Johannesburg: Sasol, 2022.

93 IEA Bioenergy. *Emerging Markets Policy Brief: Biofuels in Emerging Economies.* Paris: IEA Bioenergy, 2024.

94 Ibid

95 Ibid

partner, has built its globally renowned biofuels programme almost entirely around sugarcane, which remains the benchmark for efficient 1G bioethanol.

Although under pressure, South Africa already has a functioning sugar cane-based bioethanol industry. Four operating plants in KwaZulu Natal collectively produce hundreds of millions of litres annually for the industrial, pharmaceutical, and beverage markets.[96] These plants demonstrate that the technology risks have been largely overcome, and that domestic technical expertise exists to build, operate, and integrate bioethanol production into supply chains. This lowers barriers to expanding ethanol output from cane to meet any fuel-blending mandates.

South Africa's sugarcane industry is concentrated in KwaZulu Natal and Mpumalanga provinces, with approximately 400,000-450,000 hectares under cultivation as of the 2024/2025 season. This figure has remained relatively stable over the past few years, reflecting a balance between production demands (18-19 million metric tonnes annually) and challenges like drought, disease, and land reform.[97] The industry supports 65,000 direct jobs and 1 million livelihoods but has seen production decline from 2.5 million tonnes of sugar annually in the 2010s to 2.2 million tonnes today, with 12 active mills down from 15, under financial strain, with producers squeezed by cheap imports, rising input costs, the sugar tax, and climate variability, while some mills are operating below capacity or have reduced throughput. Domestic consumption has softened, and two mills in KwaZulu Natal have been mothballed since 2020, exacerbating job losses and forcing growers to truck cane to distant facilities, increasing costs by 20-30%. The industry is increasingly reliant on exports to absorb surplus supply.[98] [99]

Table 7 shows current plants and feedstock capacity

Table 7: Southern African bioethanol plants feedstock.

Plant/Operator	Location	Capacity (ML/year)	Feedstock	End use
Illovo Sugar, Merebank	Durban, KZN	Split for Illovo not disclosed.	Cane molasses	Potable and industrial grades
Illovo, Glendale	KwaDukuza, KZN	Split for Illovo not disclosed	Cane molasses	Potable and industrial grades
AlcoNCP Ethanol	Umbilo/Umgeni, KZN	85 Mn L/year	Maize	Beverages, Pharma, Industrial
Royal Eswatini Sugar Corporation (RESC), Simunye	eSwatini	32 Mn L/year	Cane molasses	Industrial Potable with some fuel grade capacity
USA Distillers	Big Bend, eSwatini	Not disclosed	Cane molasses	High purity potable and industrial alcohol
Tongaat Hulett, Triangle Estate	Triangle, Zimbabwe	40 Mn L/year 80 Mn L Year target	Sugar cane	Industrial and local blending markets
Green Fuel, subsidiary of Innscor Africa	Chisumbanjwe, Manicaland, Zimbabwe	120 Mn L/year with planned expansion	Sugar cane	Majority supplier in Zimbabwe, co-generation of fuel.

[96] South African Sugar Association (SASA). Industry Statistics 2024. Durban: SASA, 2024.

[97] Come Alive. 2024. “SASA Outlines Progress and next Steps for Sugarcane Master Plan.” South African Sugar Industry. October 9, 2024. https://sasa.org.za/sasa-outlines-progress-and-next-steps-for-sugarcane-master-plan/.

[98] South African Sugar Association (SASA). Trouble for Sugar in South Africa. Durban: SASA, 2023. https://sasa.org.za/trouble-for-sugar-in-south-africa/

[99] South African Sugar Association (SASA). SA Sugar Industry Faces Crisis. Durban: SASA, 2023. https://sasa.org.za/sa-sugar-industry-faces-crisis/

Source: compilation drawing on multiple company reports and disclosures (Illovo Sugar Africa, Tongaat Hulett, AlcoNCP, Green Fuel, Royal Eswatini Sugar Corporation); USDA Foreign Agricultural Service (FAS) Biofuels Annual Reports (South Africa, Zimbabwe, Eswatini); International Energy Agency (IEA) Renewables reports; industry publications and press releases; own synthesis.

Mpumalanga alone contains nearly half of the country's high potential arable land with mean annual rainfall ranging from 600-750 mm in the Lowveld to 750-970 mm in the Highveld, which is broadly suitable for rainfed or supplementary-irrigated sugarcane. In KwaZulu-Natal (KZN), coastal and midland regions already sustain extensive cane farming, but additional land with adequate rainfall remains limited by competing land uses, soil degradation, and urban expansion. Although scope exists for expansion, potentially by a few hundred thousand hectares across both provinces, the availability of suitable land is constrained by mining activity in Mpumalanga, environmental protection requirements, and the fact that much of the higher-rainfall land is already cultivated. Significant expansion would require careful spatial planning, trade-offs with other crops, and investment in logistics and infrastructure. For example, to support a 100 million litre per annum ethanol plant, an estimated 20,000-30,000 hectares would be needed including space for replanting cycles, fallow periods, and a non-productive block.

Cane delivers higher ethanol yields per hectare (6,000-7,000 L/ha under good agronomic conditions) compared to sorghum, particularly grain sorghum, where yields average only in the region of 1,200 L/ha under South African conditions.[100] [101] In addition, cane bioethanol plants typically use bagasse as an onsite energy supply in cogeneration boilers to produce steam and electricity, which often meets all of their energy requirements. This self-sufficiency in energy reduces operational costs and carbon emissions, making sugarcane ethanol production highly efficient and sustainable.[102] Cane is supported by an established milling and logistics infrastructure concentrated in KZN and Mpumalanga, whereas sorghum ethanol will require new plants, and potentially storage. Existing sugarcane mills already integrate ethanol production at marginal cost. Moreover, the sugar sector has strong political influence and export experience, while sorghum has suffered long-term declines in area planted and market share to maize and sunflower.

Sugarcane offers two main pathways for producing bioethanol: direct fermentation of cane juice and fermentation of molasses, a by-product of sugar refining. Fresh cane juice is a clean, high-sucrose feedstock that can go straight into fermentation tanks after clarification. It avoids the impurities that make molasses fermentation more complex and expensive. Juice-to-ethanol routes are widely used in Brazil, where fresh cane juice is diverted from sugar production and fermented directly, yielding high volumes of fuel-grade ethanol at relatively low cost. In contrast, South Africa and Eswatini have traditionally focused on molasses-to-ethanol, since molasses is a residual stream after sugar crystallisation; this approach leverages an existing by-product but produces smaller volumes, making it more suitable for industrial and potable alcohol markets. Both routes rely on the same basic

[100] Food and Agriculture Organization of the United Nations (FAO). Biofuels from Grasses and Sorghum: A Sustainable Option for Africa. Rome: FAO, 2010.

[101] Gnansounou, Edgard, Alain Dauriat, Charles Wyman, and Kari Suominen. "Refining Sweet Sorghum to Ethanol and Sugar: Economic Trade-offs in the Context of North China." Bioresource Technology 96, no. 9 (2005): 985–1002. https://doi.org/10.1016/j.biortech.2004.09.015

[102] Canilha, Larissa, Anuj Kumar Chandel, Thais Suzane dos Santos Milessi, Felipe Antônio Fernandes Antunes, Wagner Luiz da Costa Freitas, Maria das Graças Almeida Felipe, and Silvio Silvério da Silva. 2012. "Bioconversion of Sugarcane Biomass into Ethanol: An Overview about Composition, Pretreatment Methods, Detoxification of Hydrolysates, Enzymatic Saccharification, and Ethanol Fermentation." *Journal of Biomedicine and Biotechnology* 2012: 1–15. https://doi.org/10.1155/2012/989572.

fermentation and distillation technology, but the juice route prioritises ethanol as the main product, while the molasses route is secondary to sugar production, limiting scale but reducing feedstock risk.[103] [104]

Both Illovo Sugar and Tongaat Hulett recognise that the viability of large-scale bioethanol production in Southern Africa depends on the implementation of blending mandates. Tongaat has been more explicit, with announcements in 2019 about plans to double ethanol production capacity in Zimbabwe directly linked to mandated fuel blends. Illovo, by contrast, highlights ethanol as part of its broader downstream product mix but has not published firm commitments tied to fuel-grade blending policy in South Africa. This likely reflects the sector's caution after years of stalled mandate implementation.

The bioethanol blending mandate could provide a new, stable domestic outlet for surplus sugar, reducing dependence on volatile export markets and strengthening mill utilisation. By creating predictable demand for sugarcane-derived ethanol, this will revitalise idle or underused milling infrastructure, improve grower margins, and accelerate diversification of the sector, aligning it with South Africa's broader renewable energy and just transition goals.

The two biggest producers of grain sorghum bioethanol, the US and China, primarily use sorghum as an alternative or adjunct feedstock in ethanol plants that are primarily designed to process corn (maize). In the US, many ethanol facilities operate flexibly with corn (maize) as the main feedstock but incorporate grain sorghum when it is available and economically viable, especially in drier regions where sorghum tolerance to drought offers a reliable supply advantage. These plants blend sorghum with maize to maintain continuous operations without significant process changes. Estimates put grain sorghum contributions between 5 and 10% of ethanol in regions like Texas, Kansas, and Nebraska, where sorghum is a key crop due to drought tolerance.

Grain sorghum bioethanol from the planned Mabele plant in Bothaville could give investors a healthy return that exceeds the general hurdle rate for African infrastructure investments. Sorghum can play a significant role growing over time, as demand for mandated fuel greatly exceeds supply for some considerable time to come.[105]

Policy uncertainty and logistics challenges

International experience shows that stable policy and blending mandates are critical to unlocking investment in biofuels. The US Ethanol Industry Outlook (2025) [106] demonstrates how the RFS created long-term market certainty, scaling ethanol output to over 16 billion gallons annually and enabling flexible plants to incorporate grain sorghum alongside maize as a drought-resilient feedstock. For South Africa, delayed tariff adjustments and policy uncertainty have undermined competitiveness in other sectors reinforcing the importance of timely implementation of South Africa's regulated bioethanol price and blending mandates.[107]

Originally, the Regulations Regarding the Mandatory Blending of Biofuels with Petrol and Diesel were officially gazetted in 2012 and meant to take effect in October 2015. The regulations specify minimum blending percentages of 5% by volume of biodiesel (B5), and 2-10% by volume of bioethanol: (E2-

[103] Food and Agriculture Organization of the United Nations (FAO). Biofuels from Grasses and Sorghum: A Sustainable Option for Africa. Rome: FAO, 2010.

[104] Goldemberg, José. "Ethanol for a Sustainable Energy Future." Science 315, no. 5813 (2007): 808–810.

[105] Gnansounou, Edgard, and Alain Dauriat. "Ethanol from Sweet Sorghum: A Review." *Bioresource Technology* 101, no. 13 (2010): 4859–4868.

[106] Ethanol Producers Association. Ethanol Industry Outlook 2025. Washington, D.C.: Ethanol Producers Association, 2025

[107] South Africa. International Trade Administration Commission (ITAC). Import Duty Review Report. Pretoria: ITAC, September 23, 2025.

E10).[108] In 2020, amendments were made to include second- and third-generation biofuels, which are derived from non-food sources like waste and algae. With 2023 consumption at 11.8 billion litres of petrol[109], a 2-10% mandate would require approximately 236-1,180 million litres of bioethanol annually. The absence of a pricing structure and investment incentives have been the main barrier to implementation, and concerns about economic viability of the sector without clear policy have left projects unable to reach financial close. However, the demand for bioethanol in South Africa should grow now that pricing details have been gazetted in August 2025.[110]

Case Study: Zimbabwe's fuel blending mandates

The Zimbabwe experience provides lessons. Mandatory blending was implemented in 2012 and moved to E10-E15 by 2013. The introduction of ethanol blending initially reduced pump prices, since ethanol was cheaper than imported petrol, and it helped ease foreign exchange pressures. While price benefits have fluctuated due to supply constraints, the overall effect was to make blended petrol more affordable than unblended petrol.[111] [112]

On the positive side, the policy has bolstered local ethanol production, reducing reliance on fuel imports and saving significant foreign currency, with reduced emissions and improved. environmental health. It supports the agricultural sector, creating jobs in sugarcane farming and processing at facilities like Green Fuel in Chisumbanje. However, the experience has drawn criticism for driving up fuel prices and making blended petrol more expensive than regional unleaded options. Critics argue the mandate benefits politically connected figures like businessman Billy Rautenbach[113], who holds a near-monopoly via Green Fuel, leading to accusations of higher costs for consumers amid economic strains. Practical issues include reduced vehicle mileage, potential engine damage in the aging fleet, and rising fuel contamination from illegal blending or smuggled methanol, as reported by regulators in 2025.[114] Despite these challenges, and evidence of opposing sentiment on social platforms related to affordability and equity, ongoing efforts persist to expand production in Zimbabwe.

Case Study: Origin Materials

Origin Materials (USD ORGN), based in California, is a carbon-negative materials company focused on converting biomass (e.g., cellulose from wood or agricultural waste) into sustainable building-block chemicals via its proprietary process. Although not a pure biofuels firm, the company has stated plans to produce biofuels and the inclusion of this company as a case study, intends to illustrate the technology and capital risks in the advanced biorefinery space.

---

[108] "(E) and (F) of the Petroleum Products Act." 1977, no. 35623: 3. https://www.gov.za/sites/default/files/gcis_document/201409/35623rg9808gon671.pdf.

[109] jade. 2024. "The South African Retail Fuel Market 2024 | Kalibrate Global." Kalibrate Global. September 4, 2024. https://kalibrate.com/insights/blog/location-intelligence/the-south-african-retail-fuel-market-2024.

[110] "Government Notices • GoewermentskennisGewinGs DRME." 2025. https://www.gov.za/sites/default/files/gcis_document/202508/5314gon6499.pdf.

[111] Zimbabwe Energy Regulatory Authority (ZERA). Petroleum Blending Announcements 2012–2014. Harare: ZERA.

[112] Matondi, Prosper. "The Political Economy of Biofuels in Southern Africa: The Case of Zimbabwe." Journal of Peasant Studies 40, no. 3 (2013): 447–465.

[113] "Mnangagwa's Fuel Baron at the Centre of Zimbabwe Political Storm - the Africa Report.com." 2019. The Africa Report.com. 2019. https://www.theafricareport.com/361042/mnangagwas-fuel-baron-at-the-centre-of-zimbabwe-political-storm/?utm_source=Twitter&utm_campaign=Twitter&utm_medium=Social%20media#=.

[114] Eze, Martins. 2024. "Zimbabwe Bans Unleaded Petrol in the Country." The Electricity Hub. September 2, 2024. https://theelectricityhub.com/zimbabwe-bans-unleaded-petrol-in-the-country/.

The performance of Origin Materials (ORGN) since its Nasdaq listing highlights the inherent challenges of pursuing an integrated biorefinery model based on biomass, despite access to US capital markets. The challenges include long lead times for plants to come on stream, technology risks and need for patient capital. Origin's share price shown below is a useful indicator of how the market assesses the company's risk profile.[115]

Figure 6: Origin Materials (ORGN) share price (Nasdaq) in 2021.

Source: ORGN - Origin Materials Inc Stock Price and Quote." 2023. Finviz.com. 2023

Unlike conventional 1G ethanol plants, which rely on starch (maize, sorghum) or sugar (cane, molasses), Origin uses a proprietary process to transform lignocellulosic feedstocks into chloromethyl furfural (CMF) and related furan derivatives, which are then upgraded into PET plastics, polymers, textiles, specialty chemicals, and low-carbon fuels. This positions them closer to a 2G advanced biorefinery model, bypassing food crops and integrating multiple product pathways.

Financially, the company raised about USD500 million through its 2021 Special Purpose Acquisition Company (SPAC) listing, with its first commercial facility ("Origin 1" in Ontario) budgeted at ~USD125-130 million. Despite securing more than USD7 billion in offtake and capacity reservations from partners across packaging, chemicals, and consumer goods sectors, ORGN has faced cost overruns, weak revenue (~USD28.7m TTM), and continuing losses. As of September 2025, its stock trades near USD0.52 (52-week range USD0.40-1.90), with a market cap of about USD75-80 million, reflecting investor concerns over technology scale-up and capital intensity.

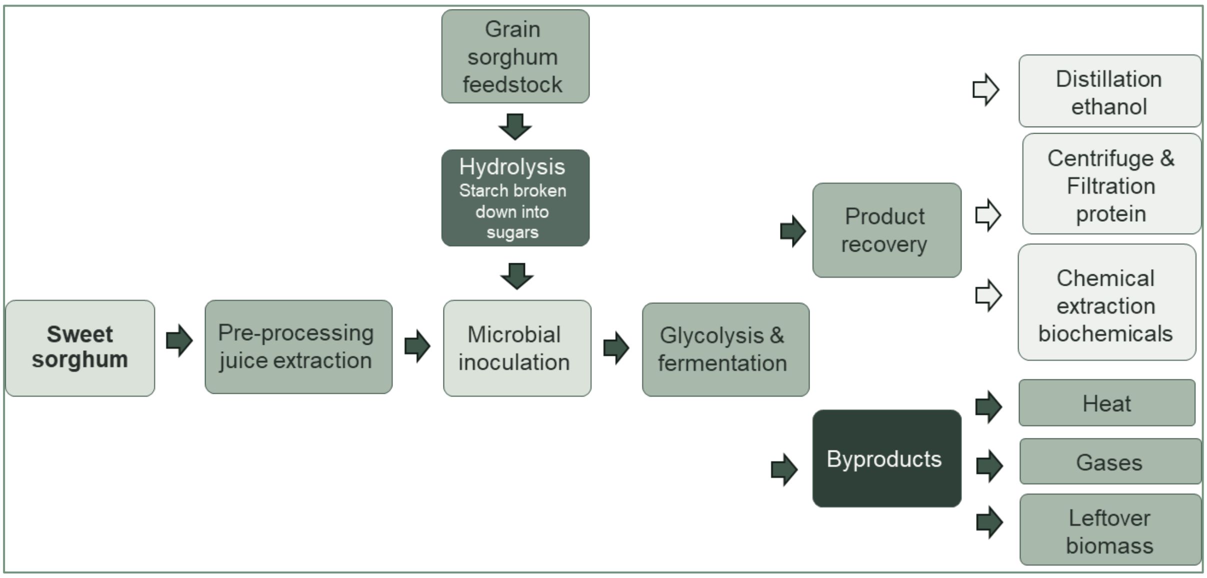
3.3 Bioethanol technology overview

Commercial bioethanol production today is dominated by 1G technologies, which process starch crops such as maize, wheat, and grain sorghum through milling, hydrolysis, fermentation, and distillation, as well as sugar crops such as sugarcane and sweet sorghum that can be fermented directly. These routes are fully commercial and account for most of the ethanol in the US, Brazil, India, and Europe, with individual 1G plants often ranging from 150 to 400 million litres per year in capacity and typical capital costs of USD 0.40-0.70 per litre of annual capacity.[116]

[115] "ORGN - Origin Materials Inc Stock Price and Quote." 2023. Finviz.com. 2023. https://finviz.com/quote.ashx?t=ORGN&ty=c&ta=1&p=d.

[116] International Energy Agency (IEA). *Renewables 2023: Analysis and forecast to 2028.* Paris : IEA, 2023. https://www.iea.org/reports/renewables-2023

Figure 7: 1G process flow from starch and sugar crops.



Source: Blueprint Holdings (Pty) Ltd

In contrast, 2G technologies convert lignocellulosic biomass, corn (maize) stover, wheat straw, sugarcane bagasse, and dedicated energy crops such as biomass sorghum, using pretreatment and enzymatic hydrolysis followed by fermentation. While technically proven, 2G plants are fewer and smaller, generally in the 30-100 million litre per year range, with capital costs often exceeding USD 1.00 per litre of capacity, reflecting both the complexity of pretreatment and enzyme costs.[117]

Notable examples include POET-DSM's Project Liberty in Iowa (75 million L/yr design capacity), Raízen's bagasse-based "E2G" facilities in Brazil (40-80 million L/yr each), and the Crescentino plant in Italy (60 million L/yr).[118]. Emerging concepts such as integrated biorefineries, which co-produce ethanol, power, biogas, and bioplastics, and multi-feedstock plants that can switch between grain and lignocellulosic inputs, are largely still at pilot or demonstration stage, with capacities under 10 million litres. These innovations highlight the sector's promise but also underscore the technology risk and higher unit costs of advanced pathways, which are crucial considerations for designing national bioethanol programmes and investment pipelines. [119]

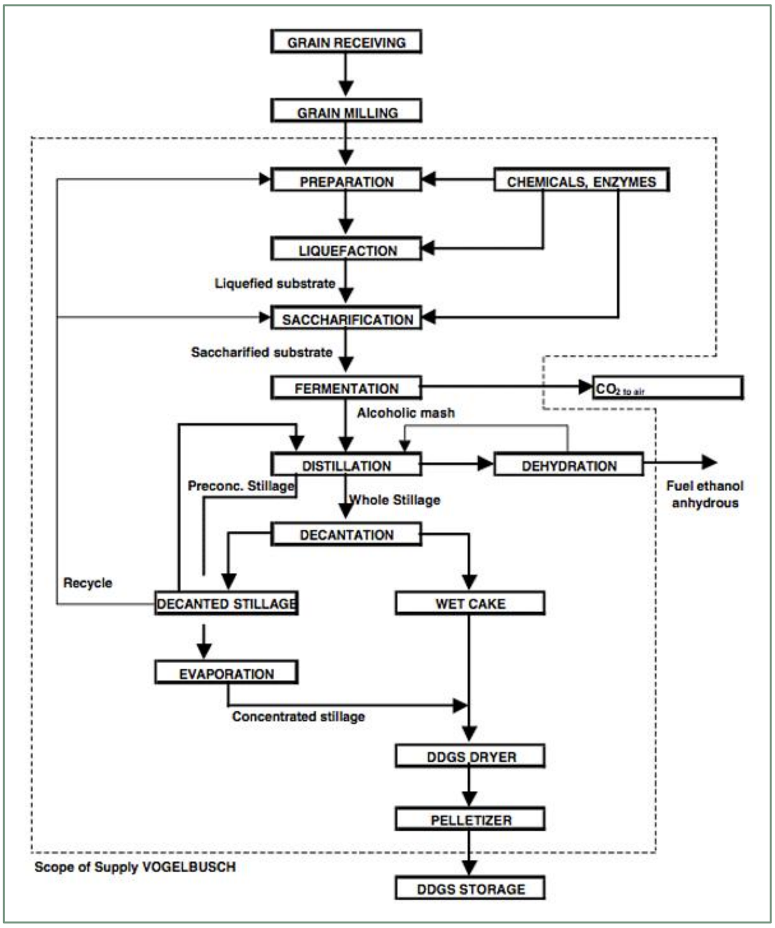
[117] Gnansounou, Edgard, et al. "Bioethanol Production from Sweet Sorghum: Status and Perspectives in India." Bioresource Technology 92, no. 1 (2004): 85–89. https://doi.org/10.1016/j.biortech.2003.07.011

[118] International Energy Agency (IEA). Renewables 2023: Analysis and forecast to 2028. Paris: IEA, 2023. https://www.iea.org/reports/renewables-2023

UNICA. Ethanol Industry Update. São Paulo: União da Indústria de Cana-de-Açúcar, 2024. https://unica.com.br

[119] International Energy Agency (IEA). *Renewables 2023: Analysis and forecast to 2028.* Paris: IEA, 2023. https://www.iea.org/reports/renewables-2023

Figure 8: Vogelbusch process.



Source: Vogelbusch Biocommodities GmbH. (n.d.). *Vogelbusch bioethanol process (dry/wet milling process flow diagram)*. Company technical documentation and process design materials

The Vogelbusch design, one of the technology candidates for the proposed Mabele sorghum plant, is more refined, starting with dry milling followed by a two-step enzymatic treatment (liquefaction with alpha-amylase and saccharification with glucoamylase), enhancing starch conversion efficiency to 90-95% and producing fuel-grade ethanol at >99.5% purity. Its proprietary continuous fermentation system contrasts with the batch fermentation common in wet-mill processes, offering a steady-state operation that reduces downtime and improves yeast utilisation. The distillation and sieve dehydration system achieves higher purity compared to traditional azeotropic distillation, while the integrated stillage separation maximizes byproduct recovery more effectively than the wet-mill's complex fibre and oil extraction. This design, is also more energy efficiency and scalable less integrated & batch-oriented alternatives used for corn (maize) or sugarcane, though it is more expensive.[120]

3.4 Integrated biorefineries

Integrated biorefineries are facilities that convert biomass into multiple products, such as fuels, chemicals, and energy, maximizing the value extracted from a single feedstock. Rather than focusing on one product, such as bioethanol, an integrated approach leverages both first-generation (sugar/starch) and second-generation (lignocellulosic) fractions of crops like sweet sorghum. For

[120] "Home» VOGELBUSCH Biocommodities." n.d. Www.vogelbusch-Biocommodities.com. https://www.vogelbusch-biocommodities.com/en/.

example, the juice can be fermented into ethanol, while the fibrous bagasse can be processed for second-generation bioethanol, biogas, or even bio-based materials such as pellets or bioplastics. By co-producing multiple outputs, integrated biorefineries improve economic resilience, reduce waste, and enhance overall sustainability. They also enable year-round production, as feedstocks can be stored in forms like syrup or silage until processing capacity is available, allowing a plant to smooth production cycles and optimize energy and labour usage.[121]

A biorefinery producing both first- and second-generation bioethanol from sweet sorghum works by sequentially processing different parts of the plant. The sugar-rich juice is extracted from the stalks and fermented directly into first-generation ethanol using conventional yeast or bacterial fermentation. After juice extraction, the fibrous bagasse, which contains cellulose and hemicellulose, undergoes pretreatment and enzymatic hydrolysis to release fermentable sugars for second-generation ethanol production. By integrating these processes, the facility maximizes ethanol yield from a single crop, reduces waste, and allows the plant to operate year-round, with syrup or bagasse stored until processing capacity is available. This dual approach enhances economic returns and makes the biorefinery more resilient to feedstock variability. Overall, on-farm syrup production improves logistics and continuity but requires close coordination between farmer and biorefinery. Some responsibilities, such as quality control, syrup hygiene, and initial processing equipment, shift to the farm, and bagasse must still be collected and transported separately for second-generation ethanol.[122]

The bagasse, containing cellulose and hemicellulose, is collected and sent to the plant for pre-treatment and enzymatic hydrolysis to produce second-generation ethanol. By integrating these processes, the biorefinery maximizes ethanol yield from a single crop, reduces waste, and enables year-round production, while shifting some initial processing and quality control responsibilities to the farm. This approach improves logistics, enhances economic returns, and increases resilience to feedstock variability.[123]

3.5 Multi-feedstock: the future of sorghum processing

Integrated processing of sweet sorghum juice, grain, and bagasse into bioethanol represents a high potential but high-risk pathway for the future of sorghum biorefineries. This model involves utilizing the soluble sugars in the stalk juice for first-generation 1G ethanol production, fermenting the starch in the grain for additional 1G ethanol, and converting the lignocellulosic bagasse into 2G ethanol through enzymatic hydrolysis and fermentation.

The approach has the potential to maximizes the use of all plant parts, reducing waste and enhancing overall ethanol yields, and allows for year-round ethanol production by processing grain during the off-season for sweet sorghum juice. Diversified revenue streams through the sale of ethanol, animal feed and potentially biogas or electricity (from bagasse) has the potential to improve financial viability. However, because of the novelty, this approach has significant technology risk, operational and logistics risks due to the seasonal variability of ensuring consistent feedstock, and high capex requirements for

121 "Sorghum Biorefining: Integrated Processes for Converting All Sorghum Feedstock Components to Fuels and Co-Products - EASTERN REGIONAL RES CENTER." 2019. Usda.gov. 2019. https://portal.nifa.usda.gov/web/crisprojectpages/0427783-sorghum-biorefining-integrated-processes-for-converting-all-sorghum-feedstock-components-to-fuels-and-co-products.html.

122 "California Energy Commission Clean Transportation Program Feasibility of Sweet Sorghum to Ethanol and Value-Added Products Prepared For: California Energy Commission." n.d. https://www.energy.ca.gov/sites/default/files/2023-03/CEC-600-2023-003.pdf.

123 Ali Mubarak Al-Qahtani. 2023. "Sweet Sorghum and Bagasse: A Comprehensive Review of Feedstock Traits, Conversion Processes, and Economic Viability for Bioethanol and Biogas Production." Biofuels, October 1–11. https://doi.org/10.1080/17597269.2023.2261789.

the sophisticated infrastructure required to handle the different processing methods and limited commercial precedents.[124]

There are no fully operational commercial-scale bioethanol plants globally that simultaneously process both grain sorghum, sweet sorghum alongside second-generation ethanol from bagasse in an integrated facility, although several research and pilot projects explore this concept. The ICRISAT in India has piloted integrated systems in Andhra Pradesh and Maharashtra, where sweet sorghum stalks are used for 1G ethanol from juice, grains for starch-based 1G ethanol, and bagasse for 2G ethanol via enzymatic hydrolysis, achieving combined yields of 1.5-2 m^3/ha in trials, though not at commercial scale. In the US the Sorghum Checkoff Program's research at facilities like Penford Products explores hybrid approaches, using grain sorghum for 1G starch ethanol and sweet sorghum bagasse for 2G cellulosic ethanol, but these are demonstration plants rather than full commercial operations. Globally, integrated sweet sorghum processes (1G juice + 2G bagasse) are more common, as in China's Shandong Province pilots, but combining with grain sorghum remains conceptual, limited by logistics and feedstock availability.[125]

3.6 Carbon emissions from first- and second-generation feedstocks

1G biofuels made from food crops like sugarcane, corn (maize), or grain sorghum, typically deliver moderate reductions in GHG emissions compared to fossil fuels, often in the order of 20-60% savings when land use change (LUC), crop cultivation inputs (fertilizer, pesticides, energy for planting/harvesting), transport, and processing are accounted for. However, they may incur significant emissions, on a par with fossil fuels, if new land is cleared (deforestation or peatland conversion), or if crops are fertilized with Nitrogen fertilizers that release nitrous oxide. In contrast, 2G biofuels derived from non-food biomass (e.g. agricultural residues, bagasse, perennial grasses) or lignocellulosic feedstocks, generally offer greater emission reductions-studies suggest 60-90% lower GHG emissions compared to fossil fuels under good practices, because they avoid or reduce land use change, make use of waste or lower-input biomass, and often benefit from lower upstream emissions per unit of energy produced. Life-cycle assessment (LCA) studies find that when feedstock is a residue or waste, and when the conversion process is efficient, 2G biofuels often outperform 1G in carbon savings.[126]

3.7 International bioethanol market development strategies

In several countries, the development of bioethanol sectors began with imports to build and stabilise demand, before gradually shifting to domestic production once local industry matured. In the early 2000s, when the EU launched its first blending mandates under the Biofuels Directive, member states such as the UK and the Netherlands imported large volumes of Brazilian sugarcane ethanol to meet E5

[124] Punia, Pallavi, and Sumeet Kumar. 2025. “A Critical Review on Enhanced Bioethanol Production from Sweet Sorghum Using Nanotechnology.” Energy Nexus 17 (March): 100339. https://doi.org/10.1016/j.nexus.2024.100339.

[125] López-Sandin, Iosvany, Rosa M. Rodríguez-Jasso, Guadalupe Gutiérrez-Soto, Gilver Rosero-Chasoy, Shiva, K. D. González-Gloria, and Héctor A. Ruiz. 2022. “Energy Assessment of Second-Generation (2G) Bioethanol Production from Sweet Sorghum (Sorghum Bicolor (L.) Moench) Bagasse.” Agronomy 12 (12): 3106. https://doi.org/10.3390/agronomy12123106.

[126] Patel, Kulvendra. 2024. “Environmental Sustainability Analysis of Biofuels: A Critical Review of LCA Studies.” Research Communities by Springer Nature. Springer Nature. November 17, 2024. https://communities.springernature.com/posts/environmental-sustainability-analysis-of-biofuels-a-critical-review-of-lca-studies.

and E10 targets.[127] Over time, subsidies and the RED helped expand domestic maize, wheat, and sugar beet ethanol plants, reducing reliance on imports.[128] [129]

A similar pattern has played out in several developing countries. India's Ethanol Blending Programme began in the early 2000s with imports, mainly from Brazil, filling initial supply gaps. As government policy pivoted toward domestic feedstocks, molasses- and grain-based plants were incentivised, and today India produces around 10 billion litres per year, almost all for its domestic E20 rollout.[130] The Philippines, after passing its *Biofuels Act* in 2006, relied on Brazilian and U.S. imports to supply mandated E5 and E10 blends, before sugarcane- and molasses-based distilleries were built domestically.[131]

By contrast, Thailand did not rely heavily on imports; in fact, the Ministry of Energy has generally restricted fuel ethanol imports to protect local producers, who developed capacity based on sugarcane and cassava feedstocks. Today Thailand is a net exporter of ethanol, supplying both domestic blending and regional markets.[132] An import-first strategy can be a pragmatic way to secure demand and build market confidence, while creating the conditions for local investors to commit capital. However, the shift to domestic feedstocks typically requires strong policy support, blending mandates, and fiscal incentives, as well as clear signals that local production will ultimately be prioritised over continued imports.

3.8 Brazil - a bioethanol case study

Brazil's biofuel program stands as a global example of successful large-scale bioenergy implementation, driven by consistent policy support, infrastructure investment, farmer integration and significant public-private collaboration.

The country is widely regarded as the most successful bioethanol producer globally, having built a robust industry around sugarcane beginning in the 1970s. Compared to the US, where the sector has been more contested and politically volatile[133] [134], Brazil produces ethanol more sustainably, with less land, water, and fossil fuel input. The cornerstone policy was the Proálcool Program (Programa Nacional do Álcool), launched in 1975 in response to the oil crisis, which mandated ethanol blending into gasoline and provided price supports for both producers and consumers. Over time, mandates were adjusted to match supply, with blends ranging from E18 to E27 in recent years, making ethanol a permanent part of Brazil's energy mix.

Sugarcane was chosen as the dominant feedstock because of its high yields, often exceeding 6,000-7,000 litres of ethanol per hectare from an average sugarcane yield of 80 tonnes per hectare, much higher than maize or sorghum. This efficiency allowed Brazil to develop ethanol as a globally

[127] European Commission. *Directive 2003/30/EC on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport.* Brussels: EU, 2003.

[128] European Commission. *Directive 2003/30/EC on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport.* Brussels: EU, 2003.

[129] European Renewable Ethanol Association (ePURE). *Renewable Ethanol: Key Figures 2023.* Brussels: ePURE, 2023.

[130] U.S. Department of Agriculture, Foreign Agricultural Service (FAS). *India Biofuels Annual 2024.* New Delhi: USDA, 2024.

[131] U.S. Department of Agriculture, Foreign Agricultural Service (FAS). *India Biofuels Annual 2024.* New Delhi: USDA, 2024.

[132] Kumar, S., et al. "An Assessment of Thailand's Biofuel Development." *Sustainability* 5, no. 4 (2013): 1577–1593. https://doi.org/10.3390/su5041577

[133] Kelly, Stephanie, and Jarrett Renshaw. 2021. "EXCLUSIVE White House Delays Biofuel Mandates due to Political Concerns -Sources." Reuters, July 20, 2021. https://www.reuters.com/world/us/exclusive-white-house-delays-biofuel-mandates-due-political-concerns-sources-2021-07-20/

[134] Schnepf, Randy, and Brent D. Yacobucci. *Renewable Fuel Standard (RFS): Overview and Issues.* Washington, DC: Congressional Research Service, 2013.

competitive fuel, supported by a favourable agroecological environment. Alongside cane juice fermentation, the use of molasses (a by-product of sugar production) helped balance sugar and fuel markets. Mills can swing between sugar and ethanol depending on global prices, making the sector more flexible and resilient.

Infrastructure investment was critical. Brazil developed dedicated pipelines, storage depots, and flex-fuel vehicle technology, ensuring ethanol could be produced, transported, and consumed nationwide. By the early 2000s, the widespread adoption of flex-fuel cars capable of running on either petrol or ethanol helped stabilize domestic demand and gave consumers flexibility in response to price fluctuations.

Public-private partnerships underpinned the rollout. State-owned Petrobras invested heavily in distribution and blending, while private sugar mills diversified into ethanol production, often supported by subsidised credit lines from development banks. International partnerships also emerged as Brazil became a leading exporter of ethanol to the US, EU, and Asia.[135]

Despite its successes, the industry has faced challenges. Sugarcane expansion raised concerns about land use change, labour conditions, and competition with food crops. Climate variability, particularly droughts in the Centre-South region, has periodically constrained output. Moreover, global oil price volatility has at times undermined ethanol's competitiveness, requiring government interventions such as tax incentives and minimum blend guarantees.[136]

Overall, Brazil's experience shows how long-term policy commitment, strong public-private collaboration, and a single dominant feedstock can create a resilient biofuel sector. The model also demonstrates the importance of consumer-facing innovations-such as flex-fuel vehicles-in driving sustained demand. Today, Brazil remains the world's second-largest ethanol producer after the US, with ethanol providing more than 40% of the country's transport fuel needs.

3.9 South African bioethanol - import parity analysis

Import parity is used to assess whether it is more cost-effective to import a commodity (such as fuel, ethanol, or grain) rather than produce it domestically. It represents the landed cost of an imported good - including the free-on-board (FOB) export price, ocean freight and insurance, customs duties and tariffs, plus domestic transport and handling costs to bring the product to the local market. If the import parity price is lower than or equal to local production costs, imports are competitive and may set the market price. If it is higher, then local production is more viable, provided domestic supply is sufficient. Policymakers and investors use import parity analysis to design support measures (like tariffs, subsidies, or blending mandates) to ensure local industries can compete against international supply.

South Africa's estimated sugarcane- and molasses-based bioethanol production cost in 2021 was reported at about USD0.55-0.63/L[137]. Since then, production economics have been influenced by sustained input inflation. The South African Consumer Price Index (CPI) has averaged 5-6% per year between 2021 and 2025 and feedstock costs (molasses, sugarcane) and energy inputs are especially sensitive to these trends, while labour and logistics costs have also increased.

[135] Walter, Arnaldo, et al. "A Sustainability Analysis of the Brazilian Ethanol Programme." *Renewable and Sustainable Energy Reviews* 13, no. 9 (2009): 1998–2008.

[136] OECD/FAO. *Agricultural Outlook 2020–2029: Biofuels Chapter (Brazil).* Paris: OECD, 2020.

[137] *Engineering News.* "EU Regulations Can Benefit Bioethanol Production in South Africa." June 9, 2021.

Recent analyses of sugarcane ethanol feasibility in South Africa highlight that production costs are highly sensitive to energy prices and feedstock yields.[138]Applying a conservative cumulative inflation adjustment of ~20-25% to the 2021 base cost suggests that the current cost of producing bioethanol from sugarcane or molasses in South Africa in late 2025 is approximately USD0.70-0.80/L. At an exchange rate of 17.8 ZAR/USD, this translates to about ZAR12.5-14.3/L, assuming stable plant efficiency and scale.

Table 8: Import parity figures for bioethanol imports (at USD/ZAR exchange rate of 17.8)

Item	U.S. (FOB Houston)	Brazil (FOB Santos)
FOB price	USD0.56/L[139]	USD0.79-0.83/L[140] [141]
Freight + insurance (to Durban)	USD0.06-0.12/L[142]	USD0.06-0.12/L [143]
CIF Durban	USD0.62-0.68/L	USD0.85-0.95/L
Customs duty (HS 2207.20, 317 c/li)	≈ USD0.18/L [144]	≈ USD0.18/L
Duty-paid landed cost (USD/L)	USD0.80-0.86/L	USD1.03-1.13/L
Duty-paid landed cost (ZAR/L)	**R14.2-15.3/L [145] (SARB 2025, R17.8/USD)**	**R18.3-20.1/L (SARB 2025, R17.8/USD)**

Source: Calculations by Blueprint Holdings (Pty) Ltd with data derived from U.S. Grains Council Ethanol Market and Pricing Reports (2025–2026); International Energy Agency (IEA) Renewables (2023–2024); USDA Foreign Agricultural Service (FAS) Biofuels Annual Reports; industry shipping estimates; South African Revenue Service (SARS) tariff schedules (HS 2207); South African Reserve Bank (SARB) exchange rate data (2025)

With the recent bioethanol set pricing gazetted the price of bioethanol is equivalent to the basic fuel price plus a zone differential to cover the cost of transport from refineries or inland distribution nodes. The current basic fuel price is calculated monthly by the CEF based on international crude oil prices and is currently (November 2025) set at ZAR10.31, with an additional cost of 79c in Gauteng.[146] This is significantly lower than the import parity prices outlined in Table 8 above.

Within this new policy landscape, sorghum stands out as the most strategically viable feedstock for new entrants: maize is excluded by policy, sugarcane is constrained by land, water, and the financial stress of the existing milling sector, and domestic production costs are competitive against the landed price of imported ethanol even after duty. The investment case now turns not on technology or policy uncertainty, but on the economics and logistics of the sorghum supply chain.

[138] Mvelase, L., and S. Ferrer. "The Comparative Financial Feasibility Analysis and the Environmental Implications of Bioethanol Production from Sugarcane in South Africa." *Energy Conversion and Management: X* 24 (2024): 100729.

[139] Argus Media. Biofuels: U.S. Ethanol Export Prices. London: Argus Media, 2024.

[140] USDA Foreign Agricultural Service (FAS). *Brazil Biofuels Annual.* GAIN Report BR2023-0056. Washington, DC: USDA, 2023.

[141] International Sugar Organization (ISO). *Ethanol Market Report.* London: ISO, 2024.

[142] Clarksons Research. *Chemical and Product Tanker Shipping Costs.* London: Clarksons, 2023.

[143] Clarksons Research. *Chemical and Product Tanker Shipping Costs.* London: Clarksons, 2023.

[144] South African Revenue Service (SARS). *Customs and Excise Tariff – Heading 22.07.* Pretoria: SARS, 2024.

[145] South African Reserve Bank (SARB). *Exchange Rates: Annual Average 2024.* Pretoria: SARB, 2025.

[146] "Fuel Price Media Statement: September 2025." 2025. DMRE. September 2025. https://www.dmre.gov.za/news-room/post/28

4. Sorghum value chains

While the core value chain under investigation is the sorghum to bioethanol value chain for this study, sorghum supports a range of complementary value chains that extend from food to fuel, reflecting its versatility and adaptability. At its core, grain sorghum is used in human nutrition, providing gluten-free flour, porridges, and specialty foods, with growing demand in health-conscious consumer markets. It also underpins the traditional brewing industry in Africa, where it is a base ingredient for opaque beer and related beverages. In livestock systems, sorghum grain and stover are used as animal feed, supplying both energy and roughage. Sweet sorghum, cultivated for its sugar-rich stalks, feeds directly into bioethanol production, yielding ethanol, and syrups, while its fibrous bagasse supports 2G biofuel opportunities.[147]

These chains are grouped into two primary streams - grain-based and stalk-based - each feeding distinct industrial and household markets.

At its core, sorghum drives three major pathways outlined below (yields are average estimates):

i. *Bioethanol from grain sorghum.* This is produced through starch-based fermentation, with conversion rates typically ranging from 380 to 420 litres of ethanol per tonne of grain depending on starch content and processing efficiency.[148], [149] At a moderate yield of 3 tonnes /ha achieved through commercial mechanised farming, 1,100 -1,300 L/ha can be achieved, making it broadly comparable to maize as a biofuel feedstock.
ii. *Grain sorghum to food value chain.* This begins at the farm, where yields typically range from 1-2 t/ha in Sub-Saharan Africa and India to 3-5 t/ha in the United States, Brazil, and Australia.[150] Harvested grain is milled into flour, semolina, or grits and processed into staple foods such as porridge, flatbreads, couscous, and gluten-free products, meeting both household food security and commercial demand;
iii. *Traditional brewing*. In many African countries, grain sorghum underpins a traditional beer industry, where malted sorghum is brewed into local beverages such as opaque beer, supporting small-scale brewers and providing rural employment.[151]

---

[147] Gnansounou, Edgard, and Alain Dauriat. "Ethanol from Sweet Sorghum: A Review." Bioresource Technology 101, no. 13 (2010): 4859–4868.

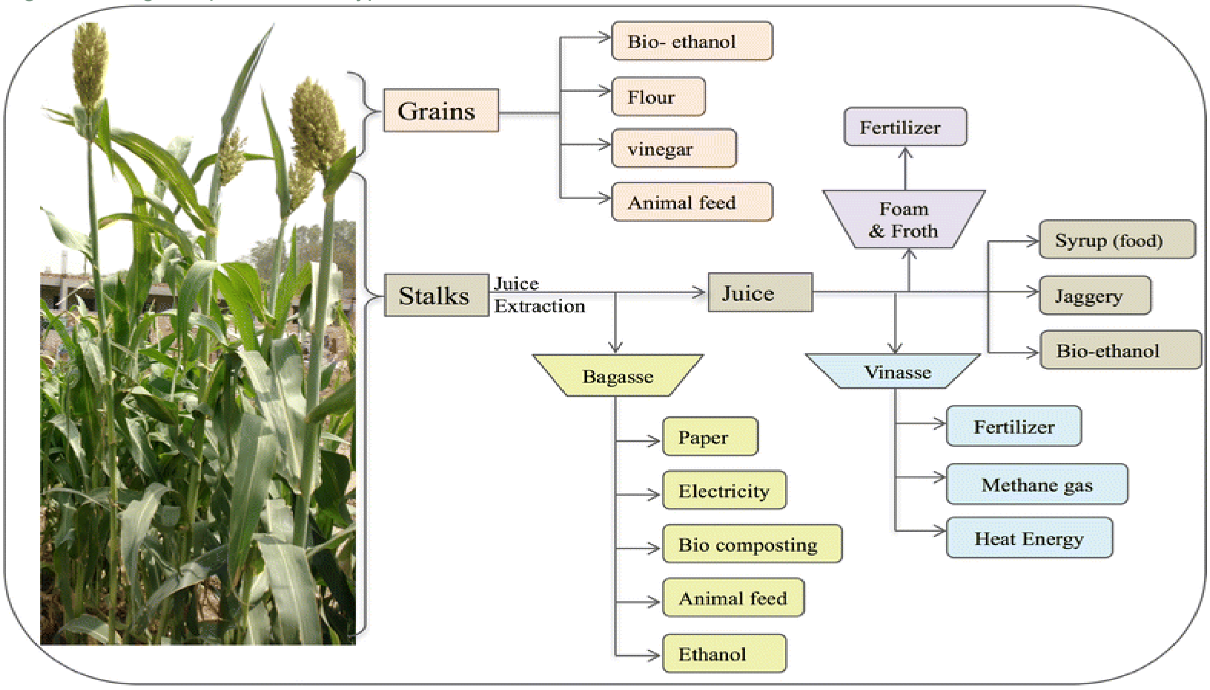
[148] Food and Agriculture Organization (FAO). FAOSTAT Crops and Livestock Data. Rome: FAO, 2023. https://www.fao.org/faostat/en/#data

[149] Zhao, Y., K. Bean, and D. Wang. "Ethanol Production from Grain Sorghum: Effect of Starch Concentration and Enzyme Dosage." Cereal Chemistry 86, no. 6 (2009): 597–600. https://doi.org/10.1094/CCHEM-86-6-0597

[150] Food and Agriculture Organization (FAO). FAOSTAT Crops and Livestock Data. Rome: FAO, 2023. https://www.fao.org/faostat/en/#data

[151] Food and Agriculture Organization (FAO). *The Future of Food and Agriculture: Alternative Pathways to 2050*. Rome: FAO, 2018. https://www.fao.org/documents/card/en/c/CA1553EN

Figure 9: Sorghum product and byproduct value chains



Source: General FAO reports on bio-energy. *"Evaluation of bioethanol production from juice and bagasse of sweet sorghum"*

The stalk-based stream comprises two additional pathways yields are average estimates)**:**

iv. *Bioethanol from sweet sorghum*. This is derived from sugar-rich stalk juice, with typical conversion rates of 40 - 60 litres of ethanol per tonne of stalk (≈ 8-12% fermentable sugars), while additional bagasse can be used for second-generation ethanol, making it a dual-purpose biofuel feedstock. [152]. Depending on the yield, 1,800 - 2,500L/Ha can be achieved;[153]

v. *The sweet sorghum to syrup value chain* starts with harvesting the sugar-rich stalks, which are crushed to extract juice that is clarified and boiled into sorghum syrup or jaggery, yielding on average 3-5 tonnes of syrup per hectare depending on stalk yield and sugar content, and providing both a traditional sweetener in Asia and Africa and a niche natural sweetener market in the United States.[154] [155]

By-products across these chains[156] include distillers' dried grains with solubles (DDGS) for feed, CO_2 for beverage and industrial use, and bioplastics or paper pulps from stalk residues. Sorghum's drought tolerance positions it as a climate-resilient bioeconomy crop, attractive for smallholder integration and industrial scale-up. The combination of food, feed, fuel, and fibre pathways ensures a wide spectrum of potential markets, while by-products add value and reduce waste, reinforcing its role as a multi-output crop in sustainable value chains.[157]

---

[152] Reddy, B. V. S., S. Ramesh, and P. Sanjana Reddy. "Sweet Sorghum: A Water Saving Bio-Energy Crop." ICRISAT, 2005. https://oar.icrisat.org/7579/

[153] Barcelos, Cláudio A., et al. "Sweet Sorghum as a Whole-Crop Feedstock for Ethanol Production." *Biomass and Bioenergy* 94 (2016): 46–56. https://doi.org/10.1016/j.biombioe.2016.08.002

[154] Reddy, B. V. S., S. Ramesh, and P. Sanjana Reddy. "Sweet Sorghum: A Water Saving Bio-Energy Crop." International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 2005. https://oar.icrisat.org/7579/

[155] Gnansounou, Edgard, et al. "Bioethanol Production from Sweet Sorghum: Status and Perspectives in India." Bioresource Technology 92, no. 1 (2004): 85–89. https://doi.org/10.1016/j.biortech.2003.07.011

[156] Refer separate detailed report

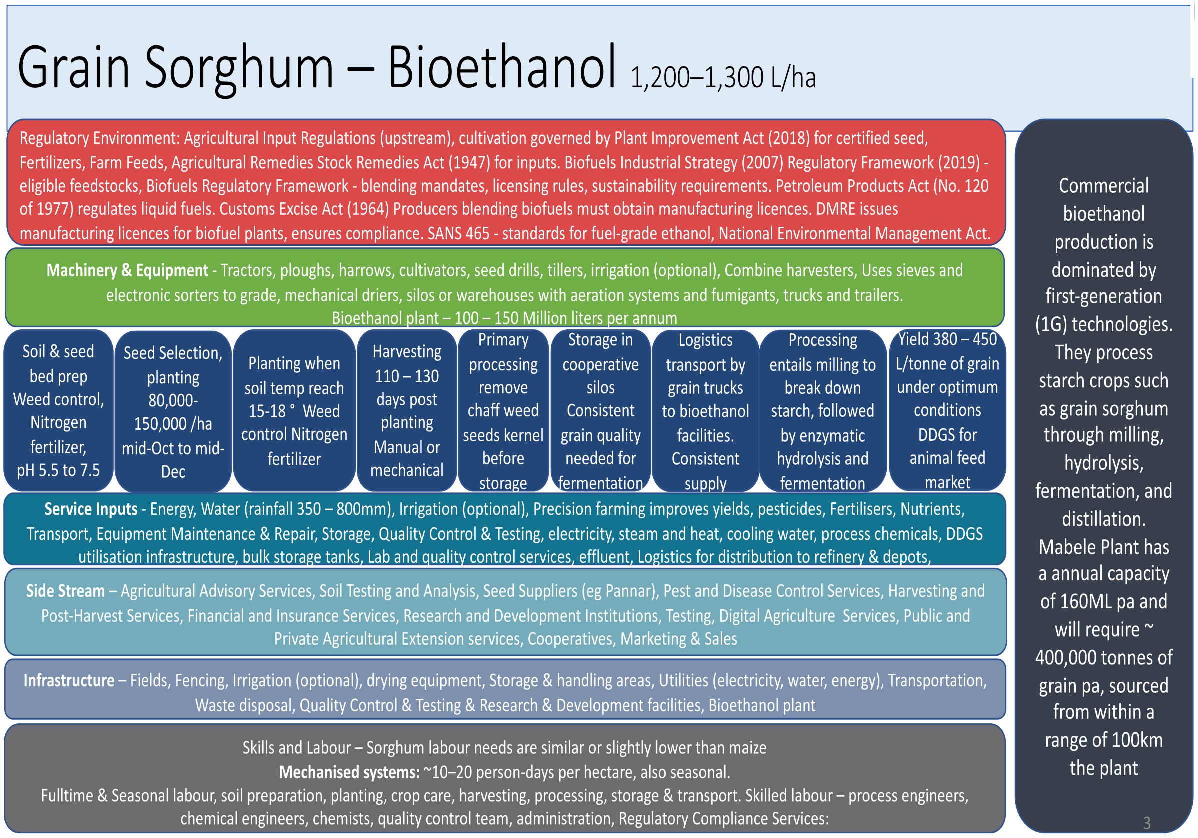
[157] Taylor, J.R.N., and Kwaku G. Dewar. "Sorghum: Origin, History, Technology, and Production." In Encyclopedia of Food Grains, 2nd ed., edited by Colin Wrigley, Harold Corke, and Koushik Seetharaman, 2016.

4.1 Grain sorghum to bioethanol

As a starch-rich cereal with comparable fermentation characteristics to maize, sorghum can be milled and hydrolysed using existing first-generation ethanol infrastructure with minimal adaptation. Because of its drought tolerance, sorghum gives ethanol producers in water-stressed areas an element of feedstock security. The bulk of grain sorghum as a feedstock quoted in the literature is used alongside maize however there are anecdotal reports from stakeholder interviews of Chinese maize-based bioethanol plants switching to grain sorghum.

The value chain for grain sorghum bioethanol spans from input supply and cultivation through to processing and by-product utilisation. It is structured around 1G bioethanol technology, which uses sorghum's starch content as the feedstock. Ethanol yields are estimated at approximately 1,100–1,300 L/ha (which depends on the agronomic conditions and yield performance, with the upper end of the range reflecting well-managed, higher-yield production systems) and grain yields of 380-450 L/tonne under optimum conditions. The example in **Error! Reference source not found.** refers to the Mabele Plant, requiring 400,000 tonnes of sorghum annually to produce 160 million litres of ethanol. The key stages in this value chain are outlined below.

Figure 10: Grain sorghum to bioethanol value chain.



Source: Generated by Blueprint Holdings (Pty) Ltd leveraging data sourced during this project

A high-level synopsis of the value chain is shown in Figure 11 **Error! Reference source not found.**below, indicating risks and requirements along the chain.

Figure 11: Grain sorghum to bioethanol value chain flow - Stages, Risks & Opportunities

Input Supply seed, fertiliser, energy, equipment	**Production** sowing, growing, harvesting	**Storage** silos, drying, quality control	**Logistics** trucking (100 km radius)	**Processing** milling, hydrolysis, fermentation, distillation	**Outputs** ethanol, DDGS, by-products
High input costs; rainfall variability	Yield risk; pest and disease pressure	Post-harvest losses; inconsistent quality	High costs if distance > 100 km	High water and energy demand	Market and policy risk; price volatility
Certified input; R&D support	Job creation; marginal land use	Co-op storage; quality premiums	Clustered supply; logistics efficiency	Large-scale plant; by-product value	Diversified income; export potential

Source: Generated by Blueprint Holdings (Pty) Ltd leveraging data sourced during this project

Regulatory and policy framework

The sorghum sector operates within a complex regulatory environment, spanning seed certification under the Plant Improvement Act, blending mandates and licensing through the Biofuels Regulatory Framework, petroleum product regulation, fuel excise duties, and adherence to South African National Standards (SANS) fuel-quality standards. While these frameworks are essential to ensure product integrity, consumer safety, and environmental compliance, they are highly fragmented and administered by multiple authorities, often leading to uncertainty, duplication, and delays. For prospective investors, this creates not only compliance costs but also entry barriers, particularly for new or smaller players without the capacity to navigate bureaucratic complexity and red tape.

The lack of alignment between agricultural, energy, and environmental policy further constrains the sector's growth potential. Biofuel developers require long-term certainty to commit capital to large-scale processing facilities yet shifting mandates and regulatory bottlenecks undermine investor confidence. A clear, stable, and integrated policy environment, one that harmonises agricultural production, energy demand, and climate goals is therefore critical to unlock private capital, incentivise value-chain development, and position sorghum as a credible complementary feedstock to sugarcane in South Africa's bioethanol strategy.

In Brazil for example, private capital was unlocked for bioethanol through a combination of clear mandates, strong policy signals, and risk-reducing frameworks that created a stable environment for investment. Since the 1970s, Brazil has maintained compulsory blending of ethanol into petrol (gasoline). Current mandates require 27% anhydrous ethanol in petrol nationwide. This guaranteed demand certainty, encouraging private firms to invest in ethanol plants knowing there would be a stable domestic market. It also implemented government-backed programmes and incentives, where it provided low interest loans, tax incentives, and infrastructure support to kickstart ethanol production.

Over time, as the sector matured, subsidies were scaled back but by then, private capital was already deeply embedded in the industry. The country also adopted Flexible Fuel Vehicles (FFVs). Since the early 2000s, Brazil's auto industry, backed by government incentives rolled out vehicles that can run on any mixture of petrol and ethanol (E25-E100). This broadened consumer choice and created a self-reinforcing market, as more FFVs drove greater ethanol demand, encouraging further private investment. A stable regulatory environment was created by classifying ethanol as a strategic national fuel, giving investors long-term confidence. Clear regulatory oversight reduced uncertainty and helped attract international capital. In short, Brazil unlocked private capital by combining policy certainty, mandatory demand, and financial incentives with an enabling market ecosystem. Investors could clearly see long-term profitability, and risk was mitigated through both state support and robust regulatory design.

Stage one: primary production (farm level)

At this level of the value chain, key activities are soil preparation, seed selection, planting, fertilisation, weed control, and harvesting. Key inputs include land, certified high yield seed nitrogen fertiliser, irrigation (where available), energy, and mechanisation. There is a combination of mechanised operations (10-20 persons/100 ha) and skilled labour (engineers, chemists, equipment operators) that is required. Risks at this stage include rainfall dependency, heat variance, pest control, and input costs. Yields become an important if not central element. The Table 9 indicates the marginal nature of the business case for a farmer at yields less than 5 tonnes per hectare. The average yield across the country for the past 5 years has been 3.12 tonnes per hectare with a five-year range of approximately 2.5–4.2 t/ha (dry).

Table 9: Grain cultivation costs (GSA)

Production year 2024-2025					
Current product price for the best grade (R/tonne) (Safex marketing cost) 4,930.00 (Rand/tonne)					
Estimated Yields (tonnes/ha)	4.00	4.50	5.00	5.50	6.00
Current Product Price (R/ton)	4 930.00	4 930.00	4 930.00	4 930.00	4 930.00
Gross Production Value (R/ha)	19 720.00	22 185.00	24 650.00	27 115.00	29 580.00
VARIABLE COSTS					
Seed (R/ha)	1 058.40	1 058.40	1 058.40	1 209.60	1 209.60
Fertiliser (R/ha)	3 672.60	4 176.80	4 681.00	5 185.20	5 814.80
Lime (R/ha)	252.75	252.75	252.75	252.75	252.75
Fuel (R/ha)	1 524.35	1 555.30	1 586.25	1 617.20	1 648.15
Reparation (R/ha)	714.75	727.55	727.55	731.60	735.65
Herbicide (R/ha)	1 807.80	1 807.80	1 807.80	1 807.80	1 807.80
Pest Control (R/ha)	1 704.94	1 704.94	1 704.94	1 704.94	1 704.94
Input Insurance (R/ha)	447.49	503.42	559.615	671.23	671.23
Grain hedging (R/ha)	-	-	-	-	-
Harvest Insurance (R/ha)	686.46	772.27	858.08	943.88	1 029.69
Aerial spray (R/ha)	-	-	-	-	-
Casual labour (R/ha)	-	-	-	-	-
Drying costs (R/ha)	-	-	-	-	-
Packaging and packaging material (R/ha)	-	-	-	-	-
Interest on Production (R/ha)	697.61	737.62	777.62	826.51	873.88
Total Direct Allocated Variable Cost (R/ha)	**12 571.82**	**13 292.78**	**14 013.74**	**14 894.77**	**15 748.60**
Total Overhead Cost (R/ha)	**2 526.00**	**2 526.00**	**2 526.00**	**2 526.00**	**2 526.00**
Total Cost per ha (before marketing cost R/ha)	**15 097.82**	**15 818.78**	**16 539.74**	**17 420.77**	**18 274.60**
Total Cost per ton (before marketing R/Tonne)	**3 774.46**	**3 515.28**	**3 307.95**	**3 167.41**	**3 045.75**

Marketing Cost (R/ton)	**63.00**	**63.00**	**63.00**	**63.00**	**63.00**
Minimum Safex Price (Without Profit)	3 837.46	3 578.28	3 370.95	3 230.41	3 108.75
Safex Price	4 930.00	4 930.00	4 930.00	4 930.00	4 930.00
Gross Margin (R/ha)	7 148	8 892	10 636	12 220	13 832
Net Margin (R/ha)	4 622	6 366	8 110	9 694	11 306

Disclaimer: The information herein has been obtained from various sources, the accuracy and/or completeness of which GrainSA does not guarantee and for which GrainSA accepts no liability. Andy prices or levels contained herein are preliminary and indicative only and do not represent bids or offers. These indications are provided solely for your information and consideration.

For bioethanol production, seed selection is critical, as hybrids bred for high grain yield, starch content, and standability perform significantly better than traditional landraces. In South Africa, the ARC and private seed companies supply a range of grain sorghum hybrids. Beyond ARC, the most established local portfolio is from Pannar (Corteva), which runs one of South Africa's longest-running sorghum breeding programmes and markets multiple grain hybrids nationally; Agricol also distributes grain and forage sorghum genetics; and regional players such as Seed Co (via Limagrain/"LG Seeds SA" channel) supply hybrids across SADC that are traded and planted in South Africa. Grain SA's cultivar trial days regularly feature Pannar, Agricol and K2/LG materials, underscoring a competitive private-sector seed base that can meet industrial-use demand.[158 159 160 161]

Target plant populations typically fall around 80,000-150,000 plants/ha under South African conditions, which corresponds to 3-7 kg of seed/ha depending on kernel size (30,000-40,000 seeds/kg) and expected field emergence; row spacing and moisture regime then refine the exact target. Public, on-shelf seed price lists are scarce (most suppliers quote directly by hybrid, treatment and volume). Grain SA notes sorghum seed prices have risen in recent seasons, so obtaining current supplier quotes is important for budgeting. In short, South Africa already has multiple commercial channels to source certified grain sorghum seed, and recommended seeding densities of ~3-7 kg/ha provide a practical basis for costed hectare plans.[162 163 164]

Profitability is highly yielding sensitive and yield is highly variable. Farmers operating at or above 5.0 t/ha (dry yield) are well-positioned to generate strong returns under current price assumptions, while those at 4.0 t/ha are still profitable but more exposed to cost fluctuations. It provides an indicative gross margin analysis for dryland grain sorghum production in the 2024/25 season, based on varying yield scenarios from 4.0 to 6.0 tonnes per hectare. The assumed Safex market price is ZAR4,930 per tonne, at the time of writing, and costs are broken down into variable costs, overhead costs, and total production costs.

158 Pannar Seed. "Grain Sorghum." Accessed September 23, 2025. https://www.pannar.com/products/grain-sorghum. pannar.com

159 Pannar Seed. "About Pannar." Accessed September 23, 2025. https://www.pannar.com/. pannar.com

160 Agricol. "Grain Sorghum." Accessed September 23, 2025. https://www.agricol.co.za/agricol-products/grain-sorghum/

161 Limagrain South Africa (LG Seeds). "2024 Product Catalogue." Accessed September 23, 2025. https://lgseeds.co.za/Media/ENGLISH%20CATALOGUE%20DIGITAL.pdf.

162 Agricultural Research Council (ARC). Sorghum Production (Fact Sheet). Pretoria: ARC, n.d. https://www.arc.agric.za/arc-gci/Fact%20Sheets%20Library/Sorghum%20Production.pdf

163 Department of Agriculture (DAFF). Sorghum Production Guidelines. Pretoria: DAFF, n.d. https://www.africanfarming.com/wp-content/uploads/Sorghum-Production-Guidelines-DAFF.pdf

164 Grain SA. "Do Your Homework Before Buying Seeds." Accessed September 23, 2025. https://www.grainsa.co.za/do-your-homework-before-buying-seeds

At lower yields (4.0 t/ha), gross revenue per hectare is ZAR19,720, rising to ZAR29,580 at 6.0 t/ha. Variable costs increased modestly across scenarios (from ZAR12,517/ha to ZAR15,748/ha), reflecting higher proportional input usage and interest on production financing. Overheads are fixed at ZAR2,526/ha, bringing total production costs before marketing to a range of ZAR15,098/ha (at 4.0 t/ha) up to ZAR18,274/ha (at 6.0 t/ha). With marketing costs fixed at ZAR63/tonne, the minimum Safex price required for breakeven falls as yields improve from ZAR3,837/tonne at 4.0 t/ha to ZAR3,108/tonne at 6.0 t/ha. This indicates that sorghum becomes more competitive at higher yields, as cost per tonne drops significantly. The resulting gross margin per hectare ranges from ZAR7,148 (4.0 t/ha) to ZAR13,832 (6.0 t/ha). After factoring interest, the net margin improves from ZAR4,622 to ZAR11,306 across the same yield spectrum.

In sum, the analysis highlights that grain sorghum remains price competitive under current market conditions, with the breakeven Safex price well below the prevailing level of ZAR4,930 per tonne across reasonable yield scenarios- outlined in the scenario analysis to follow. Profitability, however, is strongly sensitive to yield performance. At 4.0 tonnes per hectare margins are modest but positive, while yields of 5.0 tonnes and above result in robust profitability, reflecting the critical importance of achieving higher output levels. Lower yields are typically non-viable, and the farmer will not switch to sorghum under such conditions.

The cost structure shows that fertiliser and seed are the largest drivers of variable costs, while overheads remain constant regardless of scale. This means that improvements in yield deliver a double benefit: they increase revenue while spreading fixed overheads and input costs more efficiently, thereby reducing the cost per tonne produced. Producers achieving higher yields thus benefit from a distinct economy of scale effect, which strengthens their resilience against market volatility. At the same time, the framework illustrates that lower-yielding producers face greater risk exposure, as their breakeven thresholds lie closer to market prices. Any adverse movement in input costs or output prices could significantly erode their margins. Conversely, producers who consistently achieve higher yields are positioned to sustain profitability and absorb shocks, making yield optimisation a key determinant of long-term viability.

Optimal planting occurs once soil temperatures reach 15-18 °C, typically from late October to early December, with recommended plant populations of 80,000 -150,000 plants per hectare depending on rainfall and soil fertility. Sorghum grows best on well-drained sandy loams to clay loams with a pH of 5.5-7.5, and yields can range from 2-4 t/ha in dryland systems to 5-8 t/ha under irrigated or high-input management. Nitrogen is the most important nutrient, usually applied at 40-80 kg/ha for dryland and up to 120 kg/ha for irrigated fields, while phosphorus and potassium are applied according to soil analysis. Sorghum's deep rooting system and ability to go dormant during drought make it especially attractive for semi-arid zones in Mpumalanga, Limpopo, the North West, and KwaZulu-Natal.[165], [166],

Weed control is critical in the first six weeks, as sorghum seedlings establish more slowly than some aggressive weeds, and integrated pest management is needed against sorghum midge, stem borers, and aphids. For bioethanol, hybrids with high starch content and uniform grain maturity are preferred, ensuring efficient hydrolysis and fermentation in first-generation ethanol plants. Harvesting occurs once grain moisture falls below 14%, generally 110-130 days after planting, using standard grain harvesting

[165] Agricultural Research Council (ARC). Sorghum Production. Pretoria: ARC, n.d. https://www.arc.agric.za/arc-gci/Fact%20Sheets%20Library/Sorghum%20Production.pdf

[166] Department of Agriculture, Forestry and Fisheries (DAFF). Sorghum Production Guidelines. Pretoria: DAFF, n.d. https://www.africanfarming.com/wp-content/uploads/Sorghum-Production-Guidelines-DAFF.pdf

equipment. Post-harvest handling is important, as sorghum can absorb moisture and deteriorate in storage if not dried properly. [167]

Stage two: harvesting

Grain sorghum is typically ready for harvest at 110-130 days after planting, when grain moisture drops below 14%. Post harvest handling includes the removal of seeds, kernel storage, drying, and use of silos. It is critical to have consistent grain quality for supply to bioethanol plants. Harvesting grain sorghum for bioethanol production in South Africa follows broadly the same practices as for sorghum grown for food and feed, with a focus on achieving uniform grain maturity and moisture levels suitable for storage and milling. Timely harvesting is critical to minimise field losses from bird damage, lodging, or shattering. For bioethanol, clean grain free from mould or fungal contamination is essential to ensure efficient starch conversion during hydrolysis and fermentation. Because grain sorghum can retain green leaves and stalks even at grain maturity, correct adjustment of machinery is important to reduce the intake of excess plant material that can increase drying costs and storage risks.[168] [169]

The primary equipment required includes combine harvesters fitted with either sorghum headers or modified maize headers, with adjustable reel speed and cutting height to accommodate sorghum's shorter panicles and thinner stalks requiring a 20% increase in fuel power compared to maize harvesting, as noted by local agronomists, as reflected in South African agronomic practice and supported by work from organisations such as Grain SA and ARC–Grain Crops, including contributions from agronomists such as Dr Wandile Sihlobo (Agbiz/ARC-aligned policy and agricultural analysis) and BFAP research teams. Grain platforms or row-crop headers are commonly used, depending on planting density and row spacing. Post-harvest, grain dryers may be necessary where grain is harvested above 14% moisture, particularly in high-rainfall areas of KwaZulu-Natal or Mpumalanga. Cleaning and grading equipment is used to remove chaff, weed seeds, and broken kernels before storage. The process targets a yield of 3-5 tonnes/ha, with the grain separated and stalks often left as residue or used for cattle feed, contrasting with food sorghum where grain quality and drying for storage are prioritized. Logistical coordination with nearby bioethanol facilities is critical to minimize post-harvest losses, highlighting a key difference from the more flexible food harvest timeline.[170]

Stage three: storage and logistics

Grain sorghum storage, logistics, and processing for bioethanol require careful management to maintain starch quality for industrial use. After harvesting at 20-25% moisture, grain is dried to 12-14% using mechanical dryers or natural aeration to prevent mould and preserve fermentable starch, stored in silos on-farm or warehouses with capacities of 500-1,000 tonnes, as recommended by the ARC [171] to ensure a steady supply for processing plants. Because sorghum grain is smaller and harder than

[167] Rooney, William L., David B. Dahlberg, and Phanchanok Lauapun. "Agronomy of Sorghum for Bioenergy." In Bioenergy for Sustainable Development in Africa, edited by Rainer Janssen and Dominik Rutz, 95–110. Dordrecht: Springer, 2012. https://doi.org/10.1007/978-94-007-2181-4_8

[168] Department of Agriculture, Forestry and Fisheries (DAFF). Sorghum Production Guidelines. Pretoria: DAFF, n.d. https://www.africanfarming.com/wp-content/uploads/Sorghum-Production-Guidelines-DAFF.pdf

[169] Rooney, William L., David B. Dahlberg, and Phanchanok Lauapun. "Agronomy of Sorghum for Bioenergy." In Bioenergy for Sustainable Development in Africa, edited by Rainer Janssen and Dominik Rutz, 95–110. Dordrecht: Springer, 2012. https://doi.org/10.1007/978-94-007-2181-4_8

[170] "Sorghum Production." n.d. https://www.arc.agric.za/arc-gci/Fact%20Sheets%20Library/Sorghum%20Production.pdf.

[171] ibid

maize, storage and handling systems must be calibrated to avoid excessive grain cracking or bridging in bins. Farmers in commercial zones such as Mpumalanga and Free State often rely on cooperative silos, while smallholders in Limpopo and KwaZulu-Natal may need access to shared drying and storage facilities. Consistent grain quality is vital for fermentation, as fungal toxins (e.g., aflatoxins) can reduce conversion efficiency and raise safety risks for by-product feed markets.

Logistics involves transporting grain via trucks to nearby bioethanol facilities ideally within 50-km (maximum 100kms) within 48 hours to avoid quality loss, with costs estimated at R0.50-1.00/tonne/km by the South African Grain Laboratory.[172] Volumes must be aggregated to ensure year-round feedstock availability. There is a high dependence at this stage on efficient road logistics as costs increase significantly if transport distances exceed 100 km radius from the plant.

Stage four: processing

Grain sorghum to ethanol processing follows a conventional dry-mill pathway similar to that used for maize. Processing begins with milling the grain to release starch granules, after which enzymatic hydrolysis breaks these down into fermentable sugars. These sugars are then converted into ethanol through fermentation with Saccharomyces cerevisiae, with typical yields ranging from 380 to 450 litres of ethanol per tonne of grain under optimum operating conditions.

Although sorghum is highly compatible with standard maize-based ethanol plants, certain adjustments may be required. Sorghum typically has a higher protein content than maize, which can affect mash viscosity, while tannin-rich varieties may inhibit enzyme activity or yeast fermentation efficiency. These challenges are well-documented and manageable using tailored enzyme cocktails, tannin-tolerant yeast strains, or blending with other feedstocks. Importantly, sorghum’s fermentation, distillation, and ethanol recovery steps are technically identical to maize, requiring minimal modification of plant infrastructure.

A further advantage lies in the integration of co-products. The dried distillers’ grains with solubles (DDGS) produced during ethanol processing provide a high-protein, high-energy animal feed, which has an established market in South Africa’s livestock sector. This dual output, fuel and feed, strengthens the economics of sorghum-based ethanol plants.

However, bioethanol production remains a scale-driven industry. Plants require access to large and consistent volumes of grain, as well as reliable supplies of water, energy, and skilled process operators to remain cost-effective. In the South African context, this underscores the importance of clustering sorghum production near processing facilities, supported by efficient storage and logistics systems. When these conditions are met, sorghum offers a practical, flexible feedstock pathway for bioethanol supply, generating by-product value and contributing to rural industrialisation.

I. Side streams and service inputs

As the value chain shows, South Africa's agricultural sector benefits from a mature support network. A wide range of side-stream services is already in place to boost competitiveness and lower risks for producers. These include advisory services, soil testing, pest and disease control, financial and insurance products, laboratory testing, and digital agriculture platforms that are increasingly integrated into farm decision-making. In practice, sorghum producers and prospective bioethanol investors can draw on an established network of machinery and equipment suppliers, input distributors, and after-sales support, as well as professional services such as legal, accounting, and export facilitation that

[172] “South African Sorghum Crop.” n.d. Accessed September 12, 2025. https://sagl.co.za/wp-content/uploads/Sorghum-Crop-Quality-Report-2022-2023.pdf.

enable firms to participate effectively in regional and global markets. South Africa boasts a well-capitalised banking sector with deep expertise in agribusiness, alongside insurance products designed to hedge against climate variability and price risk.

However, these strengths are not equally accessible across the sector. Larger commercial operations generally capture the benefits of this support ecosystem; while emerging and smallholder farmers often face barriers of cost, geographic access, and capacity in engaging with formal financial institutions, laboratories, or digital tools. Bridging this gap will be critical if sorghum-to-bioethanol value chains are to expand inclusively. Targeted interventions to extend side-stream services to smaller producers could help ensure that the industry's growth also delivers on South Africa's broader goals of transformation, rural development, and job creation.

II. Infrastructure

The viability of grain sorghum as a bioethanol feedstock depends not only on agronomic performance and processing technology but also on the infrastructure systems that connect production to processing facilities and markets. These requirements span farm-level, processing, and national logistics infrastructure, with transport standing out as a critical determinant of competitiveness. This begins with irrigation and on-farm infrastructure. Although sorghum is relatively drought-tolerant compared to maize, irrigation infrastructure is still important for stabilising yields in semi-arid areas- although it can be costly. Access to boreholes, pivot systems, or communal irrigation schemes can make the difference between reliable feedstock supply and volatile output. Investment in farm-level drying and cleaning facilities is also essential to ensure grain meets the quality standards required by ethanol plants.

At the next level as noted above, storage infrastructure is needed. Efficient, decentralised silo capacity is vital. Sorghum must be dried and stored at safe moisture levels to prevent spoilage and quality loss. Cooperative silos and commercial grain handling companies provide much of this capacity in South Africa, but localisation near ethanol facilities will reduce double handling and costs. On-farm or village-level storage solutions could help integrate smallholder farmers into the value chain.

To ensure smooth supply chain integration, bioethanol plants will require on-site bulk ethanol storage of around 2-3 million litres, enough for 7-10 days of production. This would likely be configured as three 1-million-litre tanks with associated loading gantries and safety systems, consistent with best practice in biofuel logistics. At the receiving end, refineries will need dedicated ethanol reception and blending infrastructure, including 1.5-2 million litres of storage, spread across multiple smaller tanks to allow flexibility in scheduling and blending operations. Such tankage is typical in global bioethanol supply chains, where buffer storage is designed to absorb fluctuations in production, transport, or refinery throughput.

Processing-related infrastructure is focused on the fact that bioethanol plants are highly resource-intensive and require secure access to reliable power supply, and in South Africa this means both grid connections and backup generation are necessary to ensure continuous operation. Processing also consumes substantial volumes of water, especially in fermentation, cooling, and cleaning. Plants must be sited near reliable water sources or integrate recycling systems.

The handling of effluent and waste management requires treatment systems to manage stillage and wastewater. These can be converted into biogas or organic fertilisers, creating secondary value streams.

Transport infrastructure is the backbone of the value chain, given that plants require large, consistent feedstock volumes. For example, the Mabele plant model requires 400,000 tonnes of sorghum per year, which translates into thousands of truckloads. South Africa relies heavily on road haulage due to a significantly under functioning rail system, but costs escalate steeply once distances exceed about 100 km from the processing facility. Road congestion, axle-load restrictions, and rising diesel costs all affect competitiveness. Feedstock security therefore depends on clustering sorghum production within a defined catchment area around ethanol plants. In principle, rail offers a cheaper bulk transport solution over longer distances, reducing per-tonne costs and easing road congestion. However, Transnet Freight Rail's inefficiencies, high tariffs, and service unreliability currently limit rail's attractiveness. Unless reforms or private sector partnerships improve performance, ethanol investors will remain reluctant to rely on rail. The optimal approach combines road for short-haul farm-to-silo or farm-to-railhead transport, and rail for longer-haul movement to processing plants. Investments in sidings, loading facilities, and public-private partnerships with Transnet may be needed to unlock this efficiency.

South Africa has many of the required infrastructure elements already in place, cooperative silos, strong road networks, established legal and financial services, but gaps in logistics efficiency, irrigation, and reliable rail transport remain bottlenecks. Unless addressed, these constraints risk undermining the cost competitiveness of sorghum-based ethanol. Conversely, targeted investments in clustered production zones, rail revitalisation, and water-efficient processing systems could transform the infrastructure landscape, making sorghum a truly practical and scalable feedstock to South Africa's bioethanol industry.

Stage five: from bioethanol plant to blended fuel

Beyond the plant gate, ethanol must be distributed through fuel blending depots and distribution terminals, integrated into the petroleum products supply chain. South Africa already has infrastructure for petrol blending and distribution but scaling ethanol will require coordinated planning with oil companies.

Once ethanol is produced at a bioethanol plant, it requires dedicated downstream handling infrastructure. Ethanol is hygroscopic and absorbs water from the atmosphere and therefore cannot be moved through South Africa's multi-fuel pipelines that carry petrol, diesel, and jet fuel. Instead, it must be stored in dedicated tanks and transported by road or rail to petroleum refineries or blending terminals. At these facilities, ethanol is blended into petrol at E2-E10 levels, while biodiesel is blended into diesel at B5-B10, under tightly controlled conditions that meet the SANS. This blending model aligns with global best practice, where refinery or terminal blending is the dominant approach, ensuring consistent fuel quality and reducing costs compared to splash-blending at retail sites.

However, South Africa's blending and distribution capacity is directly linked to its crude oil refinery network, which has been in steady decline due to closures, flood damage, and economic pressures. Total refining capacity has fallen sharply, concentrating blending activity in a handful of facilities. This reduction places pressure on distribution logistics, raising the importance of efficient ethanol transport corridors.

As

Table 10 shows, by 2025, only a limited number of refineries (Calref, Natref, PetroSA, and Sasol Secunda) remained in operation, many at reduced or intermittent capacity. This constrained refinery base means that ethanol blending will be concentrated at fewer sites, amplifying the importance of transport logistics and regional storage hubs to connect bioethanol plants to blending facilities.

Table 10: Refinery landscape (2025)

Refinery	Location	Operator (Latest)	Capacity (barrels/day)	Status (2025)
Sapref	Durban	Shell / BP	180,000	Closed (2022)
Enref	Durban	Engen / Petronas	120,000	Closed (2023)
Calref	Cape Town	Chevron / Astron	100,000	Operating, reduced
Natref	Sasolburg	Sasol / TotalEnergies	108,000	Operating
PetroSA (Mossel Bay GTL)	Mossel Bay	PetroSA	45,000 (GTL capacity)	Operating intermittently, reduced
Sasol Secunda	Secunda	Sasol	150,000 (synthetic fuels)	Operating

Source: South African Petroleum Industry Association (SAPIA). Overview of South Africa's Refining Sector. SAPIA Report, 2023.

South Africa's bioethanol blending infrastructure is centred on a few strategic inland and coastal depots. Inland, the key hubs are Alrode (Alberton) and Tarlton in Gauteng, which handle large-scale blending and dispatch into the national network, along with Sasolburg, which links directly to Sasol's operations. On the coast, the Durban Island View Precinct (IVP) is the country's largest liquid-bulk hub and a natural anchor for bioethanol blending and export, complemented by Durban South basin terminals tied into the Transnet pipeline system. Other important coastal depots include Cape Town (Milnerton/Astron Energy), Port Elizabeth (Gqeberha), and East London, which serve regional distribution needs.[173]

Cape Town presents a special case, while it has blending and distribution infrastructure through Astron Energy's refinery and depot system, it has no local bioethanol production. Supply could therefore be secured through direct imports or more plausibly through coastal shipping from Durban IVP. In this scenario, cane-based ethanol from KwaZulu-Natal, produced by repurposed sugar mills or juice-fermentation facilities, would not only supply Durban's pool but also be shipped coastally to the Cape. This is more cost-effective than railing inland sorghum ethanol to the Western Cape, which would be better directed toward inland demand in Gauteng.[174, 175]

Secondary blending depots, numbering more than 200, are distributed across all provinces in South Africa, extending the potential for ethanol distribution beyond the main hubs. These facilities perform top-up blending, adjusting ethanol levels in petrol consignments to meet mandated blend ratios, thereby ensuring compliance and flexibility across both inland and coastal fuel markets. The least-cost design is to produce ethanol as close as possible to the feedstock and animal feed markets (in the case of grain sorghum).[176] Ethanol will then be shipped to refineries and depots for blending.

---

[173] Transnet National Ports Authority (TNPA). Island View Precinct Strategy Fact Sheet. Durban: TNPA, 2022. https://www.transnetnationalportsauthority.net/Media%20Room/Documents/Fact%20sheet_TNPA%20Island%20View%20Precinct%20Strategy.pdf.

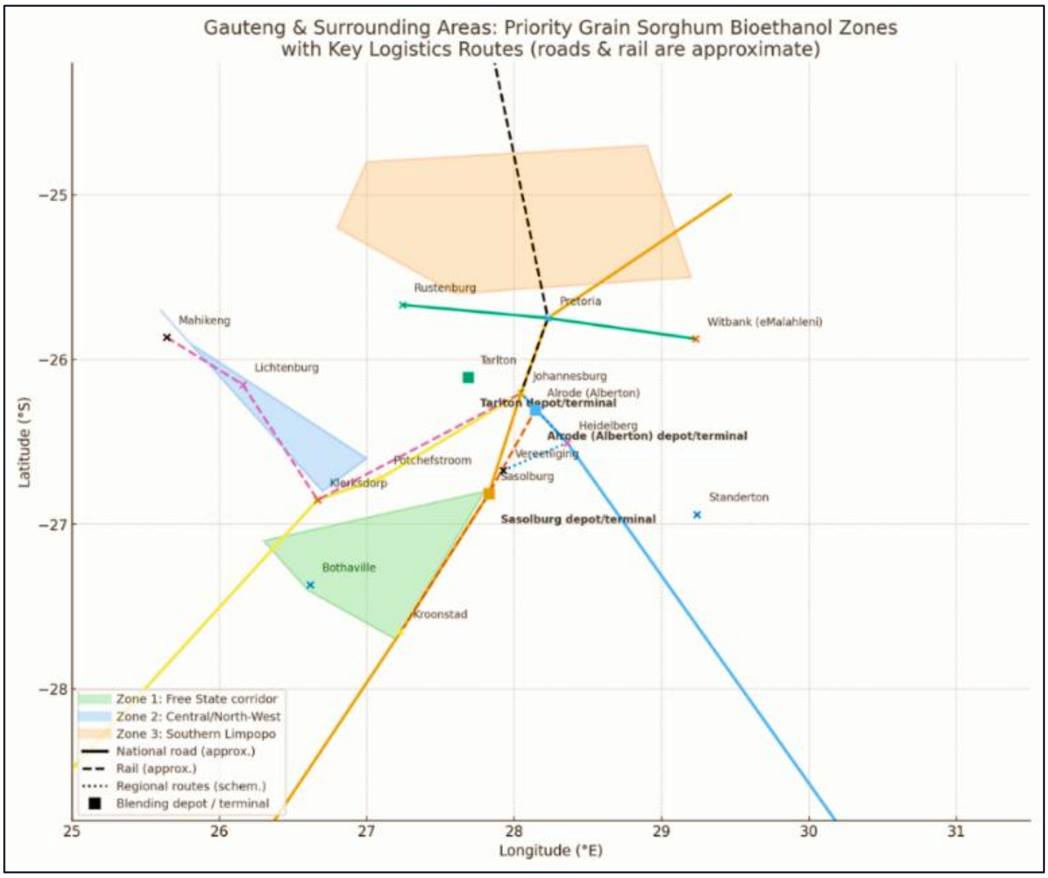
[174] Cartwright, A. *An Analysis of South African Bioethanol*. London: IIED, 2009. https://www.iied.org/sites/default/files/pdfs/migrate/G02285.pdf.

[175] Liquatrans. "Transnet's R1.1 billion Liquid Bulk Terminal at Durban Port." Liquatrans News, June 5, 2023. https://liquatrans.com/en/blog/transnets-r11-billion-liquid-bulk-terminal-at-durban-port/

[176] Ibid

Figure 12 below shows the three core potential priority zones for sorghum, blending and logistics.

Figure 12: Priority zones for grain sorghum cultivation and associated logistics corridors.



Source: Analysis by Blueprint Holdings (Pty) Ltd based on BFAP modelling outputs, DALRRD land capability datasets, Statistics South Africa agricultural data, and national road and rail network information (SANRAL; Transnet). Routes and zones are indicative.

For grain sorghum bioethanol plants, primary zones are the i) Northern/Western Free State (Bothaville-Kroonstad-Sasolburg corridor). This area has the strongest grain logistics, including rail sidings, existing agro-processing ecosystem, and is close to Gauteng demand and the Sasolburg/Alrode/Tarlton terminals ii) the Central/North-West (Lichtenburg-Klerksdorp-Mahikeng) area which is suitable for dryland sorghum/maize rotations, and has cattle and poultry feed demand for DDGS. It is also a practical distance to Gauteng, and iii) as a secondary option, the southern Limpopo (Waterberg fringe) area where commercial sorghum is viable and rail links southward exist, this could be used only if reliable grain origination contracts can be secured.

Stage six: from blender to the pump

From the point of production to the retail pump, the biofuels value chain involves six critical steps.

i. *Quality Assurance and Standards Compliance*: Ethanol for blending must meet SANS 465 fuel ethanol specifications (purity, water content, and denaturant content), while biodiesel must comply with SANS 1935 for B100. Independent verification and testing at depots and refineries ensure quality; non-compliant fuels are rejected or diverted to non-fuel markets. [177] [178]

[177] South African Bureau of Standards (SABS). SANS 465: Fuel Ethanol Specification. Pretoria: SABS, 2021a.

[178] South African Bureau of Standards (SABS). SANS 1935 : Biodiesel (B100) Specification. Pretoria : SABS, 2021b.

ii. *Denaturing Process*: Fuel ethanol cannot be sold in potable form. It is typically denatured with 2-5% petrol at the bioethanol plant before distribution, both to comply with regulations and prevent diversion into the liquor market.[179]

iii. *Distribution Networks*: Ethanol requires road tankers (40,000-45,000 L per load) for short-haul movements and rail for long-haul inland transport. Once blended with petrol or diesel, fuels can move through Transnet's pipeline network. Blending leverages existing petroleum infrastructure, with approximately 200 depots nationwide handling much of the process alongside refineries, minimizing the need for new facilities. Strategic depots in Gauteng (Alrode, Waltloo), KwaZulu-Natal (Island View, Richards Bay, Pietermaritzburg), Western Cape (Milnerton, Mossel Bay), and the Eastern Cape (East London, Port Elizabeth) act as hubs for dispatch to retail stations.[180]

iv. *Certification and Reporting*: Oil companies and wholesalers must report blended volumes quarterly to the DMRE. Compliance is enforced through penalties, and traceability systems ensure that blending ratios remain within the mandated E2 and B5 levels. This strengthens supply chain integrity and aligns with global sustainability trends.[181]

v. *Retail Integration and Branding*: At the retail level, low-level blends (E2, B5) are expected to follow a "silent blending" model, where consumers are not explicitly informed at the pump, since performance differences are negligible. Higher blends (e.g., E85) may be branded in the future, as seen in Brazil and the U.S., once infrastructure and consumer awareness mature.[182]

vi. *Co-products and By-products*: Biofuel production yields valuable co-products- DDGS from grain sorghum, bagasse from sugarcane (used for cogeneration), molasses residues for feed or industrial use, and CO_2 from fermentation, which can be captured for beverages and industrial markets. These co-products improve plant economics, diversify revenue, and enhance sustainability. [183]

In summary, the South African value chain from plant to pump integrates established refinery and depot infrastructure, rigorous quality standards, and compliance reporting systems, while offering co-product opportunities that strengthen financial viability. Together, these elements ensure that biofuels can be reliably scaled into the national energy mix in support of the blending mandate and broader just transition goals.

4.2 Grain sorghum value chain demand for bioethanol in South Africa

South Africa's 2024 petrol consumption was 8.763 billion litres (national total, all grades), down from 9.037 billion litres in 2023 as high prices, weak growth and efficiency gains continued to suppress

[179] South Africa. Department of Mineral Resources and Energy (DMRE). *Biofuels Regulatory Framework*. Pretoria: DMRE, 2019.

[180] Rooney, William L., David B. Dahlberg, and Phanchanok Lauapun. "Agronomy of Sorghum for Bioenergy." In *Bioenergy for Sustainable Development in Africa*, edited by Rainer Janssen and Dominik Rutz, 95–110. Dordrecht: Springer, 2012. https://doi.org/10.1007/978-94-007-2181-4_8.

[181] South Africa. Department of Mineral Resources and Energy (DMRE). Biofuels Regulatory Framework. Pretoria: DMRE, 2019.

[182] Renewable Fuels Association (RFA). *Grain Sorghum and Ethanol Production in the United States*. Washington, D.C.: RFA, 2022.

[183] Rooney, William L., David B. Dahlberg, and Phanchanok Lauapun. "Agronomy of Sorghum for Bioenergy." In Bioenergy for Sustainable Development in Africa, edited by Rainer Janssen and Dominik Rutz, 95–110. Dordrecht: Springer, 2012. https://doi.org/10.1007/978-94-007-2181-4_8

gasoline demand. This figure is published by the Fuels Industry Association of South Africa (FIASA), drawing on DMRE's national fuel sales series.[184]

If government introduced ethanol blending mandates, the theoretical ethanol requirement scales directly with the petrol pool. Using the standard volume-share definition of blends (E2/E5/E10) and no energy-penalty adjustment, the annual ethanol volumes implied by the 2024 petrol pool are as follows:

Table 11: Blend scenarios by volume (arithmetic)

Blend scenario (by volume)	2024 petrol pool (L)	Theoretical ethanol required (L)
E2	8,763,000,000	**175,260,000**
E5	8,763,000,000	**438,150,000**
E10	8,763,000,000	**876,300,000**

Sources: Calculations by Blueprint Holdings (Pty) Ltd with data derived from Department of Mineral Resources and Energy (DMRE) petroleum products consumption data (2023–2024); SAPIA industry statistics

The blend scenarios are calculated based on South Africa's total petrol consumption (petrol pool) for 2024, estimated at approximately 8.76 billion litres, with ethanol requirements derived arithmetically as 2%, 5%, and 10% of this total.

These are arithmetic volumes (ethanol share × petrol pool). In practice, because ethanol's energy density is lower than gasoline (roughly two-thirds on a volumetric basis), fleets experience a small increase in fuel consumption as blends rise. For policy modelling, U.S practice commonly assumes a small penalty of 0.6% for E2, 1.5% for E5, and 3% for E10; these adjustments are consistent with the U.S Renewable Fuels Association technical materials comparing ethanol's lower heating value to gasoline and are widely used in blending demand planning.[185] In practice, ethanol requirements are slightly higher than the theoretical volumes above, because total litres sold into the vehicle fleet rise marginally to deliver the same vehicle-kilometres. This suggests the following levels of demand:

Table 12: Blend scenarios by volume practical[186]

Blend scenario	Assumed increase in total fuel consumption	Practical ethanol required (L)	Petrol displaced (L)	Total blended fuel sold (L)
E2	+0.6%	**180,767,000**	8,582,233,000	8,816,578,000
E5	+1.5%	**451,723,000**	8,396,277,000	8,894,445,000
E10	+3.0%	**902,589,000**	8,035,411,000	9,025,590,000

Sources: Calculations by Blueprint Holdings (Pty) Ltd with data derived from DMRE petroleum products sales data (2023–2024); Renewable Fuels Association (RFA) ethanol blend modelling methodologies; International Energy Agency (IEA) Renewables; South African Bureau of Standards (SANS 342/1928) fuel blending specifications; industry logistics constraints (pipeline incompatibility of ethanol)

[184] Annual-Report-2024.pdf https://www.fuelsindustry.org.za

[185] https://ethanolrfa.org/file/2145/RFA%202022%20Outlook.pdf

[186] Method: ethanol volume = blend % × (petrol pool × (1 + penalty)); petrol displaced = total blended litres – ethanol volume. The penalty assumptions and the "annual litres of ethanol required at various mandates" framing follow RFA methods used internationally for mandate sizing.

The practical blend volumes are calculated using a standard volume-based methodology, where ethanol demand is derived as a percentage of the petrol pool adjusted for a modest consumption uplift, consistent with international biofuel modelling approaches (RFA; IEA). Two distribution realities anchor these figures. Ethanol is hydrophilic and cannot move in South Africa's multi-product pipelines, it must be handled in dedicated storage and taken by road/rail to refineries or terminal depots for controlled blending under SANS specifications. Second, blending capacity is increasingly concentrated because crude refining capacity has fallen following closures/flood damage, and South Africa now imports 75% of its liquid fuel needs, heightening the importance of terminal/refinery blending rather than forecourt splash-blending.[187]

In 2024 South Africa had no national ethanol blending mandate, so actual fuel-ethanol demand was effectively zero (beyond small pilot/spot activity). The refinery/terminal network therefore did not draw ethanol into the petrol pool at scale. The country's constrained refining base and the concentration of compliant terminals make terminal/refinery blending the only credible route should a mandate be introduced, again underscoring the logistics planning noted above.

South Africa does, however, operate a sizeable non-fuel ethanol industry serving beverages, pharmaceuticals, personal-care and solvents. The installed capacity for non-fuel ethanol is about 282 million litres per year across four plants, namely:

i. AlcoNCP in Durban which produces 85 ML/yr of maize-based neutral alcohol for beverages, cosmetics, and pharmaceuticals;
ii. Illovo Sugar SA in Merebank and Glendale, KwaZulu-Natal which supplies more than 50 ML/yr of cane molasses ethanol, sold mainly into potable and industrial uses;
iii. Sasol in Secunda's HPE unit which manufactures ~108 ML/yr of high-purity synthetic ethanol as a by-product of coal-to-liquids, directed mainly into industrial solvents, coatings, adhesives, cleaning products, pharmaceuticals, and specialty chemicals rather than fuel blending;
iv. Royal Eswatini Sugar Corporation located in Simunye, Eswatini. This facility produces ~32 ML/yr, primarily for potable/industrial ethanol. While the facility is in Eswatini, a portion of its potable/industrial ethanol is imported into South Africa to supplement domestic demand.

Customs statistics indicate that South Africa is typically a small net importer of specific grades but a significant exporter overall in the ethanol HS 2207 headings, consistent with a domestic non-fuel industry that meets local demand and sells surplus into Africa and global markets. In 2023, South Africa imported about 304,000 L of very small volumes of undenatured high-strength ethanol (HS 220710) and 91,600 L of denatured ethanol (HS 220720) [188] These patterns confirm that the industrial/potable market is well supplied domestically; imports are niche/grade-specific, and South Africa places surplus into export markets.

[187] Annual-Report-2024.pdf https://www.fuelsindustry.org.za
[188] https://wits.worldbank.org/trade/comtrade/en/country/ZAF/year/2023/tradeflow/Imports/partner/ALL/product/220710

Table 13: Overall demand for ethanol in South Africa (2024)

Segment (2024)	Demand (indicative)	Domestic supply/capacity (indicative)	Comment
Fuel ethanol (petrol blending)	0 L (no national mandate)	N/A for fuel (no fuel-grade production into petrol pool)	If E2/E5/E10 were introduced, 175 m / 438 m / 876 m L/yr would be required on the 2024 petrol pool (theoretical), rising slightly with energy-penalty adjustments per RFA conventions.
Industrial + potable ethanol	Sufficient to support beverages, pharma, personal-care, solvents; netted by trade data	282 m L/yr installed non-fuel capacity (molasses + Sasol HPE)	Capacity estimate from U.S. Grains Council; Sasol HPE 85,000 t/yr (108 m L) within this envelope; Illovo confirms ongoing ENA/industrial production.

Sources: Calculations by Blueprint Holdings (Pty) Ltd with data derived from Department of Mineral Resources and Energy (DMRE) petroleum products consumption data (2023–2024); Renewable Fuels Association (RFA) ethanol blending methodology; U.S. Grains Council (USGC) country market assessments and capacity estimates (Southern Africa); company disclosures (Sasol Limited; Illovo Sugar Africa; AlcoNCP); South African Revenue Service (SARS) trade data (HS 2207)

Fuel ethanol demand is calculated as a percentage of the DMRE petrol pool, with adjustments based on RFA blending conventions. Industrial demand is inferred from production capacity and trade data (SARS HS 2207), with supply estimates based on USGC and company disclosures.

South Africa already has an industrial/potable ethanol base that functions and trades but does not currently have a fuel market to absorb bioethanol at scale. The market gap is therefore very large: at E10, the 2024 petrol pool would require on the order of 0.9 billion litres of fuel-grade ethanol per year, three times the country's entire installed non-fuel capacity, before any growth in petrol demand. Even E5 would require 0.44-0.45 billion litres (practical). On the 2024 baseline, that is well beyond current domestic supply configured for fuel use.

Two system constraints condition how fast this gap could be closed. First, blending happens at terminals/refineries, and South Africa's refining capacity has halved, with only a few plants operating and large volumes of refined products imported. These concentrates blending nodes and raises the stakes on reliable road/rail corridors from ethanol plants to terminals. Second, ethanol is not pipeline-compatible so the industry must scale dedicated tanks, truck/rail logistics, and terminal injection skids. *These factors do not negate the opportunity; they simply define the enabling investments required*.

Even with a shrinking petrol pool (8.763 bn L in 2024 versus >11 bn L pre-2019) for South Africa, the combination of any national blend mandate and the GHG advantages of ethanol creates a sizeable structural market. Moreover, clean-fuels specifications and decarbonisation strategies (national and corporate) point to long-term demand for lower-CI liquid fuels, with sugarcane ethanol achieving particularly strong lifecycle GHG reductions in the South African context given the fossil baseline.

In sum, the South African (and potentially southern African) fuel market is currently unserved while industrial/potable demand is largely met domestically. The moment a blending mandate is implemented, even at E5, the demand step-change outstrips present domestic ethanol capacity by a wide margin-creating scope for sugarcane, sorghum and synthetic/advanced routes to participate, provided logistics, terminal blending capacity and quality-assured handling are built out.

To develop a sustainable value chain that works there must be investment in infrastructure which in turn must be justified by the available market, and potential returns if such an investment were to be made. As a private investor (and a blended (PPP) or even public investor) evaluating the development of a grain sorghum-to-bioethanol value chain in South Africa, the central consideration is the relationship between ethanol market demand, investment in enabling infrastructure, the price of grain sorghum at the ethanol plant gate, in order to deliver the necessary financial returns.

A preferable bioethanol infrastructure strategy would combine rapid-start coastal sugarcane capacity with longer-term inland grain sorghum anchors, creating a balanced, phased supply system. In the near term, KwaZulu-Natal coastal mills offer the quickest route to market where mothballed sugar mills could be reactivated or adapted to switch from molasses to direct sugar-juice fermentation, bringing 100-150 million litres per year of cane ethanol online within one to two years. This coastal production would plug directly into the Durban Island View Precinct (IVP) for blending and distribution.[189] A smaller sweet sorghum pilot in KZN or Mpumalanga (20-40 million litres per year) could be run as a seasonal campaign during cane off-peak, testing agronomy and logistics while leveraging existing sugar infrastructure.

Over the medium term (five years plus), the focus shifts inland, where new grain sorghum ethanol anchors would underpin national volumes. The Free State corridor (Sasolburg/Bothaville/Kroonstad), at around 150 million litres per year, would be the flagship inland facility, dispatching ethanol by rail to Gauteng depots (Alrode, Tarlton) and supplying DDGS into regional feed markets, with optional CO_2 offtake. A second anchor in the North West (Lichtenburg/Klerksdorp) at 100-150 million litres per year would integrate with local silos and feedlots, with ethanol again flowing to Gauteng. A conditional Limpopo satellite (Waterberg fringe) could follow at 100 million litres per year, but only if reliable grower contracts are secured. These inland projects require newbuild timelines of around five years, given permitting, financing, and construction lead times.[190] Sugarcane provides fast-track coastal ethanol into Durban IVP within two years, while sorghum anchors establish a long-term inland base supplying Gauteng over five years.

At present, the demand case is very clear but unrealised. South Africa's annual petrol pool in 2024 stood at 8.763 billion litres, which under even modest blending mandates (E2-E10) would translate into a new market of between 175 million and 902 million litres of fuel-grade ethanol annually. This is far larger than the current domestic ethanol industry, which supplies only 282 million litres per year, almost entirely to industrial and potable markets (molasses-based plants and Sasol's synthetic facility).[191] In other words, the fuel market does not yet exist, but the potential demand step-change is enormous once policy is in effect.

For investors, this creates a market-making situation. The market is guaranteed by mandate, but only if government provides the regulatory certainty and blending infrastructure required. Without that certainty, private capital faces significant risk. However, should blending mandates be implemented, the demand volumes dwarf existing supply, ensuring that multiple feedstock pathways (sugarcane, sorghum, synthetics, and eventually cellulosic) can co-exist without displacing one another. This is a fundamental investment reassurance. The market is big enough for all, and first movers gain competitive advantage in scale and logistics.

The investment case must also weigh infrastructure requirements to enable clustering of production near blending nodes critical. Investors will therefore need to commit not just to production facilities, but also to storage tanks, truck fleets or rail sidings, and possibly co-investment in blending infrastructure. These upfront capital requirements are significant, but they are also barriers to entry that can protect early movers once the market is established. From a return perspective, three elements strengthen the investment proposition as follows:

---

[189] Maritime Review Africa. "Another Strategy Revision for Island View Precinct." *Maritime Review Africa*, February 26, 2024. https://maritimereview.co.za/Articles/ArtMID/397/ArticleID/535/CategoryID/28/CategoryName/Tender-News/Another-strategy-revision-for-Island-View-Precinct.

[190] African Centre for Biodiversity (ACBio). *South Africa's Agrofuels Industry*. Johannesburg: ACBio, 2022. https://acbio.org.za/wp-content/uploads/2022/04/Agrofuels.pdf.

[191] https://grains.org/bioethanol/ethanol-market-profiles/south-africa/

i. **Guaranteed demand under mandate** (with strong policy precedents globally, such as Brazil's Proálcool and RenovaBio) when there is sufficient supply, in a phased in manner;
ii. **Multiple revenue streams**, as sorghum-based ethanol also generates valuable animal-feed co-products (DDGS); and
iii. **Climate and ESG positioning**, as lower-carbon fuels are increasingly rewarded by international capital markets and potentially by domestic climate policy (carbon budgets, carbon tax offsets).

4.3 Case study: Mabele fuels

Mabele Fuels was formed in 2005 with the vision of playing a pioneering role in the nascent South African biofuels sector. [192] In 2007, the Biofuels Industrial Strategy was published with the aim to establish a biofuels industry to enhance energy security, create rural jobs, and reduce greenhouse gas emissions. Eight years later in 2015, the Minister of Energy determined that the Mandatory Blending of Biofuels with Petrol and Diesel regulations would come into effect.[193] That year Mabele announced its intention to build a 158 million-litre per annum bioethanol refinery in Bothaville. Eight years later, in October 2023, Mabele Fuels re-signed a fixed-price, lump-sum turnkey Engineering, Procurement, and Construction (EPC) contract with a Chinese company to build the Bothaville sorghum-to-bioethanol plan, with the company's website stating that, with financial close and EPC execution, construction would take about 24 months. However, the government pricing legislation, which was required to de-risk the sector, was not finalised.

In August 2025, the DMRE gazetted the final regulatory piece of the puzzle. Bioethanol pricing has been set at the same price as the basic fuel price plus a zone differential. The basic fuel price is defined in the notice as a pricing mechanism used by the Department to determine the price of imported petroleum products and the zone differential reflects the cost of moving petroleum products from coastal port or refinery location to inland distribution centres by pipeline, rail or road.[194]. Given this key input data, Mabele advises it now moving towards financial close. According to a Mabele executive interviewed for this report, the project has an expected Internal Rate of Return (IRR) somewhere between the high teens and 30% depending on price forecasts. In terms of by-products, DDGS used for animal feeds is expected to contribute up to 20% of the plant revenue.[195]

Feedstock security is a key risk and the viability of the Mabele plant depends on the availability of sufficient grain sorghum feedstock within an economic sourcing radius. Ethanol plants of this scale are highly sensitive to logistics costs, and international studies suggest that feedstock generally needs to be sourced within 100 km of the plant to remain cost competitive.[196]

[192] "Mabele Fuels |." 2023. Mabelefuels.com. 2023. https://www.mabelefuels.com/.

[193] "Mandatory Blending of Biofuels with Petrol and Diesel to Start in October 2015." 2015. Polity.org.za. 2015. https://www.polity.org.za/article/mandatory-blending-of-biofuels-with-petrol-and-diesel-to-start-in-october-2015-2013-10-08.

[194] "Government Notices • GoewermentskennisGewinGs DEPARTMENT of MINERAL RESOURCES and ENERGY." 2025. https://www.gov.za/sites/default/files/gcis_document/202508/5314gon6499.pdf.

[195] Source: Interviews with stakeholders

[196] "Bioenergy Accelerating to Net Zero." n.d. Accessed September 19, 2025. https://www.ieabioenergy.com/wp-content/uploads/2025/06/IEA-Bioenergy-Annual-Report-2024.pdf.

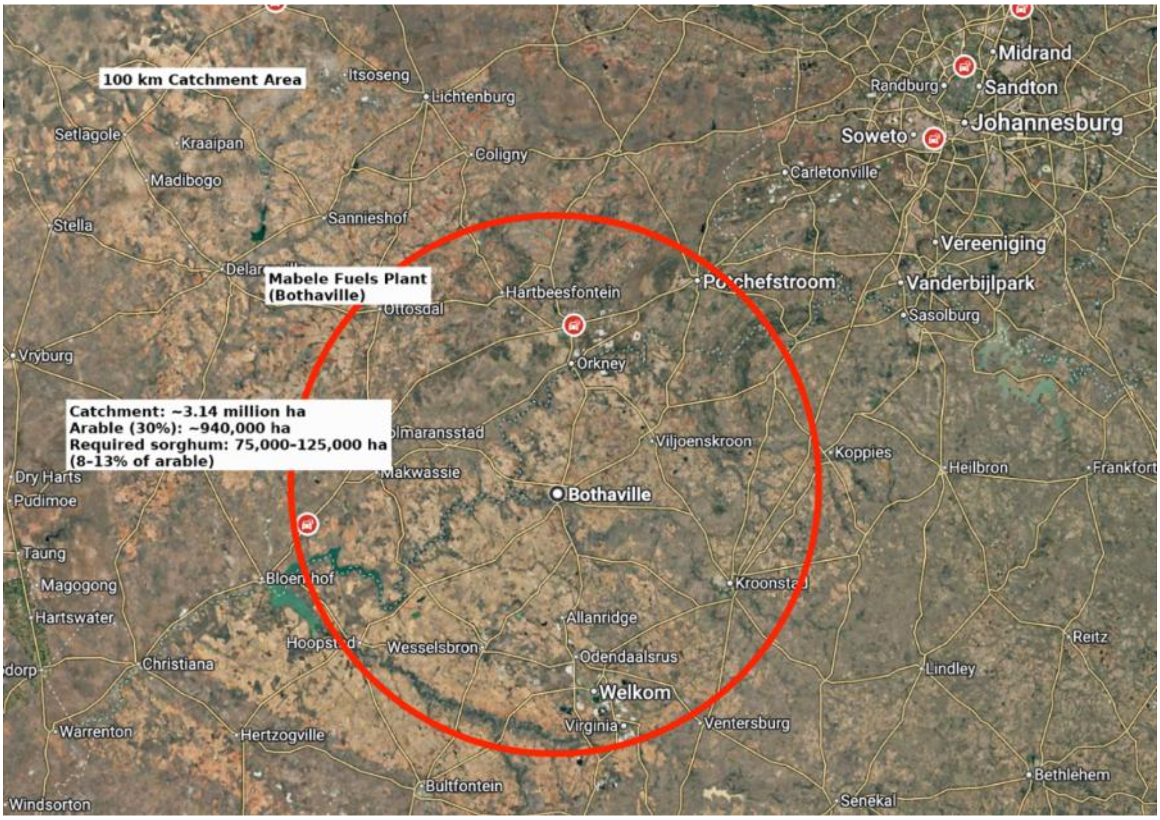
Table 14: Land requirements to supply Mabele at yields from 2t/ha to 3.5 t/ha

Yield (t/ha)	Ethanol yield (L/ha)	Hectares needed
2.0 (low input, smallholder)	800	125,000
2.5 (moderate support)	1,000	100,000
3.35 (current South African commercial average	1,340	74,600

Sources: Calculations by Blueprint Holdings (Pty) Ltd with data derived from Mabele Fuels project information

The Free State maize belt around Bothaville is among the most intensively cropped regions in South Africa.[197] Remote sensing analyses and satellite imagery, as per Figure 13, show dense continuous cropland mosaics across 100 km radius out from the town. Interviews with farmers indicate that a consistent contracted offtake price is a necessary starting condition for farmers to switch to sorghum. Mabele executives are confident that there is sufficient cultivation potential for grain sorghum with the 100km radius. They have contracted Specialised Agri Solutions to ensure availability of feedstock.[198] Approximately 5- 10% of arable land would need to switch to sorghum cultivation to provide feedstock security for Mabele Fuels, depending on yields.

Figure 13: The Free State maize belt around Bothaville



Sources: Calculations by Blueprint Holdings (Pty) Ltd with data derived from Mabele Fuels project information; satellite basemap (Google Maps/Google Earth); and indicative feedstock catchment modelling assumptions.

[197] Roy, Samapriya. 2023. "South African National Land Cover (SANLC) - Awesome-Gee-Community-Catalog." Gee-Community-Catalog.org. September 8, 2023. https://gee-community-catalog.org/projects/sa_nlc/.

[198] "Specialised Agri Solutions – the Future of Farming Partnerships." 2025. Specialisedagriculture.com. 2025. https://www.specialisedagriculture.com/.

Rainfall changes and heat driven by climate change are likely to make some maize areas, particularly in the west marginal for maize, opening up land for sorghum cultivation. Recent data on improved yields and soil health when rotating between maize and grain sorghum may provide an added incentive to maize farmers to rotate maize with sorghum further increasing feedstock security for Mabele. The Bothaville catchment has more than enough arable land to support the required sorghum hectares. Even under conservative assumptions, the conversion of 5-10% of arable land to sorghum would be sufficient. The true constraints are however farmer incentives, logistics, and policy certainty.

Downgraded maize as feedstock

Like most starch-based bioethanol plants, Mabele's grain-based ethanol process is feedstock-flexible: it can process sorghum but can also absorb downgraded or surplus maize, damaged by drought, fungal contamination, or pest shock.[199] The annual Maize Crop Quality Reports published by the Southern African Grain Laboratory (SAGL), surveys commercial crops through representative sampling indicate that a significant percentage of the country's annual maize crop, from 10% - 15%, is downgraded to animal feed. According to stakeholders, the quality of especially white maize in the current year has been particularly bad due to diplodia and f USrium fungi because of a wet late season. Downgraded maize trades at a discount of 15 - 30% or more if aflatoxin contamination is present.[200]

Given the annual maize crop in the region of 15M tonnes, and annual spoilage data, there is more than sufficient downgraded and discounted maize available each year to keep Mabele fuels entirely running on downgraded Maize, without impacting food security.[201] However the South African Biofuels Industrial Strategy (2007) and the Biofuels Feedstock Protocol exclude maize as a feedstock for biofuels and it appears that this protocol applies to maize for animal feeds as well as for food value chains. To change this stricture would require at the least amending the Feedstock protocol or relevant legislation to carve out a defined category of waste or degraded maize under strict conditions.

Allowing this lower quality maize stream to be channelled into biofuels would have several benefits. It would secure an additional, locally available feedstock without competing with human food supply; stabilise farmer incomes in seasons of surplus or downgraded harvests; and improve plant utilisation rates for ethanol producers. Such a mechanism would align with the objectives of the Biofuels Industrial Strategy, which already seeks to balance food security and rural development, while strengthening South Africa's energy diversification.[202]

In sum, the use of downgraded maize due to quality concerns or contamination as a feedstock for Mabele would reduce the feedstock risk significantly without impacting on food security.

Table 15: Downgraded maize relative to total crop (2024)

199 Hell, Kerstin, and Paul Van Rij. "Maize, Aflatoxins and ethanol production: Risk management in Sub-Saharan Africa." FAO Technical Paper, 2015.

200 Southern African Grain Laboratory (SAGL). South African Maize Crop Quality Report 2022/23. Pretoria: SAGL, 2023. Grain SA. Market Reports and SAFEX Prices 2023–2025. Bothaville: Grain SA.

201 "How Does Corn Quality Impact Ethanol Yield?" n.d. Accessed September 22, 2025. https://biosolutions.novozymes.com/sites/default/files/file_download/Corn%20quality%20impact%20ethanol%20yield_0.pdf.

202 Wa, apos; Matimba House, and Visagie Street. 2020. "44*-16 V4;140 Energy Mineral Resources Government Notices • GoewermentskennisGewinGs DEPARTMENT of MINERAL RESOURCES and ENERGY." GAZETTE, no. 43003. https://www.gov.za/sites/default/files/gcis_document/202002/43003gon116.pdf.

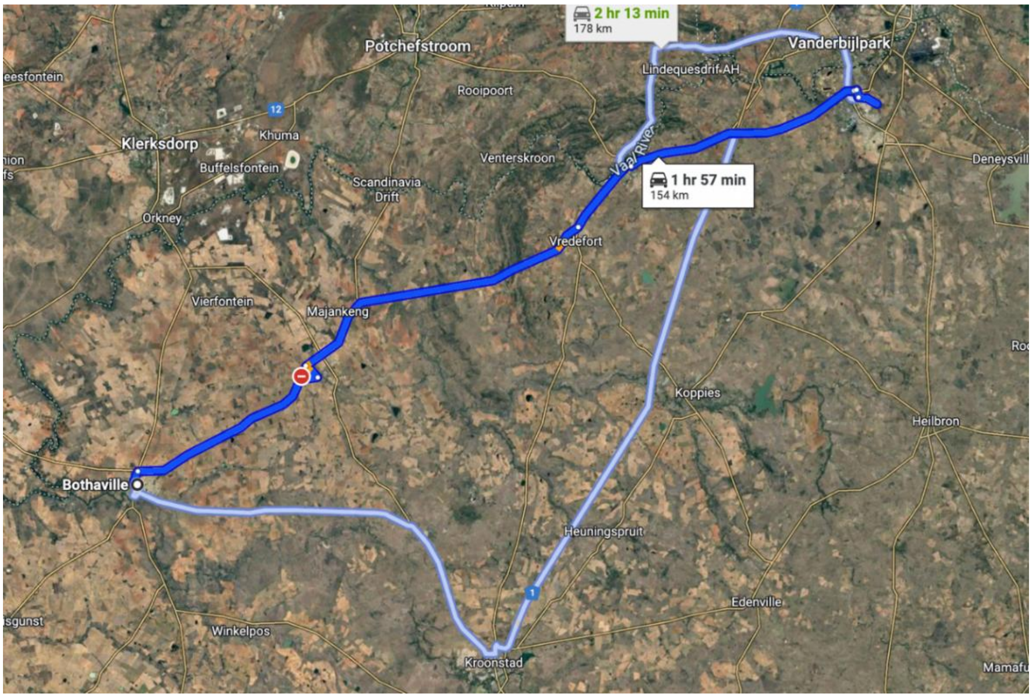
Crops	Units	Comment
Annual maize crop (tonnes)	15,000,000	SAGIS data (fluctuates annually but increasing)
Annual crop downgraded (10%)	1,500,000	Maize crop quality reports
Litres of bioethanol from 1 tonne maize	400	Standard conversion
Tonnes of Maize (or sorghum) to supply Mabele at full capacity 150 ML/a)	375,0000	Represents 2.5% of South African annual maize production

Source: Calculations by Blueprint Holdings (Pty) Ltd with data derived from SAGIS

One of the primary routes to market (refineries) indicate that the location of Mabele Fuels is competitive with regard to logistics as it is located in the Northern/Western Free State (Bothaville-Kroonstad-Sasolburg corridor). This area has the strongest grain logistics, including rail sidings, existing agro-processing ecosystem, and is close to Gauteng demand and the Sasolburg/Alrode/Tarlton terminals.

The least-cost design is to produce ethanol as close as possible to the feedstock and animal feed markets (in the case of grain sorghum).[203] Ethanol will then be shipped to refineries and depots for blending.

Figure 14: Road logistics routes from Mabele Fuels to Natref in Sasolburg.



Source: Analysis by Blueprint Holdings (Pty) Ltd based on Mabele Fuels project information; satellite basemap (Google Maps/Google Earth)

To ensure smooth supply chain integration, Mabele Fuels or other bioethanol plants will require on-site bulk ethanol storage of around 2-3 million litres, enough for 7-10 days of production. This would likely

203 ibid

be configured as three 1-million-litre tanks with associated loading gantries and safety systems, consistent with best practice in biofuel logistics. At the receiving end, refineries will need dedicated ethanol reception and blending infrastructure, including 1.5-2 million litres of storage, spread across multiple smaller tanks to allow flexibility in scheduling and blending operations. Such tankage is typical in global bioethanol supply chains, where buffer storage is designed to absorb fluctuations in production, transport, or refinery throughput.

4.4 Sweet sorghum to bioethanol

Like maize and sugarcane, sorghum can support different ethanol production pathways, but what differentiates sorghum is that it can support all three ethanol routes, grain sorghum, sweet sorghum and sugar cane. [204] Sweet sorghum (Sorghum bicolor) is a C4 grass whose stalks store high levels of fermentable sugars, while also producing grain and lignocellulosic residues. It is drought-tolerant, matures in about four months, and performs well on marginal land, making it attractive as a 'food-feed-fuel' crop. From a biofuel perspective, sweet sorghum supports two ethanol pathways: juice-to-ethanol, analogous to sugarcane, and starch/lignocellulosic routes from grain and bagasse. Trials have reported 20-119 t/ha of biomass and ethanol yields ranging from 1,500-8,000 L/ha depending on genotype and management. Its main bottlenecks include sugar stability, short harvest windows, and bulky logistics, which can be mitigated by staggered planting, syrup concentration, and co-location with other crops or infrastructure.[205]

Global market and demand

Fuel ethanol markets are dominated by sugarcane in Brazil and maize in the US. Sweet sorghum has been promoted in India, China, and parts of Africa as a complementary feedstock, especially in semi-arid regions. Despite agronomic potential, large-scale uptake has been limited by logistics, cost competitiveness, and policy uncertainty. Expanding blend mandates globally (e.g., Brazil raising ethanol blending to 30% by 2025) are tightening demand for diverse feedstocks. Sweet sorghum can occupy a niche where water scarcity, land limitations, or diversification policies make it attractive.

Processing sweet sorghum is technologically mature and mirrors cane-milling: juice extraction, clarification, fermentation with Saccharomyces cerevisiae, and distillation. Grain and bagasse can be valorised through ethanol, animal feed, or energy co-products. Typical ethanol yields are 40-85 L/t stalk, with conservative farm-level outcomes at ~,500-4,000 L/ha and research trials reaching up to 8,000 L/ha. The main constraints are logistical, not technological. The crop’s carbon intensity profile is attractive given its water efficiency and marginal-land suitability, but project bankability depends on reliable feedstock logistics, co-product integration, and clear policy signals.

Sweet sorghum occupies niche or pilot roles in countries facing water constraints or seeking non-food complements. Notably, India and China have run multi-year programs assessing sweet sorghum for ethanol to reduce reliance on molasses and grains; policy and cost hurdles have slowed scale-up, but

---

[204] Ameen, Muaz, Athar Mahmood, Ahmad Naeem Shahzad, Muhammad Anjum Zia, and Muhammad Mansoor Javaid. 2024. “Sorghum’s Potential Unleashed: A Comprehensive Exploration of Bio-Energy Production Strategies and Innovations.” Bioresource Technology Reports 27 (July): 101906–6. https://doi.org/10.1016/j.biteb.2024.101906.

[205] Nana Baah Appiah-Nkansah, Jun Li, William Rooney, Donghai Wang (2019). A review of sweet sorghum as a viable renewable bioenergy crop and its techno-economic analysis, *Renewable Energy, Volume 143,* https://www.sciencedirect.com/science/article/pii/S0960148119307268

both markets continue to include sweet sorghum in biofuel R&D and planning documents. R & D is an important factor in sweet sorghum relative to the position with grain sorghum.[206]

Table 16: Snapshot- Market, Demand and Technology

Level	Comment
Feedstock & agronomy	Drought-tolerant C4 crop, 4-month cycle, performs on marginal land; yields vary by genotype and management.
Primary pathway	Juice → fermentation → ethanol; grain and bagasse valorised for ethanol, feed, or energy.
Yields	40-85 L/t stalk; 1,500-4,000 L/ha (field) to 8,000 L/ha (trials).
Bottlenecks	Short harvest window, juice spoilage, bulky logistics; mitigated by staggered planting, syrup concentration.
Global role	Niche in India/China pilots; potential in semi-arid Africa; complements sugarcane/maize ethanol.
Policy context	Relies on blend mandates and incentives; global demand rising with decarbonisation targets.
ESG profile	Lower water intensity, climate resilience, use of marginal land; favourable carbon-intensity metrics.

Sources: Food and Agriculture Organization (FAO) crop profiles; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) sorghum research; International Energy Agency (IEA) Renewables (2023–2024); U.S. Department of Energy (DOE) Bioenergy Technologies Office; USDA and FAO yield datasets; peer-reviewed literature on sweet sorghum ethanol (e.g. Ratnavathi et al., 2016; Almodares & Hadi, 2009); own synthesis

From a biofuel perspective, sweet sorghum's value lies in two parallel ethanol pathways: (i) juice-to-ethanol, analogous to sugarcane processing, and (ii) starch/lignocellulosic routes from grain and bagasse, enabling whole-plant valorisation in integrated biorefineries. Reported field and pilot studies show substantial ranges for biomass, sugar concentration, and ethanol yield depending on genotype and environment, with modern trials reporting 20-119 t/ha fresh biomass, 14-20% stalk sugars, and potential ethanol yields up to 8,000 L/ha under high-input conditions, while more conservative on-farm studies in semi-arid settings report 20-40 t/ha with proportionally lower ethanol recovery.[207]

Recent biofuel policy updates show expanding blend mandates globally (e.g., Brazil's step-up from 27% to 30% ethanol in gasoline in 2025), which is tightening demand for low-cost, low-CI feedstocks. Brazil's response has been a rapid maize-ethanol expansion, but industry commentary notes scope for sorghum in rotation or as a regional complement where cane or maize are less competitive. The signal for investors is clear: as blend mandates rise, markets seek diversified, climate-resilient feedstock portfolios, a role sweet sorghum can fill where agronomic fit and logistics align.

Beyond fuels, industrial and potable ethanol markets (beverages, pharma, solvents) remain sizable in many countries and can offtake sweet-sorghum ethanol where specifications are met. The USDA-ARS has also explored biobutanol and broader biochemical routes from sweet sorghum, underscoring optionality in product slates when ethanol margins tighten.[208] Relative to sugarcane and maize, sweet sorghum is commercially less entrenched but technically ready where agronomic and logistics conditions favour it. Its water and input efficiency and ability to use marginal or rotation land give it a compelling ESG and carbon-intensity profile in semi-arid geographies; however, fully loaded delivered-sugar costs (including harvest/haul/handling) and capacity utilisation across seasons are the decisive

[206] https://oar.icrisat.org/6500/1/Basavaraetal._Energy%20Policy_Assesing_2013.pdf ICRISAT

[207] Alsanad, Mohammed A., and Eman I. R. Emara. 2024. Optimizing Bioethanol (C_2H_5OH) Yield of Sweet Sorghum Varieties in a Semi-Arid Environment: The Impact of Deheading and Deficit Irrigation *Water* 16, no. 10: 1456. https://doi.org/10.3390/w16101456

[208] https://www.ars.usda.gov/news-events/news/research-news/2022/sorghum-a-sweet-proposition-for-sustainable-biofuel/

variables for levelised ethanol cost. IEA Bioenergy underscores that moving from technically feasible to commercially bankable requires credible policy signals and logistics integration, particularly when projects rely on cellulosic upgrades; the same logic applies to sweet-sorghum juice mills that must solve seasonality and radius economics.[209]

4.5 Sweet sorghum value chain

Sweet sorghum and grain sorghum belong to the same species, but their value chains diverge significantly in South Africa. Grain sorghum is primarily cultivated for food and feed markets, with applications in brewing, milling, and animal feed. Production is modest, fluctuating between 100,000 and 150,000 tonnes annually, and is strongly influenced by rainfall patterns and competition with maize, which dominates the cereal sector.[210] In contrast, sweet sorghum is cultivated for its high-sugar stalks, which can be processed into ethanol in a manner similar to sugarcane. While grain sorghum supports staple food security and agro-industrial chains, sweet sorghum positions itself as an energy crop, with potential to supplement South Africa's constrained bioethanol supply.

South Africa's regulatory framework does not prohibit sweet sorghum. This gives sweet sorghum a potential comparative advantage over both maize and grain sorghum in energy markets. Sweet sorghum is drought-tolerant, requires fewer inputs than maize, and can be grown on marginal land, aligning well with national goals of climate resilience and rural job creation. Moreover, its short growing cycle of about four months allows for flexible rotations and staggered planting, which could mitigate some of the feedstock bottlenecks that plague the sugarcane ethanol industry.

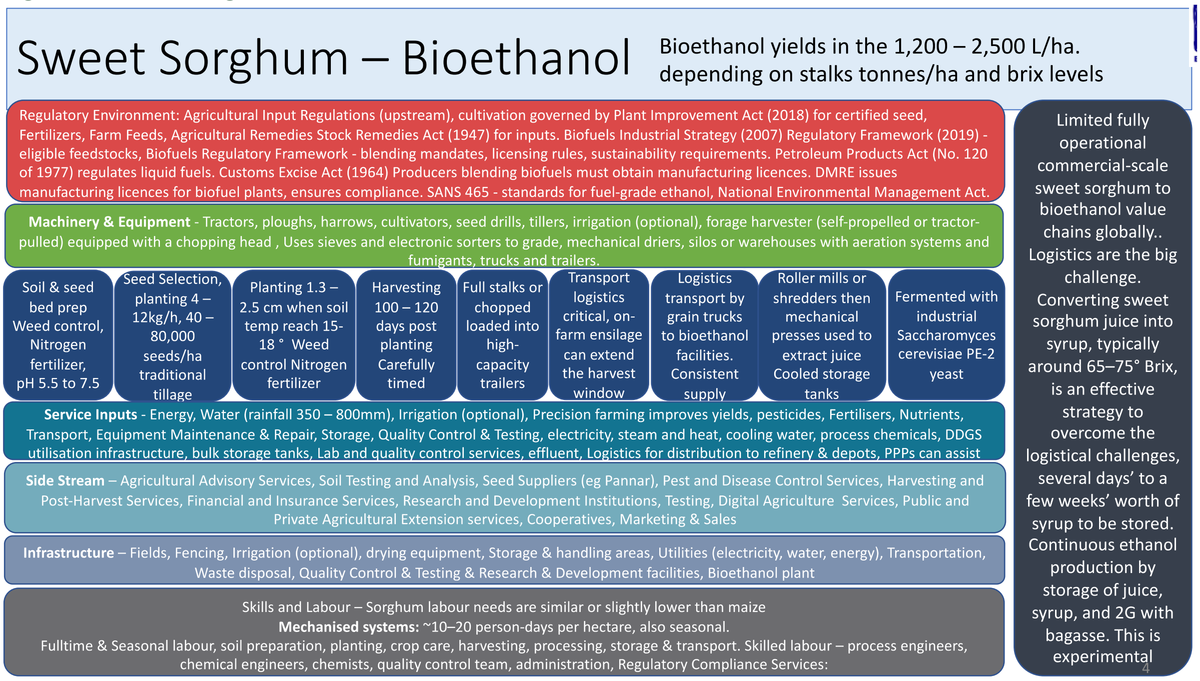
From a technological perspective, the processing pathways for sweet sorghum juice to ethanol are already proven globally. Countries such as India and China have piloted and, in some cases, commercialised sweet sorghum ethanol programmes, leveraging syrup concentration (65-75° Brix) to overcome logistical bottlenecks related to the crop's short harvest window. Grain sorghum, by contrast, requires starch hydrolysis prior to fermentation, meaning processing plants resemble maize ethanol facilities.

Sweet sorghum can complement sugarcane in ethanol production, provide additional revenue streams for farmers in semi-arid regions, and contribute to energy diversification. However, realising this potential depends on clear blending mandates, investment in syrup logistics and terminal blending infrastructure, and the establishment of competitive farm-to-plant cost structures that can rival imported ethanol (Brazil/US) on a landed-price basis.

For South Africa's semi-arid provinces, sweet sorghum can complement sugarcane and grain routes, offering a seasonal feedstock for ethanol with lower water intensity and potential use of marginal land. The technology risk is modest as first-generation fermentation is mature, but the project risk sits in field-to-factory logistics and season extension. One possible model is likely a multi-feedstock, terminal-blending supply chain with tight catchment logistics and co-product valorisation, rather than a single-feedstock option. International experience suggests that clear blending policy and rail/road-terminal integration are preconditions for private capital to scale sweet-sorghum ethanol alongside cane and grain options.

[209] https://task39.ieabioenergy.com/wp-content/uploads/sites/37/2023/10/IEA-BIOENERGY-T39-BIOFUEL-NEWS-63-1.pdf
[210] Grain SA (2024)

Figure 15: Sweet sorghum to bioethanol value chain



The sweet sorghum value chain begins at the farm level, where soils are prepared, seeds selected, and crop management practices such as fertilisation, irrigation, and weed control are implemented. Once planted, the crop matures within about 100-120 days, after which it must be harvested and transported quickly to preserve sugar content. The stalks are either hauled whole to processing plants or pre-processed in the field through chopping or pressing. From there, the logistical backbone - involving trailers, trucks, and in some cases rail - links farms to bioethanol plants. This farm-to-plant segment is the most cost-sensitive, as bulk and perishability drive high transport and handling costs if not well managed.

At the processing stage, stalks are crushed to release juice, which is then fermented by yeast and distilled into ethanol. Conversion yields of about 1,200-2,500 L/ha are typical, depending on stalk tonnage and sugar concentration (Brix). Bagasse and other residues are integrated into side-stream uses, including animal feed, biogas, or electricity generation, providing both additional income and sustainability benefits. The ethanol is then dehydrated, stored in dedicated tanks (as it is hygroscopic), and transported by truck or rail to blending depots such as Sasolburg, Heidelberg, or Alrode, where it is mixed with petrol under SANS. From there, the blended fuel enters the established retail distribution network

Regulatory and policy framework South Africa

This is the same as for grain sorghum. South Africa's biofuels regime is defined by the Biofuels Regulatory Framework (BRF, 2020), which implements the 2007 Biofuels Industrial Strategy. The BRF sets eligibility rules for feedstocks, licensing and sustainability requirements; importantly, it excludes maize (and jatropha) as fuel-ethanol feedstocks on food-security grounds. Fuel quality and blending must comply with SANS specifications and be executed at refineries/terminals (not forecourts). Ethanol blending regulations were gazetted earlier, but national petrol blending has not been implemented at scale; most liquid fuels are now imported and blending capacity is concentrated at a few terminals, given the reduction in domestic refining.

For both, the policy architecture exists, but a clear, stable blending mandate and associated pricing/tax clarity are the catalytic levers for private capital. Terminal/refinery blending is the credible route given South Africa's infrastructure. As noted for grain sorghum, internationally, Brazil's long-running mandatory blending (currently E27 anhydrous in gasoline, moving higher) and carbon-intensity crediting (RenovaBio) created durable demand and de-risked private investment in feedstocks and plants; recent policy updates confirm continued, mandated growth.

Stage one: primary production (farm-level)

Sweet sorghum is a C4 crop with short cycles (~4 months), drought tolerance, and ability to perform on marginal land. Trials by FAO/ICRISAT and peers report wide ranges driven by genotype × environment: fresh biomass ~20-80+ t/ha, stalk sugars ~14-20°Brix, and ethanol yields from 1,500-4,000+ L/ha in field settings, with upper-bound trials reaching 6,000-8,000 L/ha under high inputs and optimal logistics. These data argue for conservative planning assumptions and cultivar screening in target zones.[211] Staggered planting (to spread harvest over 8-10 weeks) is critical to match crushing capacity and minimise sugar losses. ICRISAT's programme evidence shows hybrids outperforming open-pollinated types on sugar yield; seed system support and local adaptation trials are therefore central to bankability.

Based on available agricultural and industry mapping, the most suitable lands for sweet sorghum cultivation in South Africa are concentrated in the western Free State (Bothaville-Kroonstad corridor), the North West Province grain belt (Lichtenburg-Klerksdorp-Potchefstroom), and parts of southern and south-eastern Limpopo, where rainfall is sufficient but water stress favours drought-tolerant crops. These zones already support grain sorghum and maize, meaning established infrastructure, farming knowledge, and input supply chains exist, while proximity to blending depots such as Sasolburg, Heidelberg, Alrode, and Tarlton shortens haulage distances. Together, they form the priority corridors where feedstock production, logistics viability, and downstream processing potential intersect most strongly.

However, sweet sorghum can also be cultivated in or near sugarcane-growing regions, and in fact this has been a focus of pilot projects internationally. In South Africa, the main cane belts are in KwaZulu-Natal (north and south coasts, and the midlands) and in the Lowveld of Mpumalanga. These areas already have milling and ethanol-processing infrastructure, which could in principle be adapted to handle sweet sorghum during cane off-seasons or to supplement feedstock. The key advantage is logistical, sorghum could provide a rotational or supplementary crop that extends crushing windows, stabilises mill throughput, and mitigates risks from drought or disease in cane. However, cane land in KwaZulu-Natal and Mpumalanga is already highly allocated, and competition for water is significant. Expansion opportunities may therefore lie less in prime irrigated cane fields and more in adjacent marginal lands where cane yields are low but sweet sorghum could perform competitively. This makes integration possible, but land availability would need to be confirmed through regional land-use planning and feasibility studies.

Sweet sorghum is best positioned in semi-arid grain belts and as a rotation/complement to grain sorghum/maize where water is limiting. National agricultural reporting confirms ongoing (small) sorghum production footprints, indicating agronomic suitability and existing grain value chains to leverage.

Seed sourcing is critical to the value chain's success. Seed quality and genetic diversity are prioritized to enhance ethanol yield, with ongoing research focusing on drought and salt tolerance. Major hubs

[211] https://oar.icrisat.org/10852/1/Sweet%20Sorghum%20for%20Biofuel%20Industry.pdf

include the International Crops Research Institute for the Semi-Arid Tropics (https://www.icrisat.org/) in India, which develops high-yielding cultivars. Examples from ICRISAT include the CSV series such as CSV 52 SS and CSV 58 SS, which are high-yielding hybrids with Brix levels up to 18% and drought tolerance, developed through conventional breeding and genetic selection for semi-arid conditions.

In South Africa ACCI under the umbrella of the ARC is actively working on breeding programs at the University of KwaZulu-Natal, which are breeding high-yield varieties and conducting trials to enhance sorghum's role in the biofuel sector.[212] Adapted sweet sorghum varieties (e.g., hybrids like those from ARC or Pannar Seed, optimized for high stalk sugar content, drought tolerance, and ethanol yield) are not widely commercialized in South Africa for large-scale bioethanol production, as the sector remains nascent with a focus on grain or forage sorghum.[213] Seeding rates are generally in the 4-12 kg/ha range, adjusted for soil, climate, and irrigation, tailored to maximize sugar yield for bioethanol feedstock, with a cost in the ZAR 50-250/kg range.

In the US, varieties like the Roger hybrid (from Texas A&M) and those tested by Great Valley Energy in California emphasize stem sugar accumulation (up to 20%) and disease resistance, sourced from seed companies like Eagle Seed or Sorghum Partners. Bioghum is an Australian supplier of sweet sorghum seeds with a hybrid range of sorghum seeds optimised for high sugar content for ethanol and biodiesel.

Yield volatility (rainfall timing), harvest bottlenecks during a short window, and sugar inversion/spoilage if logistics slip and the main risks. Input-cost inflation and transport costs are the other big sensitivities in South Africa. While sweet sorghum economics hinge on stalk juice, investors often benchmark to grain sorghum cost curves to price land and operations. Grain SA’s producer frameworks (2024/25) show typical dryland sorghum variable + overhead cost structures (seed, fertiliser, fuel, repairs, pest control, interest), with profitability highly yield-sensitive for sweet sorghum. (Exact values vary by region and season). [214]

Table 17: Input costs - sweet sorghum

Cost component (dryland reference)	Comment / transferability to sweet sorghum
Seed & fertiliser	Largest variable drivers; sweet sorghum seed premiums possible for specialised hybrids.
Fuel, machinery, repairs	Similar order of magnitude to grain sorghum; harvest/haul intensity may be higher for stalks.
Crop protection & insurance	Comparable; variety choice and planting date crucial for pest/disease and hail risk.
Interest on production	Sensitive to working-capital cycle and timing of mill payments.

Source: GrainSA, 2024

Stage two: cultivation & harvesting

[212] “ACCI Sweet Sorghum Poised to Boost Biofuel Industry – African Centre for Crop Improvement.” 2023. Acci.org.za. 2023. https://acci.org.za/acci-sweet-sorghum-poised-to-boost-biofuel-industry/.

[213] CORDIS, cordis.europa.eu. 2025. “Sweet Sorghum: An Alternative Energy Crop.” CORDIS | European Commission. September 2025. https://cordis.europa.eu/project/id/227422/reporting.

[214] https://www.grainsa.co.za/Annual%20report%202024%20New/Grain%20SA%20Annual%20report%202024_new/files/assets/common/downloads/publication.pdf

Sweet sorghum fits well into rotations, especially double-crop systems, and can follow small grains or be planted after earlier crops. It is useful for systems seeking multiple products (juice, biofuel, fodder, etc.) and allows utilisation of periods when primary crops are not grown.

Planting and agronomic factors are tailored to sweet sorghum's resilience. It requires low water inputs (about a quarter of sugarcane's needs) thriving in 500-800 mm annual rainfall, making it ideal for double-cropping. Optimal planting occurs in spring (mid-October in South Africa) with a 100–120-day growth cycle. Soil treatments, such as traditional tillage with plow layer breaking and organic fertilizers, boost stem yields to 44.3 tonnes/ha and juice production to 25.6 m³/ha, as demonstrated in Mexican trials with the Roger variety. Agronomic management includes spacing (60-90 cm rows) and weed control, with minimum tillage reducing costs while maintaining productivity. Germination occurs best at soil temperatures of 15-18 °C (60-65 °F), with seed planted at 1.3-2.5 cm depth depending on soil texture. Optimum plant populations range from 40,000 to 80,000 plants per acre, depending on water and nutrient availability. Nutrient management emphasizes nitrogen, with 40-60 lb N/acre recommended under rain-fed conditions, and higher rates under irrigation, while phosphorus and potassium needs should be guided by soil tests; the ideal soil pH is above 5.8. Early weed control is critical since slow initial growth makes seedlings vulnerable to competition, and both mechanical and herbicidal methods are used. Common pests and diseases include sorghum anthracnose, stalk rots, armyworms, and chinch bugs, which can be managed with resistant cultivars and rotation. Growth duration is generally 100-120 days to maturity, when sugar accumulation peaks, though timing varies by cultivar.[215] [216] [217]

Harvesting is one of the most sensitive cost-risk stages in the sweet sorghum value chain. The right balance between mechanisation, labour input, and logistics design determines whether feedstock can be delivered at competitive cost and with sufficient sugar integrity for efficient ethanol conversion.

Since juice quality deteriorates quickly, distilleries require a steady daily supply of freshly harvested stalks, creating tight synchronization between field and factory. Transportation logistics are critical, with in-field trailers, carts, and small trucks frequently used to move stalks rapidly to collection centres or directly to processing units. In future dedicated collection centres equipped with mobile crushers and refrigerated silos will extend storage options and buffer supply, reducing the risks of bottlenecks. [218]

On-farm ensiling is another strategy to extend the harvest window, preserving fermentable sugars and stabilizing feedstock for up to 30 days, although some sugar loss occurs. Supply chain challenges, particularly in developing regions, include scattered production, fragmented logistics, and inconsistent delivery schedules. Public-private-people partnerships (PPPPs) have emerged as an institutional solution, linking farmer groups with centralized processing facilities through coordinated collection points and shared infrastructure. These collaborative models reduce transaction costs, enhance reliability, and help integrate smallholder producers into industrial biofuel and bioproduct value chains.

---

[215] LSU AgCenter. *Sweet Sorghum Production Guide*. Baton Rouge: Louisiana State University Agricultural Center, 2015. https://www.lsuagcenter.com/NR/rdonlyres/7FD22FA2-3B95-4C4C-A8F8-01F6974910A7/98173/pub3357sweetsorghumproductionguideFINAL1.pdf.

[216] Penn State Extension. "Sweet Sorghum Production Basics." Accessed September 22, 2025. https://extension.psu.edu/sweet-sorghum-production-basics

[217] University of Nebraska–Lincoln, Department of Agronomy and Horticulture. "Sweet Sorghum Research." Accessed September 22, 2025. https://agronomy.unl.edu/research/agrohort-research/sweet-sorghum-research/.

[218] Reddy, B.V.S., S. Ramesh, P. Sanjana Reddy, P.S. Rao, and P. Kumar. *Sweet Sorghum: A Potential Alternate Raw Material for Bioethanol and Bioenergy*. Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 2007.

Ultimately, the success of sweet sorghum harvesting and processing depends on aligning agronomic maturity, mechanization, post-harvest handling, and logistics within a closely managed value chain.[219]

Processing transforms sweet sorghum juice into bioethanol. Juice extraction yields 12-22% sugar, fermented directly with industrial Saccharomyces cerevisiae PE-2 yeast without nutrient supplementation, as shown in Mexican studies.[220] Distillation follows, producing from 1,200 to 2,500 L/ha of ethanol, with bagasse utilized for biogas or livestock feed. In India, Rusni Distillery integrates stalks and grain, achieving 19-30% cost savings over molasses-based ethanol. Technological advances, such as enzyme immobilization and nanotechnology, enhance yield, though economic viability remains debated in California due to high processing costs.[221]

Cane-style roller mills or shredders followed by mechanical presses are used to extract juice from the stalks. Double-pressure roller mills or hydraulically assisted squeezers can increase juice yield. Some plants use shredders in front of screw presses or pneumatic presses to increase extraction efficiency. Depending on juice quality, clarification, filtration, heating, or enzymatic treatment may be needed to remove solids, debris, and reduce viscosity before fermentation.

Fresh juice should ideally go directly to the fermenter, but buffer storage (cooled stainless steel tanks or airtight sealed “billet juice” containers) helps smooth logistical fluctuations if exact timing of crushing and fermentation doesn’t align perfectly. However, it is important to note that even cooled juice in stainless steel tanks can usually only be stored for about 24-48 hours before significant sugar losses and microbial activity begins. If airtight and sealed containers are used, juice shelf life may be extended to 3-5 days.

Converting sweet sorghum juice into syrup, typically around 65-75° Brix, is an effective strategy to overcome the logistical challenges of same-day processing in large-scale biofuel operations. Fresh juice is highly perishable, spoiling within hours if not processed immediately, but concentrating it into syrup reduces water activity and stabilizes the sugars, allowing storage for weeks to months under sealed conditions. The syrup can later be rehydrated to optimal sugar concentrations for fermentation, maintaining ethanol yield while decoupling harvest schedules from processing capacity. For a large-scale processing of 1,000 tonnes of sorghum per day, storage would need to accommodate several days to a few weeks’ worth of syrup, depending on harvest variability, typically requiring large, insulated tanks or modular storage containers capable of holding thousands of litres of syrup to smooth the processing flow.[222]

Continuous ethanol production from sweet sorghum can be achieved by combining strategic juice and bagasse management. Fresh juice is highly perishable, so converting it into syrup allows on-farm storage until processing capacity is available, decoupling harvest schedules from fermentation and smoothing plant operations.[223] Typically, 1 tonne of fresh sorghum yields 600-700 litres of juice, which can be concentrated into syrup at 65-70° Brix, reducing volume and stabilizing sugars for storage.

---

[219] Reddy, B.V.S., Ashok Kumar, and S. Ramesh. “Sweet Sorghum: Breeding and Agronomic Practices.” *International Sorghum and Millets Newsletter* 46 (2005): 79–86.
NC State Extension. “Sweet Sorghum Production to Support Energy and Industrial Products.” Raleigh: North Carolina State University, 2013. https://content.ces.ncsu.edu/sweet-sorghum-production-to-support-energy-and-industrial-products.

[220] “Sweet Sorghum Ethanol Production 2 SWEET SORGHUM to ETHANOL OVERVIEW.” 2014. https://content.ces.ncsu.edu/sweet-sorghum-ethanol-production.

[221] Punia, Pallavi, and Sumeet Kumar. 2025. “A Critical Review on Enhanced Bioethanol Production from Sweet Sorghum Using Nanotechnology.” Energy Nexus 17 (March): 100339. https://doi.org/10.1016/j.nexus.2024.100339.

[222] Bridgers, H. D., S. C. T. Rhee, S. L. Miller, M. D. White, J. E. Erickson, and L. R. Johnson. 2011. "On-Farm Biofuel Production from Sweet Sorghum Juice," On-Farm Biofuel Production, edited by H. D. Bridgers and S. C. T. Rhee.

[223] “On-Farm Biofuel Production from Sweet Sorghum Juice - SARE Grant Management System.” 2024. Sare.org. 2024. https://projects.sare.org/sare_project/os07-038/.

The fibrous bagasse residue, which accounts for roughly 30-35% of the harvested biomass, can be processed via enzymatic hydrolysis to release cellulose- and hemicellulose-derived sugars for second-generation ethanol, adding an additional 10-15% ethanol yield per tonne of sorghum beyond the juice.[224] For a plant processing 1,000 tonnes of sorghum per day, this might require storage tanks for 3-5 days' worth of syrup (150,000-250,000 litres), while bagasse could support continuous 2G fermentation throughout the year. By combining syrup storage and bagasse utilisation, plants can maintain year-round ethanol production, maximizing overall yield per hectare and improving operational efficiency while reducing seasonal bottlenecks.

It must be noted that commercial ethanol plants that integrate first-generation (1G) and second-generation (2G) technologies remain largely at demonstration stage internationally, with high capital and operating costs. Given South Africa's fragmented feedstock base, limited policy incentives, and need for cost-competitive solutions, such integrated plants are unlikely to be feasible in the near term.[225]

Two main mechanised approaches are used. The first is whole stalk harvesting, employing forage harvesters fitted with choppers or modified cane harvesters that cut and chop stalks into billets. These billets are then transported in bulk to the mill or bioethanol plant. The second approach is field side pressing, where harvesters with roller or shredder heads feed mobile presses to extract juice on-site. The juice can then be chilled or concentrated into syrup before transport, reducing bulk and extending storage life. Syrup systems are widely recommended by ICRISAT and FAO in hot climates, as they buffer the short crushing season and minimise sugar loss. A hybrid model, where whole stalks are first hauled to satellite presses before onward transfer to central plants, has also been piloted.

Labour requirements depend strongly on the degree of mechanisation. Fully mechanised forage harvester systems require relatively few operators (a harvester crew, tractor drivers, and transport logistics teams), but they involve high capital outlay and skilled maintenance. In South Africa's context, mechanised harvest is feasible in the Free State, North West, and Limpopo grain belts where large, contiguous fields are common. In smaller or fragmented holdings (e.g., KwaZulu-Natal or Mpumalanga), more manual labour may be involved including cutting stalks by hand with cane knives and bundling for loading, which raises both labour costs and occupational health risks. Typical manual operations can require 50-70 labour days per hectare, whereas mechanised systems reduce this dramatically, though at the cost of diesel, machinery finance, and service contracts.

[224] Marx, Sanette, Busiswa Ndaba, Idan Chiyanzu, and Corneels Schabort. 2014. "Fuel Ethanol Production from Sweet Sorghum Bagasse Using Microwave Irradiation." Biomass and Bioenergy 65 (June): 145–50. https://doi.org/10.1016/j.biombioe.2013.11.019.

[225] Macrelli, Stefano; Mats Galbe; Ola Wallberg. "Effects of production and market factors on ethanol profitability for an integrated first and second generation ethanol plant using the whole sugarcane as feedstock." *Biotechnology for Biofuels* 7, Article 26 (2014).

Table 18: Harvesting models for sweet sorghum

Aspect	Whole-stalk haul (forage harvester / billet transport)	Field-side pressing (mobile presses / syrup production)
Process steps	Cut stalks with forage harvester or modified cane harvester → chop into billets → load into trailers → transport bulk to mill for crushing.	Cut stalks with roller/shredder heads → feed into mobile press → juice collected into tanks → juice chilled or concentrated into syrup → transport reduced volume to mill.
Equipment	Forage harvesters (or cane harvesters), tractors, trailers, trucks; central mill crushing units.	Harvester with shredder/roller head, mobile presses, evaporators for syrup, insulated/chilled tanks, tankers for transport.
Labour needs	Moderate: skilled operators for harvesters and truck drivers; 1-2 support staff per machine; seasonal crews for loading. Manual systems (if used) can require 50-70 labour days/ha.	Higher at field level: operators for presses, evaporation units, and juice handling; support staff for syrup storage and tank transfers.
Capital intensity	High upfront cost for mechanisation, but lower per-tonne labour cost; better suited to large contiguous farms (Free State, North West).	Medium-high: decentralised equipment and evaporation units are less capital-intensive individually but require multiple units across catchment.
Logistics	High bulk density: transport of whole stalks/billets increases tonne-km cost; rapid delivery required (<24-48 hrs to crush).	Reduced volume (syrup at ~65-75 °Brix) lowers transport costs; syrup stable for days/weeks, extending mill operating window.
Risks	Sugar loss if transport/mill delays; equipment breakdowns critical during short harvest; high diesel use.	More complex field operations; hygiene and syrup quality risks; requires trained teams to manage multiple decentralised units.
Cost competitiveness	Lower logistics costs if catchment radius ≤100 km; becomes uncompetitive beyond ~150 km due to bulk.	More competitive at larger radii (>150 km), as syrup stabilisation reduces haul costs and spoilage risk.
Best suited zones	Free State and North West grain belts (large farms, good road networks).	KwaZulu-Natal and Mpumalanga cane belts (smaller, fragmented farms, high temperatures, shorter harvest windows).

Sources: International Energy Agency (IEA) Bioenergy Task reports; U.S. Department of Energy (DOE) Bioenergy Technologies Office; Food and Agriculture Organization (FAO); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); peer-reviewed literature on sweet sorghum harvesting and processing systems (e.g. Ratnavathi et al., 2016; Almodares & Hadi, 2009); sugarcane harvesting and logistics literature; own synthesis

The main risks in harvesting include timing where harvesting too early reduces sugar yields and too late increases inversion and fungal contamination; logistics bottlenecks, when stalks and juice deteriorate rapidly (within 24-48 hours if not cooled), so any delays in transport or mill throughput cause sugar losses; equipment breakdowns, mechanised systems are capital-intensive, and downtime during the short harvest window is costly and heat risk as in high ambient temperatures, microbial activity accelerates sugar degradation, which is why night harvesting and immediate transport or syrup production are often advised.

Stage three: storage and logistics

Three main storage and logistics models exist for sweet sorghum feedstock, each with different cost, operational, and risk implications.

The first option is whole-stalk transport to a central mill and is the simplest model, operationally similar to sugarcane. Harvested stalks are chopped or cut into billets, loaded into trailers, and transported directly to a central crushing mill. The advantage is that it requires the least on-farm infrastructure and leverages established cane-style milling systems. However, the downside is the very high bulk and moisture content, which inflates transport costs per tonne of sugar delivered. Stalks deteriorate quickly, requiring crushing within 24-48 hours to avoid sugar inversion and microbial loss. This system is only competitive within a short catchment radius (≤100-150 km by road). Beyond that, delivered sugar costs escalate sharply due to diesel consumption and bulk transport inefficiency. In South Africa, this model may be viable in the Free State and North West grain belts, where large contiguous farms and good road infrastructure exist, but less suitable in fragmented or remote areas.

The second option is field-side juicing with chilled tanks to the mill where mobile presses are deployed close to the field to extract juice immediately after harvest. The juice is then stored in chilled stainless steel tanks and transported by insulated tankers to the mill. This reduces the bulk transported by as much as 70% compared to whole stalks, cutting tonne-kilometre costs. However, the process requires strict sanitation and cold-chain infrastructure, as raw juice spoils rapidly if not kept below 10 °C. The system is technically effective but capital-intensive, requiring decentralised pressing units, chilling capacity, and reliable tanker fleets. Labour intensity is also higher at the farm level, as operators are needed for presses, pumps, and tank transfers. In South Africa, this approach could work in KZN and Mpumalanga cane-growing belts, where mills already exist and logistics infrastructure for liquids is partially in place, but the cost of establishing and maintaining cold-chain capacity could be prohibitive without policy support or concessional finance.

The final option is syrup concentration to 60-65 °Brix near the farm. This involves **con**centrating extracted juice into syrup using small-scale evaporators. The syrup is microbially stable for several weeks at ambient temperatures, which buffers the very short, sweet sorghum harvest window and allows ethanol plants to operate more continuously. Transporting syrup is also far more cost-efficient than hauling raw stalks, reducing bulk and extending viable catchment radii beyond 150 km. This model spreads capital costs across smaller decentralised evaporator units but delivers major savings in logistics and stabilisation. It is especially effective in hot climates like South Africa, where sugar losses in raw juice or stalks are accelerated. The trade-off is higher technical complexity in the field, with evaporators and quality control systems needing skilled labour and maintenance. Nonetheless, syrup systems are considered the most commercially robust strategy for bioethanol from sweet sorghum where logistics and seasonality are major barriers.

South Africa’s logistics costs are already high due to heavy road dependence and rail under-performance under Transnet (both in tariff competitiveness and service reliability). This means catchment radius economics dominate so that projects located more than 100-150 km from mills become uncompetitive unless bulk reduction strategies like syrup are used. For rail to be viable, major siding upgrades and long-term reliability contracts would be required to de-risk private investment. In practical terms, syrup systems may represent the best way to overcome South Africa’s structural logistics premium, as they reduce tonne-kilometres, extend storage life, and enable year-round utilisation of ethanol plants.

Table 19: Options comparative analysis

Aspect	Whole-stalk transport[226]	Field-side juicing with chilled tanks[227]	Syrup concentration (~60-65 °Brix)[228]
Process steps	Harvest stalks → cut/chop into billets → transport in bulk trailers to central mill → immediate crushing.	Harvest stalks → feed into mobile presses → collect raw juice → chill and transport in insulated tankers → crush at mill.	Harvest stalks → press into juice → concentrate into syrup (~65 °Brix) using small evaporators → store in tanks → transport to mill for later fermentation.
Equipment required	Forage/cane harvesters, trailers, trucks, central mill crushers.	Mobile presses, chilled storage tanks, insulated tankers, central mill fermentation units.	Mobile presses, small evaporators, storage tanks, tankers (non-insulated), central mill fermentation units.
Labour requirements	Low-moderate: machine operators, drivers, loaders; manual cutting can reach 50-70 labour days/ha if mechanisation is absent.	Moderate-high: additional operators for presses, pumps, chilling, tanker transfers; sanitation and cold-chain monitoring.	Moderate: operators for presses and evaporators, technicians for syrup quality control; fewer logistics staff needed per tonne moved compared to other models.
Capital intensity	High (mechanisation and transport fleet). Lowest on-farm capex but high centralised mill dependency.	Medium-high (presses, chillers, insulated tankers). Requires decentralised investment in multiple units.	Medium (presses, small evaporators, tanks). Lower bulk transport costs offset capex; capital spread across decentralised field units.
Logistics efficiency	Poor: bulk transport of wet stalks increases tonne-km costs; viable only within ≤100-150 km.	Improved: liquid transport reduces tonnage but still requires costly cold chain; effective within ~150 km.	Strong: syrup reduces bulk and increases stability; transport viable over 150+ km at ambient temperature.
Storage stability	Very poor: stalks must be crushed within 24-48 hours; rapid sugar inversion and microbial spoilage.	Short-term: raw juice stable for ≤48 hours unless chilled (<10 °C).	High: syrup is microbially stable for days to weeks at ambient temperatures.
Risks	High logistics costs, sugar losses if delays occur, dependence on reliable roads and quick crushing.	Risk of cold-chain failure, microbial contamination if sanitation is poor, tanker fleet availability.	Technical complexity of evaporators, quality control challenges, training needs for decentralised operations.
Best suited zones	Free State and North West (large farms, good roads, short haul).	KwaZulu-Natal and Mpumalanga (cane belt, mills nearby, but smallholder-dense areas).	Hot, semi-arid regions and fragmented farms (Free State fringe, Limpopo, KZN/Mpumalanga smallholder areas); best suited for extending crush season and lowering logistics costs.

Source: Industrial Development Corporation (IDC). 2023.

[226] ICRISAT. 2021. *Sorghum and Millets Value Chains: Opportunities and Constraints*. International Crops Research Institute for the Semi-Arid Tropics.
[227] Praj Industries (India case study). 2020. *Decentralised Juice Handling for Ethanol*.
[228] IEA Bioenergy. 2022. *Bioethanol from Non-Traditional Feedstocks: Logistics and Stabilisation*

Essentially whole-stalk systems are cheapest to start but only work close to mills; field-side juicing can cut bulk but it depends on costly cold-chain systems. Syrup concentration is the most commercially robust model for South Africa, particularly under current Transnet inefficiencies, as it reduces transport costs and stabilises feedstock supply.

Stage four: processing

The processing of sweet sorghum into ethanol broadly mirrors the established sugarcane milling pathway, making it technologically familiar and relatively low risk. After harvesting, stalks are crushed to extract juice, which undergoes clarification to remove impurities before entering fermentation tanks, typically inoculated with *Saccharomyces cerevisiae*.

Fermentation is rapid, often completed in 48-72 hours, provided sugar degradation is minimised through effective cooling and the use of antimicrobial agents, both of which are recommended in FAO technical guidance and supported by ICRISAT pilot studies The fermented mash is then distilled and dehydrated to produce fuel-grade ethanol, with typical yields ranging from 40-85 litres per tonne of stalk, depending on °Brix, extraction efficiency, and fermentation management. The process integrates co-product streams: bagasse and stillage can be combusted for steam and power generation or digested to produce biogas, thereby reducing external energy needs and enhancing economic viability. In practice, the main technical challenges are ensuring consistent feedstock quality, managing sugar stability from field to crush, and scaling syrup-handling systems to extend the operating season. These are surmountable with proven technologies, positioning sweet sorghum ethanol as a mature, first-generation pathway aligned with global best practice. Processing mirrors cane milling: extraction → clarification → fermentation (*S. cerevisiae*) → distillation → dehydration, with bagasse/stillage used for steam/biogas.

From a yield perspective, practical conversion ranges are roughly 40-85 L ethanol per tonne of stalk, depending on °Brix, extraction and fermentation efficiency; per-hectare outcomes then follow agronomy/logistics. Early Chinese/ICRISAT case literature shows 87 L/t sweet juice under controlled conditions-useful for mass-balance cross-checks.[229]

India is an example of international best practice**.** India's public R&D and industry pilots (often with Praj tech) tested sweet-sorghum juice-to-ethanol with syrup stabilisation to extend crush days; reported farm trials indicate 50-80 t/ha biomass and 1,500-2,800 L/ha ethanol in sub-tropical sites, highlighting the importance of logistics design rather than fermentation novelty. [230]

South Africa already runs molasses-to-ethanol and synthetic high-purity ethanol industries; unit operations, utilities, quality control and by-product markets (DDGS/energy) are familiar. The step-change would be feed preparation (syrup/juice handling) and terminal blending integration, and plant siting must secure water, power and effluent treatment. While first-generation fermentation is mature, delivered-sugar cost and capacity utilisation outside the short season are the decisive drivers of levelised ethanol cost. IEA Bioenergy notes that policy certainty and logistics integration, not conversion chemistry, determine bankability across first-generation routes.[231]

---

[229] https://cellulosicbiomasslab.engr.ucr.edu/sites/default/files/2019-02/Refining%20Sweet%20Sorghum%20to%20Ethanol.pdf
[230] ResearchGate
[231] IEA Bioenergy

Stage five: logistics

Ethanol plants require large, consistent daily tonnages. In South Africa road haul dominates short-haul farm-to-syrup/terminal legs and rail makes sense only for reliable, scheduled bulk flows. Given Transnet's performance and tariff issues, near-term designs should assume clustered catchments and road-based primary haul, with private sidings explored once service levels are contractable. Cost differentials (R/tonne-km) are materially in rail's favour at distance, if the service is reliable, but availability and reliability presently offset the price advantage. Once converted to bioethanol, sweet sorghum follows the same logistics pattern to the refineries, but location in KZN could result in reduced costs to refineries.

Sweet sorghum value chain demand for bioethanol in South Africa

Demand for ethanol remains the same as discussed above under grain sorghum. Internationally, ethanol wholesale prices have oscillated in 2024-25 in the USD 0.55-0.70/L (Brazil FOB anhydrous) and USD 1.70-2.30/gal (U.S. racks) ranges depending on currency and season. These benchmarks, combined with carbon policy and co-product credits (DDGS/biogas/power), frame the export-parity and import-parity bands within which a South African plant must compete. Domestically, South Africa's industrial/potable ethanol capacity of 282 ML/yr (molasses + synthetic) demonstrates technical readiness but is not geared to fuel blending today; implementing a national E-blend would create a new, sizeable market that current capacity cannot fill, opening space for sweet sorghum alongside cane and grain routes.

The decisive levers are (i) delivered-sugar cost (field → syrup/juice → mill), (ii) capacity utilisation beyond a short harvest (syrup buffering, multi-feedstock), and (iii) logistics cost per litre (road first, rail if reliable). Unit operations in the plant are conventional first-gen and competitively priced; it is the field-to-factory system design that makes or breaks Levelised Cost of Energy (LCOE) and Levelised Cost of Fuel (LCOF).

Key risks are logistics (Transnet reliability; road tariffs), policy (mandate/pricing certainty), agronomy (yield volatility and harvest timing), and working-capital/interest exposure during peak crush. These are manageable with clustered catchments, syrup strategy, fixed logistics contracts, and clear offtake/blend arrangements at terminals.

4.6 Grain based sorghum vs sweet sorghum

In South Africa, the choice of bioethanol feedstock is not simply a technical question, but a matter of cost, risk, and policy alignment. Each of the three candidate crops, grain sorghum, sweet sorghum, and sugarcane, offers different commercial and logistical implications.

Table 20 provides a comparison across agronomic, technological and economic characteristics of grain and sweet sorghum.

Sweet sorghum has strong appeal as a transitional and supplementary feedstock. Its short cycle (3-5 months) allows multiple plantings per year, providing flexibility in crop rotation and rapid response to market signals. Sweet sorghum is drought-tolerant and can be grown on marginal or lower-fertility land, reducing competition with high-value food crops. Processing is comparatively simple: the stalk juice contains fermentable sugars and can be fermented directly without saccharification. However, the crop is highly seasonal and presents logistical risks, as juice must be processed rapidly after harvest or stabilised as syrup. Commercial viability depends on overcoming these constraints through investment in syrup concentration systems and decentralised logistics models. If implemented, sweet sorghum could complement sugarcane in KwaZulu-Natal and Mpumalanga, and grain sorghum in the Free State and NorthWest, providing a buffer feedstock that adds flexibility and resilience to the value chain. However, the sweet sorghum to bioethanol value chain is largely experimental at this stage due to the challenges around feedstock logistics and the fact that sugar in the stalks degrades rapidly reducing the yields.

Grain sorghum offers the advantage of established grain ethanol technologies and co-products. Grain ethanol plants globally use dry-mill technology, producing both ethanol and DDGS, a valuable animal feed that offsets costs. In commercial terms, this is attractive: the DDGS market in South Africa is robust, linked to the livestock and poultry sectors. Grain sorghum presents a partial exception: its high-tannin varieties are not suitable for food or feed and could theoretically be channelled into ethanol production. Yet in practice, South Africa's grain sorghum acreage is currently modest, yields are variable, and the crop is not grown at the scale required to anchor a national fuel mandate.

*Sugarcan***e** remains the benchmark in terms of ethanol yields per hectare. The crop is deeply embedded in South Africa's agro-industrial landscape, with established supply chains, milling infrastructure, and by-product streams (bagasse for power, molasses for ethanol). In tropical regions, sugarcane delivers the highest ethanol output per hectare globally, and Brazil has built its bioethanol success on this base. The drawback in South Africa is twofold: cane requires very high water inputs and frost-free climates, confining it largely to KwaZulu-Natal and Mpumalanga, and recent years have seen stress from drought, mill closures, and competition with sugar export markets. Cane ethanol remains commercially attractive but geographically constrained.

Additional arguments suggest that sweet sorghum and grain sorghum both offer viable but distinct routes to bioethanol. *Grain sorghum* offers easier year-round storage, established harvesting and processing infrastructure, and fewer challenges with rapid spoilage compared to the highly perishable juice of sweet sorghum. The United States leads globally in grain sorghum-to-ethanol value chains, as many existing maize ethanol plants are feedstock flexible and can process grain sorghum as an alternative feedstock with minimal modifications.[232] Sweet sorghum on the other hand, represents a frontier crop with strong upside in integrated systems but significant logistical challenges to overcome. *Sweet sorghum* provides easily fermentable sugars from its stalk juice, making processing relatively simple and comparable to sugarcane, while also leaving bagasse that can support second-generation ethanol or other byproducts. However, its major drawback is logistics: stalks deteriorate quickly after harvest, requiring processing facilities to be located close to production areas.

Grain sorghum, by contrast, is a starch-based feedstock that fits into existing grain ethanol plants, benefits from established storage and handling infrastructure, and generates valuable animal feed

[232] "Renewable Energy - Sorghum Checkoff." 2021. Sorghum Checkoff. November 23, 2021. https://www.sorghumcheckoff.com/sustainability/renewable-energy.

byproducts commonly called DDGS.[233] While sweet sorghum promises higher ethanol yields per hectare and greater adaptability to marginal lands, grain sorghum has proven more commercially scalable because of its stability, supply chain efficiency, and integration with established grain markets.

[233] Pancini, Stefania, Alvaro Simeone, Oscar Bentancur, and Virginia Beretta. 2021. "Evaluation of Sorghum Dried Distillers' Grains plus Solubles as a Replacement of a Portion of Sorghum Grain and Soybean Meal in Growing Diets for Steers." Livestock Science 250 (August): 104564. https://doi.org/10.1016/j.livsci.2021.104564.

Table 20: Grain sorghum compared to sweet sorghum as bioethanol feedstock

Criteria	Grain Sorghum	Sweet Sorghum
Primary Feedstock Part	Grain (starch, similar to maize/corn)	Stalk juice (sugars) + fibrous bagasse (after juice extraction)
Ethanol Yield (L/ha)[234]	1,000-1,500 L/ha depending on yield & starch content (rainfed / good soils) under South African conditions.	~2,500-4,500 L/ha under favourable conditions; lower (~1,200-3,000) under semi-arid/trial conditions[235]
Input Costs per Hectare[236]	Typically, **USD400-800/ha+** under medium-to-high input conditions in developed country settings; lower under low-input / smallholder settings	Estimated **USD400-1,300/ha** in published trials; in high input, irrigated US trials - much higher; in low input/rainfed trials - toward lower end[237]
Water Requirement	Moderate; less than maize but higher than sweet stalk yield under some conditions	Lower water needs; more tolerant of drought and marginal moisture conditions
Land Suitability	Semi-arid to moderate rainfall zones; performs on marginal soils	Even more suited to marginal, dry/semi-arid lands; less sensitive to poor soils
Planting	Planted from mid-October to mid-December.	Planted from mid-October to mid-December.
Harvest Timing	Once grain matures (late season) 120 to 140 days after planting.	120 to 140 days after planting. Narrow window: harvest for maximum sugar content; juice extraction must be timed precisely
Storage Challenges	Grain stores well; can be held in silos for months / off-season use	Juice is perishable; stalks degrade; must have processing close by or use ensiling / immediate crushing
Processing Complexity	Requires milling, saccharification (enzymes), drying, fermentation	Extraction of juice + fermentation; handling of fibres (bagasse) for co-use
Byproducts	DDGS (animal feed), co-products like CO_2, possibly bran	Bagasse (feed / fibre / 2G ethanol), vinasse, possibly grain if dual-purpose
Economic Viability	More established; fits existing grain ethanol plants; less risk of spoilage etc.	High potential returns in specific settings, but elevated logistics & capital costs; scale matters
Policy Support	Has support in some regions via mandates; sometimes excluded from food security concerns	Less common in mandates; niche programs and pilot projects more frequent

[234] Naoura, Gapili, Yves Emendack, Nébié Baloua, Kirsten vom Brocke, Mahamat Alhabib Hassan, Nerbewende Sawadogo, Amos Doyam Nodjasse, Reoungal Djinodji, Gilles Trouche, and Haydee Echevarria Laza. 2020. "Characterization of Semi-Arid Chadian Sweet Sorghum Accessions as Potential Sources for Sugar and Ethanol Production." Scientific Reports 10 (1). https://doi.org/10.1038/s41598-020-71506-9.

[235] Ekefre, Daniel E., Ajit K. Mahapatra, Mark Latimore Jr., Danielle D. Bellmer, Umakanta Jena, Gerald J. Whitehead, and Archie L. Williams. 2017. "Evaluation of Three Cultivars of Sweet Sorghum as Feedstocks for Ethanol Production in the Southeast United States." Heliyon 3 (12): e00490. https://doi.org/10.1016/j.heliyon.2017.e00490.

[236] ibid

[237] ibid

Criteria	Grain Sorghum	Sweet Sorghum
Environmental Impact	Good if rainfed; avoids high fertiliser; less water than maize; still competes with food uses	Strong advantages: lower inputs, good drought tolerance, potential for high GHG savings
Examples in Use	US (grain sorghum blended into ethanol production), Australia	India pilot plants (ICRISAT), Brazil experimental sugarcane-sweet sorghum mix

Sources: Food and Agriculture Organization (FAO) crop profiles; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) sorghum research; International Energy Agency (IEA) Bioenergy and Renewables (2023–2024); U.S. Department of Energy (DOE) Bioenergy Technologies Office; USDA agronomic and cost datasets; peer-reviewed literature on grain and sweet sorghum ethanol (e.g. Ratnavathi et al., 2016; Almodares & Hadi, 2009; Whitfield et al., 2012); sugarcane processing and logistics literature

From a business case perspective, grain sorghum offers lower risk and easier market integration. Farmers can store grain for months, sell into both the food/feed markets or ethanol plants, and benefit from stable byproducts like DDGS for animal feed, which cushions against fuel market volatility. Its compatibility with existing maize-based ethanol infrastructure also reduces upfront investment costs.

5. By Product Analysis

5.1 Sorghum by-products and processes

From an agricultural byproduct's perspective, it is useful to compare sorghum with maize, its principal crop competitor. Because sorghum retains a competitive edge in marginal, water-stressed lands, the expansion of sorghum cultivation in these areas would also impact meat production as a complementary income source to farmers.[238] However, any ethanol distillery will require on site power due to the inconsistency of long-term power supply security in South Africa.[239] If the bio-ethanol certification must be maintained, the on-site power and steam will have to be produced using renewable resources, mandating the use of sorghum stover as a partial feedstock in many cases.

Rotation

Rotating maize and grain sorghum offers significant agronomic, economic, and environmental benefits for South African farmers, especially on marginal lands. Rotational systems with maize and legumes (e.g., soybean or vetch) have shown 14% higher maize yields and up to 40% increased profitability for legumes.[240] Some of the advantages of sorghum and maize rotation are discussed.[241] Grain sorghum has a deep root system that improves soil structure and organic matter content, especially in sandy or degraded soils. Rotating maize with sorghum enhances nitrogen availability, particularly when legumes are included in the rotation. A study in South Africa showed that no-till + crop rotation with sweet sorghum and legumes increased total nitrogen, magnesium, and cation exchange capacity (CEC)[242] by up to 45% compared to conventional tillage. Further, grain sorghum is more drought-tolerant than maize, making it ideal for rotation in semi-arid regions like the North-West and Free State. Alternating with maize helps spread climate risk and ensures yield stability under variable rainfall conditions.

Crop rotation breaks pest and disease cycles, reducing the need for chemical pesticides. Sorghum and legumes disrupt the lifecycle of maize-specific pests like stem borers and rootworms, improving overall

[238] Food and Agriculture Organization (FAO). The Future of Food and Agriculture: Alternative Pathways to 2050. Rome: FAO, 2018. https://www.fao.org/documents/card/en/c/CA1553EN

[239] Personal discussion with the CFO of an ethanol project developer on the on-site power requirements required for project financing.

[240] Production and profitability of maize and soybean grown in rotation in the North-Western Free State; de Bruyn M. A. et al; African Journal of Agricultural Research; Vol. 20(2), pp. 155-162, February 2024; DOI: 10.5897/AJAR2023.16568; Article Number: 75587AC71830

[241] Malobane, Mashapa E., Adornis D. Nciizah, Fhatuwani N. Mudau, and Isaiah I.C Wakindiki. 2020. "Tillage, Crop Rotation and Crop Residue Management Effects on Nutrient Availability in a Sweet Sorghum-Based Cropping System in Marginal Soils of South Africa" Agronomy 10, no. 6: 776. https://doi.org/10.3390/agronomy10060776

[242] A soil's ability to hold and exchange positively charged nutrients (cations)

crop health. Sorghum residues have allelopathic properties that suppress weed growth. Including legumes in rotation improves microbial activity and soil aggregation, reducing erosion and compaction. Rotating maize with sorghum and legumes supports conservation agriculture, reducing reliance on synthetic fertilizers and improving carbon sequestration. It aligns with South Africa's goals for climate-smart agriculture and bioeconomy development.

Stover

The integration of cattle foraging on maize and sorghum stover into a grain farming system offers a win-win scenario, providing a range of economic, logistical, and soil-health benefits to the grain farmer. The stover provides an inexpensive forage source, significantly reducing purchased hay and stored feed. The cattle effectively harvest a portion of the residue, reducing the amount of material the farmer needs to manage (chopping, spreading, or incorporating) before planting the next cash crop.

Further, the cattle consume the stover and deposit their waste (manure and urine) directly onto the field. This process recycles nutrients into the soil as cattle excrete a vast majority (around 80-90%) of the nitrogen (N), phosphorus (P), and potassium (K) they consume. The organic matter in the urine and faeces acts as a concentrated food source for soil microbes, stimulating the biological processes that improve nutrient cycling and soil health.

The grain farmer manages the grazing to ensure that enough stover remains on the field (typically 30-50% cover) to maintain the benefits of the no-till system, such as erosion control and water conservation. This is achieved by carefully controlling the cattle's stocking rate and the duration of their grazing period. Other than acting as on field fodder for cattle as a supplementary income source for farmers, the combination of on-field sorghum and maize stover retention with modern no-till practices offers a powerful synergy with numerous advantages for soil health, water conservation, and long-term crop production, especially in semi-arid and dryland farming systems.[243]

The stover also acts as a mulch layer on the soil surface, insulating the soil and reducing direct exposure to sun and wind. This significantly decreases evaporative water loss, storing more moisture in the soil profile for the crop. The residue protects the soil surface from the impact of raindrops, which prevents surface sealing and crust formation. This, combined with the undisturbed soil structure of no-till, leads to much higher water infiltration rates and reduced surface runoff. This is critical in areas with sporadic, high-intensity rainfall. Over time, the decomposition of stover contributes to soil organic matter (SOM), which acts like a sponge, increasing the soil's capacity to absorb and hold water for plant use during dry periods.

Stover offers superior soil health and structure[244]. It is the primary source of carbon input in a no-till system. Not tilling prevents the rapid oxidation and loss of this organic matter allowing it to accumulate near the surface. Higher soil organic carbon improves almost all other soil properties. No-till preserves soil aggregates, which are the clumps of soil particles bound together by organic matter and microbial byproducts. These aggregates enhance soil aeration, drainage, and root penetration. The continuous input of stover (both above and below ground as roots) provides the materials to build and stabilize these aggregates. Eliminating tillage prevents the formation of a plow pan, and the network of undisturbed roots and increased SOM help the soil resist compaction from machinery. An undisturbed,

[243] Reduce Need for Irrigation by Maintaining Crop Residue and Reducing Soil Tillage; https://water.unl.edu/article/agricultural-irrigation/reduce-need-irrigation-maintaining-crop-residue-and-reducing-soil/#:~:text=(plowed)%20soil.-,Evaporation,reduced%20at%20the%20soil%20surface.

[244] Organic Matter in No-Till Production Systems; Jason Warren & Brian Arnall; University of Oklahoma; 2019; https://extension.okstate.edu/fact-sheets/organic-matter-in-no-till-production-systems.html#:~:text=The%20decomposition%20of%20both%20above,and%20ease%20of%20root%20growth.

residue-covered soil creates a stable, favourable habitat for beneficial soil microbes (bacteria, fungi) and macro-invertebrates (like earthworms), which are vital for nutrient cycling and creating stable soil pores.[245]

Stover provides a physical barrier that intercepts wind and water, drastically reducing both wind and water erosion of topsoil thus protecting nutrients. No-till keeps the soil structure intact, further resisting erosion. By keeping soil and its associated nutrients on the field, the practice reduces nutrient loss into waterways, protecting water quality. As the stover decomposes, it slowly releases essential plant nutrients back into the soil, providing a slow-release, natural fertilizer source.

I. Sorghum Stover as a potential fuel source

Sorghum stover produces between 1.5 tonne and 2.5 tonnes of stover per tonne of grain in South Africa and tends to partition relatively more dry matter to vegetative parts (stover) due to its morphology and stress tolerance. Grain sorghum stover, the leaves, stalks, and husks remaining after grain harvest, has strong potential as a biofuel feedstock for ethanol plants, particularly in South Africa's semi-arid regions. Stover also has valuable fuel properties as the table shows.

Table 21 reflects the standard feed composition and digestibility ranges drawn from established animal nutrition literature, including NRC, Feedipedia, FAO, and peer-reviewed studies.

Table 21: Fuel Properties of Stover

Property	Typical Value	Significance
Calorific Value (CV)	16.5-18.5 MJ/kg[246]	Comparable to other residues; suitable for combustion
Moisture Content	10-15% (air-dried); up to 30% (fresh)[247]	Affects combustion efficiency and storage
Ash Content	3-6%[248]	Moderate; influences slagging and fouling
Ash Composition	K, Ca, Si, Mg, P; trace Na, Cl, Fe	Determines melting u and suitability for pyrolysis
Bulk Density	170-180 kg/m³ (loose); 600-800 kg/m³ (briquetted)[249]	Densification improves transport and combustion

Sources: International Energy Agency (IEA) Bioenergy Task reports; Food and Agriculture Organization (FAO); U.S. Department of Energy (DOE) Bioenergy Technologies Office; European Biomass Industry Association (Bioenergy Europe); peer-reviewed literature on biomass and agricultural residues (e.g. McKendry, 2002; Demirbaş, 2004; Jenkins et al., 1998); own synthesis.

[245] Seeing is Believing: Soil Health Practices and No-Till Farming Transform Landscapes and Produce Nutritious Food; https://www.usda.gov/about-usda/news/blog/seeing-believing-soil-health-practices-and-no-till-farming-transform-landscapes-and-produce#:~:text=No%2Dtill%20planting%20into%20a,eats%2C%20along%20with%20the%20residue.

[246] Morales, Marina Moura, Aaron Kinyu Hoshide, Leticia Maria Pavesi Carvalho, and Flavio Dessaune Tardin. 2024. "Sorghum Biomass as an Alternative Source for Bioenergy" Biomass 4, no. 3: 1017-1030. https://doi.org/10.3390/biomass4030057

[247] Evaluation of constitutive conditions for production of sorghum stover; J. O. Olaoye; Arid Zone Journal of Engineering, Technology and Environment, June 2017; Vol. 13(3):398-410; Print ISSN: 1596-2490, Electronic ISSN: 2545-5818, www.azojete.com.ng

[248] Critical review of the role of ash content and composition in biomass pyrolysis; Lokeshwar Puri et al; Frontiers in Fuels; Front. Fuels, 08 March 2024 Volume 2 - 2024 | https://doi.org/10.3389/ffuel.2024.1378361

[249] Morales, Marina Moura, Aaron Kinyu Hoshide, Leticia Maria Pavesi Carvalho, and Flavio Dessaune Tardin. 2024. "Sorghum Biomass as an Alternative Source for Bioenergy" Biomass 4, no. 3: 1017-1030. https://doi.org/10.3390/biomass4030057

Stover can be fed as is to a boiler and steam generation plant for combined heat and power production, or briquetted for improved handling, storage and combustion efficiency although briquetting increases pre-processing cost as briquetting requires a blend of 64% sorghum biomass, 36% wood and 3% bio-oil.[250] Therefore, the cost of sorghum stover represents an attractive financial offering to the grain sorghum farmer considering the fact that grain sorghum stover has a higher feed value than grain sorghum.

The literature[251] estimates the relative feed value and cost of baled grain stover by comparing its nutritional characteristics to maize stover and lucerne hay, using degradability and gas production as proxies for feed value as indicated in Table 22.

Table 22: Potential Feed Value of Grain Sorghum Stover

Feed Type	Crude Protein (g/kg DM)	NDF (g/kg DM)	Degradability (g/kg DM)	Gas Production (ml/g DM)
Lucerne Hay	199	~355	830	173
Maize Stover	47-65 (depending on part)	~600-795	720-820	147-165
Grain Stover (assumed similar to maize stover)~	50-70 (estimated)	~650-800	700-800	140-160

Sources: National Research Council (NRC) Nutrient Requirements of Ruminants; Feedipedia (INRAE, CIRAD, FAO, AFZ) feed composition database; FAO animal nutrition resources; peer-reviewed literature on forage quality and digestibility (e.g. Van Soest, 1994; Menke & Steingass, 1988; Mertens, 1997); own synthesis.

Lucerne hay has the highest protein and digestibility, followed by maize stover and grain stover. Grain stover, especially from sorghum or maize, tends to have lower protein and higher fibre, making it less valuable per unit of dry matter. Assuming lucerne hay as a benchmark (100% feed value), and using degradability and gas production as proxies, the following benchmark prices for maize and therefore sorghum, stover, are valid.

- Lucerne Hay: 100% feed value → market price ≈ R2,500-R3,500/tonne (baled, depending on quality and region)[252]
- Maize Stover: 70-75% of lucerne's feed value → estimated price ≈ R1,800-R2,500/tonne

The expected price an ethanol plant may pay for sorghum grain could therefore be between R1,800-R2,500/tonne, especially if contracted on a long-term basis.

II. Grain sorghum stover vs maize stover

The precise grain-to-stover ratio for both sorghum and maize in South Africa is highly variable, depending on the specific cultivar, soil type, and most significantly, the rainfall and management practices (fertilisation and plant density). Maize generally produces between 1 tonne and 1.5 tonnes of stover per tonne of grain in South Africa. The stover tends to partition relatively dry matter

[250] Morales, Marina Moura, Aaron Kinyu Hoshide, Leticia Maria Pavesi Carvalho, and Flavio Dessaune Tardin. 2024. "Sorghum Biomass as an Alternative Source for Bioenergy" Biomass 4, no. 3: 1017-1030. https://doi.org/10.3390/biomass4030057

[251] J. O. Ouda & I. V. Nsahlai (2007) Nutritive Value of Maize Stover Harvested at Two Stages of Maturity and Mixed with Different Types and Levels of Protein Supplements, Journal of Applied Animal Research, 32:1, 89-95, DOI: 10.1080/09712119.2007.9706854

[252] https://amtrends.co.za/market-pricesv2/

to grain under optimal conditions. In comparison sorghum stover produces between 1.5 tonne and 2.5 tonnes of stover per tonne of grain in South Africa and tends to partition relatively more dry matter to vegetative parts (stover) due to its morphology and stress tolerance. This difference is primarily a result of the crops' fundamental biological strategies.[18]

Table 23: Differences between maize and sorghum - biological strategies

Feature	Maize	Grain Sorghum
Water Stress Strategy	Sensitive. When stressed, it aborts grain fill (high harvest index) to protect yield stability, leading to a quick drop in grain yield.	Tolerant/Stay-Green. Sorghum can temporarily enter a state of dormancy and maintain a larger amount of vegetative biomass (stover) even under stress. It prioritises stover stability over a high grain-to-stover ratio.
Plant Morphology	Stalks are thick and relatively short (in grain varieties). It is generally bred for high harvest index (high grain proportion).	Stalks are often taller, more rigid, and can tiller (produce side shoots) more easily, especially under favourable conditions, resulting in greater total biomass.
Implication for South Africa	In high-potential (high rainfall/irrigated) areas, maize will maximise grain yield and achieve a 1:1 ratio or better.	In semi-arid (dryland) areas, which are common in South Africa, sorghum's superior drought resistance means it can still produce a substantial amount of stover when maize stover production has failed entirely. This inherent stover advantage makes sorghum a more reliable dual-purpose (food and feed) crop in drier regions.

Sources: Food and Agriculture Organization (FAO) crop profiles; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) sorghum research; CIMMYT maize research; peer-reviewed literature on drought tolerance and crop physiology (e.g. Borrell et al., 2000; Blum, 2011; Hammer et al., 2009); South African agronomic studies (ARC–Grain Crops); own synthesis.

There is a practical trade-off where maize maximises grain when water is ample, thanks to its high harvest index, but it fails fast under stress (aborting grain fill), collapsing both grain and residue. Grain sorghum, by contrast, stays green, it sheds demand, holds biomass, and rides out dry spells, so stover and some grain still materialise in bad years. Strategically for South Africa, this means maize dominates in high-potential zones (irrigated/high rainfall), while sorghum is the safer dual-purpose choice across semi-arid dryland: it delivers more reliable residue for feed or energy and stabilises farm cash flow when rainfall is erratic. In short, the table argues for zonal specialisation, maize where you can push yield; sorghum where you have to manage risk.

The comparison of grain sorghum stover and maize stover for on-field cattle grazing in the South African context involves a trade-off between quantity/availability and nutritional quality/safety risks. Both are generally considered low-quality forages suitable for maintenance diets, especially for non-lactating, mid-to-late gestation cattle, but they have distinct differences.[253]

[253] Pasture and Forage Minute: Grazing Grain Sorghum Stover and Corn Residue https://cropwatch.unl.edu/2023/pasture-and-forage-minute-grazing-grain-sorghum-stover-and-corn-residue/#:~:text=In%20fact%2C%20it%20carries%20the,lower%20part%20of%20the%20stems.

Table 24: Differences between maize and sorghum - on field grazing

Feature	Grain Sorghum Stover	Maize Stover (Corn Stover)
Crude Protein (CP)	Generally higher than maize stover stems, often around 6% CP.	Generally lower than sorghum stover, often ranging from 4.5% to 6.0% CP in the stalk/cob material.
Digestibility / Energy (TDN)	Stems can be slightly higher in quality than maize stems. However, its overall digestible energy is low, like maize.	Overall quality is low. The most palatable and nutritious parts are the husks and leaves.
Palatability	Stover leaves remain attached to the stalk for much longer, which reduces loss from wind and may keep the leaf portion available to the cattle for a longer period.	The most nutritious and palatable components (leaves and husks) tend to detach and blow away one to two months after harvest, leading to a sharp decline in grazing value.
Spilled Grain	Spilled grain is generally safer. The grain's protein/starch matrix ferments slower, making it less likely to cause acidosis or founder if cattle consume a large amount of lost grain.	Spilled grain is more digestible and more easily accessed, posing a higher risk of acidosis (grain overload) or founder if there is significant loss in the field.

Sources: Feedipedia (INRAE, CIRAD, FAO, AFZ) feed composition database; National Research Council (NRC) Nutrient Requirements of Ruminants; FAO crop residue and livestock feeding resources; peer-reviewed literature on crop residues and grazing systems (e.g. Van Soest, 1994; Mertens, 1997; Bowman et al., 2000; Undersander et al., 2002); USDA and extension publications on corn and sorghum residue utilisation; own synthesis

Interviews with farmers also indicate that sorghum stover may have up to 2x the feed value of maize stover in South Africa.[254] Conservative assumptions suggest that a farmer planting grain sorghum could achieve 60% more cattle than a maize farmer due to the increased grazing capacity. Based on current beef carcass prices in South Africa (ZAR 70.70/kg for A2/3 grade), a typical carcass yields of 250 kg per head,[255] and a turnover rate of 60% a farmer could sell 180 more cattle per 1 000 Ha of sorghum per year. Thus, the potential revenue improvement per hectare could be as much as R3 000 per Ha, a significant improvement in income for the farm.

III. Stover as power source

Stover can also be used as a raw material to produce steam and power in a CHP plant for an ethanol plant. If stover is to be used as a plant fuel feedstock, a compelling financial case must be presented to farmers - one that clearly demonstrates why fuelling the bioethanol plant is more profitable than selling stover as livestock feed.

Sorghum processing by-products: Food Value Chain

The primary by-products (or co-products) generated in the grain sorghum food value chain depend on the processing method, which typically involves either milling for flour or grits, or fermentation/malting for beverages.

By-products from Dry Milling (Flour/Grits Production)

254 Interview, grain sorghum farmer in Biesiesvlei. North West Province.

255 https://rpo.co.za/carcass-prices/

Dry milling involves separating the outer layers (bran) and the germ from the starchy endosperm [256] and several by-products ensue.

Table 25: By-products from grain sorghum dry milling

Byproduct Name	Description	Common Utilisation
Sorghum Bran / Offal	The outer layer (pericarp) and associated fragments of the endosperm and germ removed during dehulling (pearling) and milling. It is rich in fibre and antioxidants.	Primarily used as animal feed (for cattle, poultry, swine). Increasingly being researched as a source of dietary fibre and nutraceuticals for human food fortification due to its high phenolic and antioxidant content.
Sorghum Germ Meal	The oily, protein-rich embryo portion of the grain. It may have some of its oil pressed out (becoming germ oil cake).	Used as a protein source in animal feed.
Pearled Sorghum Bran	The fine powdered form of the bran removed when creating "pearled" sorghum (an alternative to rice).	Sold as a high-fibre, antioxidant-rich ingredient for adding to baked goods, cereals, or yogurt.

Sources: Food and Agriculture Organization (FAO) sorghum processing and utilisation resources; Feedipedia (INRAE, CIRAD, FAO, AFZ); USDA grain processing and by-product data; peer-reviewed cereal science literature (e.g. Taylor & Duodu, 2015; Awika & Rooney, 2004; Dykes & Rooney, 2006); own synthesis.

These three by-products map to two distinct market pathways, bulk feed proteins/fibre today and premium food-health ingredients tomorrow. Bran/offal and germ meal already clear into animal feed on protein, fibre and energy specs, giving mills dependable volume outlets; but pearled sorghum bran and selectively processed bran fractions carry phenolic antioxidants (e.g., 3-deoxyanthocyanidins) and insoluble fibre that food formulators prize for clean-label fortification and glycaemic control. The commercial pivot is quality management: tannin profile, particle size, residual oil, micro/mycotoxin limits and colour determine whether a lot sells at feed parity or earns a food-grade premium. Strategically, a sorghum plant that adds de-tanninisation, fine milling, and HACCP/FSSC certification can ladder from commodity feed to higher-margin nutraceutical and bakery inputs, widening gross margins and diversifying revenue beyond grain/ethanol cycles.

By-products from brewing and fermentation

The three streams (indicated in Table 26) span immediate feed value and emerging premium uses. Sorghum brewer's spent grain (SBSG) moves reliably into nearby feedlots on fibre-protein value, but mills/breweries that dry, mill and standardise it (moisture <10-12%, pathogen/mycotoxin controls, particle size) can sell into bakery and snack fortification where clean-label fibre and protein premia apply; SBSG also underpins low-cost substrates for biogas and biomaterials. Malted sorghum sprouts/rootlets are a classic low-ash, high-enzymatic feed, best monetised via pelleting and inclusion in brewer's grains bundles to cut handling costs. Sorghum DDGS is the highest-value bulk by-product: pricing tracks protein, fat, digestibility (tannin management), amino acid profile and logistics; consistent colour, low moisture, and aflatoxin controls narrow the discount to maize DDGS or even earn parity in poultry and ruminant rations.

[256] Milling By-Products of Cereal Grains https://courses.ecampus.oregonstate.edu/ans312/two/milling_trans.htm#:~:text=To%20produce%20the%20food%20and,produce%20such%20products%20as%20flour.

Strategically, locking multi-year feed offtakes while building a food/biomaterials side line turns these residues from disposal problems into margin stabilisers, reducing revenue volatility in ethanol or beverage operations and widening the buyer base from feed integrators to food formulators and packaging innovators.

Table 26: By-products from grain sorghum fermentation

Byproduct Name	Description	Common Utilisation
Sorghum Brewer's Spent Grain (SBSG)	The solid residue left after the wort (liquid sugar extract) has been filtered out of the mash. It is high in protein and fibre (hemicellulose, cellulose).	The most common use is as animal feed, but it is also being valorised as a functional ingredient for human foods (added to bread, snacks, cookies) due to its high fibre and protein content. It is also explored for biofuel and biomaterial production.
Malted Sorghum Sprouts	The sprouts and rootlets produced when the grain is malted (germinated).	Used as animal feed.
Sorghum Distiller's Dried Grains with Solubles (DDGS)	The dried residue left after the fermentation and distillation process (often for bioethanol or alcoholic beverages). It is highly concentrated in protein and fat.	A valuable, high-protein animal feed supplement for all livestock. Also researched for biomaterials like biodegradable packaging films.

Sources: Feedipedia (INRAE, CIRAD, FAO, AFZ) feed database; Food and Agriculture Organization (FAO) sorghum processing and utilisation resources; USDA bioethanol co-product literature; International Energy Agency (IEA) Bioenergy reports; peer-reviewed literature on brewing and distilling by-products (e.g. Mussatto et al., 2006; Aliyu & Bala, 2011; Taylor & Duodu, 2015); own synthesis.

By-products from wet milling (starch/syrup production)

Wet milling separates the grain into its main components (starch, protein, fibre, and oil). While more common for maize, it is sometimes applied to sorghum. Sorghum gluten streams are the spec-driven end of the by-product portfolio. Gluten feed, a blend of bran/germ plus steep-liquor residues, moves as a mid-protein, high-fibre ingredient prized for rumen health and ration cost control; value hinges on consistent protein (e.g., 18-24%), moisture (<12%), fibre profile and low mycotoxins.

Table 27: By-products from grain sorghum wet milling

Byproduct Name	Description	Common Utilisation
Sorghum Gluten Feed	A mixture of the bran, germ, and steep liquor residue.	Used as animal feed.
Sorghum Gluten Meal	The protein (gluten) fraction of the grain after the starch and fibre have been separated. It is a high-protein concentrate.	Used as a premium animal feed ingredient (high-protein source).

Sources: USDA corn/sorghum wet-milling and ethanol co-product literature; Feedipedia (INRAE, CIRAD, FAO, AFZ) feed database; Food and Agriculture Organization (FAO) grain processing resources; International Energy Agency (IEA) Bioenergy reports; peer-reviewed literature on cereal processing and co-products (e.g. Rooney & Serna-Saldivar, 2000; Taylor & Duodu, 2015); own synthesis.

Gluten meal is the premium concentrate: high protein (often 55-60%+), good bypass characteristics for ruminants and strong fit in poultry/aquaculture where amino-acid balance and pigment (xanthophylls) matter. The commercial pivot is process control-clean separation, low tannin carryover, colour, and oil/fibre residues-plus food-grade QA if targeting specialty markets. For investors and operators, locking long-term offtakes with feed integrators at spec, and developing value-added formats (pellets, micro-milled meals, AA-fortified blends) can lift realisations above feed parity and stabilise plant margins when starch/ethanol prices cycle.

Sorghum bioethanol by-product

In the sorghum to bio ethanol value chain sources can be grain and stalk (sweet) sorghum. The main byproducts of grain sorghum bioethanol production are mentioned in Table 28. [257] These yields sketch a multi-revenue, circular plant design if you plan for capture and valorisation rather than disposal. DDGS (0.8-1.0 t per tonne of ethanol) are the anchor co-product; drying, pelleting and tight specs (protein, moisture, mycotoxins) convert this into bankable, contractable feed revenue, often the swing factor in EBITDA during weak ethanol margins. Fermentation CO_2 (0.8-1.2 t) is a hidden cash stream: where a food/industrial CO_2 market exists, installing recovery/compression can turn vent gas into long-term offtakes (beverage grade, dry ice); where not CO_2 can support e-fuel pilots or be paired with biogenic H_2.

Thin stillage (≈10-12 t) is typically recycled to cut water/energy use; concentrating it to syrup (CDS) lifts feed value when blended into DG and reduces evaporator bottlenecks, while side-streams can feed anaerobic digesters for on-site biogas/biomethane. Finally, lignin-rich residue (≈50-100 kg) is your thermal hedge: it displaces purchased fuel in boilers, or-if ash/contaminants are managed-can be upgraded to biochar for carbon credits and soil markets. The business takeaway: designing for CO_2 capture, CDS integration/biogas, and energy recovery turns by-products into predictable cash flows, lower utilities cost, and better lifecycle carbon, which matters to lenders, off takers, and policy crediting alike.

Table 28: By-products from grain sorghum ethanol production

Byproduct	Yield per Tonne of Ethanol	Comment
Distillers Grains (DG)	800 - 1000 kg	High-protein, high-fibre feed ingredient. Includes condensed solubles (CDS).
Carbon Dioxide (CO_2)	0.8-1.2 kg	Biogenic CO_2 from fermentation. Can be captured for industrial use.
Thin Stillage	10 000 - 12 000 kg	Liquid fraction post-distillation. Can be recycled or concentrated into syrup.
Lignin-rich Residue	50-100 kg	Non-fermentable solids. Can be used for energy recovery or biochar.

Sources: U.S. Department of Energy (DOE) Bioenergy Technologies Office; USDA ethanol co-product and DDGS literature; International Energy Agency (IEA) Bioenergy Task reports; Renewable Fuels Association (RFA) ethanol industry data; peer-reviewed literature on ethanol process mass balances (e.g. Kwiatkowski et al., 2006; Kim & Dale, 2004); own synthesis.

I. Stover as power source Distillers Dried Grains with Solubles (DDGS)[258]

DDGS (Distillers Dried Grains with Solubles), are the primary byproduct of grain sorghum ethanol production. They are rich in protein, fibre, and residual starch, making them suitable for livestock feed.

[257] Grain sorghum is a viable feedstock for ethanol production; D. Wang et al; Journal of Industrial Microbiological Biotechnology (2008) 35:313–320; DOI 10.1007/s10295-008-0313-1

[258] Liu K., Rosentrater K.A. (2012). ***Distillers Grains: Production, Properties, Utilization***. CRC Press.

Table 29: DDGS composition

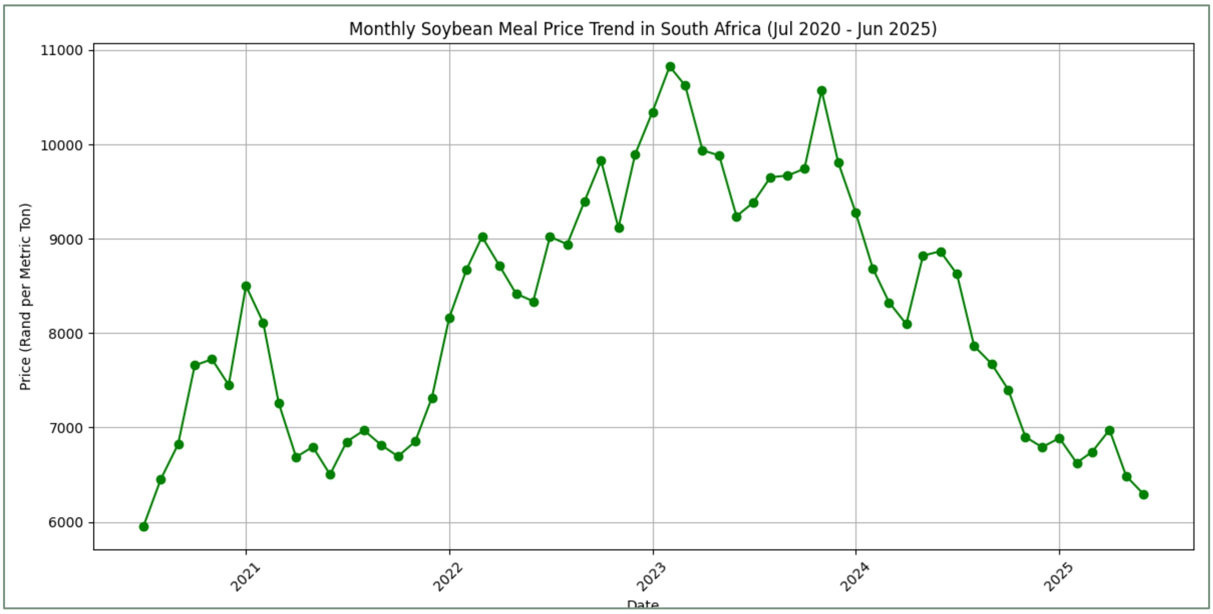
Protein	~30%	Moisture	~70%
Fat	~10%		
Fibre	Higher than maize based DDGS		

DDGS offer a cost-effective alternative to traditional feed ingredients. The high protein, fat content and high digestible fibre, make it ideal for ruminants, poultry, and swine[259].

In times of commodity price volatility, DDGS helps stabilize feed costs while providing a valuable income for the ethanol facility. South Africa currently **imports DDGS**, mainly from the U.S. and Argentina. Local production could tap into regional markets like Botswana, Namibia, and Zimbabwe, where livestock feed demand is rising. DDGS is suitable for beef cattle, dairy, poultry, and swine. Growing demand for cost-effective, high-protein feed supports DDGS adoption. In order to estimate the potential value of DDGS for a bio-ethanol plant we researched the cost of soybean meal and maize chop as comparative feed material for animals.

Internationally DDGS sells for approximately 10-15% lower than soybean meal.[260] Figure 16 shows soybean meal pricing data from 2020 to 2025.[261] The price spiked in 2023 at R10 800 per tonne.

Figure 16: Soybean meal price trend



Source: Own analysis based on SAGIS (South African Grain Information Service) soybean meal price data (2020–2025).

259 Feeding Distillers Dried Grains and Solubles Market Trends and Insights; May 2025; https://www.datainsightsmarket.com/reports/feeding-distillers-dried-grains-and-solubles-290001

260 https://www.mordorintelligence.com/industry-reports/ddgs-feed-market

261 Soybean Meal Monthly Price – Rand per Metric Ton – IndexMundi; https://www.indexmundi.com/commodities/?commodity=soybean-meal&months=60&currency=zar

A typical 500 klpd bioethanol plant is expected to produce about 120 000 tonnes of DDGS per year, generating a significant income for a bio-ethanol plant.

II. Condensed Distillers Solubles (CDS)

CDS is produced by evaporating vinasse (thin stillage) and is rich in soluble nutrients, organic acids and minerals. It can be blended with DDGS to enhance feed quality and palatability for use as animal feed but is also a valuable addition to an onsite biogas plant to complement the energy requirements of the ethanol plant. As a liquid co-product, CDS is typically 25-45% dry matter (plant dependent). It is used in two main ways: (i) blended back with wet/dry distillers' grains (creating WDGS/DDGS with solubles) to lift energy density, palatability, pellet durability and reduce dust, and (ii) as a high-COD substrate for anaerobic digestion, supplying biogas for process heat and power.

In animal nutrition, CDS (or DG + solubles) fits well because the syrup brings readily fermentable energy and liquid binding that improves mix uniformity. Common practice is to include 10-30% of diet DM for feedlot cattle (often via WDGS/DDGS+solubles), lower for dairy depending on milk urea nitrogen management; swine diets use smaller rates (typically ≤10% of diet DM) due to fibre and salt constraints, and poultry usage is modest and formulation-specific.

For biogas/energy integration, CDS' high chemical oxygen demand (COD) and favourable C:N make it an excellent co-digestion feed with stillage, slurry, or press mud, typically yielding 0.25-0.40 m^3 CH_4/kg volatile solids (plant- and recipe-dependent). Routing CDS to an on-site digester can (a) cut boiler fuel purchases via CHP (steam + power), (b) reduce the COD load to wastewater treatment, and (c) generate a nutrient-rich digestate that substitutes mineral fertiliser (notably K and P) in cane/sorghum fields. Plants often optimise between "value in feed" vs "value in gas": when feed markets are weak or logistics costly, more CDS goes to the digester; when feed offtakes are strong and priced, more CDS is blended into DG. Strategically, having both pathways-feed blending and biogas-turns CDS from a disposal liability into a flexible margin lever that supports the investment case (more stable EBITDA, lower Scope 1/2 emissions, and potential eligibility for low-CI fuel credits).

III. Condensed Distillers Solubles (CDS) Carbon Dioxide (CO_2)

CO_2 production as a by-product for grain sorghum is similar to biogenic CO_2 from sweet sorghum. Fermentation CO_2 from grain sorghum and from sweet sorghum is essentially the same biogenic stream because the core reaction is identical: sugars → ethanol + CO_2 (1 mol glucose yields 2 mol ethanol and 2 mol CO_2). In practice, dry-mill grain-sorghum plants (starch → glucose → ferment) and sweet-sorghum mills (juice sugars → ferment) both vent an off-gas that is ~99% CO_2 with traces of ethanol vapour and water; after simple dehydration, scrubbing, and compression it can meet food/industrial grades. Typical quantities are ~0.75-0.95 kg CO_2 per litre of ethanol (0.75-0.95 t per 1,000 L), with the exact figure driven by conversion efficiency and vent handling.

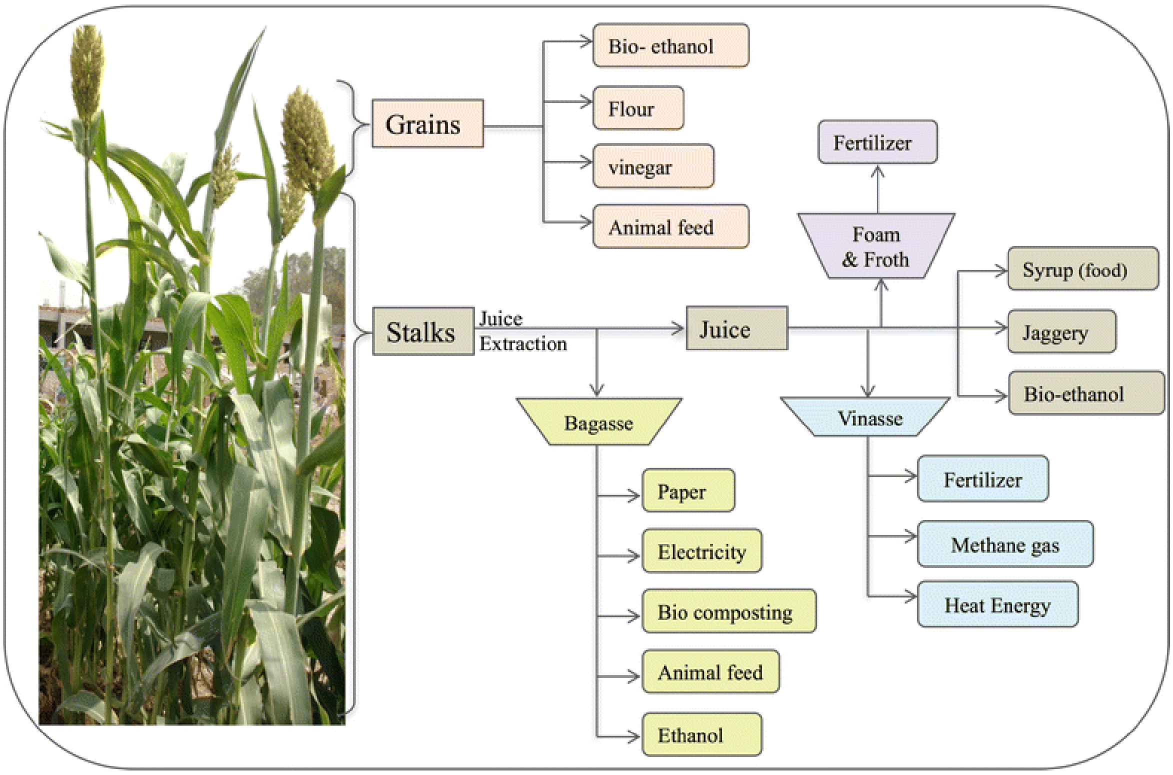
Where they can differ is operational, not chemical in that sweet sorghum tends to be seasonal and bursty, so continuous CO_2 capture may need modular or shared compression/liquefaction with a cane mill; grain-sorghum/maize dry-mills usually run year-round, supporting steadier CO_2 contracts. Either way, captured biogenic CO_2 is a valuable co-product (beverages, dry ice, greenhouses, welding/industrial gases) or a carbon-intensity lever in low-CI fuel markets (CCUS/e-fuels), improving the business case and the project's lifecycle emissions profile.

Sweet sorghum to ethanol

The sweet sorghum value chain options are shown in Figure 17Figure 17. The following

Table 30indicates key by-products, The profile points to potential for multiple revenue and cost-saving levers. Bagasse anchors on-site energy, but its value depends on designing boilers and operations to ride out seasonal variability. Vinasse looks like a waste stream until it is turned into biogas or thoughtfully returned to fields; done well, it reduces fuel and fertiliser bills and improves the project's carbon story. Filter cake is a quieter asset, blended back into soils, it closes nutrient loops and trims upstream input costs.

Figure 17: Sweet sorghum chain



Two flexible levers shape margins and risk. Fermentation CO_2 can be captured and sold (or counted for low-carbon credits), converting vent gas into a steady income line. Concentrated syrup (CMS) gives dispatchable optionality: blend it into feed co-products when that market pays for; send it to the digester when energy value is higher. Some of these streams may have the potential to be treated as co or core products, not just residues. Plants that integrate basic valorisation (energy from bagasse/vinasse, CO_2 capture, CMS flexibility) and secure offtake arrangements can build a more resilient business and smoother cash flows, lower operating costs, and a stronger low-carbon proposition.

Table 30: Summary of by-products from sweet sorghum ethanol production

Byproduct	Yield per Tonne of Ethanol	Comment
Bagasse	1000-1200 kg.[262]	Bagasse yield depends on rainfall and weather conditions on the farm
Vinasse	10,000-15,000 litres of wet vinasse.[263]	Byproduct from fermentation of sugar juice.
Filter Cake	100-150 kg	Produced from sugar juice clarification.[264]
CO_2	0.8-1.2 tonnes,	Dependent on fermentation efficiency. If Vinasse is processed in a biogas digester with methane upgrading, then more CO_2 is produced.[265]
Syrup (CMS)	Varies depending on the variety. Contains 65-85% Brix[266]	

Sources: International Energy Agency (IEA) Bioenergy Task reports; Food and Agriculture Organization (FAO) sugar and bioethanol processing resources; U.S. Department of Energy (DOE) Bioenergy Technologies Office; Brazilian sugarcane industry sources (UNICA); peer-reviewed literature on sugarcane and sweet sorghum ethanol mass balances (e.g. Dias et al., 2012; Goldemberg et al., 2008; Almodares & Hadi, 2009); own synthesis.

I. Bagasse

Bagasse is the fibrous residue remaining after juice extraction from sweet sorghum stalks. It can be used for combustion to generate energy, as animal feed, or as a feedstock for second-generation ethanol. Although ethanol can be produced from bagasse, it is currently not economically feasible[267]. Due to the careful timing required when harvesting sweet sorghum and the rapid processing required to preserve the integrity of the sugar content. As a result, it is likely that in larger commercial farming operations, the sorghum stalks will be processed on farm and concentrated into syrup to improve longevity and reduce transport costs. Consequently, most of the bagasse will be produced on farm at larger sweet sorghum farming operations.

Due to the energy requirements for syrup concentration some of the bagasse will be used to increase the juice concentration into syrup and the rest of the bagasse transported to the ethanol site for use as an energy source in the production of combined heat and power for the ethanol production site.

As with grain stover, sweet sorghum bagasse contains significant energy potential. The net calorific value of sweet sorghum bagasse is estimated at approximately 17 MJ/kg ash free.[268]

Sweet sorghum bagasse is compared as a feed source using a similar analysis as for the determination of grain sorghum stover value as a feed source. Sweet sorghum bagasse shows promising potential as

[262] Jacques et al., 1999. Handbook on Bioethanol: Production and Utilization and Drapcho et al., 2008. Biofuels Engineering Process Technology.
[263] Gnansounou et al., 2005. Bioethanol Production from Sweet Sorghum.
[264] Quintero et al., 2008. Life Cycle Assessment of Bioethanol Production.
[265] Smith and Frederiksen, 2000. Sorghum: Origin, History, Technology, and Production.
[266] Almodares et al., 2008e. Sweet Sorghum Agronomy and Processing.
[267] Jacques et al., 1999. Handbook on Bioethanol: Production and Utilization and Drapcho et al., 2008. Biofuels Engineering Process Technology.
[268] Sawargaonkar, G L and Wani, S P and Pavani, M and Ravinder Reddy, Ch (2013) Sweet sorghum bagasse – A source of organic manure. In: Developing a Sweet Sorghum Ethanol Value Chain. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, pp. 155-162. ISBN 978-92-9066-555-7

a livestock feed source, particularly for ruminants in semi-arid regions. The nutritional value is shown below, compared to lucerne and grain sorghum stover.[269]

Table 31: Nutritional value of sweet sorghum bagasse

Feed Type	CP (g/kg DM)	Digestibility	Relative Feed Value
Lucerne Hay	199	83%	100%
Maize Stover	47-65	72-82%	85-90%
Grain Sorghum Stover	50-70	70-80%	80-85%
Sweet Sorghum Bagasse	35-46	32-38%	50-60%

Sources: National Research Council (NRC) Nutrient Requirements of Ruminants; Feedipedia (INRAE, CIRAD, FAO, AFZ) feed composition database; FAO animal nutrition resources; peer-reviewed literature on forage quality and digestibility (e.g. Van Soest, 1994; Mertens, 1997; Menke & Steingass, 1988; Undersander et al., 2002); own synthesis.

Assuming lucerne hay as the benchmark (100% feed value) and using degradability and gas production as proxies we assumed the following benchmark prices for maize, and therefore sorghum, stover. Other assumptions are lucerne hay, 100% feed value → market price ≈ R2,500-R3,500/tonne (baled, depending on quality and region)[270] and maize stover at 50-60% of lucerne's feed value → estimated price ≈ R1,500-R1,800/tonne.

II. Filter cake (press mud)

Filter cake is a blackish-brown, semi-solid residue from juice clarification and filtration. Its composition is similar to sugarcane press mud but varies slightly due to the feedstock. An approximate nutrient profile and proximate composition is shown below:

Nutrient Profile		Proximate Composition	
Nitrogen (N):	1.63%-2.29%	Organic Carbon:	18.77%
Phosphorus (P):	8.4%-9.5%	pH:	Neutral (7.3)
Potassium (K):	2.5%-4.1%	C/N Ratio:	15
Calcium (Ca):	21.3%-30%	Sugar Content:	12.2%-13.3%
Magnesium (Mg):	4.1%-7.8%	Crude Wax:	6.7%-11%
Sulphur (S):	3.8%-7.4%	Ash:	19.3%-30.8%
Silicon (Si):	~9.5%	Protein:	10.2%-14.3%
Aluminium (Al):	~2.4%-2.9%	Volatile Matter:	~61.2%

Sources: FAO (agro-industrial residue and soil amendment data); Satisha & Devarajan (2007) on sugar industry by-products; Jenkins et al. (1998) biomass ash composition; Demirbaş (2004) biomass characterisation; own synthesis.

[269] Tas, T., Yucel, C., Dondu Gunel, F., Oktem, A., & Cetiner, I. H. (2021). Evaluation of Sweet Sorghum Bagasse as an Alternative Feed Resource for Livestock in Semi-Arid Regions. MAS Journal of Applied Sciences, 6(2), 303–311. https://doi.org/10.52520/masjaps.50

[270] https://amtrends.co.za/market-pricesv2/

There are various possible uses for press mud.[271] These include i) organic fertilizer, where press mud is composted and used as a soil conditioner and organic soil enhancement. It enhances soil fertility, microbial activity, and crop yield. Studies show that bioaugmentation using bacterial strains like Bacillus amyloliquefaciens and Bacillus megaterium significantly enhances compost quality by increasing nitrogen and phosphorus content. This biofortified compost accelerates nutrient mineralization and is particularly effective in rehabilitating nutrient-deficient or barren soils.[272] i) *Biogas production* where press mud is used as a biogas feedstock at ethanol refineries, especially those using sweet sorghum or sugarcane, can be a promising strategy for waste valorisation, energy recovery, and sustainability. Press mud contains high levels of organic matter (50-60%), including cellulose, hemicellulose, lignin, sugars, proteins, and fats, making it suitable for anaerobic digestion.[273] Methane yield from press mud ranges between 61.3% and 78.23% (v/v) when co-digested with distillery wastewater and supplemented with nutrients.[274] The optimal C/N ratio for press mud digestion is around 72:1 to 78:1, which supports microbial activity and methane production.[275] Considering the energy requirements of an ethanol plant in the South African context it will be important to maximise the energy production from byproducts in the on-site power plant; iii) *animal feed* where the use of press mud from sweet sorghum ethanol production as an animal feed can be a promising avenue for sustainable livestock nutrition, particularly in regions where agro-industrial byproducts are abundant. Although most studies focus on sugarcane press mud, the compositional similarities with sweet sorghum press mud suggest comparable nutritional potential. Sugarcane press mud is used below as a basis for analysis. Sugarcane press mud (SPM), a close analogue to sweet sorghum press mud, has the following characteristics on a dry matter (DM) basis.[276]

Table 32: Characteristics of sugarcane press mud

Crude Protein:	18.01 ± 0.57%	Calcium:	5.90 ± 0.27%
Crude Fibre:	12.38 ± 0.33%	Linoleic Acid:	34.85% of ether extract
Ash Content:	17.73 ± 0.36%	Gross Energy:	4294.51 ± 79.64 kcal/kg DM (comparable to maize)

Sources: Interviews, Blueprint Holdings (Pty) Ltd synthesis.

These values indicate that press mud is a rich source of protein, energy, and minerals, making it suitable for inclusion in livestock diets. For cattle, studies showed that up to 20% sun-dried press mud could be safely included in concentrate mixtures without affecting growth, feed conversion, or nutrient digestibility. Calcium intake and retention were significantly higher in press mud-fed groups, supporting

[271] Arulazhagan, A., Muthaiyan, G., Murugaiyan, S. et al. Press Mud: A Promising Resource for Green Energy Production as Fertilizer, Fuel and Feed. Sugar Tech 26, 1078–1087 (2024). https://doi.org/10.1007/s12355-024-01465-2

[272] Pressmud Compost for Improved Nitrogen and Phosphorus Content Employing Bacillus Strains; Uzma Sajid et al; Special Issue Resource Recovery from Waste Biomass; November 2024; https://www.mdpi.com/2313-4321/9/6/104

[273] Case Study on Production of Bio Gas fromPressMud; Er Alok Gupta et al; International Journal of Engineering and Techniques - Volume 10 Issue 4, August 2024; https://ijetjournal.org/wp-content/uploads/IJET-V10I4P10.pdf

[274] Almendrala, M., Tizon, Z.A., Doma, B., Evidente, R.C. (2023). Enhanced Biogas Production from Press Mud Using Molasses-Based Distillery Wastewater as Co-substrates Through an Immobilized Anaerobic Digestion. In: Caetano, N.S., Felgueiras, M.C. (eds) The 9th International Conference on Energy and Environment Research. ICEER 2022. Environmental Science and Engineering. Springer, Cham. https://doi.org/10.1007/978-3-031-43559-1_61

[275] C. Almendrala, M., Carlo T. Evidente, R., Marjorie C. Legarde, J. and Ray S. Pamintuan, K. Codigestion of Pressmud and Distillery Wastewater with Sugarcane Bagasse for Enhanced Biogas Production. DOI: 10.5220/0008692000460051 In Proceedings of the International Conference on Future Environment Pollution and Prevention (ICFEPP 2019), pages 46-51 ISBN: 978-989-758-394-0

[276] Screening of sugarcane press mud as a potential alternative feed for livestock; S. Sahu et al; Indian Journal of Animal Research; volume 50 issue 2 (april 2016): 207-210, Doi: 10.18805/ijar.6699

bone health. Feed costs were reduced significantly, making it an economically viable alternative.[277] For poultry (boilers and layers) press mud has been used in diets for broilers and layers, showing no compromise in growth or egg quality. Its sugar and mineral content support energy and shell formation.[278] For swine and lambs the use of press mud has demonstrated cost savings and stable growth performance, though further species-specific trials are recommended.[279]

III. Vinasse

Vinasse is a dark brown liquid effluent with a strong odour generated during the distillation of ethanol. It is rich in potassium and organic matter and can be used as fertilizer or for irrigation after treatment. Vinasse typically contains 85-93% water[280] and is rich in organic matter, potassium, nitrogen, phosphorus, sulphates, and chlorides.[281] Vinasse is composed of the following approximate constituents (per tonne of Vinasse).

Table 33: Vinasse characteristics

Carbon:	400 kg	Phosphorus:	1 kg
Nitrogen:	2 kg	Potassium:	5.5 kg
Heavy metals (e.g., Fe, Mn, Pb, Cu): present in trace amounts depending on soil origin[282]			

Vinasse is widely used for fertigation, especially in sugarcane and sweet sorghum fields internationally.[283] However transport of the liquid is expensive. Vinasse improves soil organic carbon, and nutrient availability (especially potassium and phosphorus).[284] Application rates vary from 50 to 310 m³/ha, depending on crop and soil type.[285]

Vinasse has a high chemical oxygen demand (COD) of up to 216 g/L and has a high biodegradability making it suitable for anaerobic digestion. The relatively low pH, typically around 4.0-4.5, high volatile solids (~68.42 mg/L) and high nutrient level: Nitrogen, potassium, phosphorus, and trace metals make vinasse an ideal substrate for anaerobic digestion (AD), but also require careful pre-treatment to optimize biogas yield:[286] Typically, its acidic pH must be neutralized to around 6.8-7.2 for optimal methanogenic activity and its high COD and salinity may inhibit microbial activity. Dilution with water or

---

277 Malapure, C.D., Saha, S.K., Kumar, D. et al. Exploring Sugarcane Press Mud as an Economical Feed Ingredient for Growing Cattle. Sugar Tech 26, 1171–1178 (2024). https://doi.org/10.1007/s12355-024-01463-4

278 Arulazhagan, A., Muthaiyan, G., Murugaiyan, S. et al. Press Mud: A Promising Resource for Green Energy Production as Fertilizer, Fuel and Feed. Sugar Tech 26, 1078–1087 (2024). https://doi.org/10.1007/s12355-024-01465-2

279 Arulazhagan, A., Muthaiyan, G., Murugaiyan, S. et al. Press Mud: A Promising Resource for Green Energy Production as Fertilizer, Fuel and Feed. Sugar Tech 26, 1078–1087 (2024). https://doi.org/10.1007/s12355-024-01465-2

280 Vinasse - from fermentation of sweet sorghum emission factor information; https://www.climatiq.io/data/emission-factor/e5525f7a-a2bf-4292-9007-b57cc040b96f

281 Taylor and Francis information on Vinasse; https://taylorandfrancis.com/knowledge/Engineering_and_technology/Biomedical_engineering/Vinasse

282 Heavy metal tracing from gold mining soil to vinasse in the downstreaming process of sweet sorghum to bioethanol; Mohammad Nurcholis et al; SAINS TANAH – Journal of Soil Science and Agroclimatology, 22(2), 2025, 190-199

283 Ethanol Production Potential from Sweet Sorghum Fertilized with Filter Cake and Vinasse from the Sugarcane Industry; ELVIRA M R PEDROSA; Journal of Experimental Agriculture International; https://doi.org/10.9734/JEAI/2018/42574

284 Sugarcane production and nutrient accumulation in commercial plantations under vinasse irrigation; del Pino A et al; Agrociencia Uruguay 2025 | Volume 29 | Article e1468
DOI: 10.31285/AGRO.29.1468

285 Ethanol Production Potential from Sweet Sorghum Fertilized with Filter Cake and Vinasse from the Sugarcane Industry; ELVIRA M R PEDROSA; Journal of Experimental Agriculture International; https://doi.org/10.9734/JEAI/2018/42574

286 Biogas production from vinasse derived from ethanol manufacturing using a continuous stirred tank reactor pilot plant; Sakina Belhamidi et al; Desalination and Water Treatment www.deswater.com; doi: 10.5004/dwt.2021.27763; 240 (2021) 216–224; November 2021

co-substrates (e.g., press mud, manure) helps balance the organic loading rate (OLR). The biochemical methane potential (BMP) of vinasse from sweet sorghum ranges from: 475-484 Nm³ CH_4/tVS for vinasse from fresh and ensiled sorghum[287] and can produce a 77% methane content in biogas under optimal conditions.[288]

IV. Biogenic CO_2

The biogenic CO_2 generated from sweet sorghum ethanol production, both from fermentation and biogas systems, offers substantial potential in the emerging CO_2 economy. This CO_2 is considered carbon-neutral because it originates from biomass, making it a valuable resource for carbon capture, utilisation, and storage (CCUS) strategies. During ethanol fermentation, CO_2 is released as a by-product when yeast converts sugars (mainly sucrose, glucose, and fructose) into ethanol. In sweet sorghum juice fermentation, CO_2 capture efficiency of up to 92% has been achieved using NaOH absorption, producing Na_2CO_3 for pretreatment of bagasse. This captured CO_2 can be reused within the biorefinery, reducing chemical costs and emissions. [289] The CO_2 from by-products digestion can be separated during biogas upgrading for further use.

5.2 Sweet sorghum to ethanol

Ethanol production from sugarcane in South Africa

There are clear reasons why Brazil, South Africa's fellow southern hemisphere BRICS partner, has built its globally renowned biofuels programme almost entirely around sugarcane, which remains the benchmark for efficient first-generation (1G) bioethanol. South Africa already has a functioning cane-based bioethanol industry. Four operating plants in KwaZulu-Natal collectively produce hundreds of millions of litres annually for the industrial, pharmaceutical, and beverage markets.[290] These plants demonstrate that the technology risks have been largely overcome, and that domestic technical expertise exists to build, operate, and integrate bioethanol production into supply chains. This lowers barriers to expanding ethanol output from cane to meet any fuel-blending mandates.

South Africa's sugarcane industry is concentrated in KwaZulu-Natal and Mpumalanga provinces, with approximately 400,000-450,000 hectares under cultivation as of the 2024/2025 season. This figure has remained relatively stable over the past few years, reflecting a balance between production demands (18-19 million metric tonnes annually) and challenges like drought, disease, and land reform.[291] The industry supports 65,000 direct jobs and 1 million livelihoods but has seen production decline from 2.5 million tonnes of sugar annually in the 2010s to 2.2 million tonnes today, with 12 active mills down from

[287] Biogas Production from By-Products of the Sweet Sorghum Bioethanol Chain; Picco, D. et al; Proceedings of the European Biomass Conference and Exhibition; 10.5071/20thEUBCE2012-2DV.3.3

[288] Biogas production from vinasse derived from ethanol manufacturing using a continuous stirred tank reactor pilot plant; Sakina Belhamidi et al; Desalination and Water Treatment www.deswater.com; doi: 10.5004/dwt.2021.27763; 240 (2021) 216–224; November 2021

[289] Nghiem, N.P.; Toht, M.J. Pretreatment of Sweet Sorghum Bagasse for Ethanol Production Using Na2CO3 Obtained by NaOH Absorption of CO2 Generated in Sweet Sorghum Juice Ethanol Fermentation. Fermentation 2019, 5, 91. https://doi.org/10.3390/fermentation5040091

[290] South African Sugar Association (SASA). Industry Statistics 2024. Durban: SASA, 2024.

[291] Come Alive. 2024. "SASA Outlines Progress and next Steps for Sugarcane Master Plan." South African Sugar Industry. October 9, 2024. https://sasa.org.za/sasa-outlines-progress-and-next-steps-for-sugarcane-master-plan/.

15, under financial strain, with producers squeezed by cheap imports, rising input costs, the sugar tax, and climate variability, while some mills are operating below capacity or have reduced throughput. Domestic consumption has softened, and two mills in KZN have been mothballed since 2020, exacerbating job losses and forcing growers to truck cane to distant facilities, increasing costs by 20-30%. The industry is increasingly reliant on exports to absorb surplus supply.[292] [293]. Should bioethanol be a viable option for the sugar industry, it would obviate the need to import while the local industry is growing.

Cane delivers far higher ethanol yields per hectare (6,000-7,000 L/ha under good agronomic conditions) compared to sorghum, particularly grain sorghum where yields average only in the region of 1,200 L/ha under South African conditions.[294],[295] In addition cane bioethanol plants typically use the bagasse as an onsite energy supply in cogeneration boilers to produce steam and electricity, which often meets all of their energy requirements. This self-sufficiency in energy reduces operational costs and carbon emissions, making sugarcane ethanol production highly efficient and sustainable.[296] Cane is supported by an established milling and logistics infrastructure concentrated in KwaZulu-Natal and Mpumalanga, whereas sorghum ethanol will require new plants, storage, and transport networks. The economics of scale are heavily in sugarcane's favour, since existing mills already integrate ethanol production at marginal cost, while sorghum must bear full capital costs. Moreover, the sugar sector has strong political influence and export experience, while sorghum has suffered long-term declines in area planted and market share to maize and sunflower.

Sugarcane offers two main pathways for producing bioethanol: direct fermentation of cane juice and fermentation of molasses, a by-product of sugar refining. Fresh cane juice is a clean, high-sucrose feedstock that can go straight into fermentation tanks after clarification. It avoids the impurities that make molasses fermentation more complex and expensive. Juice-to-ethanol routes are widely used in Brazil, where fresh cane juice is diverted from sugar production and fermented directly, yielding high volumes of fuel-grade ethanol at relatively low cost. In contrast, South Africa and Eswatini have traditionally focused on molasses-to-ethanol, since molasses is a residual stream after sugar crystallisation; this approach leverages an existing by-product but produces smaller volumes, making it more suitable for industrial and potable alcohol markets. Both routes rely on the same basic fermentation and distillation technology, but the juice route prioritises ethanol as the main product, while the molasses route is secondary to sugar production, limiting scale but reducing feedstock risk.[297] [298]

Both Illovo Sugar and Tongaat Hulett recognise that the viability of large-scale bioethanol production in Southern Africa depends on the implementation of blending mandates. Tongaat has been more explicit, with announcements in 2019 about plans to double ethanol production capacity in Zimbabwe directly linked to mandated fuel blends. Illovo, by contrast, highlights ethanol as part of its broader downstream

[292] South African Sugar Association (SASA). Trouble for Sugar in South Africa. Durban: SASA, 2023. https://sasa.org.za/trouble-for-sugar-in-south-africa/

[293] South African Sugar Association (SASA). SA Sugar Industry Faces Crisis. Durban: SASA, 2023. https://sasa.org.za/sa-sugar-industry-faces-crisis/

[294] Food and Agriculture Organization of the United Nations (FAO). Biofuels from Grasses and Sorghum: A Sustainable Option for Africa. Rome: FAO, 2010.

[295] Gnansounou, Edgard, Alain Dauriat, Charles Wyman, and Kari Suominen. "Refining Sweet Sorghum to Ethanol and Sugar: Economic Trade-offs in the Context of North China." Bioresource Technology 96, no. 9 (2005): 985–1002. https://doi.org/10.1016/j.biortech.2004.09.015

[296] Canilha, Larissa, Anuj Kumar Chandel, Thais Suzane dos Santos Milessi, Felipe Antônio Fernandes Antunes, Wagner Luiz da Costa Freitas, Maria das Graças Almeida Felipe, and Silvio Silvério da Silva. 2012. "Bioconversion of Sugarcane Biomass into Ethanol: An Overview about Composition, Pretreatment Methods, Detoxification of Hydrolysates, Enzymatic Saccharification, and Ethanol Fermentation." *Journal of Biomedicine and Biotechnology* 2012: 1–15. https://doi.org/10.1155/2012/989572.

[297] Food and Agriculture Organization of the United Nations (FAO). Biofuels from Grasses and Sorghum: A Sustainable Option for Africa. Rome: FAO, 2010.

[298] Goldemberg, José. "Ethanol for a Sustainable Energy Future." Science 315, no. 5813 (2007): 808–810.

product mix but has not published firm commitments tied to fuel-grade blending policy in South Africa. This likely reflects the sector's caution after years of stalled mandate implementation.

The bioethanol blending mandate will provide a new, stable domestic outlet for surplus sugar, reducing dependence on volatile export markets and strengthening mill utilisation. By creating predictable demand for sugarcane-derived ethanol, this could revitalise idle or underused milling infrastructure, improve grower margins, and accelerate diversification of the sector, aligning it with South Africa's broader renewable energy and just transition goals.

The two biggest producers of grain sorghum bioethanol, the USA and China, primarily use sorghum as an alternative or adjunct feedstock in ethanol plants that are primarily designed to process maize. In the United States, many ethanol facilities operate flexibly with maize as the main feedstock but incorporate grain sorghum when it is available and economically viable, especially in drier regions where sorghum tolerance to drought offers a reliable supply advantage. These plants blend sorghum with maize to maintain continuous operations without significant process changes. Estimates put grain sorghum contributions to between 5 to 10% of ethanol in regions like Texas, Kansas, and Nebraska, where sorghum is a key crop due to drought tolerance.

The executive team at Mabele Fuels appears confident that grain sorghum bioethanol from the planned plant in Bothaville can give investors a healthy return that exceeds the general hurdle rate for African infrastructure investments. Although sorghum is unlikely to displace sugarcane as the dominant ethanol crop, it can play a significant complementary role in widening the geographic and climatic base of supply and creating opportunities for smallholder inclusion in marginal areas while sugarcane continues to anchor the industry.[299]

By-products from sugarcane ethanol production[300]

The main by-products of sugarcane bioethanol production are shown in Table 34. The Mass Balance Summary is approximate.

Table 34: By-products from sugarcane ethanol - combining 1G (sugar-based) and 2G (lignocellulosic) co-product streams

Component	Yield per Tonne of Ethanol	Notes
Bagasse	1,000-1,200 kg	Used for energy or further processing
Vinasse	10,000-15,000 litres	Fertilizer or biogas feedstock
Filter Cake	100-150 kg	Compost or soil amendment
CO_2	0.8-1.2 tonnes	Can be captured or reused
Pentose Liquor	300-400 kg (dry basis)	From hemicellulose hydrolysis
Lignin	200-250 kg	Energy or material use

[299] Gnansounou, Edgard, and Alain Dauriat. "Ethanol from Sweet Sorghum: A Review." *Bioresource Technology* 101, no. 13 (2010): 4859–4868.

[300] Fraser, D. (2013). ***Bioethanol Production from Sugarcane Bagasse: Mass Balance Specifications***. University of Cape Town. https://www.studocu.com/en-za/document/university-of-cape-town/chemical-engineering/bioethanol-production-from-sugarcane-bagasse-mass-balance-analysis-che-2024/136879771

Sources: Blueprint Holdings (Pty) Ltd synthesis based on Brazilian sugarcane industry data (UNICA; EMBRAPA); International Renewable Energy Agency (IRENA) bioenergy reports; International Energy Agency (IEA) Bioenergy Task 39 and Task 42 publications; U.S. Department of Energy (DOE) lignocellulosic ethanol design reports; peer-reviewed literature on ethanol mass balances and co-products (e.g. Humbird et al., 2011; Dias et al., 2012; Wyman et al., 2005)

Bagasse is the fibrous residue left over from the sugarcane after juice extraction. The typical bagasse yield from crushing sugarcane is approximately 280 kg of wet bagasse per tonne of sugarcane. The most typical use of bagasse is combustion in steam boilers for the provision of electricity and heat for the operation of the bio-ethanol plant, a strong advantage of the sugar to bioethanol compared to sorghum and maize. Further, bagasse can be used as a feedstock for second-generation bio-ethanol plants, as animal feed. Potential future uses for bagasse are for the manufacture of paper, packaging and building material. The *vinasse* produced from sugarcane to ethanol production is very similar to sweet sorghum and the potential pathways are very similar. *Press mud* is the residue from sugar juice clarification with an approximate yield of 100-150 kg per tonne of sugarcane processed. The press mud produced from sugarcane to ethanol production is very similar to sweet sorghum and the potential pathways are very similar. Finally, the CO_2 produced from sugarcane to ethanol production is very similar to sweet sorghum and the potential pathways are very similar.

5.3 Grain sorghum compared to maize

A comparison of by-products from ethanol production from grain sorghum vs maize as a raw material in a tabular format as

Table 35 shows. At a glance, the sorghum-maize by-product slate is broadly similar in volume and options, but with useful compositional differences. Sorghum DDGS tends to be higher in fibre than maize DDGS at comparable protein and fat, which suits ruminant and many poultry rations (often at a slight discount to maize DDGS where formulators prefer lower fibre). Fermentation CO_2, vinasse, and CMS are effectively equivalent in yield and valorisation pathways for both crops, supporting the same capture, feed blending, and biogas strategies. The standout divergence is lignin: sorghum typically throws off more lignin-rich residue per tonne of ethanol, offering stronger combustion value for process steam or biochar, while maize's lower lignin reduces boiler energy but can marginally ease DDGS digestibility constraints in monogastric feeds. Practically, this means a sorghum plant can lean a little harder on internal energy self-sufficiency, whereas a maize-based plant may lean more on DDGS marketability, but both could potentially achieve comparable multi-revenue configurations with sound specifications and offtake contracts.

Table 35: By-products overview - grain sorghum vs maize (corn)

Byproduct	Grain Sorghum	Maize (Corn)
Distillers Grains (DDGS)[301]	~800-1,000 kg/tonne ethanol Higher fibre, similar protein (~30%) and fat (~10%) Good for ruminants and poultry	~800-1,000 kg/tonne ethanol Lower fibre, similar protein and fat Widely used in global feed markets
Carbon Dioxide (CO_2)[302]	~900-1,100 kg/tonne ethanol Biogenic CO_2 from fermentation Can be captured for industrial use	~900-1,100 kg/tonne ethanol Similar CO_2 yield and utilisation potential
Vinasse[303]	~10,000-12,000 kg/tonne ethanol Rich in soluble proteins, minerals, and sugars Can be recycled or concentrated	~10,000-12,000 kg/tonne ethanol Similar composition and reuse potential
CMS[304]	~100-150 kg/tonne ethanol High in nutrients Often blended with DDGS for feed	~100-150 kg/tonne ethanol Similar nutrient profile and usage
Lignin-rich Residue	~50-100 kg/tonne ethanol Higher lignin content due to sorghum's structure Used for energy recovery	~30-80 kg/tonne ethanol Lower lignin content Also used for combustion or biochar

Sources: U.S. Department of Agriculture (USDA) ethanol co-product literature; Renewable Fuels Association (RFA) industry data; U.S. Department of Energy (DOE) Bioenergy Technologies Office; International Energy Agency (IEA) Bioenergy Task reports; Feedipedia (INRAE, CIRAD, FAO, AFZ); peer-reviewed literature on sorghum and maize ethanol co-products (e.g. Kwiatkowski et al., 2006; Taylor & Duodu, 2015)

In feed terms, sorghum DDGS generally runs higher in protein but tougher in fibre: tannins (where present) and a tighter protein-starch matrix can limit enzymatic access, lowering fibre digestibility and dampening feed conversion in monogastrics. That makes sorghum DDGS a stronger fit for ruminant rations (where the rumen can handle lignocellulose) unless plants actively manage tannins and particle size or apply treatments (e.g., enzymes, alkali). Maize DDGS, by contrast, has more digestible fibre and less protein cross-linking, so it is widely accepted across both ruminant and monogastric markets, typically commanding broader demand and steadier pricing.305

301 Liu & Rosentrater (2012) – Distillers Grains: Production, Properties, Utilization 1st Edition; https://doi.org/10.1201/b11047 and Grain sorghum is a viable feedstock for ethanol production; D. Wang et al; Journal of Industrial Microbiological Biotechnology (2008) 35:313–320; DOI 10.1007/s10295-008-0313-1

302 Bothast RJ, Schlicher MA. Biotechnological processes for conversion of corn into ethanol. Appl Microbiol Biotechnol. 2005 Apr;67(1):19-25. doi: 10.1007/s00253-004-1819-8. Epub 2004 Dec 14. PMID: 15599517.

303 Liu & Rosentrater (2012) – Distillers Grains: Production, Properties, Utilization 1st Edition; https://doi.org/10.1201/b11047

304 Liu & Rosentrater (2012) – Distillers Grains: Production, Properties, Utilization 1st Edition; https://doi.org/10.1201/b11047

305 Grain sorghum is a viable feedstock for ethanol production; D Wang et al; Journal of Industrial Microbiology and Biotechnology, Volume 35, Issue 5, 1 May 2008, https://academic.oup.com/jimb/article/35/5/313/5993797

Table 36: By-products overview - grain sorghum vs maize - Distillers Grain

Grain Sorghum	Maize
Distillers Grain from sorghum tends to have higher protein content and lower fibre digestibility, especially in tannin-rich varieties. The protein matrix in sorghum can encapsulate starch granules, reducing enzymatic access and affecting fermentation efficiency.	Maize distillers grain typically has more digestible fibre and less protein cross-linking, resulting in better feed conversion for monogastric animals.
Distillers grain from sorghum **is less suitable for monogastric animals** due to lower fibre digestibility and higher lignocellulosic content.	Maize distillers' grain is **widely accepted** in both ruminant and monogastric feed markets, making it more versatile and valuable.

Sources: NRC (2001) Nutrient Requirements of Dairy Cattle; Liu (2011) Distillers Grains: Production, Properties, and Utilisation; Taylor & Duodu (2015) Sorghum and Millets; Rooney & Pflugfelder (1986); own synthesis.

5.4 Bio-Ethanol production energy requirements

Typical steam consumption for grain-based ethanol production is 6.5-7.5 tonnes per kilolitre (KL) of ethanol[306]. This is based on industrial benchmarks and process energy balances in dry milling and distillation stages. Distillation and drying are the most energy-intensive steps, requiring substantial steam input. For a 500 KLPD plant this relates to a total steam requirement of 135 to 155 tonnes/hour, split into low pressure and high-pressure steam applications.

Table 37: Bioethanol steam requirements (process engineering specifications)

Aspect	Low-Pressure Steam	High-Pressure Steam
Pressure Range[307]	≤ 3.5 bar (50 psi)	≥ 20 bar (290 psi), often up to 67 bar
Temperature Range[308]	~120-150°C	~250-485°C
Applications[309]	Fermentation temperature control, sterilization, general heating	Distillation, evaporation, DDGS drying, cogeneration
Steam Demand (500 KLPD) [310]	~20-40 TPH (15-25% of total)	~110-130 TPH (75-85% of total)
Energy Efficiency[311]	Lower thermal efficiency	Higher thermal efficiency
Integration Potential	Limited to process heating	Enables cogeneration and energy optimization

Sources: Humbird et al. (2011) NREL ethanol process design report; U.S. Department of Energy (DOE) Bioenergy Technologies Office; IEA Bioenergy Task 39 reports; Perry's Chemical Engineers' Handbook

306 Zhou J.Y., and Yan S.D., 2024, A comprehensive review of corn ethanol fuel production: from agricultural cultivation to energy application, Journal of Energy Bioscience, 15(3): 208-220 (doi: 10.5376/jeb.2024.15.0020)

307 FAO (2022) – Bioethanol Production from Sorghum: Technical Guidelines; https://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_SORGHUM.pdf

308 Zhou J.Y., and Yan S.D., 2024, A comprehensive review of corn ethanol fuel production: from agricultural cultivation to energy application, Journal of Energy Bioscience, 15(3): 208-220 (doi: 10.5376/jeb.2024.15.0020)

309 FAO (2022) – Bioethanol Production from Sorghum: Technical Guidelines; https://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_SORGHUM.pdf

310 310 Zhou J.Y., and Yan S.D., 2024, A comprehensive review of corn ethanol fuel production: from agricultural cultivation to energy application, Journal of Energy Bioscience, 15(3): 208-220 (doi: 10.5376/jeb.2024.15.0020)

311 REN21 (2023) – Global Status Report on Renewable Energy in Industry; https://www.ren21.net/gsr-2023/

Electricity consumption is typically 0.6-0.9 kWh per litre of ethanol produced.[312] This includes energy for milling, pumping, fermentation control, and drying. Dry milling and enzymatic hydrolysis are significant contributors to electricity demand. For a 500 KLPD plant this relates to a total installed electrical requirement of 12.5 to 18.7 MW. The plant operates continuously, with electricity demand varying by process and time of day. A possible demand profile is shown below.

Table 38: Electricity demand profile (operational and plant-behaviour specifications)

Time	Demand	Comment
Early Morning (00:00-06:00)	Low to moderate demand	Continuous operation of fermentation tanks and cooling systems. Basic lighting, monitoring, and control systems.
Daytime Peak (06:00-18:00)	Highest demand period	Grain milling and handling. Active fermentation control. Distillation columns and dehydration units. DDGS drying and CO_2 recovery systems. Boiler and steam turbine operations.
Evening (18:00-00:00)	Moderate demand.	Continued distillation and drying. Reduced milling activity. Maintenance and cleaning operations.

Sources: Humbird et al. (2011) NREL ethanol process design report; U.S. Department of Energy (DOE) Bioenergy Technologies Office; Renewable Fuels Association (RFA) ethanol plant operations guidance; industrial process engineering literature on continuous fermentation and distillation

The South African electricity grid has experienced frequent and consistent loadshedding in the past 5 years. Even though South Africa shed 82% less energy in 2025 than in 2024, the grid reliability remains fragile especially should economic growth recover.[313] Further, the National Transmission Company South Africa (NTCSA) Medium-Term System Adequacy Outlook[314] and the CSIR's 2025 statistics[315] mention that although the reliability of the South African grid is improving it remains vulnerable to demand spikes, transmission infrastructure delays, accelerating grid defection and an Eskom's EAF that remains below optimal levels (58%), limiting supply flexibility.

The expected delays in the roll out of national transmission infrastructure, limited by governmental finances and an uncertain regulatory environment, further point to an unstable grid in the next 5-10 years. Therefore, the requirement of 100% energy independence is crucial for the establishment of a future bio-ethanol plant in South Africa and is very likely to be a condition precedent for any project finance agreement related to bio-ethanol plant in South Africa.

5.5 The potential for on-site generation

Energy independence from combined heat and power has distinct advantages for bioethanol and fits well into the process dynamics. A bioethanol plant has a high thermal moderate electricity demand and

312 https://www.epa.gov/renewable-fuel-standard/how-prepare-efficient-producer-petition-under-renewable-fuel-standard

313 Utility-scale power generation statistics in South Africa; CSIR Energy Research Centre September 2025; https://www.csir.co.za/sites/default/files/Documents/Utility%20Statistics%20Report_Final.pdf

314 Medium-Term System Adequacy Outlook 2025-2029; NTCSA; https://www.ntcsa.co.za/wp-content/uploads/2024/10/Medium-Term-System-Adequacy-Outlook-2025-2029.pdf

315 Utility-scale power generation statistics in South Africa; CSIR Energy Research Centre September 2025; https://www.csir.co.za/sites/default/files/Documents/Utility%20Statistics%20Report_Final.pdf

continuous process requirements. CHP is ideal for bioethanol, offering integrated energy supply, improving operational resilience, cost savings and potential for carbon reduction.

The most likely CHP technologies using sorghum byproducts are biomass combustion of the by-products from the process, except for DDGS which is a valuable animal feed, supplemented possibly by purchasing baled stover from surrounding farmers and the anaerobic digestion of the thin stillage and press mud to produce biogas for heat and power or just heat. Alternative options to complement the energy requirements could come from a natural gas turbine and from solar power combined with battery energy storage. There are a number of possible options to consider.

5.6 Anaerobic digestion

Anaerobic digestion (AD) is a promising waste-to-energy technology that can be integrated into bioethanol plants to improve energy independence and reduce waste management risks. Significant quantities of thin stillage are generated, which can be processed through AD to produce biogas to be used in combined heat and power (CHP) systems to partially meet the plant's thermal and electrical energy demands.

Thin stillage is the liquid fraction remaining after the distillation of ethanol, containing dissolved solids and organic matter. Studies have shown that thin stillage can yield up to 0.33 L CH_4/g COD added in two-stage AD systems.[316] The biogas produced from AD can be utilized in CHP systems to generate electricity and process heat. Integration of AD and CHP can offset up to 40% of thermal energy requirements and 30% of electricity needs of a large grain sorghum bio-ethanol plant[317].

The digestate resulting from the AD of thin stillage in a grain sorghum bioethanol plant offers a range of agronomic, environmental, and economic benefits, making it a valuable by-product in integrated bio-ethanol plants. Digestate from thin stillage contains high levels of Nitrogen (N), often in ammonium form readily available to plants, Phosphorus (P), essential for root development, Potassium (K) which supports plant metabolism and water regulation and micronutrients such as magnesium, calcium, and sulphur.[318] These nutrients make digestate a sustainable alternative to synthetic fertilizers, improving soil fertility and crop yields.

5.7 Combustion

A biomass combustion combined heat and power (CHP) system for a grain sorghum bio-ethanol plant can be a highly efficient and sustainable solution for energy independence. The use of grain sorghum byproducts like husks and grain sorghum stover (leaves, stalks, and panicles left after harvest) as fuel also reduces waste management pressure and provides a renewable energy solution to the plant.

[316] Nasr, N., Elbeshbishy, E., Hafez, H., Nakhla, G., & El Naggar, M. H. (2012). Comparative assessment of single-stage and two-stage anaerobic digestion for the treatment of thin stillage. Bioresource Technology, 111, 122–126. https://doi.org/10.1016/j.biortech.2012.02.019

[317] Drosg, B., Fuchs, W., Meixner, K., Waltenberger, R., Kirchmayr, R., Braun, R., & Bochmann, G. (2013). Anaerobic digestion of stillage fractions – estimation of the potential for energy recovery in bioethanol plants. Water Science & Technology, 67(3), 494–505. https://iwaponline.com/wst/article/67/3/494/17234/Anaerobic-digestion-of-stillage-fractions

[318] Harnessing the Residual Nutrients in Anaerobic Digestate for Ethanol Fermentation and Digestate Remediation Using Saccharomyces cerevisiae; Victor Chinomso Ujor et al; Fermentation Journal 2020, 6, 52; doi:10.3390/fermentation6020052

Table 39: Biomass fuel properties

Property	Stover	Husks and fines
Calorific Value (CV)	16.5-18.5 MJ/kg[319]	14.85 MJ/kg (dry basis)[320]
Moisture Content	10-15% (air-dried); up to 30% (fresh)[321]	10-12%[322]
Ash Content	3-6%[323]	3-5%[324]
Ash Composition	K, Ca, Si, Mg, P; trace Na, Cl, Fe	K, Ca, Si, Mg, P; trace Na, Cl, Fe
Bulk Density	170-180 kg/m³ (loose); 600-800 kg/m³ (briquetted)[325]	130-150 kg/m³[326]

Sources: Jenkins et al. (1998) Biomass fuel properties; Demirbaş (2004) Combustion characteristics of biomass; FAO agricultural residue data; Vassilev et al. (2010) biomass composition

Working on the assumptions that i) the Bio-ethanol plant will be either in the Free State Province or the Northwest and ii) coal is not available as a fuel option due to climate finance limitations, then the limited options available for an on-site CHP plant for a bio-refinery are biomass and gas with Solar PV and BESS as a complementary option for electricity. We compare the fuel costs of the by-products listed above with natural gas as a measure of the alternatives available.

[319] Morales, Marina Moura, Aaron Kinyu Hoshide, Leticia Maria Pavesi Carvalho, and Flavio Dessaune Tardin. 2024. "Sorghum Biomass as an Alternative Source for Bioenergy" Biomass 4, no. 3: 1017-1030. https://doi.org/10.3390/biomass4030057

[320] Morales, Marina Moura, Aaron Kinyu Hoshide, Leticia Maria Pavesi Carvalho, and Flavio Dessaune Tardin. 2024. "Sorghum Biomass as an Alternative Source for Bioenergy" *Biomass* 4, no. 3: 1017-1030. https://doi.org/10.3390/biomass4030057

[321] Evaluation of constitutive conditions for production of sorghum stover; J. O. Olaoye; Arid Zone Journal of Engineering, Technology and Environment, June 2017; Vol. 13(3):398-410; Print ISSN: 1596-2490, Electronic ISSN: 2545-5818, www.azojete.com.ng

[322] Effect of moisture content on engineering properties of sorghum grains; Gely et al; Journal for Agricultural Engineering Vol 19, No.2; August 2017.

[323] Critical review of the role of ash content and composition in biomass pyrolysis; Lokeshwar Puri et al; Frontiers in Fuels; Front. Fuels, 08 March 2024 Volume 2 - 2024 | https://doi.org/10.3389/ffuel.2024.1378361

[324] Prximate and Fibre Fractions of selected cereal husks processed manually and mechanically for ruminant production; Abdurrahaman et al; FUDMA Journal of Agriculture and Agricultural Technology; Vol. 7 No. 2, December 2021: Pp.170-174; https://doi.org/10.33003/jaat.2021.0702.063

[325] Morales, Marina Moura, Aaron Kinyu Hoshide, Leticia Maria Pavesi Carvalho, and Flavio Dessaune Tardin. 2024. "Sorghum Biomass as an Alternative Source for Bioenergy" Biomass 4, no. 3: 1017-1030. https://doi.org/10.3390/biomass4030057

[326] Engineering properties of sorghum; Surpam TB et al; International Journal of Chemical Studies 2019; 7(5): 108-110; https://www.chemijournal.com/archives/2019/vol7issue5/PartC/7-4-768-408.pdf

Table 40: Fuel cost comparison

Fuel	Estimated Cost (R per GJ)	Comment
Natural Gas	R 300 - R320	The estimated cost of CNG delivered to 200km outside of Johannesburg considering the lack of pipeline gas in the areas considered for bioethanol. The use of natural gas is at risk of a supply shortage considering the medium-term decline of the Mozambique gas fields and now the resurgence of Isis.
Grain Sorghum Stover	R120 - R 167	The price of stover as a fuel has to compete with the feed value of the stover on field. Transport is a major consideration.
Sweet Sorghum Bagasse	R88 - R 106	Sweet sorghum bagasse is used on farm as a fuel for the syrup concentration process. This results in a fuel risk for the bio-ethanol plant. Transport is a major consideration

Sources: Department of Mineral Resources and Energy (DMRE) gas market data; Central Energy Fund (CEF) and NERSA energy price benchmarks; IEA Bioenergy Task 43 (biomass supply and logistics costs); South African grain and residue market data (SAGIS; BFAP); own synthesis and cost modelling assumptions.

5.8 Solar PV and BESS

To support on-site electricity needs for the grain sorghum bio-ethanol plant, a solar photovoltaic (PV) system integrated with a Battery Energy Storage System (BESS) can provide a reliable and sustainable power solution. The solar PV array would be sized to meet daytime electricity demands, particularly for operations like milling, fermentation control, and auxiliary systems. Excess solar energy generated during peak sunlight hours would be stored in the BESS, which ensures power availability during cloudy periods and nighttime operations. This setup reduces dependency on grid electricity, lowers operational costs, and enhances energy resilience. Additionally, the system can be designed to operate in parallel with the biomass CHP plant, allowing for hybrid energy management and load balancing. The integration of solar and storage also supports sustainability goals and can contribute to ISCC certification by reducing the carbon footprint of the ethanol production process.

5.9 Optimum energy mix for a bio-ethanol plant

The eventual energy supply mixture will depend on the availability of resources. However, below is a possible energy supply scenario for the bio-ethanol plant.

Table 41: Energy supply mix for a bioethanol plant

Type	Comment
Anaerobic Digestion	AD will only use on-site generated materials and has the potential to produce up to 40% of thermal energy requirements and 30% of electricity needs of a large grain sorghum bio-ethanol plant.
Combustion	The steam combustion CHP plant will supply the rest of the steam requirements for the plan and ramp up during nighttime to produce electricity.
Solar PV and BESS	The solar PV array would be sized to meet daytime electricity demands. Excess solar energy generated during peak sunlight hours would be stored in the BESS, which ensures power availability peak periods.

Sources: International Energy Agency (IEA) Bioenergy Task 37 (biogas) and Task 33 (thermal gasification and CHP); U.S. Department of Energy (DOE) Bioenergy Technologies Office; NREL (Humbird et al., 2011) ethanol plant design; IRENA renewable energy integration reports

The mix sketched here is illustrative and fairly sensible. AD converts unavoidable wet residues into firm heat and some power, but its output is load-following only within limits-yields swing with COD, temperature and dilution, so the CHP boiler remains the dispatchable anchor for both steam and nighttime electricity. Solar PV + BESS lowers daytime grid/CHP draw and curbs operating costs, yet its value hinges on right-sizing storage (hours, not minutes), round-trip losses, and seasonal irradiance; expect PV/BESS to shave peaks rather than replace firm capacity. The operational nuance is coordination: keep CHP turndown/ramp rates compatible with PV swings, use biogas first for baseload steam (displacing purchased fuel), and let battery dispatch cover short ramps/peaks while CHP covers nights and contingencies. Financially, the blend diversifies energy risk and carbon intensity, but bankability depends on stable AD feedstock management.

5.10 ISCC certification and carbon credit benefits

Considering the financing requirements for a bio-ethanol plant in South Africa, accessing international markets and carbon finance mechanisms make international sustainability certification essential. Among the leading schemes, ISCC (International Sustainability and Carbon Certification) stands out for its global recognition and compatibility with carbon credit systems. ISCC is a globally applicable certification system that verifies sustainability, traceability, and GHG reductions across the biofuel supply chain. It is recognized under the EU Renewable Energy Directive (RED II) and accepted in markets like Japan, Canada, and California, making it ideal for South African producers targeting export markets.[327] Key benefits of ISCC certification include:

i. Improved market access into regulated biofuel markets.
ii. GHG Verification support which carbon credit eligibility and facilitates participation in carbon markets like the EU ETS and voluntary offset schemes for eligible projects.[328]

[327] ISCC – International Sustainability & Carbon Certification, SGS Website; https://www.sgs.com/en-za/services/iscc-international-sustainability-and-carbon-certification

[328] Global Carbon Reduction Opportunities for US Fuel Ethanol Producers; www.grains.org/bioethanol

ISCC certification offers a robust pathway for South African grain sorghum bio-ethanol producers to access international markets and carbon finance. Compared to other schemes, ISCC provides the best balance of market access, carbon credit compatibility, and operational flexibility. When combined with regenerative practices and carbon farming, ISCC can unlock long-term financial and environmental benefits. ISCC certification allows producers to quantify and verify GHG reductions, which can be monetized through carbon credits. Carbon credits can be sold to buyers seeking offsets, generating additional revenue streams. This is particularly valuable in South Africa, where carbon pricing mechanisms are emerging for example:

i. The EU market requires 50-60% CI reduction for biofuels, achievable with ISCC-certified sorghum ethanol.
ii. Japan accepts ISCC PLUS for low-carbon ethanol imports.
iii. ISCC PLUS supports participation in voluntary offset schemes and corporate sustainability programs.

Table 42: ISCC comparison with other certification systems

Standard	Strengths	Limitations
RSB (Roundtable on Sustainable Biomaterials)	High environmental and social standards; strong ILUC safeguards; supports carbon farming and regenerative agriculture.[329]	More complex and costly audits; less widespread market recognition than ISCC.
VERRA (Verified Carbon Standard)	Focused on carbon credit generation; widely used in voluntary carbon markets.	Not a biofuel-specific sustainability certification; requires separate sustainability verification. Requires specific methodologies.
REDcert & 2BSvs	EU RED II compliance; suitable for European biofuel markets.	Regional focus; less flexible for global trade.
ISCC	Recognized in multiple jurisdictions. Integrated GHG accounting. Supports multiple feedstocks including sorghum. Compatible with voluntary and compliance carbon markets. [330]	Requires robust data collection and audit readiness.

Sources: RSB (Roundtable on Sustainable Biomaterials) Principles & Criteria; Verra (Verified Carbon Standard) programme documentation; European Commission RED II Directive (EU) 2018/2001; REDcert and 2BSvs scheme documentation; ISCC (International Sustainability and Carbon Certification) system documents; own synthesis.

[329] https://rsb.org/certification/certification-schemes/
[330] https://www.sgs.com/en-za/services/iscc-international-sustainability-and-carbon-certification

6. Risk Analysis

Risk diagnostics are critical in agricultural value chains.
The analysis assessed vulnerability to climate variability, which is particularly critical for sorghum given its role as a climate-resilient crop in semi-arid regions. Understanding how droughts, erratic rainfall, and temperature extremes impact yields, enables identification of adaptive strategies. Risk profiles have been developed for small-scale versus commercial sorghum producers, recognising that commercial farmers may have better access to inputs, technology, and markets, but also face risks related to price volatility and export market fluctuations. By addressing these agronomic, economic, and institutional barriers, the study informs targeted interventions that can enhance sorghum productivity, improve market integration, and ultimately strengthen the livelihoods of smallholder farmers while supporting the growth of commercial sorghum production.

By capturing both natural (climatic, pest-related) and institutional risks (finance, extension services), it addresses the dual challenges facing smallholder and commercial farmers. The report places emphasis on differentiated risk profiles and speaks to the respective components of the sorghum value chain and focuses on risks that could affect the successful implementation of sorghum projects in South Africa. The scope of this assessment includes all value chains of sorghum to end-products, with specific emphasis on the sorghum to bio-ethanol value chain. The objective of this risk assessment is to proactively identify potential risks that may impact the success of sorghum projects in South Africa and evaluate their likelihood and potential impact.

6.1 Risk identification

The establishment of sorghum value chains could have several risks associated with feedstock availability, cultivation, processing technology, market dynamics, environmental aspects, and social impacts along the value chain for grain sorghum to bioethanol and the value chain for sweet sorghum to bioethanol.

I. Input supply and farming: commercial farmers

A. Weak market demand / low offtake for sorghum

The dominance of maize in the South African grain economy marginalises sorghum, making it a niche commodity rather than a staple. Commercial sorghum farmers in South Africa face the challenge of weak market demand. Unlike maize, which is widely used for human consumption, animal feed, and industrial applications, sorghum demand remains limited at both consumer and industrial levels. This relatively low offtake translates into depressed farm-gate prices, discouraging farmers from expanding their production base. The absence of a robust and consistent demand base therefore undermines the profitability and scalability of commercial sorghum farming.[331] The limited end-user demand and weak market signals discourage investment in technology, mechanisation, and improved production practices for sorghum. This low demand perpetuates low production, constraining the growth of a competitive sorghum value chain.

B. Failed past biofuel / industrial initiatives creating market uncertainty

A history of failed industrial initiatives, particularly in biofuels, has created market uncertainty for sorghum growers. Over the past two decades, government and private-sector stakeholders have proposed multiple plans to use sorghum as a feedstock for ethanol and renewable energy. However, all these initiatives were halted before reaching commercial viability due to regulatory delays, funding shortfalls, or shifts in policy priorities. Farmers who invested in expanding sorghum cultivation in anticipation of these opportunities were left with unsold stock and financial losses.[332] This has eroded trust between farmers and potential industrial offtakers. As a result, commercial farmers remain reluctant to allocate land and capital to sorghum production without proof of consistent industrial demand. This uncertainty hinders long-term strategic planning, reinforcing the crop's marginal status in South Africa's grain sector.

C. Competition with other grains and uses

Price competition with maize presents a persistent barrier to sorghum's growth. Maize enjoys economies of scale, extensive market penetration, and entrenched supply contracts with millers and feed manufacturers, making it a more attractive option. Sorghum, by contrast, is often unable to match maize's lower cost, forcing it to compete in a market where price-sensitive buyers, such as feed processors, opt for the cheaper grain.[333] This price disadvantage is compounded by buyer preferences and established infrastructure tailored to maize. Even when sorghum demonstrates agronomic benefits, such as drought resilience, buyers may not see sufficient incentive to shift from the cheaper, more predictable maize supply chain. The result is that sorghum production remains uncompetitive on cost grounds, creating a barrier to scaling commercial output.

There is competition between bioethanol and other uses of sorghum biomass. In many rural South African contexts, sorghum stover and bagasse are essential for livestock feed, household fuel, or traditional brewing.[334] Diverting sweet sorghum stalks to bioethanol production may undermine these uses, raising concerns over food-feed-fuel trade-offs.[335] This competition can discourage farmer participation unless bioethanol markets offer significantly higher returns, which has not been consistently demonstrated.

D. Feedstock availability fluctuations

South Africa's sorghum production has been in long-term decline, falling from over 300,000 tonnes per annum in the 1980s to less than 100,000 tonnes per annum in recent years. This decline is compounded by significant year-to-year fluctuations caused by changing weather conditions, input use, and limited

[331] Sihlobo W. (2025). Agricultural Production: The troubling decline of the South African sorghum industry. https://wandilesihlobo.com/2025/05/04/the-troubling-decline-of-the-south-african-sorghum-industry/

[332] Sihlobo W. (2025). Agricultural Production: The troubling decline of the South African sorghum industry. https://wandilesihlobo.com/2025/05/04/the-troubling-decline-of-the-south-african-sorghum-industry/

[333] SAGIS, 2025, International Probe, Issue No 50 and previous notes from the South African Grain Information Service, The Sorghum Trust

[334] FAO (2019). The State of Agricultural Commodity Markets: Trade and Food Security. Rome: Food and Agriculture Organization of the United Nations.

[335] Pereira, L. M., et al. (2022). "Leveraging the potential of sorghum as a healthy food and sustainable crop." Frontiers in Sustainable Food Systems.

farmer uptake. Such variability makes it difficult for processors to rely on sorghum as a consistent feedstock, reducing incentives for long-term industrial partnerships.[336] While processors demand consistent supply before committing to investment, farmers are unable to provide such stability without guaranteed demand. The result is a fragmented and unreliable supply chain that undermines the commercial viability of large-scale sorghum farming.

E. Limited commercial processing capacity and technology

Most grain processing facilities in South Africa are optimised for maize and wheat, leaving little capacity for sorghum-specific milling and conversion. Retrofitting milling equipment to handle sorghum requires significant capital expenditure, which processors are often reluctant to undertake in the absence of guaranteed demand volumes. [337] This technological mismatch restricts farmers' market options, forcing them to sell into limited outlets at lower margins. The lack of investment in dedicated sorghum processing capacity thus prevents the establishment of an integrated value chain capable of driving economies of scale. Without downstream product demand pull, upstream commercial production remains constrained.

F. Land use conflicts

The decision to cultivate sweet sorghum for ethanol or food production creates land allocation conflicts. While ethanol requires high-yielding cultivars grown on relatively fertile soils to ensure profitability,[338] these same lands could otherwise be used to grow sorghum varieties more suitable for food. Farmers may prioritise ethanol contracts for higher returns, but this reallocates land away from food production, particularly in areas already facing food security challenges.[339] The result is a structural trade-off in how scarce arable land is used, with potential long-term implications for rural resilience.

G. Land use conflicts Inadequate value-chain coordination

Commercial sorghum farmers face the challenge of inadequate value-chain coordination. This means that farmers operate in fragmented markets with limited bargaining power. The absence of structured off-take agreements or fixed market prices (there is no fixed SAFEX Feeds price for sorghum) creates uncertainty about market access and exposes farmers to price volatility. [340]. This lack of coordination also makes it difficult to achieve consistent quality and volume, both of which are essential for developing long-term relationships with industrial buyers. Without institutional support for value-chain organisation, individual commercial farmers are left to navigate a risky and uncertain market environment, further deterring investment.

H. Policy and support gaps

Sorghum lags maize, wheat, and soybeans in terms of research and development (R&D) investment, government subsidies, and targeted procurement support. This reduces sorghum's competitiveness and limits the innovation needed to enhance yields and marketability. For instance, the absence of state-led

---

[336] Sihlobo W. (2025). Agricultural Production: The troubling decline of the South African sorghum industry. https://wandilesihlobo.com/2025/05/04/the-troubling-decline-of-the-south-african-sorghum-industry/

[337] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[338] Rao, P., Reddy, B., Ramesh, S., & Ashok Kumar, A. (2019). "Sweet sorghum for biofuel and strategies for improvement." Sugar Tech, 21(5), 837–850.

[339] Lal, R., & Khanna, M. (2016). "Bioethanol potential of sweet sorghum: agronomic and environmental trade-offs." Renewable and Sustainable Energy Reviews, 63, 1–15.

[340] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

procurement incentives means that public institutions such as schools and hospitals rarely include sorghum-based products in their food supply chains. [341] [342]

The lack of structured policy frameworks also discourages private sector investment in sorghum-specific research and development. Without a deliberate effort to close these policy and support gaps, sorghum will remain at a disadvantage in competing with better-supported staple crops. The South African government has recently initiated legislative and regulatory amendments intended to foster more favourable market conditions for sorghum production as a feedstock for bioethanol fuel. These steps include the commissioning of value-chain feasibility studies, establishment of cluster initiatives, and consideration of tax policy adjustments. However, significant delays in developing and implementing critical legislation and in advancing supporting research programmes continue to impede the competitiveness of sorghum relative to other staple crops, such as maize and wheat.

I. Logistics and storage constraints for scale

Sorghum faces significant logistical and storage barriers. South Africa's grain handling and storage infrastructure - including silos, transport systems, and grading facilities - is geared toward maize and wheat. Sorghum often requires specialised cleaning and handling, but dedicated infrastructure is limited. This results in higher post-harvest losses and additional costs for commercial farmers. [343] Without dedicated investment in sorghum-friendly storage and logistics systems, commercial-scale production is constrained by inefficiencies. Farmers incur higher costs to access limited facilities, eroding margins and reducing competitiveness against other grains with better-integrated infrastructure.

J. Climate variability and extreme weather exposure at scale

Although sorghum is widely recognised as more drought-tolerant than maize, it is not immune to the effects of extreme weather. The most important climate change risk is increased temperature. This affects rainfall and seasonal patterns on a global scale. It also affects plants' phenological growth (phases in the plant's development which require certain thresholds of sunlight, heat and moisture) and physical growth and exposure to pests and diseases.[344] [345]
Sweet sorghum yield is extremely sensitive to extended dryness, high temperatures during flowering and sever rains, which can cause lodging and decreased sugar buildup, even though it is drought-tolerant. This will lead to a reduced ethanol yield due to decrease in the volume of stalk juice and the concentration of fermentable sugar. South Africa's increasingly variable climate, marked by recurrent droughts, erratic rainfall, and heatwaves, has led to unpredictable yields even on large-scale farms. This variability heightens the production risk for commercial farmers who depend on stable output to meet contractual obligations. [346]

The financial implications of climate variability are significant. Because of price instability for sorghum, crop insurance schemes are often poorly tailored to sorghum production risks, while yield losses directly

---

[341] Derek Hanekom, Department of Agriculture and Land Reforms - Agricultural Policy in South Africa: Discussion Document, Pretoria, 1998

[342] Taylor, J. (2025). Stakeholder interview 23 September 2025.

[343] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[344] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[345] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[346] SNV (2022). Climate-Smart Sorghum Production Guide. Netherlands Development Organisation.

affect profitability. This makes commercial farmers more risk-averse, reducing their willingness to expand sorghum cultivation in the absence of robust climate adaptation mechanisms.

K. Pest, disease and agronomic constraints

Commercial sorghum farmers face a persistent challenge from pests, parasitic weeds, and diseases. Striga (witchweed) is a major constraint, reducing yields and requiring costly management interventions. Birds, stem borers, and other pests can also inflict significant damage on sorghum fields, often at a scale that makes losses economically severe.[347] Pests and disease risk factors for sweet sorghum include head smut (*Sporisorium reilianum*), aphids, shoot flies (*Atherigona spp.*), and stem borers (*Chilo partellus*). Disease and pest outbreaks lower juice quality and stalk output. This can lead to reduced net ethanol output and higher input costs (pesticides).

The lack of R&D investment into these constraints raises the management burden on farmers, increasing input costs including pesticides, resistant seed varieties, and crop monitoring labour. For large-scale farmers, these costs erode competitiveness relative to maize, which benefits from broader pest management support systems and genetically modified cultivars for pest resistance.

L. Access to suitable seed and improved varieties at scale

Access to high-yielding, pest-resistant sorghum hybrids is critical for commercial-scale operations, but such seed is often unavailable or limited in South Africa. Private seed companies have historically underinvested in sorghum breeding programmes compared with maize, resulting in fewer options for farmers. The lack of seed diversity restricts farmers' ability to adopt varieties suited to different climatic zones and market needs. [348] Public entities such as the Agricultural Research Council (ARC) have also failed to diversify its R&D into more drought resistant crops and have mainly focused on developing high output maize seed variants. This shortage also undermines productivity, as farmers must rely on older or less-adapted varieties that deliver lower yields and inconsistent quality. Without greater investment in seed systems, commercial farmers remain disadvantaged in achieving the scale and efficiency necessary for competitive production.

M. Financing and working-capital risks tied to uncertain returns

Commercial sorghum farming faces significant financing risks. Banks and agricultural lenders are reluctant to provide affordable credit for sorghum production due to limited markets, uncertain returns, market price uncertainty and lack of established futures contracts. This makes production finance more costly or inaccessible, limiting farmers' ability to invest in inputs, mechanisation, and risk management strategies.[349] Uncertain cash flows further exacerbate this challenge. When offtake is unpredictable and prices are volatile, farmers struggle to meet repayment obligations, leading to financial insecurity. Without improved market certainty and risk-sharing mechanisms, financing will remain a significant barrier to commercial sorghum expansion.

II. Input supply and farming- smallholder farmers

Up to 70% of households in South Africa source food from informal markets, however, with the rising rate of urbanisation and increasing availability of 'cheap, processed foods', this figure is declining,

[347] Diatta-Holgate et-al, Heliyon - Farmers' production constraints, preferred varietal traits and perceptions on sorghum grain mold in Senegal, p2-10, 2024

[348] Taylor, J. (2025). Stakeholder interview 23 September 2025.

[349] Esterhuizen, Millets & Indigenous Crops event materials (2023)

putting at risk the livelihoods of small farmers and informal traders.[350] A few smallholder farmer production schemes have been implemented, but the lack of seed stock, lack of offtake agreements and distance to processing facilities, with associated logistics costs and lack of markets have made it unprofitable to produce, other than for household use.

A. Limited land size and insecure tenure

The geographical location of smallholder farms is a direct result of historical patterns of dispossession and impoverishment imposed through apartheid legislation. The system fostered settlement of black people in marginal areas (former 'homelands'), with limited agricultural potential in terms of soil fertility and climate. Most farms are smaller than two ha, and hence the farmers face the challenge of the inadequacy of farmland. [351] These small plots limit the scale at which sorghum can be cultivated, reducing the potential for economies of scale and constraining household income from farming. [352]

Many smallholder farmers face insecure tenure arrangements, particularly in communal areas where land is allocated by traditional authorities rather than formal titles. [353] [354] Without secure rights, farmers are less likely to make long-term investments in soil fertility, irrigation, or improved sorghum varieties. This insecurity also undermines access to formal finance and government programmes, since land is frequently used as collateral or as a basis for eligibility. As a result, smallholder sorghum production suffers from low-input and low-output cycles that perpetuate subsistence-level farming rather than enabling market-oriented growth.

B. Low access to improved seed and inputs

A barrier to sorghum productivity on smallholder farms is limited access to improved seeds and the tendency to use grain from previous harvests as seed for the subsequent growing season, which reflects a lack of sufficient investment in improved inputs for sorghum production. Smallholder farmers often rely on recycled or indigenous sorghum seed, which, while adapted to local conditions, generally delivers lower yields compared with improved hybrids. Access to commercial seed markets is limited by affordability and availability, leaving smallholder farmers unable to access the productivity gains offered by modern breeding. The use of the previous crops' grain as seed for the next season is negatively influenced by a loss of quality during storage.[355] [356] Similarly, smallholder farmers struggle to access essential inputs such as fertilisers, herbicides, and pesticides, which further suppress yields.

The lack of mechanisation compounds these challenges. Without tractors, planters, or even basic animal traction, planting and weeding are delayed, resulting in poor crop establishment and lower output. Consequently, the productivity gap between smallholder farmers and commercial sorghum producers remains wide, perpetuating inequality in the sector.

---

[350] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[351] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[352] Black Agricultural Commodities Federation (BACF). 12 September 2025. Stakeholder Interview.

[353] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[354] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A Review. https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[355] Sorghum value-chain and workshop materials (Kansas State / national plans). 2023

[356] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

C. Poor access to extension services, research and technical support

Sorghum has historically attracted less research and extension investment than maize or wheat in South Africa, leaving smallholder farmers with limited access to updated production knowledge. Farmers often lack exposure to improved agronomic practices, such as optimal planting times, intercropping strategies, or water-conserving methods that could significantly improve yields.[357]

Institutional support such as extension services in smallholder systems is frequently limited. This is worsened by the long-standing challenge of institutionalised inefficiencies in extension services provision, due to government departments responsible for supporting farmers making poor use of the resources at their disposal. Some extension officers have limited knowledgeable with sorghum, which further compounds the problem of inadequate institutional support systems.[358] Without consistent support from extension agents, knowledge transfer remains limited and informal.

This gap is especially problematic in the light of climate change pressures. Smallholder farmers need tailored advice on climate-smart production practices, pest management, and soil conservation. However, many remain excluded from structured training or research outreach. As a result, their adaptive capacity remains weak, exposing them to greater vulnerability in production and income terms.

D. Post-harvest losses from lack of storage and processing

Post-harvest losses represent a significant barrier for smallholder sorghum farmers. Without access to adequate on-farm storage facilities, sorghum grain is vulnerable to mould, pest damage, and contamination. The absence of drying and cleaning technologies further leads to quality downgrades, making it difficult for smallholder farmers to meet market standards.[359][360]

Post-harvest losses reduce feedstock availability and undermine household food security. For smallholder farmers who aim to sell into local or regional markets, these quality issues reduce bargaining power and limit their ability to access higher-value buyers. Investment in community-level storage and small-scale processing facilities could address these challenges, but such initiatives remain scarce.

Sweet sorghum stalks are prone to rapid sucrose degradation once harvested, with significant reductions in sugar content occurring within 24-48 hours[361]. This creates logistical and technical risks in transporting feedstock to processing facilities, particularly in regions with weak road infrastructure. Farmers and processors must operate in close geographical proximity, but land availability and tenure challenges often restrict such co-location.[362] The perishable nature of stalks thus increases transaction costs and limits the scalability of ethanol production.

E. Weak market linkages and low bargaining power

[357] Pereira, L. M., et al. (2022). “Leveraging the potential of sorghum as a healthy food.” Frontiers in Sustainable Food Systems.

[358] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[359] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[360] Black Agricultural Commodities Federation (BACF). 12 September 2025. Stakeholder Interview.

[361] Gnansounou, E., Dauriat, A., & Wyman, C. (2005). “Refining sweet sorghum to ethanol and sugar: economic trade-offs in the context of North America, Europe, and India.” Bioresource Technology, 96(9), 985–1002.

[362] Lal, R., & Khanna, M. (2016). “Bioethanol potential of sweet sorghum: agronomic and environmental trade-offs.” Renewable and Sustainable Energy Reviews, 63, 1–15.

Market access is a persistent constraint for smallholder sorghum producers. Many farmers sell their grain informally or directly at the farm gate, where buyers set prices far below market value. Transaction costs, such as transport to central markets, are often prohibitively high, leaving smallholder farmers dependent on opportunistic traders who exploit their weak bargaining position.[363]

The absence of farmer cooperatives and aggregation mechanisms further weakens their position. Without collective bargaining mechanisms, smallholder farmers cannot negotiate better terms or access structured contracts with millers and processors. This prevents smallholder farmers' access to higher-value markets, discouraging investment in improved production. Sorghum farming could benefit from collaborative ventures in the form of collective purchasing of inputs, shared use of farming equipment, or joint marketing strategies. Such collective endeavours can significantly lower operational costs, mitigate risks, and enhance market access, thereby improving the feasibility profile of the sorghum farming venture. [364]

F. Climate vulnerability and resource degradation

Smallholder sorghum production typically occurs on marginal land with declining soil fertility and poor access to irrigation. Over-cultivation and reliance on rainfed systems make these farms particularly vulnerable to climate variability. Erratic rainfall, rising temperatures, and prolonged droughts significantly reduce yields and increase production risks. [365] Dryland agricultural production increases the susceptibility of crops to rainfall variability and uncertainty, dry spells and droughts. Moisture stress and heat stress, which often occur concurrently, are key factors that limit sorghum yields in South Africa.[366] [367]

Furthermore, resource degradation, including soil erosion and nutrient depletion, compounds climate pressures. Many smallholder farmers lack the resources to implement soil conservation measures or diversified cropping systems, leaving them exposed to environmental fluctuations. This vulnerability reduces productivity and household resilience.

Continuous sorghum cultivation without adequate fertiliser application or crop rotation often leads to nutrient depletion in already marginal soils. Soil fertility has been identified as one of the constraints to sorghum productivity, in addition to weed infestation - specifically Striga, which is a symptom of depleted soil fertility. Thus, inadequate soil fertility significantly impacts sorghum productivity on smallholder farms. Over time, this reduces yields and accelerates land degradation, threatening the sustainability of smallholder production.[368] [369]

---

[363] Pereira, L. M., et al. (2022). "Leveraging the potential of sorghum as a healthy food." Frontiers in Sustainable Food Systems.

[364] Nkosi, Z.; Marwa, N.; Akinrinde, O.O. Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture 2025, 15, 2348. https://doi.org/10.3390/agriculture14122348

[365] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[366] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[367] Assan Ng'ombe, Mupangi Sithole, Collins Muimi Musafiri, Milka Kiboi, Tomas Sales and Felix Ngetich, (2023), Sustainability 2023, 15, 15107. https://doi.org/10.3390/su152015107

[368] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[369] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

Expansion into fragile ecosystems can reduce biodiversity and increase vulnerability to pests and diseases. Without interventions to promote sustainable intensification - such as intercropping, organic amendments, resilient variety selection, use of marginal land, agroecological approaches or sustainability planning - smallholder sorghum farming risks undermining the land resource on which it depends.[370] [371]

Although sorghum is widely recognised as drought-tolerant, sweet sorghum varieties grown for bioethanol have relatively high water and fertiliser requirements to achieve commercially viable sugar yields.[372] In water-scarce regions of South Africa, this presents a sustainability dilemma: large-scale irrigation for sweet sorghum bioethanol production may compete with water needed for food crops and domestic use. This undermines the crop's "climate-smart" reputation and raises environmental justice concerns in rural communities.

G. Labour constraints and competing household needs

Smallholder households often face severe labour shortages, particularly during peak planting and harvesting periods. Rural outmigration and seasonal off-farm employment reduce the availability of household labour, while competing demands such as childcare and household food preparation further limit time spent in the fields.[373] Many households prioritise staple food security over market-oriented sorghum production. As a result, land and labour allocation often favour subsistence crops like maize or vegetables, leaving sorghum as a secondary or neglected option. This undermines the potential for smallholders to scale up sorghum production for commercial purposes.

H. Limited access to finance and insurance

Limited financial resources remain a pressing issue for many smallholder farmers, restricting their ability to invest in quality inputs such as high-yield seeds, fertilisers, and modern farming equipment. Furthermore, if farmers cannot put up fencing, animals eat and damage the plants. Policies enhancing farmers' access to credit and financial services can have a transformative effect on sorghum planting, for example microfinance programs and government-backed loan schemes could significantly boost smallholder productivity. Therefore, applying such support mechanisms can empower farmers expand their cultivation efforts and adopt best practices that enhance yields.[374] [375]

Financial exclusion is a major barrier for smallholder sorghum producers. Without formal collateral such as land titles, farmers struggle to access affordable credit from banks and microfinance institutions. This limits their ability to purchase improved inputs, hire mechanisation services, or invest in storage facilities.[376] Insurance options are also scarce. While index-based weather insurance schemes have

---

[370] Bacenetti, J., Negri, M., Fusi, A., & Fiala, M. (2016). Potential environmental impact of bioethanol production chain from fiber sorghum to be used in passenger cars. Biomass & Bioenergy, 85, 290–299. https://www.researchgate.net/publication/316451747_Potential_environmental_impact_of_bioethanol_production_chain_from_fiber_sorghum_to_be_used_in_passenger_cars

[371] Yao, X., Chen, J., & Yang, S. (2021). Phytoremediation potential of sweet sorghum in cadmium-contaminated soils and its dual-use for bioethanol. Journal of Land Science & Engineering, 3(2), 118–131. https://jlse.springeropen.com/articles/10.1186/s42825-021-00074-z

[372] Rao, P., Reddy, B., Ramesh, S., & Ashok Kumar, A. (2019). "Sweet sorghum for biofuel and strategies for improvement." Sugar Tech, 21(5), 837–850.

[373] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[374] Nkosi, Z.; Marwa, N.; Akinrinde, O.O. Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture 2025, 15, 2348. https://doi.org/10.3390/agriculture14122348

[375] Black Agricultural Commodities Federation (BACF). 12 September 2025. Stakeholder Interview.

[376] Kamara, et al; Improving the Productivity and Income of Smallholder Sorghum Farmers: The Role of Improved Crop Varieties in Nigeria; 2025

been piloted in some areas, coverage remains limited and premiums unaffordable for many smallholder farmers. This leaves them exposed to crop failure risks, discouraging them from investing in sorghum production and perpetuating low productivity.

I. Social / cultural stigma and changing dietary preferences

Sorghum has historically been a staple grain in many South African communities, but younger generations increasingly prefer maize, rice, and wheat-based foods. This shift in dietary preferences has reduced household demand for sorghum and diminished its cultural importance. For smallholder farmers, this means reduced incentives to grow sorghum for market purposes, as local demand weakens.[377] Sorghum is sometimes viewed as a "poor man's crop," reinforcing stigma and discouraging its cultivation among households seeking status and modernity. This cultural barrier undermines smallholder willingness to invest labour and land in sorghum production, especially when alternative crops carry greater social and economic value. Mostly, the negative attitudes are underpinned by lack of knowledge, as many people are unaware of the numerous value-added products derived from sorghum, the health benefits, or the availability of an existing local market.[378]

J. Policy neglect and poor inclusion in programmes

Smallholder sorghum producers are often overlooked in national agricultural programmes, which prioritise maize, wheat, and soybean. This neglect manifests in reduced research funding, fewer subsidies, and the absence of targeted procurement policies that could provide stable markets for sorghum.[379] Smallholder farmers have limited opportunities to access input support, training, and guaranteed off-take markets. Without deliberate inclusion in policy frameworks, sorghum production risks being further marginalised, weakening both household livelihoods and the potential to diversify South Africa's grain economy.

K. Limited access to mechanisation and appropriate equipment

Mechanisation gaps significantly constrain smallholder sorghum production. Most smallholder farmers rely on manual labour for planting, weeding, and harvesting, which is time-consuming and limits the size of land that can be cultivated. Appropriate small-scale equipment such as planters, threshers, and dryers tailored to sorghum are either unavailable or unaffordable.[380] The absence of such technology leads to high labour intensity and post-harvest losses, particularly during threshing and drying stages. Without investment in mechanisation solutions suited to smallholder farmers, productivity gains will remain limited and household labour burdens will continue to constrain sorghum expansion.

L. Pests and diseases

Climate change poses an imminent threat to crop productivity due to the heat and moisture stress effects. These factors also influence pathogen-host interactions, and the emergence of novel pests and diseases has also become increasingly common. Bird damage and weevils are the most prevalent and serious challenges to sorghum production. An estimated 1 million migratory pests such as Quelea birds

---

[377] Sihlobo W. (2025). Agricultural Production: The troubling decline of the South African sorghum industry. https://wandilesihlobo.com/2025/05/04/the-troubling-decline-of-the-south-african-sorghum-industry/

[378] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[379] Derek Hanekom, Department of Agriculture and Land Reforms - Agricultural Policy in South Africa: Discussion Document, Pretoria, 1998

[380] SNV (2022). Climate-Smart Sorghum Production Guide. Netherlands Development Organisation.

can destroy up to four tonnes of small grain crops per day, which can result in a complete loss of harvest, which in turn can have a major impact on the shunning of small grains as choice crops. [381] [382]

M. Educational outreach and technological advancement

Farmer education and the use of modern technologies are important. Training programs and educational initiatives bridge the knowledge gap, equipping farmers with the skills needed to implement sustainable and efficient farming practices. For example, incorporating remote sensing and advanced irrigation techniques can optimise water usage and help manage crops more effectively. Farmers with access to ongoing education and technological resources are more adaptable to environmental challenges and market fluctuations. [383]

6.2 Feedstock/inputs to the rest of the value chain

I. Feedstock availability

In May 2025, the price of sorghum dropped by 24% in comparison to May 2024. The price of sorghum is also falling from month to month - in May 2025, it fell 21% from April 2025. The reason for this current trend in sorghum price declines is reduced market demand. However, to boost the market for sorghum products, a few initiatives are being pursued to revitalise sorghum in South Africa, including proposal to remove Value Added Tax (VAT).[384]

Feedstock availability remains the most critical cross-cutting challenge for the development of a competitive sorghum value chain in South Africa. Both the quantity and quality of sorghum production have been unreliable due to declining national output, inconsistent yields, and significant year-to-year variability driven by climate fluctuations and production practices. In addition, the limited availability of high-performing sorghum varieties restricts farmers' ability to deliver consistent grain volumes and quality. Post-harvest losses, estimated to reduce up to 30% of smallholder output in some areas, further compromise supply. For processors, this means that even where demand exists, securing a steady and homogenous flow of sorghum remains a persistent constraint.[385] [386]

II. Feedstock imports

Over the past two decades, the land allocated for sorghum cultivation has declined to about 25% of its peak. The relative competitiveness of sorghum has gradually weakened compared to the rapid technological advancements observed in maize and soybeans, which have benefited from substantial investments in new cultivars and advanced seed technologies integrated with nutrition and chemical applications. The risks associated with any high dependence on sorghum imports as a critical input to

[381] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[382] Black Agricultural Commodities Federation (BACF). 12 September 2025. Stakeholder Interview.

[383] Nkosi, Z.; Marwa, N.; Akinrinde, O.O. Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture 2025, 15, 2348. https://doi.org/10.3390/agriculture14122348

[384] National Agricultural Marketing Council (NAMC). (2025). Market Intelligence Report: Quarter 1, 2025.

[385] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[386] Sihlobo W. (2025). Agricultural Production: The troubling decline of the South African sorghum industry. https://wandilesihlobo.com/2025/05/04/the-troubling-decline-of-the-south-african-sorghum-industry/

the value chain include short term availability, as well as affordability influenced by the macroeconomic environment and the exchange rate.[387]

III. Feedstock imports Seed development

An increasing proportion of the sorghum cultivars being cultivated by farmers in South Africa are obtained from the major sorghum producing countries, especially Australia, in the form of imported seed. These cultivars are not ideal for South African climatic conditions, for example the heavy soils in the Mpumalanga province, and have susceptibility to some of the important sorghum pests prevalent in South Africa. Furthermore, as the seed is imported and not multiplied locally there is the risk of seed shortage as the foreign seed companies give preference to their local markets. Hence, if the issue of sorghum breeding is not addressed, sorghum farming productivity in South Africa will become progressively less competitive, unless it imports better cultivars from other regions, resulting in higher costs. Sorghum research has historically received less funding and attention compared to maize or wheat, resulting in fewer commercial hybrids available for widespread adoption. Farmers often depend on traditional or recycled seed, which is poorly aligned with market requirements such as grain size, tannin content, and milling properties. For processors, variability in sorghum characteristics complicates blending and reduces efficiency, ultimately discouraging investment in dedicated sorghum processing facilities. Building stronger seed systems and incentivising plant breeding programmes is therefore essential to unlock yield stability and quality consistency.[388] [389] [390]

IV. Farming technology advancement

Technological advancement affects the feasibility of sorghum farming, as it could accelerate modernising sorghum agricultural practices and increasing output. By accepting and integrating technological innovations, farmers may overcome conventional farming challenges, optimise resource utilisation, and considerably increase yield outputs. The ability of technology, such as remote sensing and advanced irrigation, to provide real-time, actionable data about crop health and other agronomic factors could improve yield prediction and optimise resource use, ultimately reducing risk and boosting farmer confidence. Furthermore, these technologies might change the sector through building a more data-driven, accurate approach to sorghum farming, reducing some of the economic constraints that farmers face. Alongside these technological improvements, knowledge-sharing programs are crucial to bridging traditional practices with modern agricultural approaches.[391]

6.3 Harvesting and logistics

I. Grain mould and harvest timing

The decision when to harvest is critical. Harvesting too early leads to immature grain with low dry matter and moisture issues; harvesting too late risks rain or humidity damage, grain mould, lodging (plants

[387] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[388] Taylor, J. (2025). Stakeholder interview 23 September 2025.

[389] Reddy, B.V.S., Ramesh, S., Ashok Kumar, A., Wani, S.P., Ortiz, R., Ceballos, H., & Sreedevi, T.K. (2009). Sweet sorghum for biofuel and strategies for its improvement. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). https://www.researchgate.net/publication/288493473_Sweet_sorghum_for_biofuel_and_strategies_for_its_improvement

[390] Nkosi, Z.; Marwa, N.; Akinrinde, O.O. Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture 2025, 15, 2348. https://doi.org/10.3390/agriculture14122348

[391] Nkosi, Z.; Marwa, N.; Akinrinde, O.O. Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture 2025, 15, 2348. https://doi.org/10.3390/agriculture14122348

falling over), increased losses. Humid weather during flowering to grain maturity increases fungal infection. Therefore, the sowing/harvest timing should be adjusted to avoid grain fill during those humid periods. In addition, registered fungicides should be used.[392] Late plantings, which delay harvesting, could increase ergot infections. In addition, disease pressure (such as leaf disease, and grain mould) increase losses and reduce grain quality. That implies that harvesting under disease stress or at suboptimal timing hurts yield and quality.

A key challenge with sweet sorghum for bioethanol lies in its short harvesting window. Unlike sugarcane, which can be harvested for up to nine months, sweet sorghum has a limited harvest period of approximately 3-4 months.[393] This creates bottlenecks in bioethanol production, as processing plants risk standing idle outside the harvesting season. Without systems for staggered planting or complementary feedstocks, plants struggle to maintain year-round operation, undermining economies of scale and profitability.

II. Post-harvest losses

A large portion of losses occur during harvesting or field drying, storage, and transport to the market.[394] Smallholder farmer practice of drying sorghum has been by directly placing it on the ground, exposing the grain to soil contamination, increasing the risk of pest infestation, and reducing the grain quality. Poor storage facilities provide a favourable environment for aflatoxin contamination. Therefore, promoting mechanisms through improved physical infrastructure development lowers the risk of contamination and prevents post-harvest losses.[395] [396]. Sweet sorghum stalks are prone to rapid sucrose degradation once harvested, with significant reductions in sugar content occurring within 24-48 hours.[397] This creates logistical and technical risks in transporting feedstock to processing facilities, particularly in regions with weak road infrastructure. Farmers and processors must operate in close geographical proximity, but land availability and tenure challenges often restrict such co-location.[398] The perishable nature of stalks thus increases transaction costs and limits the scalability of ethanol production.

III. Incorrect moisture content

Grain needs to be dry enough for safe harvesting, transport and storage. If the moisture content is too high, drying is required, which is costly. Alternatively, there is the risk of spoilage. Poorly calibrated machinery (headers, threshers) can damage grain (broken kernels), reduce quality or increase the opportunity for mould.

[392] Nkoko D, Flett B. (2024). The IMPACT of grain mould on sorghum. SA Grain. https://sagrainmag.co.za/2024/03/01/the-impact-of-grain-mould-on-sorghum/

[393] Rao, P., Reddy, B., Ramesh, S., & Ashok Kumar, A. (2019). “Sweet sorghum for biofuel and strategies for improvement.” Sugar Tech, 21(5), 837–850.

[394] APHLIS. (2020). South Africa, Sorghum, 2022. https://www.aphlis.net/en/data/tables/overview/ZA/sorghum/2022

[395] Mashingaidze, N.; Madakadze, C.; Twomlow, S.; Nyamangara, J.; Hove, L. Crop yield and weed growth under conservation agriculture in semi-arid Zimbabwe. Soil Tillage Res. 2012, 124, 102–110. https://www.sciencedirect.com/science/article/abs/pii/S016719871200112?via%3Dihub

[396] Assan Ng’ombe, Mupangi Sithole, Collins Muimi Musafiri, Milka Kiboi, Tomas Sales and Felix Ngetich, (2023), Sustainability 2023, 15, 15107. https://doi.org/10.3390/su152015107

[397] Gnansounou, E., Dauriat, A., & Wyman, C. (2005). “Refining sweet sorghum to ethanol and sugar: economic trade-offs in the context of North America, Europe, and India.” Bioresource Technology, 96(9), 985–1002.

[398] Lal, R., & Khanna, M. (2016). “Bioethanol potential of sweet sorghum: agronomic and environmental trade-offs.” Renewable and Sustainable Energy Reviews, 63, 1–15.

IV. Unavailability of machinery or harvest labour

One of the primary challenges lies in the mechanisation of harvesting. Small-scale producers lack access to capital-intensive mechanisation, relying instead on manual labour. Even among commercial farmers, equipment availability is limited.[399] Some farmers (especially smallholder farmers) may not have access to combine harvesters or may need to hire equipment. Hiring delays or poor maintenance of equipment can push back the harvest. The harvest season is labour-intensive. Therefore, shortages or high cost of labour can delay the harvest. While mechanised harvesters for sugarcane can, in theory, be adapted for sweet sorghum, there are substantial cost and efficiency barriers. Equipment customisation is costly because sorghum stalks are thinner and more fragile than cane. Lack of access to capital-intensive mechanisation leads to relying on manual labour, which is slower and leads to losses in sugar recovery[400]. Delays in harvesting lead to fermentation and sucrose losses, reducing the feedstock's suitability for ethanol or syrup production[401].

V. Logistics and infrastructure gaps

The sorghum-to-ethanol supply chain in South Africa faces key infrastructure gaps including insufficient storage facilities to prevent biomass spoilage, fragmented and dispersed production locations causing high transport costs, a lack of commercially scaled bioethanol processing plants for sorghum, and weak coordination infrastructure among farmers, transporters, and processors. Efficient ensiling storage for preserving sorghum biomass is limited, and the geographic spread of farms increases logistics complexity and costs. Overcoming these requires investments in adapted storage technologies, transport and logistics optimisation, and scalable processing infrastructure to enable a more efficient supply chain.

Grain sorghum biomass, especially when including stalks and bagasse for bioethanol, has low energy density and high volume relative to its energy content, resulting in high transport costs per unit of energy delivered. This bulkiness makes transport over long distances economically challenging.[402] Sweet sorghum stalks are bulky, have low density, and are highly perishable, making long-distance transport inefficient and uneconomical.[403] Additionally, sorghum production areas are scattered across wide geographies with farms often far from processing facilities. This dispersion increases the complexity and cost of coordinating efficient transport routes and supply chain scheduling.[404] Transportation infrastructure in rural areas is often inadequate, with poor road conditions adding to time delays[405]. Smallholders are particularly disadvantaged because they are dispersed across wide geographic areas,

---

[399] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024). "Exploring the Feasibility of Sorghum Farming in South Africa." MDPI Agriculture.

[400] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024). "Exploring the Feasibility of Sorghum Farming in South Africa." MDPI Agriculture.

[401] Srinivasa Rao, P., Reddy, B. V. S., & Umakanth, A. V. (2013). "Sweet sorghum for biofuel and strategies for its improvement." Sugar Tech, 15(3), 216–227.

[402] Mutenure M., Cucek L., Isafiade A., Kravanja Z., 2016, Synthesis of South Africa's Biomass to Bioethanol Supply Network, Chemical Engineering Transactions, 52, 805-810. https://www.cetjournal.it/index.php/cet/article/view/CET1652135

[403] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[404] Cartwright A. (2007). Biofuels trade and sustainable development: An analysis of South African bioethanol. International Institute for Environment and Development (IIED). https://www.iied.org/sites/default/files/pdfs/migrate/G02285.pdf

[405] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

making aggregation of stalks costly and time-sensitive[406]. Cooperative bulking and collective transport arrangements could potentially reduce transport costs for especially smallholder farmers.

As a result, processors are reluctant to locate facilities far from production areas, while farmers without nearby processing plants struggle to access markets. Lack of sufficiently many decentralised processing plants near production sites means harvested sorghum must be transported long distances to central plants, increasing logistical burdens and costs.[407] Because sweet sorghum must be processed within 24-48 hours of harvest to prevent sugar degradation, having centralised processing hubs introduces a bottleneck unless they are strategically located within production zone[408]. Without cooperative structures or investment in mobile crushing and juice extraction units, many farmers cannot participate effectively in the value chain. [409]

VI. Handling, storage and transport

For grain sorghum, inadequate storage, poor transportation and infrastructure bottlenecks could result in losses, deteriorated quality (moisture and microbial contamination) and increased delivery expenses.[410] Lack of specialised transport and storage infrastructure to prevent spoilage leads to feedstock losses and reduced bioethanol yields. Poor rural road conditions and weak logistics networks in some sorghum-producing areas hamper reliable and timely transport, increasing risk of delays and feedstock degradation.[411] [412] [413] Existing grain storage, handling, and milling infrastructure in South Africa is overwhelmingly designed for maize and wheat, leaving sorghum disadvantaged in terms of cost, efficiency, and market access. [414] [415] The lack of dedicated sorghum logistics networks further compounds these difficulties; most existing bulk handling and silo systems are designed for maize and wheat.[416] Transportation costs and proximity to markets create variation in feedstock prices, affecting the overall pricing at regional levels.

Unlike grain sorghum, sweet sorghum stalks cannot be dried and stored without significant sugar loss. Some experimental approaches, such as ensiling stalks for later ethanol production, have been tested

[406] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[407] Mutenure, M. 2016. Optimisation of South Africa's biomass to bio-ethanol supply chain network. University of Cape Town. https://open.uct.ac.za/items/1e7607ef-7dff-45e5-bd1e-09db81e1129b

[408] Reddy, B. V. S., Ramesh, S., Ashok Kumar, A., et al. (2008). “Sweet sorghum as a biofuel crop: Where are we now?” International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

[409] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[410] Srinivasa Rao, P., Vinutha, K. S., Kumar, G. S. Anil, Chiranjeevi, T., Uma, A., Lal, Pankaj, Prakasham, R. S., Singh, H. P., Rao, R. Sreenivasa, Chopra, Surinder & Jose, Shibu, 2019. Sorghum: A Multipurpose Bioenergy Crop. Agronomy, vol. 58. United States: OSTI. https://www.osti.gov/servlets/purl/1772809

[411] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[412] Sihlobo W. (2025). Agricultural Production: The troubling decline of the South African sorghum industry. https://wandilesihlobo.com/2025/05/04/the-troubling-decline-of-the-south-african-sorghum-industry/

[413] NREL Sorghum to Ethanol Research Initiative Cooperative Research and Development Final Report CRADA Number: CRD-08-291 http://www.osti.gov/bridge

[414] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[415] Nkosi, Z.; Marwa, N.; Akinrinde, O.O. Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett’s Ranking Technique. Agriculture 2025, 15, 2348. https://doi.org/10.3390/agriculture14122348

[416] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

in other contexts[417], but these practices remain underdeveloped in South Africa. The lack of investment in R&D on storage and preservation technologies severely undermines the commercial feasibility of sweet sorghum.[418]

Addressing this requires targeted investment in cleaning, grading, and milling technologies that can accommodate sorghum's unique properties. Implementing robust storage solutions can also mitigate losses post-harvest, ensuring that surplus crops can be sold when market conditions are favourable. Potential solutions could include GIS modelling, optimised processing plant locations, and a transport mode change (for example from road to rail).[419] Coordinated investment across seed systems, procurement, processing, and logistics would create the enabling environment necessary to transform sorghum from a marginal crop into a viable component of South Africa's agricultural and industrial economy.

The logistics of the sweet sorghum value chain can be considered critical barriers to its commercialisation in South Africa. Unlike grain sorghum, which can be stored dry for extended periods, sweet sorghum is characterised by high moisture content in its stalks and sugars that deteriorate rapidly post-harvest. This creates a narrow harvest-to-processing window, significantly increasing logistical demands[420]. Farmers and processors alike are therefore constrained by the need to synchronise harvesting, transportation, and processing in ways that are rarely required for other staple crops.

VII. Processing and conversion

The sorghum ethanol sector in South Africa is nascent with underdeveloped infrastructure for large-scale feedstock supply and processing.[421] South Africa currently lacks fully operational commercial bioethanol plants specifically designed for sorghum feedstock. Existing infrastructure is limited and not adequately scaled for large volumes of sorghum, affecting consistent supply chain throughput and is mostly designed and scaled for large-scale maize processing. Insufficient local expertise in bioenergy technologies and project development poses a challenge.[422] [423] [424]

Consistency in the quality and supply of sorghum grain affects the overall process. Variability in starch content and grain quality can lead to fluctuating ethanol yields.[425] The current limited availability of sorghum as feedstock constrains the scaling up of biofuel projects. Limited and inconsistent feedstock

[417] Srinivasa Rao, P., Vinutha, K. S., Kumar, G. S. Anil, Chiranjeevi, T., Uma, A., Lal, Pankaj, Prakasham, R. S., Singh, H. P., Rao, R. Sreenivasa, Chopra, Surinder & Jose, Shibu, 2019. Sorghum: A Multipurpose Bioenergy Crop. Agronomy, vol. 58. United States: OSTI. https://www.osti.gov/servlets/purl/1772809

[418] Nkosi, Z.; Marwa, N.; Akinrinde, O.O. Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture 2025, 15, 2348. https://doi.org/10.3390/agriculture14122348

[419] Li, X., Wang, M., Zhao, S., Zhang, Z., & Li, H. (2024). GIS-based multi-objective optimization model for sweet sorghum ethanol supply chain. The Innovation: Energy, 1(1), 100038. https://www.the-innovation.org/article/doi/10.59717/j.xinn-energy.2024.100038

[420] SNV (2022). Climate-Smart Sorghum Production Guide. Netherlands Development Organisation.

[421] Sihlobo W. (2025). Agricultural Production: The troubling decline of the South African sorghum industry. https://wandilesihlobo.com/2025/05/04/the-troubling-decline-of-the-south-african-sorghum-industry/

[422] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[423] Etambakonga, C. (2013). Barriers to Widespread Biomass Energy in South Africa. The Journal of MacroTrends in Energy and Sustainability: https://macrojournals.com/assets/docs/2ES11Eta.241702.pdf

[424] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024, December). Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture: https://www.mdpi.com/2077-0472/14/12/2348

[425] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

supply in the form of grain sorghum poses challenges for scaling domestic bioethanol production. This affects market competitiveness and production stability. [426] [427] [428]

Variability and quality of feedstock have an impact on processing. For example, harvest time and variety affect the composition of sweet sorghum stalks. Changes in moisture, pollutants, and sugar/starch content have an impact on fermentation performance, enzyme dosage and conversion yields. Some examples of mitigation are standardised grading, quality checks during pre-processing, blending techniques, adaptive enzyme. Fuel formulas and plant control systems, as well as blending from multiple sources and quality testing, are some examples of mitigations.[429]

During sorghum fermentation, microbial contaminants such as lactic acid bacteria and wild yeasts can affect bioethanol yield. These contaminants compete with the fermentation yeast, causing substrate antagonism and reducing ethanol production efficiency. Managing this contamination requires good hygiene practices and cleaning protocols in the production plant. [430] Sorghum also contains high levels of tannins which can inhibit fermentation. Pretreatment to remove tannins is necessary to improve ethanol yield. [431] Furthermore, sorghum biomass requires additional enzymatic hydrolysis due to fibrous composition, increasing capital and operating costs for bioethanol plants as compared to starch or sugarcane-based feedstocks.[432] Efficient enzymatic hydrolysis of sorghum starch into fermentable sugars is critical. Increasing hydrolysis time, enzyme concentration, and nutrient supplementation can help improve sugar extraction and fermentation rate. [433]

End-product sugars (glucose and xylose), lignin and excessive solids loading can impede enzyme activity. Enzymes are expensive as well. Potential solutions are to optimise enzyme loading, hydrolysis time, and mixing to enhance sugar yields. Furthermore, additives such as surfactants can reduce enzyme binding to lignin and improve saccharification.[434] Fermentation control is critical. Microbial contamination and competition affect yeast health and fermentation efficiency. In addition, stressors like high temperatures, ethanol concentration, and high sugar levels reduce ethanol productivity. Potential solutions to improve yields include using genetically improved or stress-tolerant yeast strains,

[426] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[427] Etambakonga, C. (2013). Barriers to Widespread Biomass Energy in South Africa. The Journal of MacroTrends in Energy and Sustainability: https://macrojournals.com/assets/docs/2ES11Eta.241702.pdf

[428] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024, December). Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture: https://www.mdpi.com/2077-0472/14/12/2348

[429] Morrissey, K. G., Thoma, G. & López, D. E., 2021. Life cycle impact assessment of biofuels derived from sweet sorghum in the U.S. Biotechnology for Biofuels and Bioproducts, 14, Article 166. DOI: 10.1186/s13068-021-02009-6. Available at: https://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/s13068-021-02009-6

[430] Deenanath ED, Iyuke S, Rumbold K. The bioethanol industry in sub-Saharan Africa: history, challenges, and prospects. J Biomed Biotechnol. 2012; 2012:416491. doi: 10.1155/2012/416491. Epub 2012 Mar 29. PMID: 22536020; PMCID: PMC3321486. https://pmc.ncbi.nlm.nih.gov/articles/PMC3321486/

[431] Deenanath ED, Iyuke S, Rumbold K. The bioethanol industry in sub-Saharan Africa: history, challenges, and prospects. J Biomed Biotechnol. 2012; 2012:416491. doi: 10.1155/2012/416491. Epub 2012 Mar 29. PMID: 22536020; PMCID: PMC3321486. https://pmc.ncbi.nlm.nih.gov/articles/PMC3321486/

[432] NREL Sorghum to Ethanol Research Initiative Cooperative Research and Development Final Report CRADA Number: CRD-08-291 http://www.osti.gov/bridge

[433] Deenanath ED, Iyuke S, Rumbold K. The bioethanol industry in sub-Saharan Africa: history, challenges, and prospects. J Biomed Biotechnol. 2012; 2012:416491. doi: 10.1155/2012/416491. Epub 2012 Mar 29. PMID: 22536020; PMCID: PMC3321486. https://pmc.ncbi.nlm.nih.gov/articles/PMC3321486/

[434] Broda M, Yelle DJ, Serwańska K. Bioethanol Production from Lignocellulosic Biomass-Challenges and Solutions. Molecules. 2022 Dec 9;27(24):8717. doi: 10.3390/molecules27248717. PMID: 36557852; PMCID: PMC9785513. https://pmc.ncbi.nlm.nih.gov/articles/PMC9785513/

maintaining controlled fermentation conditions, pre-treatment of yeasts, good process control, and ensuring the use of modern biorefinery technologies.[435]

A. Formation on byproducts

The bioethanol yield will be decreased when carbon is lost to biomass, lactic acid, acetic acid or glycerol rather than ethanol. Pathways should be created that divert carbon flux towards ethanol, to reduce the production of byproducts. To further solve the problem, undesirable pathways should be limited by regulating the pH and oxygen content of the fermentation process.

B. Separation downstream and energy expenses

Ethanol distillation uses a lot of energy and water, and remaining ethanol in stillage lowers recovery yield. Therefore, margins are lowered by high utility costs and there may be less effective ethanol recovery (residual ethanol in stillage). The high cost of energy results in poor profitability for biofuel projects. [436] [437] [438] Energy efficiency (heat integration, and cogeneration), hybrid separation (membranes and distillation) and stillage/wastewater recycling optimisation are some mitigations.

C. High processing complexity and costs

Ethanol plant profitability from sorghum depends heavily on feedstock costs, government subsidies, fossil fuel price fluctuations, and ethanol market prices.[439] Initial investment requirements are substantial. During operation, enzymatic hydrolysis and pretreatment cost will also be significant. The high upfront costs for modern biomass equipment are often beyond the reach of poor communities, hindering the adoption of biomass technology. [440] [441] [442] Operational risks include equipment failure, and labour gaps). These could be addressed through preventive maintenance, and workforce training.

6.4 Distribution and markets

The economics of a bioethanol processing facility can be swiftly weakened by fluctuating grain costs, shifting biofuel regulations, subsidies or trade policies. Ethanol use is also in competition with the demand for sorghum for food or feed. Hedging, long-term offtake agreements,

---

[435] Abreu-Cavalheiro A, Monteiro G. Solving ethanol production problems with genetically modified yeast strains. Braz J Microbiol. 2014 Jan 15;44(3):665-71. doi: 10.1590/s1517-83822013000300001. PMID: 24516432; PMCID: PMC3910172. https://pmc.ncbi.nlm.nih.gov/articles/PMC3910172/

[436] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[437] Etambakonga, C. (2013). Barriers to Widespread Biomass Energy in South Africa. The Journal of MacroTrends in Energy and Sustainability: https://macrojournals.com/assets/docs/2ES11Eta.241702.pdf

[438] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024, December). Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture: https://www.mdpi.com/2077-0472/14/12/2348

[439] Yu S.Y., 2024, Potential and application prospects of sorghum as a bioenergy crop, Journal of Energy Bioscience, 15(6): X-XX (doi: 10.5376/jeb.2024.15.0030). https://bioscipublisher.com/index.php/jeb/article/html/4008/

[440] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[441] Etambakonga, C. (2013). Barriers to Widespread Biomass Energy in South Africa. The Journal of MacroTrends in Energy and Sustainability: https://macrojournals.com/assets/docs/2ES11Eta.241702.pdf

[442] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024, December). Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture: https://www.mdpi.com/2077-0472/14/12/2348

lobbying and interacting with legislators and the ability to move between the fuel and food markets are some mitigation strategies.

I. Regulatory uncertainty

South Africa has struggled with lack of regulatory clarity, particularly around the ethanol blending mandate and pricing strategy. Disagreements among stakeholders have delayed government enforcement of blending mandates such as the 2% ethanol blend in gasoline, limiting guaranteed demand for bioethanol producers.[443] In the Government Gazette (GG) No. 53146 (12 August 2025), the Regulated Biofuels Price has been published as comprising the following elements:[444]

i) the Basic Fuel Price of petroleum diesel (0,005% sulphur) for biodiesel or the Basic Fuel Price of unleaded petroleum petrol 95 (ULP) for bioethanol; and
ii) the magisterial district zone differential.

Going forward, continued advocacy is required for the implementation and continued stable and predictable biofuel policies, including blending mandates and incentives.

II. Pricing and economic competitiveness

Bioethanol has faced challenges competing with fossil fuels due to pricing and cost structures. Biofuel must compete in this market as a replacement or supplement, and it must match the competitive price of fossil fuel which may render the conversion of sorghum to ethanol unfeasible. Government subsidies may be required to address this. Failure to establish a regulated price and government incentives has hindered market growth. Import reliance to meet blending mandates also weakens local bioethanol market strength. It is necessary for the sorghum industry to remain abreast of developments of the policy framework through the Central Energy Fund (CEF) and the Department of Mineral Resources and Energy (DMRE). [445] [446]

III. Infrastructure and distribution

Insufficient infrastructure for bioethanol transport, storage, and blending limits market reach and adds logistical costs, which can deter market penetration and sales scale-up. In addition, any secondary storage facility that intends to perform blending activities must apply for a petroleum manufacture licence in terms of the Petroleum Products Act. [447] Logistics need to be considered in the economics of any biofuel project:

i. Ethanol (and therefore fuel blended with ethanol) cannot be transported in the multi-fuel pipeline, due to its absorption of water and its effects on the other fuels.
ii. Road or rail transport will add logistics costs to the fuel's delivered cost.

---

[443] United States (U.S.) Grains & BioProducts Council. (2025). https://grains.org/bioethanol/ethanol-market-profiles/south-africa/

[444] Department of Mineral Resources and Energy (DMRE). (2025). Petroleum Products Act (120/1977): Regulated biofuels price in terms of the Petroleum Products Act. Government Gazette No. 53146 (12 August 2025).

[445] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[446] United States (U.S.) Grains & BioProducts Council. (2025). https://grains.org/bioethanol/ethanol-market-profiles/south-africa/

[447] Department of Mineral Resources and Energy (DMRE). (2025). Petroleum Products Act (120/1977): Regulated biofuels price in terms of the Petroleum Products Act. Government Gazette No. 53146 (12 August 2025).

More work needs to be done to look at rail vs truck optimisation for fuel transport. In addition, distribution costs can be optimised if bioethanol is distributed regionally to blenders or users near the processing facilities.

IV. Public awareness and acceptance

Low consumer awareness about bioethanol benefits and misinformation about its efficiency slow adoption. Cultural preferences and unfamiliarity with bioethanol usage in fuel are additional barriers.[448] Potential impacts on food security, land use, and biodiversity raise regulatory and public concerns that can restrict market expansion. Ineffective strategies for disseminating information about the benefits and opportunities associated with bioenergy limit its adoption. [449] [450] [451]

V. Market demand and price fluctuation

Fossil fuels, as well as Liquid Petroleum Gas (LPG) and electric cooking technologies with more developed infrastructure and subsidies, present strong competition to bioethanol in fuel and cooking markets. [452] The market demand for bioethanol is dependent on government blending mandates, prevailing fuel prices, and the demand for biofuels. To mitigate this, long-term offtake agreements should be signed for both the bioethanol and the valuable byproduct, namely Distillers Dried Grain with Solubles (DDGS).

Hedging can act as a financial risk management tool that mitigates biofuel price volatility, secures investment returns, and supports market stability in South Africa's bioethanol industry, including the following:

i. Risk reduction for investors, by allowing bioethanol producers to lock in prices or establish contracts that protect against sudden drops in crude oil prices or feedstock costs, especially when oil prices fall below viability thresholds like USD45-65 per barrel.[453]
ii. Price stability could be achieved through hedging strategies such as futures contracts or options to fix bioethanol selling prices or buying prices for feedstocks in advance, shielding producers and consumers from unpredictable price swings.[454]
iii. Balancing supply and demand risks, through hedging mechanisms in the form of contracts between producers and fuel consumers to share price risks.

VI. Export barriers

Export barriers exist for South African produced biofuels, in the form of tariffs and certification requirements. Export markets for bioethanol are small and generally aimed only at the potable ethanol

---

[448] Osiolo H. (2025). Unlocking the Potential of Bioethanol- Navigating Consumer Demand, Supply Chains, and Policy Frameworks (Blog #1 of the series). Modern Energy Cooking services (MECS). https://mecs.org.uk/blog/unlocking-the-potential-of-bioethanol-navigating-consumer-demand-supply-chains-and-policy-frameworks-blog-1-of-the-series/

[449] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[450] Etambakonga, C. (2013). Barriers to Widespread Biomass Energy in South Africa. The Journal of MacroTrends in Energy and Sustainability: https://macrojournals.com/assets/docs/2ES11Eta.241702.pdf

[451] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024, December). Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett's Ranking Technique. Agriculture: https://www.mdpi.com/2077-0472/14/12/2348

[452] Osiolo H. (2025). Unlocking the Potential of Bioethanol- Navigating Consumer Demand, Supply Chains, and Policy Frameworks (Blog #1 of the series). Modern Energy Cooking services (MECS). https://mecs.org.uk/blog/unlocking-the-potential-of-bioethanol-navigating-consumer-demand-supply-chains-and-policy-frameworks-blog-1-of-the-series/

[453] National Biofuels Task Team. (2006). National Biofuels Study: An Investigation into the Feasibility of Establishing a Biofuels Industry in the Republic of South Africa. https://www.mabelefuels.com/wp-content/uploads/2011/12/National-Biofuels-Study.pdf

[454] Global Risk Management (GRM). (2024). Hedge your volatile biofuel prices for a stable budget. https://www.global-riskmanagement.com/biofuels/

market or the industrial market rather than the fuel ethanol market. Large-scale export to the United States (US) or the European Union (EU) faces trade barriers in the form of agricultural tariffs and/or domestic producer credits.[455] Market access may be restricted by certification requirements, sustainability rules - such as Indirect Land Use Change (ILUC) policies - and fuel quality standards. Fines and bans are possible for non-compliance. Mitigation measures include regional trade agreements, certification of biofuels such as International Sustainability and Carbon Certification (ISCC), quality control laboratories, ensuring regulatory compliance and obtaining buyer acceptance.

6.5 Regulatory environment

Policy frameworks play a significant role in the sorghum sector's growth. International and local studies emphasise the importance of simultaneous interventions across the value chain, rather than solely focusing on production. The South African Government's White Paper on Renewable Energy outlined the country's strategic approach to renewable energy, including bioenergy and biofuels, as part of its broader energy policy.[456] South Africa has a biofuels regulatory framework that includes a Feedstock Protocol to regulate agricultural production of biofuels feedstock, prioritising rain-fed crops to mitigate water scarcity:[457]

i. The then Department of Mineral Resources and Energy (DMRE) developed the regulations on the blending of biofuel, with an initial target of 2%, eventually increasing to 4.5%.
ii. Department of Agriculture, Land Reform and Rural Development (DALRRD) developed the feedstock protocol.
iii. Department of Trade, Industry and Competition (the dtic) must provide manufacturing support.
iv. DMRE must license operations.

Mandatory Blending Regulations mandate that licensed manufacturers and wholesalers of petroleum products must blend locally produced bioethanol and biodiesel, creating a demand for biofuels.[458] Commercial-scale biofuel manufacturing requires licenses for petroleum product storage facilities and a biofuels manufacturing license in terms of the Petroleum Products Act.[459] A significant barrier for the blending of biofuel into fossil fuel is that the blending depot or operation also requires a production manufacturing (VM) license or needs to be registered as a manufacturer. Blending in a depot also requires a manufacturing licence from the DMRE, as well as an amendment to the licence conditions in terms of the Petroleum Products Act. SANS 465 (Requirements and specifications for fuel ethanol as a blending component with petrol) has been developed and published.

The South African Revenue Service (SARS) already has all legislation in place for ethanol blending with petrol. SARS has stringent customs and excise regulations for the export of fuels - there are levies payable, and even though some could be recovered, it has cash flow implications. Currently, exports also present significant issues with SARS controls.

[455] Sell M, Selivanova Y, Waide P, Sugathan M, Gueye MK, Cheng S, Turner T, Stilwell M, Rose E, Zarrilli S, Denruyter JP, Earley J, Johnson F, Chaturvedi S, Coelho ST, Goldemberg J. (2006) Linking Trade, Climate Change and Energy. International Centre for Trade and Sustainable Development. https://www.jstor.org/stable/resrep66226.14

[456] Department of Mineral Resources and Energy (DMRE). (2003). White Paper on Renewable Energy

[457] Department of Mineral Resources and Energy (DMRE). (2020). South African Biofuels Regulatory Framework and National Biofuels Feedstock Protocol

[458] Department of Mineral Resources and Energy (DMRE). (2020). South African Biofuels Regulatory Framework and National Biofuels Feedstock Protocol

[459] Department of Mineral Resources and Energy (DMRE). (2003). Petroleum Products Amendment Act (Act No. 58 of 2003)

The viability of sorghum as an industrial feedstock depends on coordinated action including seed research, guaranteed procurement, expanded processing capacity, and supportive logistics infrastructure.[460] Without clear policy direction and confirmed sorghum demand, farmers are reluctant to scale up production, leading to continuous underinvestment in the sector. Large-scale commercial production requires a well-structured economic framework and supportive government policies. Regulatory uncertainties and lack of subsidies also pose risks to project viability.[461] [462] [463] [464]

South Africa currently lacks large-scale interventions in the sorghum sector, meaning that processors cannot secure the long-term volumes needed for industrial applications such as biofuels. There have been some interventions, such as fuel levy exemptions and proposed mandatory blending regulations. However, the overall government support for the biodiesel industry remains insufficient. The lack of a robust regulatory framework and delays in implementing mandatory blending policies hinder investment and development. Biofuel production may not be viable without government support, including subsidies, fuel levy exemptions, and mandatory blending of biofuels to conventional fuels.

Political interference and strong lobbying for fossil fuels and nuclear power, coupled with political interests that support and subsidise these industries, creates a disadvantage for renewable energy sources like sorghum. [465] [466] [467]

6.6 Risk register

The risk register below is provided to identify all potential risks, describe them, assign an entity for tracking them, along with other details such as the risk source. The methodology and rationale used to determine the overall risk rating as high, medium, or low was based on a qualitative risk assessment process that combines evaluations of risk severity (impact) and likelihood (probability), as follows.

i. Potential risks were identified across the sorghum value chain (input supply, farming, harvesting, processing, distribution, and regulation);
ii. Each identified risk was assessed for its potential severity (impact) on the sorghum value chain - this assessment was informed by how often a particular risk was mentioned in the literature reviewed, as well as stakeholder consultations;
iii. The probability of the risk’s occurrence was then determined - similarly, this determination was based on the literature, expert inputs and the likelihood of certain scenarios occurring;
iv. The overall risk rating was derived from combining the impact and likelihood assessments, categorising risks as high, medium, or low accordingly - this guided prioritisation and risk

[460] Department of Science and Innovation (DSI). (2021). Study to Establish Market Opportunities for Sorghum in South Africa. https://www.dsti.gov.za/images/Annexure_A_Sorghum_Study_Report_May2021_FINAL.pdf

[461] Mayet M. (2007). South Africa, Bioethanol and Gmos: A Heady Mixture. African Centre for Biosafety (ACBIO). https://acbio.org.za/wp-content/uploads/2022/03/southafrica_bioethanolgmos_areadymixture.pdf

[462] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[463] Etambakonga, C. (2013). Barriers to Widespread Biomass Energy in South Africa. The Journal of MacroTrends in Energy and Sustainability: https://macrojournals.com/assets/docs/2ES11Eta.241702.pdf

[464] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024, December). Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett’s Ranking Technique. Agriculture: https://www.mdpi.com/2077-0472/14/12/2348

[465] Dunjana, N., Dubel, E., Chauke, P., Motsepe, M., Madikiza, S., Kgakatsi, I., & Nciizah, A. (2022, October). Sorghum as a household food and livelihood security crop under climate change in South Africa: A review. South African Journal of Science: https://scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532022000600014

[466] Etambakonga, C. (2013). Barriers to Widespread Biomass Energy in South Africa. The Journal of MacroTrends in Energy and Sustainability: https://macrojournals.com/assets/docs/2ES11Eta.241702.pdf

[467] Nkosi, Z., Marwa, N., & Akinrinde, O. (2024, December). Exploring the Feasibility of Sorghum Farming in South Africa Using Garrett’s Ranking Technique. Agriculture : https://www.mdpi.com/2077-0472/14/12/2348

management planning;

v. Mitigation measures were identified for each risk, including avoidance, transfer, acceptance, reduction, and monitoring and;
vi. Finally, the role players responsible for the mitigation of each risk were identified.

The resulting risk matrix (see table below) includes descriptions of each risk, an impact rating, a likelihood rating, and an overall risk rating, each classified as high, medium, or low. This structured qualitative approach enables prioritisation of risks most critical to the success of sorghum projects in South Africa and the assignment of appropriate mitigation measures and responsible organisations. As indicated in the risk register, multiple stakeholders are responsible for or involved in the mitigation of these risks. The register is sorted by overall rating, high to low.

.

Table 43: Risk Matrix

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
1.	Weak market demand / low offtake for sorghum grain	• Sorghum farmers in South Africa face the challenge of weak market demand, depressed farm-gate prices, low profitability and scalability sorghum farming.	High	High	High	• Establish biofuel processing facilities and the corresponding supply chains, which will stimulate the demand for sorghum grain	Project Developers, IDC, LSF, DMRE
2.	Feedstock availability fluctuations	• South Africa's sorghum production has shown significant year-to-year fluctuations caused by changing weather conditions, input use, and limited farmer uptake - variability makes it difficult for processors to rely on sorghum as a consistent feedstock, reducing incentives for long-term industrial partnerships.	High	Medium	High	• Sufficient storage facilities for grain sorghum • Optimised logistics for getting feedstock from farmers to processing facilities • Staggering of planting to extend the harvesting period as long as possible • Development of cultivars suited for different climate zones and/or harvesting periods	Project Developers, LSF, DAFF, IDC, the dtic, DoT, DAFF
3.	Access to suitable seed / Lack of SA seed development	• Sorghum research has historically received less funding and attention compared to maize or wheat, resulting in fewer commercial hybrids available for widespread adoption • Farmers often depend on either imported seed or traditional / recycled seed, which is poorly aligned with market requirements such as grain size, tannin content, and milling properties that are required by sorghum processing facilities • Commercial Farmers: Access to high-yielding, pest-resistant sorghum hybrids are not available for South African conditions, due to public and private underinvestment	High	High	High	• Building stronger seed systems and incentivising plant breeding programmes to unlock yield stability and quality consistency • Development of cultivars / geoplasm in SA for local conditions • Incentives or subsidies for farmers to buy seeds	ARC, DAFF, National Treasury

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		in sorghum breeding programmes • Smallholder farmers: Limited access to improved seeds and the tendency to use grain from previous harvests as seed for the subsequent growing season, which generally delivers lower yields compared with improved hybrids					
4.	Financing and working-capital risks tied to uncertain returns	• Sorghum farming faces a lack of affordable credit for sorghum production due to limited markets, uncertain returns, market price uncertainty and lack of established futures contracts	Medium	High	High	• Implementation of policies and measures enhancing farmers' access to credit and financial services (e.g. microfinance programs and government-backed loan schemes)	DAFF, National Treasury, Private sector Financial Institutions
5.	Logistics and storage constraints for scale	• Existing grain storage, handling, and milling infrastructure in South Africa is overwhelmingly designed for maize and wheat, leaving sorghum disadvantaged in terms of cost, efficiency, and market access • Inadequate storage, poor transportation and infrastructure bottlenecks could result in losses, deteriorated quality and increased delivery expenses • The geographic spread of farms and long distances between sorghum cultivation and processing, as well as the low energy density of sorghum, increases logistics complexity and costs • Transportation infrastructure in rural areas is often inadequate, with poor road conditions adding to time delays	Medium	High	High	• Investments are required in adapted storage solutions (cleaning, grading, and milling technologies) • Transport and logistics optimisation • Cooperative bulking and collective transport arrangements • GIS modelling • Transport mode change (for example from road to rail)	DAFF, DoT, Farmers, Logistics companies, IDC
6.	Limited commercial processing capacity	• Most grain processing facilities in South Africa are optimised for maize	High	High	High	• Technology changes are required for the processing of	IDC, LSF, ARC, Project Developers

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
	and technology	and wheat, leaving little capacity for sorghum-specific milling and conversion - this restricts farmers' market options to selling into limited outlets at lower margins, and a lack of available bioethanol to meet blending mandates • Insufficient local expertise in bioenergy technologies and project development poses a significant challenge.				sorghum • Implementation of scalable processing infrastructure, to grow with the supply of sorghum and the demand for bioethanol • Optimised processing plant locations, near cultivation as far as possible	
7.	Sorghum feedstock / availability the rest of the value chain	• The consistent and sustainable supply of biomass feedstock may be affected by seasonal fluctuations, climate change, and competing uses, pests and bird predation, potentially leading to shortages and increased cost • The risks associated with the high dependence on sorghum imports as a critical input to the value chain include short term availability, as well as affordability that is influenced by the macroeconomic environment and the relative weakness of the exchange rate • Variability in starch content and grain quality can lead to fluctuating ethanol yields.	High	Medium	High	• Produce more sorghum, based on increased demand from processing facilities • South African Futures Exchange (SAFEX) linked sorghum price will motivate farmers to plant and sell sorghum to the market	Project Developers, Farmers, DAFF, JSE
8.	Pricing and economic competitiveness	• The profitability of biofuel projects is highly dependent on global energy prices, production costs, and competition from other fuels. • If biofuel is not cost-competitive, securing long-term market demand may be challenging. • Biofuel must compete in the market	High	High	High	• The entire sorghum to bioethanol value chain needs to be optimised, to ensure economic viability - investments in R&D to lower production costs and improve feedstock availability • Creating a stable policy environment with clear	DMRE, IDC, CEF

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		as a replacement or supplement to fossil fuels, and it must match the competitive price of fossil fuel which may render the conversion of sorghum to ethanol unfeasible • Import reliance to meet blending mandates also weakens local bioethanol market strength				incentives (e.g. tax breaks or blending mandates) to encourage investment and support scaling up of biofuel production - the recently gazetted regulated bioethanol price will address this partially • It is necessary for the sorghum industry to remain abreast of developments of the policy framework	
9.	Market Demand and Price Fluctuation	• The market demand for bioethanol is dependent on government blending mandates, prevailing fuel prices, and the demand for biofuels • Fossil fuels, as well as LPG and electric cooking technologies with more developed infrastructure and subsidies, present strong competition to bioethanol in fuel and cooking markets	High	Medium	High	• Mandatory Blending Regulations mandate that licensed manufacturers and wholesalers of petroleum products must blend locally produced bioethanol and biodiesel, creating a demand for biofuels • Long-term offtake agreements should be signed for both the bioethanol and the valuable byproduct, DDGS • Hedging can act as a financial risk management tool that mitigates biofuel price volatility, secures investment returns, and supports market stability in South Africa's bioethanol industry	DMRE, CEF, IDC, Project Developers, Sasol, Private Financial Institutions
10.	Regulatory Environment	• Changes in government policies, environmental regulations, and biofuel blending mandates could impact project feasibility, investment confidence, and long-term sustainability. • Inconsistent enforcement and a lack of clear incentives may discourage	High	High	High	• Government needs to balance the development of biofuels with other renewable energy sources, ensuring that biofuels are integrated into a broader, sustainable energy strategy (e.g. IRP) • The viability of sorghum as an	DMRE, DAFF, National Treasury, CEF, LSF, Project Developers

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation

		private sector participation
		• Commercial-scale biofuel manufacturing requires licenses for petroleum product storage facilities and a biofuels manufacturing license in terms of the Petroleum Products Act
		• A significant barrier for the blending of biofuel into fossil fuel is that the blending depot or operation also requires a production manufacturing license or needs to be registered as a manufacturer
		• Blending in a depot also requires a manufacturing licence from the DMRE, as well as an amendment to the licence conditions in terms of the Petroleum Products Act
		• SARS have stringent customs and excise regulations for the export of fuels - there are levies payable, and even though some could be recovered, it has cash flow implications
		• Currently, exports also present significant issues with SARS controls
		• Biofuel production may not be viable without government support, including subsidies, fuel levy exemptions, and mandatory blending of biofuels to conventional fuels
		• BRF is too complicated and perceived as too risky for industrialists - it includes the following elements:
		  ○ Agricultural subsidy
		  ○ Manufacturing subsidy
						industrial feedstock depends on clear policy direction and confirmed sorghum demand, as well as coordinated action including seed research, guaranteed procurement, expanded processing capacity, and supportive logistics infrastructure
						• Develop clear regulations for each of the BRF elements
						• Streamline approval processes
						• Design and implement a financial incentive scheme for bioenergy projects	

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		○ BEE requirements ○ DoE licensing.					
11.	Land use conflicts	• Most smallholder farms are smaller than two ha, with insecure tenure and limited agricultural potential in terms of soil fertility and climate • The decision to cultivate sweet sorghum for ethanol or food production creates land allocation conflicts between sorghum for ethanol vs food.	Low	Medium	Low	• Establishment of cooperatives to farm together • Aggregation of harvested material for transport • Precision farming could increase yields, but it is expensive	ARC, DAFF, Provincial Governments, National Treasury
12.	Hydrolysis Efficiency	• Sorghum biomass requires additional enzymatic hydrolysis due to fibrous composition, increasing capital and operating costs for bioethanol plants as compared to starch or sugarcane-based feedstocks • End-product sugars, lignin and excessive solids loading could impede enzyme activity - enzymes are expensive	Medium	Low	Low	• Increasing hydrolysis time, enzyme concentration, and nutrient supplementation can help improve sugar extraction and fermentation rate • Potential solutions are to optimise enzyme loading, hydrolysis time, and mixing to enhance sugar yields. • Additives such as surfactants can reduce enzyme binding to lignin and improve saccharification	LSF, IDC, Project Developers
13.	Fermentation efficiencies and yields	• During sorghum fermentation, microbial contaminants such as lactic acid bacteria and wild yeasts can affect bioethanol yield • Sorghum contains high levels of tannins which can inhibit fermentation • Microbial contamination and competition affect yeast health and fermentation efficiency • Stressors like high temperatures, ethanol concentration, and high sugar levels reduce ethanol	Medium	Low	Low	• Managing this contamination requires good hygiene practices and cleaning protocols in the production plant • Pretreatment to remove tannins is necessary to improve ethanol yield • Yields can be improved by using genetically improved or stress-tolerant yeast strains, maintaining controlled fermentation conditions, pre-treatment of yeasts, good	LSF, IDC, Project Developers

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		productivity				process control, and ensuring the use of modern biorefinery technologies	
14.	Formation of byproducts	• The bioethanol yield will be decreased when carbon is lost to biomass, lactic acid, acetic acid or glycerol rather than ethanol	• Medium	• Low	• Low	• Pathways should be created that divert carbon flux towards ethanol, to reduce the production of byproducts • Undesirable pathways should be limited by regulating the pH and oxygen content of the fermentation process	• LSF, IDC, Project Developers
15.	Export barriers	• Export markets for bioethanol are small and generally aimed only at the potable ethanol market or the industrial market rather than the fuel ethanol market • Large-scale export to the US or the EU faces trade barriers in the form of agricultural tariffs and/or domestic producer credits • Market access may be restricted by certification requirements, sustainability and fuel quality standards	Low	Medium	Low	• Implement measures such as regional trade agreements, certification of biofuels, quality control laboratories, ensuring regulatory compliance and obtaining buyer acceptance	National Government, Project Developers, CEF, DMRE
16.	Competition of sorghum with other grains uses	• Price competition with maize presents a persistent barrier to sorghum's growth - maize enjoys economies of scale, extensive market penetration, and entrenched supply contracts with millers and feed manufacturers, while sorghum cannot match maize's lower cost, forcing it to compete in a market with price-sensitive buyers, such as feed processors • There is competition between bioethanol and other uses of	High	Medium	Medium	• Incentives for the cultivation of sorghum • Sorghum to be SAFEX price linked • Programmes and R&D to ensure seed availability	DAFF, the dtic, National Treasury, ARC

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		sorghum biomass. In many rural South African contexts, sorghum stover and bagasse are essential for livestock feed, household fuel, or traditional brewing.					
17.	Inadequate value-chain coordination	• Commercial farmers: There is a challenge of inadequate value-chain coordination, including limited bargaining power, the absence of structured off-take agreements and price volatility. • Smallholder farmers: Market access is a persistent constraint, as many farmers sell their grain informally or directly at the farm gate, where buyers set prices far below market value, transport to central markets, are often prohibitively high, and there is an absence of farmer cooperatives and aggregation mechanisms	Medium	Low	Medium	• Locate bioenergy facilities near the feedstock supply • Optimising Route Planning, Leveraging Intermodal Transportation (i.e. combination of road, rail, pipeline), and negotiation of supply contracts • Diversifying supply chains or using backup infrastructure options. • Sorghum farming could benefit from collaborative ventures in the form of collective purchasing of inputs, shared use of farming equipment, or joint marketing strategies - this can significantly lower operational costs, mitigate risks, and enhance market access, thereby improving the feasibility profile of sorghum farming	Project Developers
18.	Climate variability and weather exposure	• Commercial farmers: South Africa's increasingly variable climate, marked by recurrent droughts, erratic rainfall, and heatwaves, has led to unpredictable sorghum yields, which heightens the production risk for farmers who depend on stable output to meet contractual obligations • Smallholder farmers: Dryland agricultural production increases the susceptibility of crops to rainfall	Medium	High	Medium	• Selection of the right farmland (rainfall, good drainage, etc.) • Development of cultivars that are adapted for specific conditions • Good farming practices • Farming extension services for smallholder farmers	Seed developers, DAFF, ARC, Farmers

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		variability and uncertainty, dry spells and droughts, which are key factors that limit sorghum yields • Sweet sorghum yield is extremely sensitive to extended dryness, high temperatures during flowering and sever rains, which can cause lodging and decreased sugar buildup.					
19.	Pest, disease and agronomic constraints	• Sorghum farmers face a persistent challenge from pests, parasitic weeds, and diseases - this reduces yields and require costly management interventions (pesticides, resistant seed varieties, and labour for crop monitoring)	Medium	Medium	Medium	• Development of pest-resistant cultivars • Good farming practices • Farming extension services for smallholder farmers • Development and implementation of pest control measures	DAFF, ARC, Farmers
20.	Low access to inputs for smallholder farmers	• Smallholder farmers struggle to access essential inputs such as fertilisers, herbicides, and pesticides, which reduce yields	Medium	Medium	Medium	• Incentives or subsidies for smallholder farmers • Regional support centres for harvesting and input support, as well as equipment rental • Agricultural extension services • Ensuring seed availability and affordability	ARC, DAFF, Provincial Governments, National Treasury
21.	Policy neglect and poor inclusion in programmes for smallholder farmers	• Due to limited extension services to smallholder farmers, they often lack exposure to improved agronomic practices, such as optimal planting times, intercropping strategies, or water-conserving methods that could significantly improve yields. • Smallholder sorghum producers are often overlooked in national	Medium	High	Medium	1. Focused agricultural extension services for smallholder farmers • Support from DAFF, ARC for other crops than maize	DAFF, ARC, Provincial Departments of Agriculture

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		agricultural programmes, which prioritise maize, wheat, and soybean - this results in reduced research funding, fewer subsidies, and the absence of targeted procurement policies that could provide stable markets for sorghum					
22.	Resource degradation for smallholder farmers	• Many smallholder farmers lack the resources to implement soil conservation measures, apply adequate fertilisation or diversified cropping systems, which leads to erosion and nutrient depletion in already marginal soils	Medium	Medium	Medium	• Deployment of extension officers for smallholder farmers • Provision of training and skills development regarding farming practices, and farm layouts • Funding support for farming inputs • Implementation of inter-cropping practices	DAFF, Provincial Departments of Agriculture, National Treasury
23.	Labour constraints and competing household needs for smallholder farmers	• Smallholder households often face severe labour shortages, particularly during peak planting and harvesting periods • Land and labour allocation often favour subsistence crops like maize or vegetables, leaving sorghum as a secondary or neglected option	Medium	High	Medium	• Provision of extension services • Training and skills development to encourage smallholder farmers to look beyond subsistence farming, and grow sorghum for the market	DAFF, Provincial Departments of Agriculture
24.	Social / cultural stigma and changing dietary preferences for smallholder farmers	• Sorghum is sometimes viewed as a “poor man’s crop,” reinforcing stigma and discouraging its cultivation among households seeking status and modernity, which makes farmers unwilling to invest labour and land in sorghum production • Younger generations increasingly prefer maize, rice, and wheat-based foods - this shift in dietary	Medium	High	Medium	• Raising awareness regarding sorghum being a healthier grain than others • Training and skills development to encourage smallholder farmers to look beyond subsistence farming, and grow sorghum for the market	DAFF, Provincial Departments of Agriculture

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		preferences has reduced household demand for sorghum and diminished its cultural importance					
25.	Limited access to mechanisation and appropriate equipment for smallholder farmers	• Most smallholder farmers rely on manual labour for planting, weeding, and harvesting, which is time-consuming and limits the size of land that can be cultivated • Appropriate small-scale equipment such as planters, threshers, and dryers tailored to sorghum are either unavailable or unaffordable	Medium	High	Medium	• Establishment of farming cooperatives, which can have aggregated demand for inputs, as well as collaborative marketing efforts • Regional support centres for harvesting and input support, as well as equipment rental • Agricultural extension services • Regional integration of smallholder farmers with commercial farmers that have equipment available	DAFF, Provincial Departments of Agriculture, Farmers
24.	Unavailability of harvest labour	• Small-scale farmers, and some commercial farmers, lack access to capital-intensive mechanisation, relying instead on manual labour, which is slower and leads to post-harvest losses • Hiring delays can delay the harvest • Shortages or high cost of labour can negatively affect the harvest	Medium	High	Medium	• Establishment of farming cooperatives, for aggregated demand and supply of labour • Regional support centres for harvesting and input support • Regional integration of smallholder farmers with commercial farmers that have equipment available	DAFF, Provincial Departments of Agriculture, Farmers
25.	Harvest losses	• Harvesting too early leads to immature grain with low dry matter and moisture issues • Harvesting too late risks rain or humidity damage, grain mould, lodging (plants falling over), increased losses • Poorly calibrated machinery can damage grain, reduce quality or increase the opportunity for mould • A key challenge with sweet	Medium	Medium	Medium	• The sowing / harvest timing should be adjusted to avoid immature grains and/or humidity damage • Pest control, especially for birds • Proper warehousing and storage of harvested crops • Transportation to central storage and processing facilities to prevent losses • Implement systems for	Farmers, DAFF, ARC, DoT

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		sorghum for bioethanol lies in its short harvesting window of 3-4 months				staggered planting or complementary feedstocks to prevent processing plants standing idle outside the harvesting season, and for economies of scale and profitability	
26.	Post-harvest losses	• Commercial farmers: Sorghum losses occur during harvesting or field drying, storage, and transport to the market • Smallholder farmers: The practice of drying sorghum by directly placing it on the ground, exposes the grain to soil contamination, increasing the risk of pest infestation, and reducing the grain quality • Sweet sorghum stalks are prone to rapid sucrose degradation once harvested, with significant reductions in sugar content occurring within 24-48 hours	Medium	Medium	Medium	• Improved physical infrastructure development to lower the risk of contamination and mould, and prevent post-harvest losses • Farmers and processors must operate in close geographical proximity, as far as possible	Farmers, Project Developers, IDC, DAFF
27.	Implementation Delays for Bioethanol projects	• Securing approvals for EIAs, land use permits, and financing agreements can be a time-consuming process. • Delays in obtaining these approvals could result in cost overruns, missed investment windows, and strained relationships with stakeholders.	Medium	High	Medium	• Establishing long-term, consistent policies with clear targets can reduce uncertainty and encourage investment. • Streamlining regulatory processes can expedite project approvals and reduce bureaucratic delays. • Implementing financial support mechanisms such as grants, subsidies, and carbon pricing can make bioenergy projects more viable and reduce financial risks. • Conducting thorough feasibility studies and project planning can help anticipate and mitigate	DMRE, DAFF, National Treasury, Project Developers

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
						potential delays. • Choosing appropriate procurement strategies (e.g., EPC vs. EPCM) can manage interface risks and ensure timely completion.	
28.	Separation downstream and energy expenses	• Ethanol distillation uses a lot of energy and water - margins are lowered by high utility costs • Remaining ethanol in stillage lowers recovery yield	High	Medium	Medium	• Energy efficiency), hybrid separation and stillage / wastewater recycling optimisation should be implemented	LSF, IDC, Project Developers
29.	High processing complexity and costs	• Bioenergy projects require substantial upfront capital investment, and securing financing may be difficult if investors perceive bioenergy as high-risk. • Unfavourable lending terms, lengthy approval processes, and a lack of structured funding mechanisms could further limit financial viability. • Initial investment requirements are substantial • During operation, enzymatic hydrolysis and pretreatment cost are significant • Operational risks include equipment failure, and labour gaps • The economics of a bioethanol processing facility can be swiftly weakened by fluctuating grain costs, shifting biofuel regulations, subsidies or trade policies	Medium	Medium	Medium	• Risk Sharing (e.g. PPPs) among partners, making projects more attractive to private investors by sharing financial burdens and responsibilities. • Government to establish consistent and supportive regulatory frameworks that provide long-term stability and incentives for investors. • Access to finance and/or incentives are critical for startup capital, as well as initial operating costs • Equipment reliability could be addressed through preventive maintenance • Labour gaps need to be filled by workforce training • Business economics could be addressed through hedging, long-term offtake agreements, lobbying and interacting with legislators and the ability to move between the fuel and food markets	IDC, CEF, Project Developers, DMRE, DAFF, National Treasury

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
30.	Bioethanol storage and blending	• Insufficient infrastructure for bioethanol storage, and blending limits market reach and adds costs, which can deter market penetration and sales scale-up • Any secondary storage facility that intends to perform blending activities must apply for a petroleum manufacture licence in terms of the Petroleum Products Act.	Medium	Medium	Medium	• Investment in infrastructure for the storage of biomass • Utilise existing infrastructure (fuel storage, pipelines) - maintain and bring these back into use	CEF, PetroSA, Sasol, DoT, Project Developers
31.	Bioethanol transport	• Existing infrastructure is often geared towards fossil fuel-based energy systems (e.g. multi-fuel pipeline), which can hinder the efficient transportation and processing of biomass. • Poorly maintained infrastructure (roads, pipelines, storage facilities, electrical grid etc.) could result in supply chain disruptions. • Ethanol (and therefore fuel blended with ethanol) cannot be transported in the multi-fuel pipeline, due to its absorption of water and its effects on the other fuels • Road or rail transport will add logistics costs to the fuel's delivered cost	Medium	Medium	Medium	• Investment in infrastructure for the transportation of biomass • Utilise existing infrastructure (pipelines) - maintain and bring these back into use • Locate bioenergy facilities near the feedstock supply • More work needs to be done to look at rail vs truck optimisation for fuel transport • Distribution costs can be optimised if bioethanol is distributed regionally to blenders or users near the processing facilities.	CEF, PetroSA, Sasol, DoT, Project Developers, Logistics companies
32.	Public Awareness and Acceptance	• Stakeholders, such as environmental advocacy groups, may oppose bioenergy projects due to concerns over land use and emissions. • Without effective stakeholder engagement, opposition could lead to legal battles and reputational risks	High	Medium	Medium	• Early and Inclusive Stakeholder Engagement (including communities, NGOs, government authorities, private sector representatives, and marginalised groups) • Addressing local concerns, needs, priorities, and potential risks	Project Developers

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
		• Projects could face resistance from communities if they do not see direct socio-economic benefits. • Low consumer awareness about bioethanol benefits and misinformation about its efficiency slow adoption • Cultural preferences and unfamiliarity with bioethanol usage in fuel are additional barriers • Potential impacts on food security, land use, and biodiversity raise regulatory and public concerns that can restrict market expansion				• Foster partnerships where stakeholders are actively involved in decision-making and share responsibility for project outcomes • Provide training or resources to stakeholders so they can better understand the technical aspects of bioenergy projects • Proactive Community Engagement (Raising Awareness, Consultation, and Participation) • Ensure the project location and transport routes minimise disruption to communities • Implement measures to reduce emissions, noise, and odours to alleviate health concerns • Demonstrating tangible benefits such as job creation, improved infrastructure, and environmental restoration.	
33.	Political Influence	• The five-year term of elected local government officials can lead to shifts in priorities and delays in project implementation, complicating long-term planning for bioenergy initiatives • Political interference and strong lobbying for fossil fuels and nuclear power, coupled with political interests that support and subsidise these industries, creates a disadvantage for renewable energy sources like sorghum	High	Medium	Medium	• Streamlining approval processes prior to project implementation (EIAs, operating licenses, etc.) • Enter into long-term offtake agreements for feedstock • Implement projects in line with JET principles • Develop and implement consistent, supportive policies for bioenergy, including clear regulations and incentives • Improve the efficiency of government institutions involved in energy policy and project	Project Developers, DMRE, DFFE

	Risk	Impact Description	Impact Rating	Likelihood Rating	Overall Rating	Response / Mitigation Measure	Responsible Organisation
						approval processes. This includes streamlining decision-making and reducing corruption. • Implement mechanisms to hold officials accountable for their actions, reducing the potential for corruption and political manipulation.	

7. Benchmarking

South Africa's interest in bioethanol from sorghum arises at the intersection of agricultural development and clean energy policy. Globally, the US has traditionally been the largest producer[468]. In recent years, African countries like Nigeria and Sudan have also emerged among top producers, though largely for subsistence use.[469] Sorghum's importance varies by region; in Africa and parts of India it remains a vital food security crop, whereas in the US, Argentina, Australia, and others it is a commercial crop often used for livestock feed or ethanol. Sorghum's resilience to heat and drought and ability to grow on marginal land have spurred interest in its use for biofuels in climates less suited to water-intensive crops like maize or sugarcane.[470] [471]

South Africa's 2007 Biofuels Industrial Strategy identified sorghum (alongside sugarcane) as a preferred feedstock for ethanol explicitly excluding maize to protect food security - with an initial goal of achieving a 2% biofuel blend in the national liquid fuel supply.[472] However, progress over the past decade has been limited. Sorghum production in South Africa has declined, and today sorghum occupies <1% of South Africa's arable land. The decline reflects weak market demand and stagnant yields, with an average yield around 2.5-3 t/ha, which, while higher than the African smallholder average (1 t/ha), lags far behind US productivity (>4 t/ha).[473] Farmers indicate they will dedicate more land to sorghum only if a stable, sizable market (like a bioethanol industry) offers favourable returns. This poses the central question: *can South Africa competitively produce sorghum for bioethanol at scale, or would it be cheaper to import ethanol from established producers?* The benchmarking analysis compares South Africa's sorghum-to-ethanol value chain against global leaders and regional peers. It focuses on both grain and sweet sorghum pathways and evaluates competitiveness across the entire chain, from land and production, through processing and logistics, to end-use markets, with attention to climate alignment and economic viability.

Six countries are benchmarked: the US, Brazil, India, Kenya, Zimbabwe, and South Africa, which were selected for their relevance as major sorghum producers or users and for insights into bioethanol integration. These case studies span different models in that the US exemplifies high-yield grain sorghum production integrated into a mature ethanol industry; Brazil is a biofuel giant that has experimented with sweet sorghum; India represents a large semi-arid producer with sweet sorghum R&D and a growing ethanol mandate; Kenya and Zimbabwe provide regional perspectives as an importer/user of sorghum and an ethanol mandate case, respectively; and South Africa is the focal point for comparative assessment.

The analysis covers: (1) agro-climatic conditions, production volumes, and yields; (2) value chain structure (farm economics, logistics, processing capacity, markets); (3) performance metrics like ethanol yield per tonne of feedstock, feedstock pricing, and GHG emissions; (4) policy and regulatory

---

468 https://sagl.co.za/wp-content/uploads/Sorghum-Crop-Quality-Report-2022-2023.pdf
469 https://teras.ng/api/asset/document/8788c0d9-d0ab-4f3a-9e69-4fee66dec573
470 (PDF) The Economics of Ethanol from Sweet Sorghum Using the MixAlco Process
471 Bioenergy giant sorghum is high in yield and potential | Great Lakes Bioenergy Research Center
472 https://www.wrc.org.za/wp-content/uploads/mdocs/1874-2-151.pdf
473 https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=The+declining+trend+of+sorghum+production+in+South+Africa_Pretoria_South+Africa+-+Republic+of_9-28-2018.pdf

incentives; and (5) competitive dynamics using Porter's Diamond (national competitiveness factors) and Porter's Five Forces (industry structure) for each country.

Data are drawn from the latest available sources (circa 2023-2025), including FAOSTAT, USDA, government reports, and life-cycle studies, with all monetary figures in USD unless noted. Quantitative comparisons are supplemented by qualitative analysis to identify not just what the competitive positions are, but why i.e. underlying drivers and structural factors. The goal is to derive strategic lessons for South Africa's sorghum ethanol prospects, highlighting what would be required for South Africa to compete and thrive in a climate-aligned biofuel future.

7.1 US: sorghum to ethanol value chain

The US case sees grain sorghum in a mature ethanol complex. The US is a top global producer of grain sorghum and has a highly developed maize (corn) ethanol industry in which sorghum plays a supporting role. US sorghum is grown mostly in semi-arid Great Plains states (Kansas, Texas, Oklahoma, Colorado), on large, mechanized farms. In 2021, the US produced 11.4 million tonnes (Mt) of sorghum (19% of world output[474]), although production fluctuates with market conditions (e.g. drought cut output to 8.7 Mt in 2022). Average yields are in the order of 4.0-4.5 t/ha, among the highest in the world, thanks to advanced hybrids, fertilizer use, and some irrigation. Sorghum occupies 2 million hectares in the US (often in rotation with maize or cotton), thriving in areas too hot and dry for consistent maize success. The crop is primarily used for livestock feed, ethanol, and export. The US has integrated grain sorghum into its bioethanol sector and most sorghum is interchangeable with maize in ethanol dry mills. By 2012 the US Environmental Protection Agency (EPA) had approved a sorghum ethanol pathway, noting it yields the same amount of ethanol per bushel as maize (about 2.7 gallons per bushel, roughly 400 L per tonne of grain).[475] In other words, grain sorghum in the US produces ethanol equivalent to maize starch. This allows many US ethanol plants to switch between maize and sorghum depending on price and availability. When sorghum prices are lower than maize, ethanol producers readily substitute it, and vice versa. In some years, Chinese import demand for US sorghum drives its price above maize, pulling more sorghum into export channels; in other years, sorghum trades at a discount and finds its way into domestic ethanol. On average, about 15-20% of US sorghum production has gone to ethanol in recent years, though this varies (it was higher when China curbed imports during 2018 tariffs, leaving more sorghum for domestic use).

Production costs and farm economics

The production system in the US is high-yield commercial grain sorghum, integrated with maize ethanol capacity and logistics; flexible dry-mill assets can process maize or sorghum, enabling margin-based switching. US sorghum farmers benefit from world-class agricultural infrastructure and R&D. Plants are large-scale with DDGS/CO_2 monetisation and there is access to RFS and LCFS-like CI markets (California) for CI-differentiated value. Value addition includes DDGS, distillers' sorghum oil (biodiesel) and captured CO_2. High-quality seed (hybrids developed by seed companies and universities), mechanisation, and crop insurance are widely available. Sorghum is generally a lower-input crop than maize, needing about one-third less water and often less fertilizer, yet under good management can achieve respectable yields. Production cost studies indicate sorghum can be very cost-competitive: one analysis found farm-gate production costs for sweet sorghum (a parallel case) could be as low as USD0.05-USD0.06 per litre of ethanol produced (assuming yields >30 t/ha of sweet sorghum stalk),

474 https://sagl.co.za/wp-content/uploads/Sorghum-Crop-Quality-Report-2022-2023.pdf
475 Advanced BioFuels USA – EPA Grants Biofuel Pathway for Grain Sorghum

suggesting that grain sorghum, with existing commercial yields and infrastructure, can also be produced cheaply.[476]

US sorghum prices typically track corn (yellow maize) prices, since both grains can substitute in feed and ethanol. Chinese demand heavily influences US sorghum profitability. In the 2020s China accounted for 80-90% of global sorghum imports, mostly from the US. For example, in 2023 China imported 5.2 Mt of sorghum by May, 4.1 Mt of which was supplied by the US. When China buys aggressively, US sorghum prices rise (sometimes exceeding maize); when tariffs or oversupply hit (e.g. 2018 trade war), sorghum prices drop and stocks build up. Thus, US ethanol producers enjoy cheaper sorghum feedstock in those latter scenarios, improving their margins.[477] Overall, American sorghum farmers have the advantage of scale and market flexibility because they can sell into feed, ethanol, or export channels, whichever offers the best return.

Policy support includes the Renewable Fuel Standard (RFS) (RINs), CI credit monetisation and opportunities. The Environmental Protection Agency (EPA) determination means that grain-sorghum ethanol qualifies as renewable fuel with 32% GHG reduction (natural-gas dry mill baseline). US farmers also benefit from federal policies, sorghum used for ethanol qualifies under the Renewable Fuel Standard, and since 2012 sorghum ethanol produced with certain process improvements (like using biogas power) has qualified as an advanced biofuel (50% GHG reduction) under EPA rules. This policy incentive (and associated higher-value renewable Identification Number (RIN) credits for advanced biofuel) can add to the crop’s profitability in ethanol uses.

Ethanol processing and integration

The US ethanol industry is the largest in the world, producing 15 billion gallons (57 billion litres) of ethanol per year chiefly from maize. Sorghum’s integration into this industry is facilitated by technical compatibility with maize processes. Dozens of Midwest ethanol plants can use sorghum interchangeably with maize grain. The Renewable Fuel Standard (RFS) policy has been a key driver: it mandates biofuel volumes and has categories for conventional vs advanced biofuels. Maize ethanol is classified as conventional biofuel. Uniquely, sorghum-based ethanol can qualify as an “advanced biofuel” under RFS if produced with certain process innovations that lower its lifecycle emissions. In practice, the EPA ruled in 2012 that ethanol from grain sorghum meets the ≥50% GHG reduction threshold (vs gasoline) *if* the production facility uses biogas for process energy and other optimisations.

Several sorghum-ethanol plants implemented such measures (e.g. anaerobic digesters to capture methane from waste) to earn valuable “D5” credits (Renewable Identification Numbers, RINs). This policy quirk effectively rewarded sorghum ethanol with a price premium (via RIN trading) when produced in a low-carbon way, enhancing its competitiveness. From a Greenhouse Gas (GHG)performance standpoint, standard grain sorghum ethanol (with natural gas process fuel) typically achieves around 20-30% greenhouse gas savings relative to gasoline (similar to maize ethanol), but with biogas and efficient farming it can exceed 50% savings. The ability to reach advanced biofuel status is a unique strength of sorghum in the US context, aligning the value chain with climate goals.

---

476 https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1168&context=ageconfacpub
477 Advanced BioFuels USA – EPA Grants Biofuel Pathway for Grain Sorghum

In sum, the US delivers high-yield grain sorghum integrated in a mature ethanol industry; EPA has certified grain-sorghum ethanol as qualifying under RFS with 32% lifecycle GHG reduction (baseline gasoline), helping carbon-intensity monetisation where crediting exists.[478]

Logistics and market

The US grain handling and biofuel logistics system is highly advanced. The US sorghum belt is well-served by grain elevators, rail lines, and barge facilities, enabling efficient movement to domestic end-users or ports for export. Sorghum destined for ethanol is usually processed in existing maize ethanol plants with minimal modifications. Distillers' grains from sorghum are slightly lower in protein than corn (maize) DDGS but still find ready markets in animal feed. CO_2 from fermentation is captured in many plants for the food/beverage or oil recovery markets. Sorghum moves from farm to storage silos to ethanol plants or export terminals primarily by truck and rail. The Mississippi River and Gulf ports ship bulk sorghum to China and Mexico. For ethanol, an extensive distribution network (railcars, trucks, barges) moves fuel ethanol from Midwest plants to blending terminals nationwide.

Ethanol blending in the US is 10% (E10) nationwide, with some regions using higher blends (and flex-fuel vehicles capable of E85). Sorghum-based ethanol, being chemically identical to maize ethanol, slots into this system seamlessly. The *market structure* is competitive: dozens of firms (farmer cooperatives and private companies) operate ethanol plants, and they compete to buy feedstock and sell ethanol.

Thanks to the Renewable Fuel Standard (RFS), there is a guaranteed demand for ethanol and consequently ethanol producers focus on operating efficiency and feedstock procurement. In recent years, maize has dominated feedstock supply, but sorghum provides a strategic alternative that diversifies feedstock risk and can be economically advantageous when priced right. For example, in 2015 when sorghum was cheap, over 100 million bushels of sorghum (2.5 Mt) went into ethanol. By contrast, in 2018 when China imposed tariffs, sorghum that would have been exported flooded local markets, temporarily benefiting ethanol plants with low-cost sorghum until farmers reduced plantings. Thus, the US experience demonstrates how a flexible feedstock approach and strong market infrastructure underpin sorghum ethanol competitiveness.

On the export side, the US remains the world's largest sorghum exporter, typically shipping 5-7 million tonnes annually in recent peak years (mostly to China). Gulf Coast sorghum export prices and basis tend to be influenced by Chinese purchasing: a surge in Chinese buying tightens US supply and raises sorghum prices (sometimes above maize), whereas a lull in Chinese demand sees sorghum trade at a discount to maize and encourages domestic uptake in ethanol and feed. This dynamic has made China the "demand swing factor" in the global sorghum markets.

Sweet vs. grain sorghum

In the US, grain sorghum is the focus, and sweet sorghum has not been widely adopted for ethanol.[479] There have been some trials of sweet sorghum in the Southwest and Midwest, but logistical challenges

[478] US EPA. "Supplemental determination-grain sorghum ethanol pathway under RFS2." *Federal Register* 77(113), June 12, 2012; plus, related rulemakings (2012/2018).

[479] Ana Bušić et al., "Bioethanol Production from Renewable Raw Materials and Its Separation and Purification: A Review," *Fermentation* 4, no. 1 (2018): 1–25. https://doi.org/10.3390/fermentation4010002. PMC; Renewable Fuels Association

(bulky, perishable stalks) and competition with the well-oiled maize system limited its appeal.[480] One study in the Upper Midwest found that if sweet sorghum yields exceeded 30 t/ha, it could be farmed at competitive cost, but reliably achieving those yields in the US rainfed context proved difficult. Moreover, harvesting and transporting heavy sorghum cane would require new equipment and processing facilities near fields, whereas grain sorghum can use existing combine harvesters and ethanol plants. As a result, US innovation focused on improving grain sorghum strains (for higher yield and drought tolerance) and on integrating grain sorghum into existing maize ethanol biorefineries. This leverages grain sorghum's main advantage, it is a drop-in substitute in the starch-to-ethanol process, unlike sweet sorghum which would require sugar extraction similar to mini-sugarcane operations. In short, grain sorghum's compatibility with current infrastructure made it the economically rational choice in the US.[481]

GHG performance

US grain sorghum ethanol can be low carbon when best practices are used. The EPA's analysis in approving the sorghum pathway found that with biogas energy, sorghum ethanol can achieve 53% GHG reduction versus gasoline (qualifying it as advanced biofuel). In U.S. regulatory analyses and recent LCAs, when process energy is supplied by biogas and combined heat and power (CHP), sorghum ethanol achieves roughly a 50-55% lifecycle GHG reduction versus gasoline, meeting the advanced biofuel threshold under the Renewable Fuel Standard (RFS).[482] Without such measures (i.e., with conventional natural-gas process energy), the GHG savings are materially smaller and align with conventional renewable fuel performance (around 30% reductions in earlier EPA modelling), while recent Argonne modelling still shows sorghum ethanol substantially below petroleum gasoline (total direct CI ~46 gCO_2e/MJ vs. gasoline 93 gCO_2e/MJ).[483]

Even baseline sorghum ethanol has a somewhat lower carbon intensity than baseline maize ethanol, partly because sorghum cultivation in its semi-arid niche involves fewer nitrous oxide emissions (due to

(RFA), *Trends in the Operational Efficiency of the U.S. Ethanol Industry* (Washington, DC, February 9, 2024), esp. p. 3 (sorghum volumes small relative to corn). https://ethanolrfa.org. Renewable Fuels Association; United Sorghum Checkoff Program, "Renewable Energy," accessed October 7, 2025. https://www.sorghumcheckoff.com/sustainability/renewable-energy/ (notes sorghum and corn are interchangeable in starch-based ethanol)

[480] N. B. Appiah-Nkansah et al., "A Review of Sweet Sorghum as a Viable Renewable Resource for Biofuel Production," *Renewable and Sustainable Energy Reviews* 110 (2019): 74–87 (discusses post-harvest sugar losses, high moisture/low bulk density, short harvest window). https://doi.org/10.1016/j.rser.2019.04.047. ScienceDirect; T. D. Hoang, V. S. Nghiem, and M. R. Johns, "Recent Developments and Current Status of Commercial Bioethanol Production," *Fermentation* 7, no. 4 (2021): 314 (notes US reliance on corn dry-grind; other grains also processed by dry-grind). https://doi.org/10.3390/fermentation7040314. MDPI; Richard Perrin, Lilyan Fulginiti, Subir Bairagi, and Ismail Dweikat, "Sweet Sorghum as Feedstock in Great Plains Corn Ethanol Plants: The Role of Biofuel Policy," *Journal of Agricultural and Resource Economics* 43, no. 1 (2018): 34–45 (economic feasibility sensitive to RIN policy; sparse cultivation raises transport costs). https://jareonline.org/ar

[481] R. K. Pradhan et al., "Impact of Mixing Grain Sorghum with Corn on Ethanol and Coproduct Yields," *Cereal Chemistry* 101 (2024): e12735 (demonstrates grain sorghum in dry-grind systems and coproduct value effects). https://doi.org/10.1002/cche.12735. ResearchGate; Z. Mohammadi Shad et al., "Corn Distillers Dried Grains with Solubles: Production, Characterization, and Utilization," *Cereal Chemistry* 98, no. 4 (2021): 699–716 (context on dry-grind process and coproducts, applicable to sorghum integration). https://doi.org/10.1002/cche.10445. Wiley Online Library

C. H. Briand, S. B. Geleta, and R. J. Kratochvil, "Sweet Sorghum (Sorghum bicolor [L.] Moench) a Potential Biofuel Feedstock: Analysis of Cultivar Performance in the Mid-Atlantic," *Renewable Energy* 129 (2018): 328–33 (US field trials; cultivar performance for ethanol). https://doi.org/10.1016/j.renene.2018.06.

[482] U.S. Environmental Protection Agency, "Lifecycle Greenhouse Gas Results," *Fuels Registration, Reporting, and Compliance Help*, updated May 29, 2025 (RFS reduction thresholds and pathway summaries). EPA; Hao Cai et al., *Life Cycle Analysis of Greenhouse Gas Emissions of Clean Fuels with the R&D GREET 2024 Model* (Argonne National Laboratory, Feb. 2025), esp. Table 5 reporting sorghum ethanol total direct CI ~43–46 gCO_2e/MJ and discussion of process-energy effects.

[483] United Sorghum Checkoff Program, *Mid-Atlantic Production Guide* (Lubbock, TX: USCP, 2021), 22 ("Grain sorghum requires less nitrogen than corn …"). sorghumcheckoff.com; Tyler J. Ostmeyer, Jaspreet Sandhu, and Vara Prasad, "Enhancing Sorghum Yield Through Efficient Use of Nitrogen," *Frontiers in Plant Science* 13 (2022): 845443 (sorghum's nitrogen-use efficiency and performance under low-N, water-limited conditions)

lower fertiliser use) and because sorghum's drought resilience means less year-to-year land-use change for failed crops. Additionally, the bagasse (residual fibre) from sorghum grain processing is similar to maize fibre, which some next-generation processes ferment into cellulosic ethanol or burn for energy. In summary, the US has demonstrated that grain sorghum can be a competitive and even strategically superior feedstock under certain policy and market conditions.

Policy and incentives

The United States' feedstock-agnostic regulatory architecture converts policy into bankable demand and carbon-based value: the Renewable Fuel Standard (RFS) makes E10 the de facto national blend and transmits incentives through RIN credits, while EPA-approved grain-sorghum pathways, especially with biogas/CHP, qualify for lower-CI tiers, letting dry-mills switch between maize and sorghum and monetise carbon performance. Relative to South Africa's still-emerging mandate and pricing framework, this mature, predictable compliance market is reinforced by expanding retail infrastructure for higher blends and gives U.S. sorghum a clear route-to-market and superior risk-adjusted returns.

The US does not subsidise sorghum-for-ethanol directly; instead, the crop fits into a broader set of fuel-neutral policies that create demand and reward lower-carbon pathways. At the federal level, the RFS establishes annually updated volume obligations for four nested categories (renewable, advanced, biomass-based diesel, cellulosic) and requires fuel suppliers to demonstrate compliance with tradable RINs. In 2023 the EPA issued the first post-statute Set Rule (2023-2025), locking in rising national biofuel volumes and sustaining the market signal to blend ethanol nationwide; a federal appeals court left those standards in place in June 2025, reinforcing policy certainty while remanding limited issues for further EPA review.[484] Although there is no national E10 law, the RFS effectively made E10 the de facto blend (E10 accounts for most U.S. gasoline), with E15 and E85 expanding regionally.[485]

Each qualifying gallon of renewable fuel generates a RIN; obligated parties retire RINs to meet their annual quotas or purchase them on the market. When RIN prices are higher, the effective value of ethanol to blenders rises and plants' margins improve; when RIN prices fall, compliance costs drop and producer margins tighten. In short, RINs act as the price signal that transmits RFS policy into day-to-day economics for maize- and sorghum-using dry-mills.

Sorghum's policy edge comes from lifecycle carbon performance. EPA's most recent Lifecycle GHG Results recognise grain-sorghum ethanol pathways; when plants use biogas/CHP or similar process-energy upgrades, lifecycle GHG reductions are roughly ≥50% vs. petrol, qualifying the output as advanced biofuel (D5) rather than conventional (D6). [486]Argonne's 2024/2025 GREET modelling likewise reports total direct CI 43-46 gCO_2e/MJ for sorghum ethanol with contemporary assumptions, far below gasoline's 93 gCO_2e/MJ. [487] In parallel, EPA's Efficient Producer (EP3) petitions and recent determinations explicitly cover co-processing maize and grain sorghum starch (and kernel fibre) to generate conventional and cellulosic RINs in the same facility is practically important because it allows maize-ethanol plants to "drop-in" sorghum when it is cost-effective without major retooling.[488] Industry

[484] U.S. Environmental Protection Agency, "Final Renewable Fuels Standards Rule for 2023, 2024, and 2025," EPA RFS Program page (accessed Oct. 7, 2025). EPA; Ren*ewable Fuel Standard (RFS) Program: Standards for 2023–2025 and Other Changes*, Federal Register (July 12, 2023)

[485] EIA, "Biomass-based diesel and ethanol compliance credit (RIN) prices and implications," *Today in Energy*, Feb. 27, 2024. U.S. Energy Information Administration; □ S. EPA, "Renewable Identification Numbers (RINs) under the RFS," updated Jan. 17, 2025.

[486] U.S. EPA, "Lifecycle Greenhouse Gas Results" (RFS LCA summary page), updated May 29, 2025.

[487] Hao Cai et al., "Life Cycle Analysis of GHG Emissions of Clean Fuels in R&D GREET 2024," Argonne National Laboratory, Feb. 2025 (PDF

[488] U.S. EPA, "Lifecycle Greenhouse Gas Results" (RFS LCA summary page), updated May 29, 2025.

development support has also come from the farmer-funded United Sorghum Checkoff Program, which invests in R&D, market development and policy engagement rather than paying direct crop subsidies.[489]

While not sorghum-specific to ethanol, US crop insurance and commodity programmes reduce farmers' income risk and stabilise supply. Sorghum growers can ensure yield/quality (e.g., RMA's 2023-onward handbooks for silage/grain products), and they may enrol sorghum base acres in ARC/PLC commodity safety-net programmes administered by USDA. These mechanisms cushion downside price or yield shocks and make rotations into sorghum less risky when ethanol plants are pulling grain.[490]

A number of state and regional policies indirectly support sorghum-using plants by improving ethanol's marketability and rewarding low-carbon intensity. California's Low-carbon Fuel Standard (LCFS) creates a second credit stream for low-CI ethanol shipped into that market; Oregon and Washington operate similar clean-fuels programmes. Beyond carbon policy, both federal and state infrastructure grants have expanded higher-blend retailing, increasing demand outlets for ethanol from any starch (maize or sorghum). USDA's Higher Blends Infrastructure Incentive Program (HBIIP) committed USD537 million to 543 projects across 29 states in 2025, while Iowa's Renewable Fuels Infrastructure Program offers cost-share grants and, from 2026, an E15 access standard that pushes retailers to provide mid-level blends. Similar cost-share or tax-credit schemes exist or are emerging in other sorghum-belt states.[491]

In summary, the U.S. case shows that policy-driven demand (RFS volumes that make E10 universal) plus innovation incentives (RIN/LCFS value for lower-CI production) were sufficient to integrate grain sorghum into a very competitive ethanol sector, without sorghum-specific price supports. Plants switch between maize and sorghum as relative prices and carbon credits dictate; farmers face lower risk due to insurance and commodity programmes; and infrastructure grants expand the retail space for higher blends. *For South Africa's benchmarking, the lesson is that a feedstock-agnostic mandate, transparent carbon-intensity incentives, and retail infrastructure support can pull sorghum into ethanol at scale, provided the farm-gate economics and logistics are competitive.*

US diamond analysis

Factor conditions are exceptionally strong in the US. It has abundant semi-arid land suitable for sorghum, advanced agronomic technology (hybrid seeds, mechanization, precision farming), established ethanol plants, and superb transport/logistics infrastructure. Farmer skill and capital are high, and extensive R&D exists (e.g. USDA and universities developing drought-tolerant varieties). These endowments give the US a productivity edge (average 4+ t/ha yields). A minor factor limitation is water in sorghum regions as reliance on rainfall can cause output swings, but irrigation is available in some areas, and sorghum's drought tolerance mitigates water stress. Overall, factor conditions for grain sorghum ethanol in the US are among the best globally.

---

[489] United Sorghum Checkoff Program, "Renewable Energy" (programme focus on ethanol market development), accessed Oct. 7, 2025

[490] USDA Risk Management Agency, "Silage Sorghum Loss Adjustment Standards Handbook," effective 2023 and succeeding crop years. Risk Management Agency; USDA Economic Research Service, "Title I: Crop Commodity Program Provisions (ARC/PLC overview)," Jan. 8, 2025

[491] FDC, "Biofuel Infrastructure Grants (Iowa RFIP summary)." Alternative Fuels Data Center;
Kansas Legislature (testimony), "Providing an income tax credit for the sale and distribution of higher-blend ethanol," Jan. 27, 2025; see also trade press on pending Kansas ethanol tax credit and state economic-development incentives

Demand conditions. There is strong domestic demand for ethanol due to the national E10 blending and a large gasoline market. The US fuel market (140 billion gallons gasoline/year) creates a huge pull for ethanol as an oxygenate and octane booster. There is also robust demand for sorghum in feed and export markets, especially to China, which indirectly strengthens the value chain by giving producers options. Moreover, environmental demand (policy-driven for low-carbon fuels) spurred some preference for sorghum ethanol (as advanced). Domestic consumers don't specifically demand sorghum ethanol (it is fungible with maize ethanol), but the broad demand for biofuel and high-octane fuel sustains the industry.

Related and supporting industries are highly developed. The US has a mature grain industry (silos, trading networks, export terminals) and an enormous ethanol industry with supporting industries like enzyme and yeast suppliers, engineering firms, and equipment manufacturers. Sorghum farmers benefit from the maize sector's infrastructure: transport, storage, and processing are shared. The presence of world-class agricultural equipment manufacturers and biotechnology firms supports continuous improvement. Additionally, the livestock industry provides a market for co-products (distillers grains), enhancing profitability. These supporting industries reinforce competitiveness by driving down costs and enabling innovation.

Firm Strategy, Structure, Rivalry. Ethanol production in the US is largely done by private companies and farmer co-ops operating in a competitive market. Rivalry is vigorous because firms strive for efficiency to survive thin margins. This competition has driven cost innovations (e.g. using sorghum when cheaper, adopting new enzymes, capturing CO_2 for sale, etc.). Sorghum producers, through their checkoff, strategically market sorghum as a versatile crop. The industry structure allows flexibility: firms can adapt feedstock mixes rapidly based on market signals. This adaptability is a competitive strength. The sorghum sector's strategy has been to position itself as a complementary grain to maize, rather than a direct competitor, carving a resilient niche (especially for drought-prone regions). Rivalry from maize is significant (maize dominates ethanol), but sorghum competes by thriving where maize cannot and by leveraging policy advantages. Overall, strong competition and profit motives push continuous improvement in the US value chain.

Government. US government policy (RFS) has been crucial in creating the ethanol market. Without the blending mandate and RIN system, ethanol (and thus sorghum ethanol) would likely be much smaller. Government also funds agricultural research (including sorghum breeding) and provides crop insurance and occasional trade assistance (e.g. payments when tariffs hit exports), all of which reduce risk for sorghum farmers. "Chance" events like oil price spikes or droughts have sometimes boosted ethanol's appeal or sorghum's relative advantage (e.g. 2012 drought hurt maize yields more than sorghum). By and large, proactive government support and some luck (Chinese demand surging) have benefited the US sorghum-ethanol competitiveness. The US scores strongly on nearly all Diamond dimensions, explaining its success as a grain-ethanol powerhouse.

US five forces analysis

Industry rivalry is high. Ethanol producers face intense rivalry, as many firms produce an undifferentiated product (fuel ethanol). Profit margins are slim, so there is strong competition on efficiency. Sorghum competes with maize within these plants; rivalry isn't between "sorghum ethanol firms" per se (since most firms do both), but rather rivalry in the broader ethanol industry forces each producer to minimize feedstock costs and maximize yield. The presence of many ethanol plants in the Midwest keeps competition high. However, because demand is mandated and generally exceeds domestic production at current blend levels, the rivalry is tempered by a guaranteed market - firms compete for market share and feedstock rather than worrying about insufficient demand.

Threat of new entrants is medium as building a new ethanol plant in the US is capital-intensive (USD100+ million investment) and subject to regulatory compliance, which are significant barriers. Additionally, the market is near saturation for E10, meaning any new entrant would be predicated on expanding demand (e.g. E15/E85 or export markets). However, knowledge and technology for ethanol production are widely available, and if cellulosic or other tech opens niches, new entrants could emerge. In the sorghum belt, a few new sorghum-to-ethanol initiatives could in theory appear (especially if policy favoured advanced biofuels more strongly). But overall, entry is limited by high capital needs and a well-established incumbent network.

Bargaining power of suppliers is medium as the key suppliers are sorghum farmers (and input suppliers to those farmers). Individual farmers are price-takers in a commodities market; their power is limited because ethanol plants and exporters can source grain from a broad area. However, suppliers collectively have some power in that if sorghum acreage drops or if Chinese buyers bid up the price, ethanol plants must pay more or switch to maize. The ease of switching to maize somewhat reduces sorghum farmers' power: if they demand too high a price, ethanol buyers will simply buy maize instead. On the flip side, if maize prices spike (e.g. due to a corn Belt drought) and sorghum has a good crop, sorghum farmers might have bargaining leverage as an alternative source of starch. Input suppliers (seeds, equipment) in the US are large corporations (like DuPont, John Deere), but their pricing affects all crops, similarly, not giving sorghum-specific disadvantage. In sum, while no single farmer can dictate terms, the overall availability and pricing of sorghum (often influenced by external demand) can sway ethanol economics - making this force moderate.

Bargaining power of buyers is low to moderate. Buyers of ethanol in the US are typically fuel blenders and refiners (e.g. oil companies) who are obligated to blend ethanol under the RFS. Since ethanol is a mandated commodity, these buyers have limited discretion: they need to procure ethanol to comply. On price, they have some leverage because ethanol competes with gasoline and because they can import ethanol (e.g. from Brazil) if US prices are too high. However, in practice the RFS sets a floor for demand. Ethanol producers usually sell to a few large blenders, but the existence of a market-wide mandate and a secondary market for RIN credits means no single buyer can strong-arm producers on price beyond what the market sets. Thus, buyer power is not as strong as in an open market - it is somewhat muted by policy-created demand inelasticity. Fuel distributors do have negotiating power on logistics and quality specs, but again, the product is standardised. Consumers at gas pumps have virtually no direct influence (they just get E10 by default and generally only notice if price or mileage is affected). Overall, the buyers (refiners/marketers) have moderate power mainly through fuel price competition, but not enough to suppress the industry.

Threat of substitutes. This is moderate in the mid-term, higher in long-term. The main substitute for ethanol is fossil gasoline (or other octane additives) if the mandate were reduced or not enforced. To some extent, other biofuels (like biodiesel or renewable gasoline) could substitute in fulfilling renewable goals. However, given current policies, ethanol is entrenched in the fuel supply. Longer-term, electric vehicles (EVs) pose a substitute threat to liquid fuels overall as EV adoption rises, gasoline (and thus ethanol blend) demand could plateau or decline. This is a threat to the whole ethanol industry in the 2030+ horizon. In terms of feedstock substitution, maize is a substitute input for ethanol plants (but that's within the industry). Maize clearly dominates in the US, so one could say sorghum ethanol faces an ever-present substitute threat from maize ethanol if it cannot keep costs competitive. Overall, substitutes to ethanol fuel are limited in the short run due to infrastructure and policy lock-in, but future tech (EVs) and other feedstocks keep this force in play.

In sum, the US demonstrates that with favourable natural endowments, strong policy support, and integration into existing industries, grain sorghum can be a competitive ethanol feedstock. US sorghum ethanol leverages high yields, flex-feedstock processing, and economies of scale to achieve low unit costs. The US example highlights the importance of high productivity (4+ t/ha yields vs 2-3 t/ha in South Africa) and robust demand (mandated blending) in making a sorghum-ethanol chain viable. It also shows that diversification (having multiple markets for sorghum) and innovation (GHG credits, etc.)

can create niches where sorghum excels. For South Africa, key lessons include investment in yield improvement, building flexible processing that can handle multiple feedstocks, and ensuring policy creates a guaranteed market. Without these, a sorghum ethanol industry would struggle to replicate the US's success.

7.2 Brazil: sugarcane ethanol leader

Brazil is the world's second-largest ethanol producer (after the US), with a well-established sugarcane-to-ethanol industry.[492] Brazil was selected as a benchmark for its pioneering efforts to integrate sweet sorghum into sugarcane ethanol systems.[493] R&D tends to focus on the application of sweet sorghum as off-crop extender near mills (where agronomy/logistics allow). While Brazil's grain sorghum production is modest, roughly 2-3 Mt in recent years, and primarily used for livestock feed, production has been rising.[494] The country has conducted extensive R&D on sweet sorghum as a complementary ethanol feedstock. The core idea is to plant sweet sorghum on existing sugarcane land during the cane off-season, keeping distilleries supplied beyond the normal cane harvest window; recent Brazilian studies and reviews emphasise this season-extension role.[495] Although the magnitude depends on local yields and mill downtime, recent reviews that synthesise earlier demonstration projects indicate that off-season sorghum can materially increase annual plant utilisation (and thus throughput) when the cane idle period is long, and figures on the order of one-fifth have been reported in those case studies.[496]

Sweet sorghum's growth cycle (120 days) is much shorter than sugarcane's 12-18 months, enabling such fits in the calendar.[497] Under favourable Center-South conditions (e.g., São Paulo), sweet sorghum stalk yields of 40-60 t/ha have been documented, translating to about 1,500-2,000 L/ha of ethanol in a single short season (with higher values reported in some trials depending on °Brix and process energy).[498] For comparison, Brazilian sugarcane ethanol typically ranges around 6,500-7,500 L/ha per year under commercial conditions.[499]Moreover, double-cropping to raise biofuel output per hectare-year is a proven Brazilian strategy in other feedstock pairings (e.g., maize after soybean), and

[492] IEA, "Brazil-Countries & Regions," accessed October 7, 2025. International Energy Agency; Ethanol Producer Magazine, "Brazil Produces Record 9.73 Billion Gallons of Ethanol in 2024," February 6, 2025

[493] A. M. Martins et al., "Characterization of Sweet Sorghum Genotypes regarding Biofuel Traits," *Ciencia e Agrotecnologia* (SciELO), 2025 (on sweet sorghum assisting ethanol production between cane harvests). SciELO; A. C. Pereira et al., "Performance agronômica de sorgo sacarino… (Mato Grosso)," *Research, Society and Development* 11, no. 12 (2022) (short cycle, mechanisation; use in off-season

[494] Southern African Grain Laboratory (SAGL), "World Sorghum Production and Consumption (2018/19–2022/23)," 2023-Brazil range 2.1–3.0 Mt.; USDA FAS (Brasília), *Cultivating Growth: The State of Sorghum Production in Brazil* (GAIN BR2025-0022), July 10, 2025 (production trends; predominant feed use).

[496] O. E. Ferreira et al., "Sweet Sorghum Broth Clarification… Improves Wort Quality," *Bioscience Journal* 37, no. 6 (2021): notes that a 90–120-day lifecycle "can be harvested during the sugarcane off-season, increasing the ethanol production period without larger planted area.

[497] G. M. R. Lombardi et al., "Heterozygosity, Adaptability, and Phenotypic Stability of Sweet Sorghum…," *Revista Caatinga* (2024): short ~120-day cycle; biomass ≥ 50 t/ha; 13–24 °Brix; A. Grandis and M. S. Buckeridge, "Scientific Research on Bioethanol in Brazil: History and Perspectives," *Sustainability* 16, no. 10 (2024): sugarcane biology, multi-month crop cycle in Brazil.

[498] TechScience (Phyton), "Tolerance of Sweet Sorghum… (BRS 506 in Brazil)," 2025-reports stalk yields 40–60 Mg/ha and 120–130-day cycle.

[499] J. Colussi, "Brazil Emerges as Corn-Ethanol Producer…," *farmdoc daily* (University of Illinois), June 2023-compares typical Brazilian sugarcane ethanol yields ~6,500–7,500 L/ha

the same utilisation logic underpins sorghum-in-cane off-season integration.[500] Policy is supportive via stable mandates (E27→E30), and RenovaBio (CBIOs) rewarding lower CI.

Production and harvesting

Brazil's production system has a dominant cane base with rising maize ethanol. E30 is now approved nationally, lifting an already large ethanol market. Production is typically cane mills with cogeneration, and maize ethanol in the Centre-West region. Brazil's climate (tropical to subtropical) is favourable for both cane and sweet sorghum, given sufficient rainfall or irrigation.[501] Sweet sorghum trials were often done with some irrigation to ensure good yields in the dry season. [502]The crop was grown on cane farms, using existing farm equipment adapted slightly for sorghum (planters, harvesters).[503] However, agronomic challenges emerged in that sweet sorghum varieties needed for Brazil had to mature at the right time and resist diseases in that environment. [504] Considerable breeding work (by Embrapa and others) went into developing sorghum cultivars with high sucrose content and appropriate maturity for different regions. Harvesting sweet sorghum is akin to harvesting maize or cane: Brazilian mills experimented with both manual cutting and modified cane harvesters to cut and chip the sorghum stalks.[505]

A key challenge is the logistics of rapid processing, once cut, sweet sorghum stalks start degrading (sugars can ferment in the field). Brazil leveraged its cane processing infrastructure and sorghum stalks were crushed in the same mills that crush cane. However, unlike cane which can sometimes be left in windrows for a short time, sorghum stalks proved even more urgent to process.[506] Some projects tested producing sorghum syrup (evaporating the juice) to allow storage and transport, but typically the model was local use at the mill. In summary, Brazil demonstrated that sweet sorghum can be grown and processed with existing infrastructure, but timing and coordination are critical (the harvest must be synchronized with mill availability, and the window is just a few weeks).[507] Brazilian producers add value via power export, vinasse fertigation, CO_2, and DDGS (maize plants).

Ethanol yields and processing

[500] A. C. Gurgel et al., "Contribution of Double-Cropped Maize Ethanol in Brazil to Sustainable Development," *Nature Sustainability* (2024)-demonstrates per-hectare-year energy gains from double-cropping systems; utilisation logic transferable to sorghum–cane off-season concepts. Nature

[501] USDA Foreign Agricultural Service (FAS), *Cultivating Growth: The State of Sorghum Production in Brazil* (BR2025-0022), 10 July 2025 (adaptation across Brazil's regions). USDA Apps; USDA FAS, *Sugar Annual* (BR2025-0011), 22 April 2025 (Center-South cane conditions/yields)

[502] D. J. Mathias et al., "Sweet Sorghum as a Potential Fallow Crop in Sugarcane Farming… (Queensland)," *Energies* 16, no. 18 (2023): methods show furrow irrigation and two 100-mm irrigations. MDPI; M. A. Alsanad et al., "Optimizing Bioethanol Yield of Sweet Sorghum under Water Deficit and Irrigation Regimes," *Water* 16, no. 10 (2024)

[503] USDA FAS (BR2025-0022), section noting sweet sorghum is "harvested for its stalks… and crushed, similar to sugarcane." USDA Apps; G. Eggleston, "Sugarcane, Sugar Beet, and Sweet Sorghum Processing," *Sugar Tech* (2025) (processing principles and equipment commonalities across sugar-rich crops)

[504] A. M. Martins et al., "Characterization of Sweet Sorghum Genotypes Regarding Adaptability and Stability for Biofuel Production," *Ciência e Agrotecnologia* 49 (2025) (Embrapa-led multi-environment trials).

[505] Q. He et al., "Design and Experimental Study of Sorghum Cutting Tables," *Engenharia Agrícola* (SciELO Brazil), 2025 (mechanised harvester adaptations for sorghum)

[506] *Sweet Sorghum – an Overview*, ScienceDirect Topics (accessed 2025): short optimal harvest window and rapid sugar degradation if stored.

[507] K. T. Klasson et al., "Bioethanol Fermentation of Clarified Sweet Sorghum Syrup; Storage and Sugar Losses," *Industrial Crops and Products* 170 (2021) (syrup storage with 11–18% sugar loss over 10 weeks).

In Brazilian pilot studies, sweet sorghum juice was fermented much like cane juice, using the same front-end preparation, clarification, and yeast-based fermentation sequences employed at cane mills.[508] or context, typical Brazilian conversion for sugarcane in official statistics and industry reporting is on the order of 80-85 L per tonne of cane, depending on Total Recoverable Sugars (TRS) and allocation, underscoring why sorghum's lower stalk sugar (often 15 % soluble sugars versus 20 % in cane) translates into a lower L/t outcome even with similar fermentation performance.[509] Co-products mirrored cane operations: sorghum bagasse (fibre) was burned for process heat, but its higher moisture (67-71 %) and different fibre/ash profile required drying and, in some trials, co-firing/blending with cane bagasse to stabilise boiler performance.[510] Some sweet-sorghum cultivars set a modest grain head, and Brazilian trials occasionally collected grain for feed or malt, though most mill-integration programs favoured low-grain, high-Brix types to direct assimilates to stalk sugar.[511] On costs, a recurrent finding in Brazil's literature and policy analysis is that using idle cane-mill capacity in the intercrop season is the primary economic lever: CAPEX is already sunk, utilities and staff are in place, and payment systems can index farmer remuneration to sugar content (ATR) by analogy to CONSECANA pricing used for cane.[512] For illustration, if one tonne of sweet sorghum yields ~70 L and ethanol sells near USD0.50/L, gross value is USD35/t; a split in the order of USD15-20/t to growers can be feasible once processing and overheads are netted out provided field yields and sugar quality are reliable, and the mill's off-season window is well coordinated.[513] same cost as marginal sugarcane ethanol, provided yields were decent and prices for sorghum were linked to ethanol output. For instance, one approach was to pay farmers a price per tonne of sorghum based on its sugar content relative to cane, if 1 tonne of sorghum yielded 70 L ethanol and ethanol was selling at USD0.50/L, the gross value is USD35, of which maybe USD15-USD20 could be paid to the farmer (the rest covering processing). In Brazil's context, this was attractive relative to alternative uses of that land during the off-season, and relative to cane itself.

Market and usage

Brazil's ethanol market is immense and dynamic. Annual ethanol production is around 30-32 billion litres (2024/25), almost all consumed domestically in the E27 blend gasoline and as E100 hydrous ethanol in flex-fuel cars.[514] Virtually all of this comes from sugarcane (though maize ethanol has grown to 2-3 billion litres, 8-10 percent of supply in recent years in Brazil's west). Sweet sorghum's role so far is still experimental. During the early 2010s, a few mills (with support from Petrobras Biocombustível and others) produced limited batches of ethanol from sorghum. As of 2025, sweet sorghum is not yet a mainstream feedstock - it did not see large-scale adoption after the initial excitement. Reasons included variable yields (in some years, drought or pest issues made sorghum yields disappointing),

[508] Glen Eggleston, "Sugarcane, Sugar Beet, and Sweet Sorghum Processing," *Sugar Tech* (2025)-on front-end/fermentation commonalities and season-extension concepts.

[509] USDA Foreign Agricultural Service (FAS), *Brazil Biofuels Annual* (BR2023-0018): "1 metric ton of sugarcane = 80 L ethanol" conversion factor used in official analysis

[510] G. A. Türp et al., "Enhancing energy potential of sweet sorghum by biomass management," *Industrial Crops & Products* 201 (2023): effects of harvest timing and bagasse characteristics for combustion.

[511] A. M. Martins et al., "Characterization of sweet sorghum genotypes…," *Ciência e Agrotecnologia* 49 (2025): Brazilian breeding toward high-Brix/low-grain materials for ethanol timing windows

[512] UNICA/CZAPP data on ATR price series (São Paulo), 2024.

[513] EPE (Empresa de Pesquisa Energética), *Analysis of Current Biofuels Outlook – Year 2023* (technical note, 13 Sept 2024): market context for Brazilian ethanol prices/volumes;

[514] IEA Bioenergy, "Implementation of Bioenergy in Brazil – 2024 Update" (December 2024), 7–9 (E27 and widespread E100 use in FFVs; ethanol share in transport)

logistics and perishability constraints for stalk-to-juice systems, and the expansion of maize ethanol, which provided off-season supply in Brazil's Center-West.[515]

However, interest remains, especially as climate change and land constraints push the search for multi-feedstock flexibility. If sugar prices are high, mills focus on sugar; if ethanol economics are favourable and cane is limited, sorghum could be reconsidered. Brazil's RenovaBio program, a carbon-credit system, also creates incentives for lower-carbon fuel and can reward mills that improve overall biofuel yield per hectare (including through complementary crops).[516] The GHG performance of Brazilian ethanol is excellent, recent life-cycle work using RenovaBio data puts typical cane-ethanol carbon intensity around one-third to two-fifths of gasoline (60-75 percent reduction).[517] Studies on sweet sorghum ethanol (outside Brazil) report roughly 50-60 percent lifecycle GHG reductions versus gasoline depending on system boundaries and energy sources, suggesting that, under Brazil's bioenergy-powered mills, performance could be equal or better. [518] UNICA/ANP and market reporting indicate Brazil's total ethanol output in 2024/25 is closer to 35-37 billion litres, and maize ethanol already supplies 20-23 percent (7.5-8.2 billion litres) of national ethanol well above the 8-10 percent share seen earlier in the 2020s.[13] [14] [15]

Sweet vs. grain sorghum

Brazil's experience with grain sorghum is mostly unrelated to ethanol. Grain sorghum (locally called "sorgo granífero") is grown on about 0.7-0.9 million ha as a second crop (safrinha) after soybeans, particularly in Goiás, Mato Grosso.[519] Its average yields are 2-3 t/ha. The grain is used for poultry and cattle feed domestically and occasionally exported. Virtually none of it is used for ethanol, since Brazil's ethanol has been so sugarcane-dominated (and now maize is the grain of choice for new ethanol plants because maize yields and starch content are higher).[520] One could conceive of a grain-sorghum ethanol plant in Northeast Brazil (a dry region where sorghum grows better than maize), but historically the Northeast's biofuel strategy was also cane-focused or cassava/molasses-based.[521] Thus, sweet sorghum stands out as Brazil's unique angle with this crop for ethanol. Brazil effectively treated sweet sorghum as an extension of its sugarcane industry, not a competitor, this complementary approach shows how a new feedstock can piggyback on existing infrastructure.[522] Recent official series place Brazil's grain-sorghum area around 1.5 million ha and yields at 3.1 t/ha, with production at 5.0 MMT, reflecting rapid growth since the late 2010s; sorghum remains primarily for feed, with limited exports.

Policy and incentives

---

[515] D. Jiang et al., "Optimization and benefit analysis of the supply chain for sweet sorghum bioenergy," *The Innovation in Energy* (2024) – public summary (seasonality, logistics/perishability challenges)

[516] USDA FAS, Brazil Biofuels Annual (Sept 5, 2023), 4–6 (RenovaBio design: CI targets, certification, CBIO credits)

[517] Xinyu Liu et al., "Life Cycle Greenhouse Gas Emissions of Brazilian Sugar Cane Ethanol…" *Environmental Science & Technology* 57, no. 19 (2023): 7124–7137 (≈61% reduction WTW vs gasoline; RenovaBio-based data)

[518] K.G. Morrissey et al., "Life cycle impact assessment of biofuels derived from sweet sorghum," *Biotechnology for Biofuels and Bioproducts* 14 (2021): Article 120 (≈48% climate-change impact reduction vs fossil baseline).

[519] USDA/FAS, Production, Supply & Distribution "Country Summary" (Brazil, Sorghum), 2025/26 (area ≈1.55 Mha; yield ≈3.16 t/ha; time series).

[520] USDA/FAS, *Sugar Annual* (BR2025-0011), Apr 22, 2025 (ethanol output dominated by cane; North-Northeast and Center-South volumes).

[521] E. P. Santos Júnior et al., "Potentialities and Impacts of Biomass Energy in the Northeast of Brazil," *Energies* 16, no. 9 (2023): article discusses cassava residues and non-cane biomass options explored in the region

[522] Embrapa (Infoteca-e), "Sorgo sacarino" technical brief, 2025

Brazil's biofuel policy mix, anchored by a high, now-E30 national blend mandate and the feedstock-neutral RenovaBio carbon-credit scheme, creates durable demand and directly rewards low-carbon pathways, giving mills a rational incentive to trial complementary off-season feedstocks such as sweet sorghum using existing cane assets. The main gaps are not in policy ambition but in agronomy and logistics (short processing window, rapid juice degradation) and in certification detail (ensuring any new feedstock/hybrid routes are fully parameterised in RenovaCalc and recognised in ANP rules). For South Africa, the transferable lesson is clear: emulate Brazil's demand certainty (stable blends), keep certification feedstock-neutral but rigorous (CI-based credits), and let mills monetise low-CI performance, then agronomy and supply-chain execution determine success.

Brazil's government and companies actively supported sweet sorghum trials.[523] During the state-owned Petrobras's biofuel initiatives (circa 2010-2015), there was funding for pilot projects.[524] The government's broader ethanol policies such as mandatory blending (recently increased to E27-E30) and tax incentives for biofuel created a favourable environment to experiment.[525] Ethanol pricing in Brazil is generally market-driven but influenced by gasoline price policies.[526] When ethanol prices are high, mills have incentive to maximise ethanol production (which could include sorghum use). There is also an innovation-friendly environment: RenovaBio (since 2019) issues carbon-intensity credits (CBIOs) that reward producers for each tonne of CO_2 avoided. A mill that adds sweet sorghum might marginally improve its annual throughput and potentially its carbon score (especially if the sorghum yields do not require much additional fertiliser or land clearing). However, one deterrent was that Brazilian fuel regulations define ethanol types by feedstock, such that introducing sorghum would require slight tweaks in regulatory treatment (not a big hurdle, but something that needed standardisation).[527] In summary, policy has been supportive in principle (stable mandates, carbon credits), but no direct subsidy existed for sorghum and it had to compete on its merits within the sugarcane ethanol framework.[528]

Economics and competitiveness

The competitiveness of sweet sorghum ethanol in Brazil hinges on a few factors: yield per hectare, cost of production relative to cane, and opportunity cost of land use.[529] In years and locales where sorghum yield was good and cane was supply-constrained, sorghum ethanol looked attractive. The ability to use the same mill and workforce in the off-season is a huge advantage - essentially diluting capital costs over a longer season. Mills reported that even an extra 60 days of ethanol production via sorghum could noticeably improve annual financial performance, as long as the sorghum feedstock cost was reasonable.[530] On the other hand, if cane is abundant or sugar prices are booming, mills focus on

[523] A. M. Martins et al., "Characterization of Sweet Sorghum Genotypes Regarding Adaptability and Stability for Biofuel," *Ciencia e Agrotecnologia* (SciELO Brazil), 2025. (Evidence of continuing, institution-backed sweet-sorghum trials and evaluation for biofuels.)

[524] "Petrobras in Talks with Raízen, BP for Partnership in 'Big' Comeback on Ethanol," *Reuters*, Nov. 22, 2024; and "Brazil's Petrobras Has No Planned Investments in Ethanol… with Raízen," *Reuters*, Aug. 18, 2025.

[525] "Brazil Raises Biofuel Levels, Sees Gasoline Self-Sufficiency," *Reuters*, June 25, 2025; and USDA FAS, *Brazil Biofuels Annual 2024* (tax components at the pump).

[526] "Brazil's Petrobras Ups Gasoline Prices 7%, First Hike under New CEO," *Reuters*, July 8, 2024

[527] ANP, *Resolution 758/2018* (RenovaCalc pathways include feedstock-specific routes such as cane, corn, and hybrids); and Bio3 Consultoria, "Biofuels Certification-ANP 758/2018 Update," July 2025.

[528] USDA FAS, *Brazil Biofuels Annual 2024*

[529] California Energy Commission (CEC), *Feasibility of Sweet Sorghum to Ethanol and Value-Added Co-Products* (CEC-600-2023-003), 2023: co-processing with cane assets, cost drivers, and the need for rapid juice processing or syrup concentration

[530] Y. R. Cortés-Peña et al., "Economic and Environmental Sustainability of 'Lipid-Cane' Biorefineries with 60-Day Off-Season Integration," *ACS Sustainable Chemistry & Engineering* 10 (2022)

cane. Sorghum must also compete with maize ethanol, which has arisen in Mato Grosso and elsewhere; some sugar companies opted to build maize-ethanol capacity at or alongside cane mills (off-season use) because maize supply is storable and reliable compared with perishable sorghum stalks.[531] Maize can be dried and stored, whereas sorghum stalks must be processed quickly or concentrated into syrup to limit sugar loss.[532] Thus, from a competitiveness standpoint, sorghum's challenge is its perishability and tight seasonal fit. Brazil's case shows that integrating a new feedstock requires alignment of agronomy, logistics, and market timing. The *mechanism* (season extension improves mill economics) is well supported post-2020; the specific 15-60 days figure appears in earlier industry case reports. Recent work modelling off-season integration (including analogous "60-day" extensions in cane biorefineries) corroborates the economic logic.[533]

Brazil diamond analysis

Factor conditions are very strong for sugarcane and good for sorghum in certain regions. Brazil has vast arable land, tropical climate with a distinct wet/dry cycle ideal for sugar crops (wet summer for cane growth, dry winter for harvest). Sweet sorghum benefits from this climate too, though it may need supplemental irrigation in the dry season. From the infrastructure perspective, the centre-south has modern mills, but field-to-mill transport can be challenging (roads can be poor in some farm areas). Brazil's human capital in sugarcane agronomy and engineering is excellent, and this was leveraged for sorghum trials. However, specific sorghum knowledge was initially limited. Factor-wise, Brazil has the sunlight, land, and industrial base to support sorghum ethanol, yet lacks the extensive breeding history with sorghum that the US or India have. The existence of idle crushing capacity and skilled labour in mills is a unique factor advantage for integrating sorghum.

Demand conditions are extremely favourable for domestic demand for ethanol. Brazilian consumers and distributors are accustomed to ethanol as a major fuel (with flex-fuel cars enabling fuel choice). The government mandate of 27% ethanol in gasoline ensures a steady baseline demand, and the additional demand comes from pure ethanol (E100) usage by millions of FFVs. This large, inelastic demand makes any viable feedstock for ethanol potentially valuable. There is also a secondary demand driver, Brazil aims to increase renewable fuel use for energy security and climate reasons, so there is political will behind ethanol. Consumers are generally supportive (they will choose ethanol when priced advantageously due to tax or energy content parity). Demand conditions encourage production expansion and experimentation with new feedstocks.

Related and supporting industries are robust in Brazil. There are equipment manufacturers for mills, a domestic industry of yeast/enzyme suppliers (often subsidiaries of global firms) tailored to sugar fermentation, and a strong agricultural input sector (fertilizers, irrigation systems). The automotive industry cooperated by producing flex-fuel engines, supporting the ethanol market. In terms of sorghum's supporting network: Embrapa (the ag research agency) and various seed companies have been working on sorghum breeding, though not at the scale of cane breeding. There's also a related industry in sugar production; mills can toggle between sugar and ethanol outputs. If sorghum syrup were ever to be crystallized (e.g. for a jaggery-like product) that could open another co-product, but currently not the case. The logistics industry (pipelines, fuel depots) supports ethanol nationwide, so

[531] Joana Colussi, "Brazil Emerges as Corn-Ethanol Producer with Expansion of Second-Crop Corn," *farmdoc daily* (University of Illinois), 9 June 2023: corn-ethanol plants in MT, GO, MS; mix of corn-only and flex (cane+corn) facilities.

[532] USDA ARS summary of Klasson (2021): quantitative sugar-loss ranges (e.g., 11–18% in 50°Bx syrups over 10 weeks) and contamination effects on fermentations

[533] Y. R. Cortés-Peña et al., "Economic and Environmental Sustainability of 'Lipid-Cane' Biorefineries with 60-Day Off-Season Integration," *ACS Sustainable Chemistry & Engineering* 10 (2022): analogous modelling shows strong economics from ~60-day off-season utilisation

distribution of any extra ethanol from sorghum is not a problem. Overall, Brazil's cluster of sugar, energy, and automotive industries form a conducive environment. Sorghum slots into this as a supplement, and benefits from the presence of world-class milling and research capabilities.

Firm strategy, structure, rivalry is strong**.** The Brazilian ethanol industry comprises large, sophisticated firms (e.g. Raízen, Bunge, São Martinho) as well as smaller independent mills. Rivalry is strong but tempered by some level of cooperation (through industry associations) and by the fact that the market is growing (up to E30 blend approved, plus exports). Firms constantly seek efficiency gains and feedstock security. The strategy around sorghum was typically driven by individual firms in partnership with researchers - a way to hedge against sugarcane shortfalls. Rivalry played a role: a company that could produce during the off-season might gain a market edge or fulfil contracts more consistently. However, the risk of failure (if sorghum crop failed) made firms cautious. Structure suggest that a new idea (sorghum) must prove itself in a competitive environment. To date, rivalry has not forced everyone to adopt sorghum because other options (maize ethanol, diversifying geographically) exist. Firm strategy in Brazil has been to diversify feedstocks: e.g. build maize ethanol plants next to cane mills for year-round operation. This suggests that companies value multi-feedstock flexibility, which bodes well for sweet sorghum if it can match maize's reliability. In summary, Brazilian firms are innovative and competition drives them to consider all options but ultimately firms will only adopt sweet sorghum widely if it clearly improves their competitive position.

Government. The Brazilian government's role has been pivotal in creating one of the world's most successful biofuel markets. Decades of consistent ethanol mandates, the promotion of flex-fuel vehicles, and programs like Proálcool (1975+) set the stage. More recently, measures like raising the blend to E27 and introducing RenovaBio credits show ongoing support. While government did not directly subsidize sorghum, it did fund some R&D through Embrapa and provided an enabling regulatory environment for experiments. Importantly, even state governments (e.g. Minas Gerais) gave tax breaks for ethanol and possibly for diversification projects. Government also influences gasoline prices (through Petrobras policy) which affects ethanol's market competitiveness. In times when the government kept gasoline artificially cheap, ethanol producers struggled - highlighting that policy can both help and hurt. Currently, government is aligned with expanding biofuels for climate commitments. Chance events in Brazil include periodic droughts in cane regions (which made alternative feedstocks more valuable) and global sugar price swings (which influence ethanol output). Those chance factors have periodically increased interest in sorghum (e.g. a bad cane drought year might push sorghum trials to make up volume). Overall, government support is a strong positive in Brazil's Diamond; the uncertainty of some external factors is a manageable challenge.

Brazil five forces analysis (sweet sorghum focus)

Industry rivalry is moderately high. Brazil's ethanol industry has many producers, often in competition, but also somewhat regionally structured (clusters of mills). They compete on efficiency, scale, and access to feedstock. With sugarcane, rivalry is balanced by the fact that mills have local zones for cane suppliers (reducing direct competition for the same cane). When it comes to ethanol market share, there is competition to supply the domestic market and to export in high production years. The introduction of sweet sorghum does not fundamentally change rivalry and is more an internal efficiency improvement. However, if one mill uses sorghum to extend run time, rivals may consider doing the same to not fall behind, which is competitive imitation. The rivalry between ethanol and sugar outputs internally is also a strategic factor - mills "compete" to profit from either product depending on prices. Rivalry is strong but the pie is big enough due to mandated blends so that every efficient producer can sell their ethanol.

Threat of new entrants is fairly low**.** Building a new ethanol mill in Brazil (greenfield) is costly and time-consuming (land acquisition, capital, environmental licenses). The market is well-served by existing mills; new entrants more commonly come via acquisition of distressed mills or joint ventures (e.g. foreign firms investing). The recent trend was entry of some maize-only ethanol plants in Mato Grosso - a new entrant category that did not directly compete with cane mills in the centre-south market but added volume. A new entrant focusing on sorghum: will find it difficult as sorghum is only viable in Brazil when integrated with cane. Thus, any entrant would likely be an existing sugar company adopting sorghum. Barriers such as high capital, strong incumbents, and need for supply chain integration keep this threat low.

Bargaining power of suppliers is low to moderate. For cane ethanol, many mills are vertically integrated, and they often own a large portion of the plantations or have dedicated grower contracts. This limits growers' bargaining power as cane prices are formula-based (linked to sugar/ethanol prices), and mills have leverage. In cases of independent cane growers, their switching options are limited (sell cane to the local mill or let it rot). For sweet sorghum, initially the mill would likely contract local farmers or use its own fallow land. Farmers' power would be modest; sorghum is a perishable feedstock with no alternative market nearly as lucrative, so a farmer growing sweet sorghum for ethanol must sell to that mill. However, if not given a good price, farmers could choose to plant something else (like soybeans or leave land fallow to avoid costs). Given that sweet sorghum is one-season and does not have to be replanted like cane, farmers have flexibility each year and they will not plant sorghum unless contract terms make sense. The mill as buyer has more power, especially if they can fall back to using more maize or just accept shorter seasons. Input suppliers (equipment, fertilizer) are broad-market and don't particularly empower or weaken sorghum economics differently than cane.

Bargaining power of buyers is low. The buyers here are fuel distributors and end consumers in Brazil's domestic market, as well as some export customers. Because ethanol is a mandated and ubiquitous fuel in Brazil, distributors have little choice but to purchase what is available to meet blending laws or consumer demand for E100. Petrobras and other fuel distributors can negotiate on price to some extent, but prices are largely driven by market (ethanol trades on an exchange and has linkage to gasoline prices). With many producers and a transparent market, no single buyer can dictate terms. Moreover, the government often intervenes to maintain a balance (e.g. adjusting taxes to keep ethanol competitive for consumers). On the consumer end, drivers can choose gasoline or ethanol in their FFVs, giving them some say in demand: if ethanol is too expensive relative to its energy content, they buy less of it. This imposes a natural discipline on pricing. But within a narrow band, mills and fuel stations adjust prices to keep ethanol attractive (usually ethanol is priced around 70% of gasoline price per litre to account for lower mileage). Thus, consumer choice exerts some pressure. Internationally, export buyers (like Japan or South Korea occasionally buying Brazilian ethanol) could source from the US or elsewhere, but those volumes are not huge. Overall, the buyers in Brazil's ethanol market are numerous and have to take the fuel that is offered; their power to push prices down is limited because of the mandate and limited substitutes (aside from switching to petrol, which is constrained by policy or vehicle cost).

Threat of substitutes. The main substitute is gasoline and because Brazil has a large oil sector, there is always a temptation or pressure to use more gasoline if ethanol falters. However, policy (taxation, mandate) strongly disfavours substituting ethanol with pure gasoline. Another substitute is maize ethanol within Brazil, rather than sorghum, mills in some areas can use maize shipped in to produce ethanol during the off-season. This has happened and can be seen as a substitute for sweet sorghum as a way to extend operations. Maize has the advantage of storable feedstock and often higher starch content, but the disadvantage of needing to be transported and processed in a different way (dry milling vs. cane crushing). The success of maize ethanol in Brazil's off-season is a real substitute threat to sweet sorghum adoption. In terms of fuel substitutes: in the long term, EVs may substitute some fuel use, but Brazil also explores other biofuels (biogas, etc.). There are none close to scale yet for transport. For the ethanol producers, making sugar is an internal substitute (they can pivot to sugar if it is more profitable than ethanol, which they often do). That dynamic is not an outside substitution but does cap how far ethanol production will go if sugar yields better returns. All considered, substitutes exist but are mitigated by Brazil's strong commitment to ethanol in transport. The internal substitute (maize in off-season) is probably the more pertinent competitor to sweet sorghum specifically.

In sum, Brazil's foray into sweet sorghum underscores a best-case scenario for integration, using an existing world-class biofuel industry to trial a new feedstock. The country has complementary factor advantages (climate, infrastructure) and strong demand pull, which allowed sweet sorghum to be tested at scale. The mixed outcome (promising results but not yet wide adoption) teaches South Africa several lessons: (1) Feedstock scheduling and logistics are crucial, and a sorghum-to-ethanol system must synchronize with processing capabilities to avoid gluts or spoilage. (2) High yields are needed to make it worthwhile (Brazil aimed for 40-50 t/ha; (3) Policy stability and market demand can encourage innovation; Brazil's steady ethanol demand meant mills were willing to experiment, knowing any extra ethanol would find a market. (4) Competing options (like other feedstocks or uses of land) will determine if sorghum is chosen. In Brazil, maize emerged as a rival approach to year-round production. For South Africa, which has a sugar industry and a similar climate in KwaZulu-Natal, the Brazilian model suggests *potential* to integrate sweet sorghum into sugar mills, but it would require varietals suited to the climate, close coordination with mill crush schedules, and perhaps irrigation to ensure consistent yields. Additionally, South Africa lacks Brazil's scale of demand and policy certainty; these would need to be bolstered to justify such integration.

7.3 India: E20 at scale; smallholder-compatible sweet sorghum options

India is one of the world's leading sorghum producers (typically 4-5 million tonnes in recent years), ranking fourth globally; cultivation is concentrated among smallholders in semi-arid belts of Maharashtra, Karnataka, Telangana, and Rajasthan ("jowar").[534] Sorghum remains important for food and fodder in dry rural areas even as diets have shifted toward wheat and rice. Average yields are low (1 t/ha) because much of the crop is rain-fed and low-input.[535] It is grown in two seasons, kharif (June-Oct) and post-rainy rabi (Oct-Feb). Rabi sorghum is prized for higher grain quality for food uses but typically yields less due to water stress.[536] India's ethanol has historically come from molasses and, increasingly since 2020, from excess grains (maize, damaged rice) under the government's EBP/E20 push and sorghum is not yet a primary commercial feedstock, though it has been the subject of research and pilots, especially for sweet sorghum. These have been led by ICRISAT and ICAR institutions to test stalk-to-juice ethanol routes and village-level syrup models in dryland regions. It implements OMC procurement, decentralised syrup and grain routes in some states and sweet sorghum R&D with syrup to ease perishability/logistics.

Bioethanol in India has historically come from molasses and, increasingly, from excess grain (maize and damaged/broken rice).[537] Sorghum has not been a primary feedstock for commercial ethanol in India, but it has been the subject of considerable research and pilot projects as a potential feedstock, particularly sweet sorghum. Indian institutions like ICRISAT and the Indian Agricultural Research

[534] USDA Foreign Agricultural Service, "Sorghum-Total Production (2024/25): Country Shares," FAS Production Data (accessed Oct. 2025)

[535] ANGRAU (Acharya N. G. Ranga Agricultural University), *Sorghum Outlook 2023–24* (June–July 2023)

[536] Ruth DeFries et al., "Climate resilience of dry-season cereals in India," *Current Research in Environmental Sustainability* 5 (2023)

[537] Ministry of Petroleum & Natural Gas (MoPNG), Government of India, "Ethanol Blended Petrol (EBP) Programme" (policy page, accessed Oct. 2025): feedstocks allowed since 2018–19 (B-heavy/C-heavy molasses, juice, sugar/syrup, damaged food grains).

system pioneered sweet-sorghum ethanol trials in the 2000s, motivated by the crop's drought tolerance and the need for non-food biofuel options in dry regions; this work continues in updated breeding and agronomy programmes.[538] Several pilot projects were launched, where farmers grew sweet sorghum and either sold stalks to a distillery or crushed them into syrup at village-level facilities.[539]

From the sweet sorghum pilot-project perspective, one notable programme involved decentralised crushing: farmers would bring stalks to local crushers to produce sorghum syrup, which could be stored for days or weeks and then transported to ethanol distilleries, an approach designed to stabilise a perishable juice by concentrating it to50-60% sugars.[540] In trials in Maharashtra, for example, cooperatives experimented with this approach. Results demonstrated technical feasibility as syrup was fermented at sugar mills or stand-alone distilleries to produce ethanol but also highlighted coordination and economics challenges.

Yields under smallholder conditions were variable, research-station tests with improved cultivars have reported fresh stalk yields 45-60 t/ha (≈2,000-3,000 L ethanol/ha potential), whereas farmer-field, rain-fed yields often fell in the 10-20 t/ha range, with 25 t/ha achievable under better on-farm management.[541] The farm-level economics were tight: growers needed sufficient stalk revenue to displace alternative crops. Sorghum's advantage is its performance on marginal land where cane struggles; on better land, farmers may favour maize or other remunerative crops unless sorghum prices are attractive.[542]

Feedstock pricing and farmer incentives

India's approach was to peg the price of sweet-sorghum stalks to sugar content and the prevailing molasses/ethanol economics, so that ethanol from sorghum priced out competitively with molasses routes under the EBP programme.[543] In practice, planners and pilot operators back-calculated a stalk price from litres-per-tonne (e.g., molasses at 250 L/t vs sweet sorghum at 70 L/t) to achieve a similar ethanol cost.[544] In early pilots, a buy-back price around ₹700-1,000 per tonne was reported in Maharashtra/Andhra Pradesh clusters, adequate on marginal land but rarely compelling on better land without value addition. To overcome perishability and logistics constraints, several projects tested on-farm syrup making (50-60% sugars) via decentralised crushing units, allowing short-term storage and transport to distilleries; technically feasible, this model still faced coordination and cost challenges at scale.[545] States and central schemes have, at different times, offered capital support for biofuel crops/units and grain-ethanol capacity, but sweet sorghum uptake remained limited as policy and

[538] NITI Aayog, *Roadmap for Ethanol Blending in India 2020–25* (J K. T. Klasson et al., "Bioethanol fermentation of clarified sweet sorghum syrups; storage and sugar losses," *Industrial Crops & Products* 170 (2021): feasibility of syrup storage and subsequent fermentation; operational loss ranges.une 2021): summary of non-food feedstock options, discussion of decentralised models and supply-chain constraints for non-cane routes.

[540] California Energy Commission (CEC), *Feasibility of Sweet Sorghum to Ethanol and Value-Added Co-Products* (CEC-600-2023-003), 2023: modern treatment of syrup stabilisation and decentralised logistics as a solution to juice perishability.

[541] USDA FAS, *India Biofuels Annual* (IN2024-0024), July 24, 2024: updates on grain-based ethanol scale-up and constraints; supports variability and competitiveness narrative vis-à-vis maize/rice

[542] F. S. Baloch et al., "Recent advancements in the breeding of sorghum," *Frontiers in Genetics* 14 (2023): programme advances for drought-tolerant, high-Brix materials; relevance to dryland India

[543]USDA Foreign Agricultural Service (FAS), *India Biofuels Annual* (IN2025-0031), June 20, 2025: authorised feedstocks (molasses, juice, grains), price-setting with OMCs, and E20 acceleration.

[544] B. V. S. Reddy et al., "Developing a Sweet Sorghum Ethanol Value Chain," ICRISAT (2013): pilots report ₹700–1,000/t stalk buy-back in Maharashtra/AP

[545] NSI Kanpur, *Sharkara* (Oct–Dec 2022): comparative studies of sweet-sorghum genotypes and processing traits; ongoing NSI/ICAR-IIMR work; aligns with decentralised crushing concept.

industry prioritised molasses, sugarcane juice and later grain (maize/broken rice) for the rapid E20 rollout.[546] By the mid-2010s many sorghum pilots slowed due to harvest-crushing synchronisation issues, competing uses for stalks as cattle fodder, and policy uncertainty around non-cane feedstocks; recent initiatives (NSI/ICAR-IIMR, BPCL-NSI MoU) have revived R&D interest, yet commercial deployment is still nascent.[547]

Ethanol program and policy

India's national biofuel policy targets E20 by 2025, and the 2021 NITI Aayog roadmap formalised the pathway. Subsequent policy circulars under the Ethanol Blended Petrol (EBP) Programme broadened authorised feedstocks beyond C-heavy molasses to include B-heavy molasses, sugarcane juice/sugar/syrup, and surplus/damaged food grains (e.g., maize, rice), with administered ex-mill prices differentiated by feedstock and procured by the OMCs.[548] By 2023-24 the notified schedules included fixed prices for grain-based ethanol (e.g., maize and damaged rice), which enabled project viability for many new distilleries.[549]Sorghum is not explicitly enumerated in these circulars, in principle it could fall under grain-based ethanol, but in practice sorghum grain clears at higher value in food/feed relative to surplus rice, which has underpinned most grain-ethanol scale-up to date.[550] In parallel, the government launched flex-fuel vehicle pilots and backed second-generation (2G) ethanol (e.g., IOCL Panipat rice-straw plant) as part of the E20 ecosystem; sorghum stover could theoretically feed 2G units, though the current wave of 2G capacity in India is focused on crop residues like rice straw.[551]

Grain sorghum use

Grain sorghum in India is primarily a food crop, especially post-rainy ("rabi") sorghum used for flatbreads (jowar bhakri/jolada rotti) in parts of Maharashtra and Karnataka with additional use in poultry feed (partial substitution for maize when prices favour it) and in traditional brewing/distilling. If grain were diverted to ethanol, food-security sensitivities would arise in poorer dryland regions unless surplus output and higher-yielding varieties were assured.[552] In practice, any consideration of sorghum grain for ethanol is overshadowed by the policy-backed availability of surplus/FCI rice and other damaged grains for ethanol under India's EBP programme; the government has repeatedly enabled or adjusted

[546] USDA FAS, *India Biofuels Annual* (IN2024-0024), July 24, 2024: continued policy preference and financing for molasses/juice and grain ethanol capacity; limited commercial sorghum use.

[547] S&P Global Commodity Insights, "India eyes sweet sorghum as alternative feedstock to boost ethanol production," Nov. 11, 2024; and Advanced Biofuels USA news digest on BPCL–NSI MoU (Feb. 2025): evidence of renewed institutional interest post-2020.

[548] Ministry of Petroleum & Natural Gas (MoPNG), "Ethanol Blended Petrol (EBP) Programme," policy page (accessed Oct. 2025): lists authorised feedstocks-B-heavy, juice/sugar/syrup, and damaged food grains like wheat and rice-and notes differentiated ex-mill pricing by feedstock

[549]Advanced Biofuels USA (industry brief), "OMCs to procure…," Feb. 2023 cites representative administered prices (e.g., ₹71.86/L for maize, ₹64/L for damaged rice, ₹56.28/L for C-heavy),

[550] NITI Aayog, *Roadmap for Ethanol Blending in India 2020–25* (New Delhi, 2021), sets the E20 objective for 2025/26 and outlines supply/vehicle readiness

[551] Centre for High Technology (Govt. of India), "IOCL – Bohali, Panipat, Haryana: 2G Ethanol Commercial Project" (status as of Feb. 29, 2024): 100 KLPD 2G ethanol, rice-straw feedstock. Chhattisgarh Government

[552] USDA Foreign Agricultural Service, "India Biofuels Annual (IN2024-0024; IN2025-0031)," 2024–2025: documents India's policy to prioritise molasses/juice and surplus grains (damaged rice, maize) for ethanol.

procurement and administered prices to channel excess rice/maize toward blending targets.[553] Consequently, grain sorghum for ethanol is neither economic.

Sweet vs. grain usage

Sweet sorghum was explored in India as a novel ethanol feedstock to utilise drylands and smallholder production, with an emphasis on decentralised crushing and syrup-making to reduce transport and perishability constraints.[554] Grain sorghum ("jowar"), while regionally abundant, remains a valued staple in post-rainy (rabi) belts of Maharashtra and Karnataka and is also used in poultry feed and traditional beverages; diverting grain to fuel has therefore raised food-security sensitivities unless surplus and higher-yielding varieties are assured.[555] India's policy architecture under the Ethanol Blended Petrol programme historically prioritised molasses and, more recently, authorised sugarcane juice and surplus or out-of-edible-quality grains (notably damaged rice and maize) with administered prices, while sorghum has not been explicitly priced or prioritised; this stance broadly aligns with policy preferences that avoid using staple grains for fuel unless clear surplus exists.[556]

GHG and sustainability

Sorghum ethanol in India (from sweet sorghum) was framed as a potentially sustainable biofuel with social benefits by engaging smallholders in drylands, often through decentralised crushing and syrup-making to overcome transport and perishability constraints.[557] Life-cycle assessments indicate that sweet-sorghum ethanol can reduce greenhouse-gas emissions by roughly 30-50 percent versus petrol, with higher savings when process energy comes from biogas/CHP and when residues are valorised, and lower savings when conventional fossil process energy is used.[558]A further attraction is water: trials and reviews consistently note that sweet sorghum requires far less irrigation than sugarcane in many Indian dryland settings, helping to avoid the water-footprint and irrigation-intensity issues associated with cane expansion.[559] For smallholders, several cultivars are dual-purpose, producing a modest grain harvest (about 0.5-1.0 t/ha under farmer conditions) alongside fermentable stalks, which supports food use while supplying ethanol feedstock; however, breeding and agronomy face a recognised trade-off between grain yield and stalk sugar (°Brix), so achieving both high grain and high sugar concurrently is challenging and genotype- and season-dependent.[560]

---

[553] SWS (Govt. of India), "Ethanol Policy and Helpdesk," updated Oct. 2025: E20 target, authorised feedstocks, and administered-price procurement by OMCs.

[554] Ministry of Petroleum and Natural Gas (MoPNG), "Ethanol Blended Petrol (EBP) Programme," policy materials, accessed October 2025.

[555] ASSOCHAM, Millets Report 2022 (regional consumption patterns; role of jowar in food systems).

[556] NSWS (Government of India), "Ethanol Policy and Helpdesk," updated October 2025 (administered pricing schedules for molasses, juice, and grain routes; emphasis on surplus/damaged grains).

[557] California Energy Commission, Feasibility of Sweet Sorghum to Ethanol and Value-Added Co-Products (CEC-600-2023-003), 2023.

[558]Hao Cai et al., Life-Cycle Analysis of GHG Emissions of Clean Fuels in R&D GREET 2024 (Argonne National Laboratory, 2025), sorghum ethanol scenarios with CHP/biogas.

[559] D. J. Mathias et al., "Sweet sorghum as a potential fallow crop in sugarcane farming systems," Energies 16, no. 18 (2023).

[560]C. Endalamaw et al., "Evaluation of sweet sorghum genotypes for dual-purpose use," Agrosystems, Geosciences & Environment (2025).

Key challenges

India's sorghum-to-ethanol ambitions faced and still face some specific hurdles. (1) *Fragmented landholdings*, coordinating dozens of small farms to supply a distillery or operate a crusher network is logistically complex. (2) *Monsoon variability*, sorghum crops could fail or yield poorly if rains are inadequate, jeopardizing feedstock supply consistency to a fuel plant. (3) *Competing uses*, farmers have alternative markets: if sorghum grain prices rise (e.g. due to a drought in maize or demand for livestock feed), they might divert attention to grain production rather than maximizing stalk sugar. (4) *Economies of scale,* Indian ethanol plants (molasses-based) often are sized around 30-60 million litres/year; supplying one at scale would require tens of thousands of hectares of sweet sorghum, which is difficult given current yields and land use patterns. Some proposed a hub-and-spoke model (many syrup units feeding a central distillery) to circumvent transport issues, but this is operationally intensive.

Despite these challenges, India's experiences have yielded important insights and incremental improvements in sweet sorghum breeding and management. Varieties like CSH22SS were developed for higher sugar content, and sowing windows were optimized to align harvest with weather and distillery schedules. By the mid-2020s, the focus in India shifted more to using surplus grains for ethanol (including potentially sorghum grain if it is in excess). In drought years, India sometimes has sorghum surplus because it grows where other crops fail; theoretically that could be turned to ethanol, but there is no established mechanism.

India diamond analysis

Factor conditions are mixed. India has vast semi-arid areas where sorghum is well adapted representing a factor advantage in terms of land and climate for sorghum. A long tradition of sorghum cultivation means a rich genetic base and local knowledge (though primarily for grain, not juice). India also has a huge labour force; harvesting sorghum can be labour-intensive (if not mechanized) which suits rural employment in some contexts. Basic infrastructure (roads, electricity) in rural India is improving but still variable, so that transporting heavy sorghum stalks from villages to a central plant can be challenging. In terms of capital and technology, India's ethanol distillery capacity is growing and reasonably advanced (especially in sugar mills). However, sweet sorghum-specific machinery (like modified harvesters, crushers) had to be prototyped; those factor inputs were not initially on hand. Water is a critical factor. India's water scarcity in many sorghum regions means sweet sorghum yields without irrigation are modest. Unlike the US or Brazil, many Indian sorghum farmers cannot easily access irrigation or high inputs. So, while the natural resource (land/climate) is suitable, the yield gap due to limited input use is a factor weakness. India does have significant research and breeding capacity (ICRISAT, ICAR system), which is a positive factor condition for innovation. Overall, factor conditions allow sorghum to grow widely but not necessarily at high productivity, and logistical factors are a constraint.

Demand conditions have been historically weak for bioethanol but are now rapidly strengthening due to policy. India's fuel ethanol demand is almost entirely policy-driven; by 2025 it is supposed to reach 10-12 billion litres per year to achieve E20 in gasoline. Domestic demand for ethanol as a transport fuel was negligible until the government mandated blending (currently 10% in many states). Consumers are indifferent to ethanol in petrol as long as it does not affect engine performance or fuel cost significantly. There is also some demand for ethanol in industrial chemicals and potable alcohol, which has existed for decades (and India has a large distillery sector for liquors). Those markets could accept sorghum-based alcohol if economical. As for sorghum itself, domestic demand is mainly for food and feed; that has been stable or declining (people shifting to rice/wheat). The critical demand side factor for sorghum ethanol is the government's push - without this, there would be essentially no market pull for sorghum fuel. With it, however, India presents a potentially large guaranteed market (the oil companies will buy all ethanol that meets spec up to the blend requirement). One could say demand conditions for ethanol are favourable given the E20 mandate, but demand conditions specifically favouring *sorghum* ethanol are not naturally present (unlike Brazil where a mill may want to extend season, or the US where RFS favoured sorghum via RIN). In short, the demand exists for ethanol in general; capturing it with sorghum will depend on cost competitiveness relative to other feedstocks.

Related and supporting industries. This is moderately good. India has a robust sugar industry (supporting ethanol from molasses/juice) and a nascent grain ethanol industry ramping up. Those provide infrastructure and knowledge that could support sorghum ethanol (distillation technology, fermentation know-how, distribution networks for fuel, etc.). Additionally, India has a sizable brewery and distillery industry (one of the world's largest liquor producers), meaning expertise in handling different fermentable materials. Another supporting industry is farm machinery, though many sorghum farms are not mechanized, India does manufacture small-scale harvesters, chippers, and crushers (there's an agricultural equipment sector that can innovate if market exists). The presence of cooperatives (in sugar and dairy) suggests a model that could support farmers collectively supplying feedstock; indeed, some sugar cooperatives were involved in sweet sorghum trials. Also, India's biotech and seed industry, while heavily focused on cotton, rice, etc., includes some development of improved sorghum hybrids. A drawback is that no large commercial player specifically champions sorghum ethanol, unlike sugar mills who have a vested interest in molasses ethanol, or grain processors in grain ethanol. So, sorghum lacks a strong industrial ally aside from research institutions. In sum, the industrial ecosystem is there to potentially integrate sorghum, but it is not tailor-made for it; adaptation is needed.

Firm strategy, structure, rivalry. The ethanol production sector in India is undergoing change. Traditionally, sugar mills produced ethanol (as an offshoot of sugar). Now, standalone grain distilleries are being set up. Rivalry is moderate; oil companies tender out purchases and multiple distilleries compete to supply. Firms are trying to scale up production given government encouragement. In this context, sorghum ethanol has no dedicated firms, it would likely be an add-on for existing sugar or grain alcohol producers. The strategy in pilot projects was often led by public-private initiatives rather than pure corporate competition. Small farmers in sorghum are atomistic players with no market power (they were price-takers in deals coordinated by a larger entity). The rivalry in ethanol generally is starting to increase as capacity grows, but demand is also growing fast. If E20 overshoots, rivalry could spike and lower-cost producers (using cheapest feedstock like subsidised rice) could outcompete others. Sorghum's strategic niche might be one where it can produce ethanol in regions or seasons where others cannot (e.g. drought-prone areas not suitable for cane, or off-season production). Indian firms do have a strategy of feedstock diversification to mitigate risk, and some grain distilleries can use various grains (maize, broken rice, etc.). Sorghum grain could fit in that flex-feedstock approach if price allowed. But for sweet sorghum, a firm (say a sugar mill) would need to change structure and engage directly with many farmers and crush a new crop, which is a big strategic shift from how they currently operate (with cane they already have a fixed supply chain. Mills could find this outside their usual business model, to manage a short-term crop like sorghum with different logistics. Overall, the competitive strategy environment in India's ethanol sector has not strongly incorporated sorghum and has been largely experimental. Without strong commercial champions, sorghum has not been fully integrated into firms' strategy, which is a weak point.

Government. Government influence in India is profound on this issue. The entire biofuel value chain is steered by central government policies: the blending mandate, pricing mechanism for ethanol, soft loans for ethanol plant expansion, etc. Government also invested in R&D for sweet sorghum and even field pilot programs (often through public sector oil companies or ag agencies). This top-down approach means if the government decided to promote sorghum explicitly, for example, include it in procurement programs, it could drastically change sorghum's fortunes. So far, the government's stance is neutral-positive. They have not discouraged sorghum, but they focus on easier wins (molasses, excess grain).

The policy of excluding food grains initially was basically a directive to look at crops like sorghum, but then politics shifted to allow grain when huge rice stocks accumulated. State governments also matter. For example, Karnataka and Maharashtra had some interest in dryland farmer welfare and supported alternative biofuel crops. However, bureaucratic follow-through has been inconsistent. Monsoon patterns (chance factor) and global oil price swings can influence how urgently India pursues domestic biofuels. When oil prices spiked or when monsoons failed (affecting sugar output), there was more urgency to find alternatives like sweet sorghum. Conversely, when sugar was abundant and global ethanol cheap, interest waned. The Indian government position indicates how government-driven markets can be fickle if underlying economics are not solid. In summary, government is the decisive factor in creating demand and enabling or hindering certain feedstocks. For sorghum, supportive R&D was there, but not a strong mandate or incentive specific to adoption. Going forward, if India faces constraints in traditional feedstocks (say, limited cane expansion due to water, and if grain diversion threatens food prices), the government might revisit sorghum as a strategic resource - the capacity to do so (via extension services, etc.) exists because of earlier groundwork.

India five forces analysis

Industry rivalry. This is currently low in the specific domain of sorghum ethanol because there are no significant commercial sorghum-ethanol producers. Rivalry in the broader ethanol industry is moderate: sugar mills vs standalone distilleries compete to supply OMCs, but since demand exceeds supply, it is more of a ramp-up phase than price-cutting rivalry. If one imagines a future with several sorghum-based ethanol units, they would be competing not just with each other but with other feedstock ethanol for the OMC contracts. Given government-set prices, competition would be in meeting volume and quality rather than undercutting prices. Within sorghum, a hypothetical rivalry could arise between ethanol use and other uses (e.g. breweries might compete for sorghum grain, feed industry for sorghum). But again, since sorghum ethanol isn’t established, rivalry force is mostly latent. For now, ethanol producers focus on molasses and grain; any who consider sorghum are likely doing so to fill a gap rather than to beat a competitor.

Threat of new entrants. This is moderate to high. The Indian government is actively encouraging new ethanol capacity essentially inviting entrants (through interest subvention schemes and guaranteed offtake).[561] Many new grain distilleries are coming up. For sorghum ethanol specifically, an entrant could be any existing distillery deciding to source sorghum or any entrepreneur setting up in a sorghum-growing area. Barriers include securing a steady feedstock supply from many small farmers, which is a non-trivial barrier that might dissuade entrants. Also, new entrants must navigate licensing, but that has been eased. The technology barrier is low (standard fermentation tech), and government will buy ethanol as long as it meets specs, so market entry is feasible if feedstock is arranged. One might say that new entrants using conventional feedstocks are more of a threat (since they could flood the ethanol market and meet targets, leaving no room or incentive for niche feedstocks). But if those face limits, new entrants could explore sweet sorghum especially in states with lots of marginal land. Overall, entry into ethanol industry is being facilitated, but entry *with sorghum* would require innovative business models, making it moderate in difficulty.

Bargaining power of suppliers. For sweet sorghum, suppliers are thousands of small farmers. Individually they have almost no bargaining power, and typically prices would be pre-agreed or dictated by the processing company or cooperative. However, collectively if the price offered is too low, farmers simply won’t participate (they grow food crops or something else). In pilots, ensuring farmer buy-in

[561] Bharat Petroleum et al., “Dedicated Ethanol Plants (DEPs) Long-term Offtake Agreement (LTOA) clauses cited in OMC tender notice for ESY 2024–25,” July 1, 2025; and “OMCs float tender for 1050 crore litres of ethanol supply for 2025–26,” September 23, 2025.

required guaranteed procurement and sometimes floor prices. Because sorghum is not a plantation crop like cane, farmers can pivot annually. If a project does not pay well or on time, next season farmers will not plant sorghum. For grain sorghum as a feedstock, suppliers (farmers) can always sell in the open market for grain if an ethanol plant offers less, thus a plant would have to at least match feed market prices, reducing its ability to push price down. In general, India's fragmented farm structure means processors have to work with many suppliers and often through intermediaries or cooperatives, which can raise transaction costs. That dynamic slightly strengthens the suppliers' hand compared to, say, a scenario of one giant plantation. But practically, given poverty and few market options in sorghum regions, farmers would accept modest prices if it were a sure market. Supplier power remains somewhat limited.

Bargaining power of buyers. The buyer for fuel ethanol in India is essentially the government (via state-owned oil companies who procure ethanol). They have significant power in that they set the purchase price and allocate procurement quotas. Ethanol producers cannot sell to fuel stations directly they must go through these tenders. This is a monopsony-like situation nationally. However, the government's interest is to get as much ethanol as possible to meet blending targets, so they have been setting prices at attractive levels to spur supply. If an ethanol producer cannot meet the fixed price, they cannot bid a higher price. In that sense, the buyer has full control of price.

Since targets are not yet met, OMCs essentially purchase whatever is produced (no ethanol goes unsold). Once supply approaches demand, OMCs might become more selective or push prices down (especially if overproduction risk emerges). For a sorghum ethanol producer, they are a price taker. There is no alternative market except possibly export or the chemical sector, but those are smaller and also fairly price sensitive. Thus, the buyer (oil companies/government) wields high power. The only mitigating factor is political, If producers lobby, they might get the government to raise prices or give sorghum a premium classification, etc. At the consumer level, Indian drivers neither know nor care what feedstock the ethanol came from, they care about fuel price and mileage. They will buy petrol regardless of ethanol source, so they have no direct influence on sorghum ethanol specifically.

Threat of substitutes. This is high. In the context of feedstocks, substitute feedstocks are a major threat, sugar molasses, sugarcane juice, damaged rice, maize are all alternatives to produce ethanol, and many are easier or cheaper than sorghum given current conditions. Every litre that can be economically made from those reduces the necessity to experiment with sorghum. As of now, India has enough molasses and grain potential to reach near E20 (especially with planned grain distilleries), meaning sweet sorghum might only come into play if those sources fall short or become too costly. Another substitute is simply imported ethanol, which India has been averse to (preferring domestic), but could consider if domestic production lags (currently some imports happen for industrial use, but fuel is mostly domestic). Longer term, advanced biofuels (cellulosic ethanol from agri waste) could become a substitute for dedicating crops like sorghum. If those technologies succeed, the government might prefer converting rice straw or bamboo to ethanol, again bypassing sorghum. For consumers, the substitute for ethanol-blended petrol is just petrol (with less ethanol) but with E20 soon mandatory, that substitute is constrained by regulation. EVs are a future substitute in India's context (likely not significantly eroding petrol demand until late 2030s given current trends). Summarily, the most immediate substitutes threatening sorghum ethanol are *other feedstocks for ethanol production*. Unless sorghum offers some unique edge (like thriving in drought when other crops fail), it is at risk of being crowded out by those alternatives in India's race to meet blending targets.

In sum, India's case provides valuable lessons on smallholder biofuel feedstock integration and the realities of a policy-driven market. It shows the difficulty of mobilizing a traditional crop like sorghum into a modern fuel chain but also illustrates innovative solutions (like syrup processing) that could be relevant to South Africa. For South Africa, parallels include the need to engage small farmers (in communal areas) if sorghum expansion is desired; India's approach of decentralized crushing could be a model to reduce transport costs in rural South Africa as well. The India experience also highlights the importance of reliable yields and farmer incentives - without consistent production and profit for growers, the chain collapses. Policy support is crucial: India's blending program demonstrates that once a government is committed, it can galvanize industries; however, that support will naturally flow to the most efficient feedstocks first. Therefore, a key takeaway is that sorghum must find its comparative niche either by outperforming others in certain niches (e.g. rainfed conditions, low-carbon footprint, or as a dual-use crop for food+fuel) or by piggybacking on existing industries (like how Indian sugar mills briefly piggybacked ethanol on sweet sorghum, similar to Brazil's model). As South Africa contemplates sorghum for ethanol, it will need to ensure yield improvements (through R&D and extension) and perhaps adopt some of India's decentralized approaches to avoid logistic bottlenecks. Additionally, aligning any sorghum biofuel initiative with rural development goals (as India did) could garner social and political support. In essence, India's journey with sorghum ethanol is one of *cautious progress with many hurdles*, underscoring that competitiveness is not just about agronomics but about organizing a fragmented value chain under enabling policy.

7.4 Kenya: brewing-led demand

Kenya is not a major producer of sorghum-based ethanol, but it is a notable consumer of sorghum for industrial use, especially brewing. [562] It has also become a net importer of sorghum grain in Africa.[563] Benchmarking Kenya is relevant for understanding market-driven sorghum demand and the potential for regional trade. Kenya's sorghum production is on the order of a few hundred thousand tonnes annually, for example approximately 150,000 to 180,000 tonnes in recent years, although figures vary.[564] While small in global terms, this volume is significant regionally. The climate in eastern Kenya, and parts of western Kenya, is suitable for sorghum. Traditionally it has been a subsistence crop in drier districts.[565]In the past decade, a key change has been the emergence of commercial sorghum farming for beer production[566] East African Breweries Ltd (EABL) launched a sorghum-based lager, Senator Keg, in the mid-2000s targeted at low-income consumers and substituting sorghum for imported barley malt. The Kenyan government supported this shift with an excise remission for sorghum beer to formalise traditional brews and to provide a market for farmers.[567] This policy framework led to a surge in contract farming. At one point, EABL was contracting more than 45,000 smallholders in semi-arid areas such as the former Eastern Province.[568] The preferred white sorghum variety in these brewing chains has been Gadam.[569] Sorghum farm-gate prices were stabilised, and the crop became an important cash earner in participating communities.

Current sorghum use and trade

Because of East African Breweries' demand and other uses such as flour and animal feed, Kenya's domestic sorghum supply proved insufficient or volatile, which increased reliance on imports.[570] Kenya began importing grain sorghum from regional neighbours such as Uganda and Tanzania and, in some

[562] FAO, MAFAP, "Analysis of Incentives and Disincentives for Sorghum in Kenya," Technical Notes, February 2013.

[563] UN Comtrade, "Kenya: Imports of grain sorghum, 2019–2023," extracted via WITS; figures show sustained net import positions in recent years.

[564] FAOSTAT, "Crops and livestock products: Sorghum, Kenya," accessed 2024; Tegemeo Institute, Sorghum Production in Kenya: Farm-level Characteristics, Constraints and Opportunities, Technical Report TR34, 2018.

[565] Kenya National Bureau of Statistics (KNBS), National Agriculture Production Reports, 2024–2025; FAO MAFAP, "Analysis of Incentives and Disincentives for Sorghum in Kenya," 2013.

[566] ICRISAT and partners, A. Orr et al., "The Value Chain for Sorghum Beer in Kenya," ISEDPS 16, 2014.

[567] ICRISAT and partners, A. Orr et al., "The Value Chain for Sorghum Beer in Kenya," ISEDPS 16, 2014.

[568] Business Daily Africa, "45,000 Farmers to Get EABL Deals in Sh15bn Investment," 11 December 202

[569] Kenya Breweries Ltd/EABL, A Guide to Sorghum and Barley Farming with KBL, 2023

[570] Orr et al., "The Value Chain for Sorghum Beer in Kenya," ICRISAT Socioeconomics Discussion Paper Series 16, 2014

years when regional supply was tight, from extra-regional origins including the US and Australia.[571] By value, Kenya ranked among Africa's largest sorghum importers in 2023, at approximately USD45 million. In quantity terms, United Nations Comtrade data record Kenya's 2023 grain-sorghum imports at approximately 105,000 tonnes. These figures indicate that Kenya's market has been "anchored" by industrial buyers, particularly the brewing sector. Notably, sorghum beer created a stable offtake that encouraged smallholders to plant sorghum.[572] When the excise remission was withdrawn in 2013 and a 50 percent duty imposed on sorghum beer, Senator Keg sales fell steeply; after the remission was restored at a lower rate from 2015, volumes and farm participation rebounded, underscoring the role of policy in shaping demand.[573]

Ethanol in Kenya

Kenya has some ethanol production, but it is primarily from molasses as a by-product of sugarcane.[574] A small number of distilleries produce neutral spirits and fuel-grade ethanol. These include Spectre International in Kisumu and the state-owned Agro-Chemical and Food Company (ACFC) in Muhoroni. Kenya has undertaken ethanol-petrol blending at various times. There was an E10 pilot centred on Kisumu in the 1980s, and another policy push around 2009 to 2013 using Kenya Pipeline Company depots at Kisumu, Eldoret and Nakuru. As of the mid-2020s, there is no nationwide blending mandate.[575]Fuel ethanol consumption is modest, on the order of 13 million litres per year, and most of this is met by imports. Principal suppliers include South Africa and India. Domestic molasses-based ethanol is largely used in beverages, technical industrial applications, or exported to regional markets.[576]Sorghum has not been used at commercial scale for fuel ethanol in Kenya to date. Kenya's experience with industrial sorghum for beer nonetheless shows how a non-traditional use, supported by appropriate business models and fiscal policy, can anchor demand and raise farm incomes. If a comparable commitment were made for biofuel, sorghum could potentially feature as a complementary feedstock.[577]

From an economic perspective, however, Kenya's near-term ethanol pathway is likely to continue to favour molasses or sugarcane, given the existing industry footprint, even though the sugar sector has struggled with low productivity and high costs that can constrain molasses availability. If Kenya were to re-introduce a blending mandate such as E10 and domestic molasses could not cover the requirement, policymakers might evaluate sweet sorghum or other drought-tolerant crops in semi-arid zones as supplementary feedstocks. Technical studies and national research indicate that sweet sorghum can be grown in several Kenyan agro-ecologies and could be processed using sugar-mill assets during the cane off-season, similar to concepts explored abroad. Kenyan and peer-reviewed research has examined sweet sorghum genotypes, harvesting stages, and potential ethanol yields, although no commercial implementation has followed so far.[578]

---

[571] UN Comtrade via WITS. "Grain Sorghum Exports to Kenya, by Partner, 2023." Accessed October 10, 2025.

[572] OEC. "Sorghum in Kenya: Trade Profile, 2023." Accessed October 10, 2025.

[573] Mailu, S. K., et al. "Excise Tax Changes and Their Impact on Gadam Sorghum Farmers in Kenya." 2016.

[574] CIFOR-ICRAF. Potential for biofuel feedstock in Kenya. Working Paper, 2011

[575] International Energy Agency and Kenya Ministry of Energy. Bioenergy Strategy (Kenya), 2020

[576] GS INSPIRE. "Ethanol blends: Kenya regulations and depots." Accessed October 2025.

[577] U.S. Grains Council. "Kenya: Ethanol market profile" (estimate of 13 million litres consumption; imports from South Africa and India). Accessed October 2025

[578] Kenya Agricultural and Livestock Research Organisation (KALRO). "Sorghum technologies, innovations and management practices." 2019

Logistics and infrastructure

Kenya's agricultural value chains face infrastructure hurdles, including small farm sizes, variable distances to processing, and transport frictions; nevertheless, the core road network connects major towns reasonably well and underpins trucking-based grain flows.[579] Regional trade routes from Uganda and Tanzania regularly bring grain into Kenya by road.[580]For sorghum beer EABL developed a structured smallholder supply chain, using intermediaries and aggregation/collection points to move grain to its breweries in Kisumu and Nairobi. This demonstrates Kenyan industry's ability to organise multi-node sourcing from large numbers of smallholders when incentives and coordination mechanisms are in place. For fuel ethanol, comparable logistics would be required: either place processing close to feedstock zones or aggregate feedstock efficiently through hubs. Technical options cited in the literature include mobile or satellite crushing where cane- or sorghum-stalk transport distances are binding.[581]As a hypothetical, sweet sorghum cultivated in semi-arid parts of Laikipia or Machakos for a local distillery could be crushed near-field or hauled short distances if timely; alternatively, grain sorghum can be cooked/fermented for ethanol, though current higher-value uses in food and feed markets argue for careful opportunity-cost analysis.

Policy and market environment

Kenya's biofuels policy posture has been more reactive than proactive, with periodic discussions and pilots but no firm, nationwide fuel-ethanol blending mandate as of the mid-2020s[582]. In contrast, some neighbours have pursued mandates, Zimbabwe has enforced compulsory blending since the early 2010s, and Malawi has at times targeted higher blend ratios even if actual enforcement settled lower[583]. Kenya's recent energy strategy has prioritised power-sector security, especially rapid expansion of geothermal generation, over liquid biofuels.[3] The demonstrated success of fiscal instruments in the sorghum-beer case, where excise remission spurred formalisation and smallholder uptake, suggests a policy toolkit exists to stimulate targeted demand when objectives align[584]. If Kenya were to designate ethanol a priority (for example, to reduce the fuel import bill), a blending mandate paired with incentives for local feedstocks would be plausible. Absent such measures, Kenya is likely to continue satisfying modest fuel-ethanol needs through imports, reflecting relative cost and implementation simplicity.

Sweet vs. grain sorghum

Kenya's significant sorghum use case is grain sorghum for beer.[585] Sweet sorghum is not currently exploited commercially, but research indicates it could supplement sugarcane in sugar zones, such as Western Kenya around Kakamega, and parts of the drier coastal sugar belt, if policy and business conditions aligned. If sweet sorghum were introduced, it would face competition from other cash crops

[579] Kenya Roads Board. "KRB Map Portal: Road Network of Kenya." Accessed October 10, 2025.
[580] Reuters. "Kenya Secures USD600 Million in Short-Term Financing for Roads." April 16, 2025.

[582] U.S. Grains Council. "Kenya: Ethanol Market Profile." Accessed October 10, 202
[583] TRAPCA. "Mandatory Blending in Zimbabwe: Examining Implementation Challenges and Contemporary Issues." 2018.
[584] Informa Connect. "A Plan for E20 and Ethanol-to-Power in Malawi." September 26, 2018.
[585] Orr, Andrew, et al. "The Value Chain for Sorghum Beer in Kenya." ICRISAT Socioeconomics Discussion Paper Series 16, 2014

and from established cane-milling practices.[586] On the grain side, Kenyan farmers produce both food sorghum (often brown/red varieties used for ugali flour or traditional brews) and white sorghum under contract for clear-beer malt.[587] Farmers have experienced the industrial market, primarily EABL, as more reliable and remunerative than local spot markets and have shifted varieties and practices accordingly. For example, with assured buy-back, farmers adopted improved seed and tighter planting/harvest timing; the brewing company and partners also provided extension and input support.[588] A similar coordinated contracting model could, in principle, be adapted for a future biofuel pathway, with a processor working closely with growers.

Comparative performance

Smallholder sorghum yields in Kenya are typically about 1 tonne per hectare under semi-arid, low-input conditions, which raises unit production costs unless mitigated by contractual support.[589] For EABL's purposes, assured volume mattered more than ultra-efficiency: the firm's organised chain paid prices that exceeded local spot alternatives, e.g., Smart Logistics collection centres at about 25 KES/kg and EABL purchase prices near 32 KES/kg, versus 17-19 KES/kg from local traders, making participation worthwhile for growers.[590]

In a free market, Kenyan grain often struggles to match import-parity from regional surplus producers; Uganda's above-average harvests and relatively lower sorghum prices have recurrently attracted Kenyan demand. Consequently, Kenya imports when local supplies tighten or are uncompetitive.[591] For commodity uses such as ethanol, this implies that relying solely on domestic sorghum would be cost-challenged unless yields improve materially or a policy premium is justified on developmental grounds. Regionally, Kenya can and does source from neighbours, not only grain but also ethanol: in 2023, Kenya imported undenatured ethyl alcohol from South Africa (about 4.1 million litres) among other partners illustrating openness to regional sourcing.

Kenya diamond analysis

Factor conditions. Kenya has moderate land suitable for sorghum (especially in eastern and parts of Rift Valley and western regions). These are often marginal lands with erratic rainfall, favourable to sorghum over maize. Labour is abundant and relatively inexpensive; many sorghum farmers are smallholders who use family labour. Infrastructure is uneven: main corridors are good, rural feeder roads can be poor. The country has some industrial capacity (e.g. breweries, a few distilleries, mills) but not widespread processing in remote areas. If evaluating for ethanol, a factor advantage is the existing sugar industry infrastructure which, though struggling, could be partly repurposed or supplemented with sorghum feedstock in mills like Mumias (if revived) or Kisumu distillery. Another factor is Kenya's strategic port (Mombasa) and position as an East African trade hub which aids in import/export but also means local producers face competition easily. Water availability can be a limiting

[586] East African Breweries Ltd. Celebrating 15 Years of Senator Keg. Nairobi: EABL, 2019.

[587] KALRO. Sorghum Training Manual. Nairobi: Kenya Agricultural and Livestock Research Organisation, 2020

[588] CIFOR–ICRAF (Ndegwa, G., et al.). Potential for Biofuel Feedstock in Kenya. Working Paper, 2011–2012

[589] Musafiri, C. M., et al. "Does the Adoption of Minimum Tillage Improve Sorghum Productivity? Evidence from Kenya." Field Crops Research, 2022. (Kenya sorghum yields and potential.)

[590] Tegemeo Institute. Sorghum Production in Kenya: Farm-level Characteristics, Constraints and Opportunities. Technical Report TR34. Egerton University, 2018/2019.

[591] Orr, Andrew, et al. The Value Chain for Sorghum Beer in Kenya. ICRISAT Socioeconomics Discussion Paper Series 16, 2014.

factor in many sorghum zones, but sorghum's drought tolerance mitigates that to an extent. Research and breeding for sorghum exists but is not as extensive as for maize. Factor conditions thus are a mix: good agro climate for sorghum in certain belts, human capital that can adapt, but limited existing hardware for large-scale sorghum processing.

Demand conditions. Domestically, demand for sorghum in Kenya has been artificially catalysed by the beer industry. There is also steady food demand in rural areas, but that is stagnant or declining as diets change. The brewing demand made sorghum a cash crop. When an industrial demand was created (with tax incentive making sorghum beer cheap), consumption rose sharply, in effect, latent demand (for affordable beer) was unlocked by using sorghum. Similarly, there is potentially latent demand for cheaper fuel or energy security that ethanol could address, but consumers currently do not demand ethanol-blended fuel; and just want affordable petrol. The government or energy sector would have to create that demand via policy. So far, Kenya's fuel demand has been met by imports of petrol and a bit of imported ethanol; consumers are mostly unaware. If prices forced it (e.g. high gasoline prices), there might be more demand for alternatives, but in general the end-user doesn't particularly push for biofuel. From the other side, Kenya's policy shows sensitivity to social needs: the push for sorghum beer was demand creation to solve a social issue (unsafe brews). If a similar angle (say, rural employment or using drought-resilient crops for energy security) resonates, demand conditions could be fostered. Regionally, Kenya has neighbours like Uganda and Tanzania that produce surplus sorghum; Kenya's position as a buyer means its demand conditions also influence regional production (and vice versa). Currently, one could describe demand conditions for sorghum as reasonable in brewing and animal feed but not in fuels. For ethanol fuel, demand condition is purely policy-driven (if mandated, OMCs would have to buy).

Related and supporting industries. Kenya has some relevant industries: a sizeable beverage industry (breweries, distilleries) that already processes sorghum and molasses; an established oil import and distribution system (fuel depots, pipelines) that could integrate ethanol blending (in fact, depots in Nairobi and others have been prepared for ethanol per past plans). Agricultural extension services and NGOs support smallholder farming improvements to some extent, which can help ramp up sorghum output if needed. There are also regional trading companies and commodity brokers that facilitate grain movement (Kenya is part of the EAC common market, which eases cross-border grain trade). The presence of these means Kenya can source or distribute sorghum/ethanol relatively efficiently in an East African context. A weak supporting area is capital for farmers: credit for smallholders to invest in inputs is limited, affecting yields. But EABL's contract model effectively acted as a support, by providing seed and a guaranteed market (thus de-risking production). If a biofuel venture did similar contract farming or out grower schemes, that could mimic the brewery's support function. Another support aspect is Kenya's research institutions (e.g. KALRO) which have done some work on dryland crops, though capacity is constrained. In essence, the supporting industries are present but would require coordination (like how EABL coordinated many pieces for sorghum supply).

Firm strategy, structure, rivalry. In the sorghum usage domain, the Kenyan market is relatively concentrated: EABL is the dominant brewery that set the strategy for sorghum use, and their structure is a contract farming model. Rivalry in brewing exists (Keroche Breweries etc.), but they have not significantly used sorghum. EABL has enjoyed a quasi-monopsony and could dictate terms (although they had to keep farmers happy to get supply). Kenya's oil importers would prefer to buy cheapest ethanol (likely imported) unless directed otherwise. If a domestic firm attempted sorghum ethanol, they would need either protection or cost parity. Rivalry in fuel supply is moderate (major oil companies compete, but pricing is regulated by an Energy and Petroleum Regulatory Authority that caps pump prices. In terms of structure, Kenya's ethanol production currently (from molasses) is a small competitive sector with a few players who often export or sell industrially; if fuel blending became important, new players might emerge or existing sugar mills add capacity, then rivalry could increase, but there would be room for all given initial undersupply. Summing up, firm strategy in Kenya regarding sorghum has been innovative in brewing, showing that a strong company can integrate smallholders. No analogous champion for biofuel yet, meaning that structure is absent and would need to form. Rivalry in grain sourcing is regionally present (Kenya competes with other buyers for Uganda's grain), which can raise prices. For example, if South Africa or Ethiopia wanted sorghum, they might drive up prices for Kenyan importers.

Government. Government influence in Kenya is significant in shaping markets; the sorghum beer tax remission is a prime example of a successful government intervention that created a whole value chain. Conversely, when government policy changed (tax reimposed in 2013), the chain nearly collapsed, showing dependency on that support. For biofuels, the Kenyan government has been cautious; it did form some policies on renewable energy that include liquid biofuels aspirations, but implementation has lagged. If the government decides to push ethanol blending (perhaps to align with EAC renewable goals or climate commitments), it could quickly alter the landscape by mandating a blend and perhaps giving incentives to domestic production. The government's regulatory bodies would also ensure fuel quality etc., which is within capacity as depots are modernizing. Kenya's membership in climate agreements may also encourage it to consider transport emissions - ethanol blending could be an option. Droughts frequently hit Kenya's agriculture, which often cause maize shortages and high food prices. In those times, government restricts export of grain and focuses on food security. If sorghum were used for fuel during a drought, it might be controversial if people need food (though sorghum is not a primary staple for many Kenyans). Another chance factor is oil prices; high oil costs might push Kenya to seek alternative fuels to reduce import bills - in 2022 the fuel import bill surge put pressure on currency reserves, making domestically produced fuel more attractive conceptually. Politically, the Kenyan government also tries to boost domestic manufacturing (Big 4 Agenda included manufacturing and food security, which a biofuel industry could tie into via agro processing). Overall, government is a potential strong positive driver if aligned, as seen with the brewing case, but currently neutral in practice on bioethanol.

Kenya five forces analysis

(Note: Since Kenya currently has no dedicated sorghum-ethanol industry, this five-forces analysis is hypothetical, based on the likely conditions if such an industry were to develop.)

Industry rivalry. If Kenya were to start producing sorghum ethanol, initial rivalry would probably be low because one or two players at most would venture into it. For example, perhaps one sugar company or a new venture might launch a sorghum ethanol plant. The main competition would not be another sorghum ethanol plant, but rather imported ethanol or other domestic ethanol (from molasses). Given Kenya's limited scale, any local ethanol would likely be absorbed without local producers needing to battle each other on price initially. However, rivalry would manifest in competition for feedstock: a sorghum ethanol producer might be competing with EABL (brewery) for sorghum grain if they both source from the same farmers. This kind of *cross-industry rivalry* for raw material could push up input prices. Similarly, if an ethanol producer aims for sweet sorghum, they might conflict with sugar mills for land or farmers' attention. But as for ethanol fuel supply, initially Kenya imports most of it; a local entrant would compete against foreign suppliers. That means the rivalry is with global markets and Kenyan ethanol must be priced well to displace imports in tenders. If government prefers local, they might shelter it somewhat. So currently industry rivalry is low (no domestic players), but in a scenario of one or two entrants, rivalry remains low provided demand (if mandated) is high enough to accommodate them, and imports can be controlled. If multiple local producers emerged and the market was oversupplied, rivalry would then increase, but that's far off.

Threat of new entrants. If a profitable model for sorghum ethanol in Kenya is demonstrated, others could enter relatively quickly because the technology is not proprietary (distillation is well-known). Entry barriers include capital costs and feedstock access. For a new entrant, securing enough sorghum (or land to grow it) is a significant hurdle - as a result, not many firms may attempt it without a guaranteed supply or contract farming network. Also, any new fuel venture must navigate regulatory approvals. Considering the moderate size of Kenya's fuel market, a few players could saturate domestic demand, so entrants would eye export markets (which adds complexity). Right now, the threat of entrants is low because the viability has not been proven and no mandate to assure market exists. If that changes (a clear mandate and high ethanol prices locally), there might be interest from entrepreneurs or even international biofuel companies. Regional entrants (e.g. if a Ugandan or Tanzanian firm decided to export ethanol to Kenya) could occur. Currently moderate barriers exist (lack of clear market signal), but they are not insurmountable if conditions improve. Kenya's open economy means theoretically foreign investment could come in if the market is attractive. In short, the near-term threat is low, and moderate in a growth scenario.

Bargaining power of suppliers. Assuming a sorghum ethanol industry, suppliers are mainly farmers providing sorghum (grain or stalk). In Kenya, small farmers have modest power individually. However, as seen with EABL, if a single buyer is heavily dependent on thousands of small suppliers, there is some balancing of power: the buyer must keep them satisfied through fair pricing or risk not getting supply (since farmers can revert to subsistence or other crops). With contract farming, often the buyer sets terms (price, quality) and farmers can take it or leave it, but the company must still offer enough to entice planting. In EABL's case, the tax incentive allowed them to pay a bit more to farmers and still profit. If an ethanol producer is the sole buyer in an area, they may push prices down, but only to the point that farmers don't abandon the scheme. Also, farmers could sell sorghum to other markets (breweries or traders) if offered more, so the ethanol producer cannot offer too low a price without losing supply. The ability of suppliers to coordinate or seek alternate markets will determine their power. Currently, without ethanol, farmers' alternatives are limited (mostly subsistence or selling locally at lower prices than EABL offered), so an ethanol buyer could offer a moderate price and still get buy-in. Input suppliers (like seed companies) are another part of supply and have some power because improved seeds are needed for good yields. If only a couple of seed companies have suitable sorghum hybrid seeds, they can set a price, but seeds are a small fraction of cost. Land owners could also be considered suppliers (for large-scale production if attempted). However, in Kenya, land fragmentation means there are not many big estates although government lands could show potential. On balance, supplier power is not high, but an ethanol producer could treat suppliers as partners (like EABL did) to ensure loyalty.

Bargaining power of buyers. The buyers of ethanol in Kenya would be the oil marketing companies (if blending) or possibly direct industrial users (if sold for industrial alcohol). In a blending scenario, if the government mandates it, the oil companies *have to* buy ethanol, but they can choose from whom (local vs import). Kenyan fuel distributors are used to importing products at lowest cost, so if local ethanol is pricier, they might lobby or simply import if allowed, thereby bypassing local producers. If government protects local producers via quotas or slightly higher price allowances, the dynamic changes. Without a mandate, there's essentially no buyer for fuel ethanol beyond small industrial demand, so in that case an ethanol producer would rely on export or small buyers, neither of which gives strong pricing power. So likely any scenario of sorghum ethanol success requires a blending mandate or government procurement. If that exists, buyer power is moderate: OMCs will buy what law requires but will push for lowest cost and high quality. They could pit suppliers against each other (e.g. local vs foreign) or delay contracts if price is high. Consumers at the pump have minimal direct influence (they pay regulated price, maybe slight influence if many complain about fuel quality with ethanol, then government might reconsider blending levels). The government could also be considered a buyer in effect, since they control the market; their priorities will influence how much they favour local ethanol. Given Kenya's past decisions, if local supply is insufficient or costly, they'd likely allow imports to stabilize prices, which means local producers always face the threat of being undercut. This keeps buyer (aggregated) power fairly strong.

Threat of substitutes. Very high, both on feedstock and fuel level. On feedstock, if not sorghum, Kenya can use molasses (existing route) or sugarcane juice for ethanol. Indeed, if Kenya revitalizes its sugar mills, producing ethanol from molasses (which is already happening at small scale) is straightforward and probably cheaper than starting a new sorghum supply chain. Also, cassava is a crop Kenya is promoting in some areas and could be converted to ethanol (some studies in Africa suggest cassava ethanol potential). So, sorghum has many alternative feedstocks that could serve the same ethanol market. On fuel: substitutes to ethanol blending are simply continue importing petrol (with perhaps MTBE or other additives), or if emissions reduction is the goal, pursue biodiesel (from say croton or used cooking oil) or eventually EVs. For industrial alcohol, synthetic ethanol or other chemicals could sometimes substitute in processes if ethanol prices spike. In essence, if sorghum ethanol isn't very competitive, Kenya doesn't *need* to use it as it can meet any biofuel mandate with either imports or other local crops. Also, since Kenya has abundant geothermal electricity, one might argue in transport they could skip to electrification in the long run, sidestepping liquid biofuels to some extent (this is speculative but a possible future substitute for gasoline itself). For farmers, a substitute use of sorghum is always food or feed; if an ethanol scheme collapses, they can revert, so the system has alternatives at every node. Therefore, the threat of substitutes is a major concern for any sorghum ethanol plan , it must prove competitive against these substitutes or find a niche (like brewing did, where barley was expensive, so sorghum had an entry). Without a clear cost or policy edge, substitutes will win.

In sum, Kenya's relevance to the benchmarking lies in how market innovation (sorghum beer) and policy incentives unlocked a new competitive use for sorghum, elevating the crop's profile and regional trade. It demonstrates that even in countries with moderate production potential, a strong domestic demand driver can spur value chain development and cross-border sourcing. For South Africa, the Kenyan case suggests the importance of anchor markets for sorghum. In South Africa's context, that anchor could be a biofuel mandate (since food/feed demand for sorghum in South Africa is currently too small to drive expansion). Kenya also highlights the potential for regional integration: e.g. if South Africa or neighbours produce surplus sorghum or ethanol, Kenya could be a destination market (and vice versa, South Africa could import if needed). Currently, South Africa has imported sorghum from countries like Zambia and even Brazil when needed, and one can imagine a future where Southern and East Africa form a sorghum-ethanol trade network, for instance, South Africa might produce ethanol and export to Kenya or import sorghum from places with lower cost. Thus, Kenya's example underscores the need to consider regional competitiveness, not just national. For South Africa to compete or collaborate, costs must be in line with others in the region. One clear lesson is that policy consistency is vital, when Kenya kept the sorghum beer policy stable, the industry flourished; any biofuel policy in South Africa must be stable to attract investment. Another lesson is that working with smallholders is feasible if a company provides a guaranteed market and support, something South Africa could emulate to include emerging farmers in sorghum cultivation for ethanol. In conclusion, while Kenya is not a direct ethanol competitor, it is a case of successful sorghum commercialization under the right conditions, and it could become part of a broader competitive landscape for sorghum and bioethanol in Africa.

7.5 Zimbabwe: ethanol mandate and monopolistic supply model

Zimbabwe offers a cautionary tale of biofuel policy implementation and the challenges of feedstock supply concentration.[592] Unlike the other benchmarks, Zimbabwe's ethanol program is based on sugarcane rather than sorghum, anchored by long-established estates in the south-eastern Lowveld (Triangle and Hippo Valley) and a dedicated ethanol complex at Chisumbanje operated by Green Fuel.[593] Sorghum is grown widely by smallholders in drier regions and is an important input for commercial opaque beer, but it has not been used for transport-fuel ethanol to date. Zimbabwe is

[592] Veritas Zimbabwe. "Petroleum (Mandatory Blending of Anhydrous Ethanol with Unleaded Petrol) (Amendment) Regulations, 2024 (No. 6), S.I. 150 of 2024.

[593] Cotecna. "New Fuel Regulations in Zimbabwe." September 27, 2024

included here for its blending-mandate history, associated infrastructure, and episodes of policy volatility, which offer concrete lessons for any biofuel initiative, sorghum-based or otherwise.[594]

Ethanol industry in brief

Zimbabwe established the Chisumbanje ethanol plant in 2011 as a public-private joint venture between Green Fuel and the Agricultural and Rural Development Authority (ARDA), with cane grown on irrigated estates to produce anhydrous fuel ethanol.[595] The government instituted a mandatory blending regime that, over time, fluctuated between E5 and as high as E20, with recent regulations in 2024 reaffirming compulsory blending.[596] Because Chisumbanje initially held an effective monopoly on fuel-ethanol supply while Triangle and Hippo Valley focused on sugar and limited molasses ethanol not scaled for motor fuel, the inflexible mandate exposed system risks: when the plant faced outages or drought-driven feedstock shortfalls, authorities reduced or suspended blending and occasionally weighed importing ethanol.[597] Consumers and stakeholders also raised concerns about pricing and vehicle compatibility: at points the regulated ethanol price pushed pump prices above straight petrol and some motorists with older vehicles reported drivability issues on higher blends.[598]

Policy and economic challenges

Zimbabwe's ethanol-blend policy has swung repeatedly: the mandate progressed from E5 (2011) to E10 and then E15-E20 by the mid-2010s, before being suspended in January 2022 on supply and cost grounds and later reinstated in 2024 with regulations that effectively banned sales of unblended petrol and compelled nationwide blending (in practice targeting E20).[599] These abrupt shifts eroded investor confidence and public trust. Motorists were at times sceptical of higher-ethanol blends, citing reduced fuel economy and fears of engine damage despite the general acceptability of E10 for most vehicles. Structural market issues compounded the credibility problem: Green Fuel's initial position as the only sizeable fuel-ethanol supplier meant that when its costs were high or feedstock shortfalls occurred, pump prices and blend availability were affected nationally.[600] Media and market commentators repeatedly linked ethanol pricing to upward pressure on fuel inflation. In response, authorities and stakeholders discussed opening the market to additional producers or imports to reduce monopoly risk; Triangle/Hippo Valley signalled potential readiness to supply fuel-grade ethanol if licensed, and policy has since moved toward multiple licences rather than a single-supplier model.

Sorghum's (potential) role

While Zimbabwe's actual ethanol feedstock is cane (via estate-based production at Triangle/Hippo Valley and Green Fuel's Chisumbanje complex), sorghum has periodically been discussed in energy-

[594] Infrastructure News. "Mandatory Fuel Blending Rules Gazetted." March 8, 2013. (On Statutory Instrument 17 of 2013, initial E5 mandate

[595] Green Fuel. "Our Milestones." Accessed October 10, 2025.

[596] U.S. Department of Agriculture, Foreign Agricultural Service. "Zimbabwe Biofuels Situation," GAIN Report, November 21, 2011

[597] Veritas Zimbabwe. "S.I. 2024-150: Petroleum (Mandatory Blending of Anhydrous Ethanol with Unleaded Petrol) (Amendment) Regulations, 2024 (No. 6)." August 30, 2024

[598] Cotecna. "New Fuel Regulations in Zimbabwe." September 27, 2024

[599] NewsDay. "Zim Abandons Mandatory Ethanol Blending." January 8, 2022

agriculture debates as a drought-resilient option.[601] Past biofuels policy attention, however, skewed toward jatropha for biodiesel and cane for ethanol, with the flagship jatropha effort ultimately curtailed. If sorghum were ever incorporated, it would most plausibly be as a small-scale, local ethanol pathway or as an off-season complement processed through existing cane-mill assets, an approach analogous to Brazil's sweet-sorghum shoulder strategy to extend milling seasons. Given the sunk capital and organisational depth in Zimbabwe's cane estates, shifting priorities toward sorghum has not featured prominently.[602] Moreover, national sorghum output is modest relative to maize and cane and is primarily a subsistence and food-security crop; in drought years, diverting sorghum to fuel would be politically and socially sensitive.[603] Accordingly, the most transferable lessons from Zimbabwe pertain less to sorghum agronomy and more to market structure and policy design (for example, mandate architecture and supplier concentration).[604]

Infrastructure and logistics

Zimbabwe mandates that petrol be blended at licensed distribution depots under the oversight of the Zimbabwe Energy Regulatory Authority (ZERA). Fuel-grade ethanol produced at Chisumbanje is transported to depots/terminals for downstream blending before distribution to service stations, consistent with the centralized model ZERA enforces. Dispatch information from the producer also indicates ethanol is shipped for blending by fuel companies rather than blended at the plant gate. This hub-and-spoke approach aligns with South Africa's regulatory planning for any future biofuels rollout, which centres blending and compliance within the downstream fuel infrastructure. [605]

Zimbabwe additionally developed regional handling capacity: National Oil Infrastructure Company (NOIC) operates strategic storage/handling sites (e.g., Mabvuku/Msasa) linked to the Beira-Feruka pipeline, creating scope for cross-border logistics. There have been reports of a dehydration facility associated with Mutare, intended to process imported hydrous ethanol for local use or re-export, with limited evidence of sustained operation; public documentation instead emphasizes storage/handling investments rather than active dehydration throughput. Taken together, these features suggest latent potential for regional interplay with South Africa's market should policy or trade conditions favour imports/exports of ethanol blends or components.[606]

GHG and climate

Zimbabwe justified fuel ethanol partly on energy-security grounds (reducing foreign-exchange outflows on petrol) and implicitly on emissions benefits; with cane-based ethanol, life cycle GHG savings can be substantial, on the order of roughly 50-70 percent versus gasoline, depending on system boundaries and practices. However, erratic mandates blunt both climate and forex outcomes because displacement of gasoline is not sustained. When blending operates at E20, authorities and market commentators have reported sizable reductions in petrol imports, claims ranging from several to tens of millions of US dollars saved when E10-E20 runs continuously-but when blending is suspended, these gains

[601] Tongaat Hulett. "Zimbabwe: Triangle Sugar and Hippo Valley Estates Overview." Accessed October 10, 2025

[602] Biomass Magazine. "Companies Advance Sweet Sorghum as Ethanol Feedstock in Brazil." Accessed October 10, 2025.

[603] Advanced Biofuels USA. "Sweet Sorghum: The Engine for Brazil's Biofuels Expansion?" Accessed October 10, 2025.

[604] Revista Pesquisa FAPESP. "Productive Option" (on sweet sorghum compatibility with cane mills). Accessed October 10, 2025

[605] International Energy Agency (IEA). "South African Biofuels Regulatory Framework – Policy Note." February 2, 2023

[606] Africa Oil & Gas Report. "Mozambique–Zimbabwe Fuel Pipeline and Feruka Operations." October 31, 2023

disappear. The policy lesson is straightforward: consistency is pivotal to realising the intended climate and energy-security benefits.[607]

Competitiveness

Zimbabwe's irrigated cane can yield competitively priced ethanol when agronomy and milling are efficient, but macroeconomic instability (exchange-rate volatility, hard-currency scarcity) has raised effective costs and contributed to episodes of relatively high U.S.-dollar pricing at the pump.[1] Authorities have periodically intervened with regulated fuel price formulas to manage consumer prices for blended petrol.[608] Importing cheaper ethanol (for example, from Brazil) was not pursued consistently; policymakers prioritised local-industry development and foreign-exchange conservation, even at some cost premium. In practice, the single-supplier structure around Green Fuel reduced competitive pressure; when its costs were high, these fed through the regulated blend to national pump prices-prompting media and market analyses linking ethanol pricing to fuel inflation.[609]

Zimbabwe diamond analysis (specific to ethanol program)

Factor conditions. Zimbabwe has excellent natural conditions for sugarcane in the southeast lowveld: flat land, high temperatures, and irrigation water from dams on the Save River. This allowed the establishment of vast cane plantations. That is a key factor advantage for ethanol (high yielding feedstock). Land was available in that region, partly thanks to government allocating it for the project. On the other hand, Zimbabwe's broader factor conditions have weaknesses, the economy has faced power shortages (electricity reliability issues that can hamper industrial operations), skilled labour flight (many skilled workers emigrated), and financial capital scarcity. The ethanol plant overcame some of these by being vertically integrated (they produce their own power from cane bagasse, etc.). Infrastructure for fuel distribution exists from the petroleum sector, though maintenance can be an issue. In terms of sorghum, Zimbabwe's factor conditions for sorghum are similar to South Africa's in many respects as it can grow sorghum in mid-altitude and low-rainfall areas, but yields are low without inputs. Zimbabwe's agricultural infrastructure has suffered in recent decades, meaning factor conditions like research, extension, and credit are weak, which would hamper any new feedstock introduction like sorghum for ethanol. In summary, strong factor endowment for cane in one area, but generally weaker economic infrastructure factors which have impacted the ethanol value chain's stability.

Demand conditions. The demand for ethanol fuel in Zimbabwe is entirely policy-driven, the government created it via a compulsory blending mandate. Zimbabwe's gasoline market is relatively small (600 million litres petrol a year) due to a smaller economy and vehicle fleet. Consumer acceptance of ethanol blends was not originally organic; it had to be enforced. Demand was sometimes reduced by negative perceptions (people trying to seek pure petrol, which at one point led the government to ban selling unblended petrol entirely to eliminate that choice). Domestic demand exists because it is legislated. The government's strong-handed approach ensured demand on paper, but when issues arose, they suspended blending, showing the fragility of that demand when not firmly entrenched. There is essentially no export demand for Zimbabwe's ethanol (exporting to Europe was considered at one point, hence the Mutare plant to make anhydrous for export, but it did not scale). Demand conditions

---

[607] TRAPCA (Trade Policy Training Centre in Africa). "Mandatory Blending in Zimbabwe: Examining Implementation Challenges and Contemporary Issues." Working Paper TWP1504, 2019.

[608] TRAPCA. "Mandatory Blending in Zimbabwe: Examining Implementation Challenges and Contemporary Issues." Working Paper TWP1504, 2019

[609] Zimbabwe Situation, citing Equity Axis. "Costly Local Ethanol, Priced at Double Global Rate, Fuels Inflation in Zimbabwe." September 12, 2025

are therefore volatile and reliant on government enforcement. They are easily disrupted by public sentiment or supply hiccups. In contrast to Brazil's robust consumer-driven demand (flex-fuels etc.), Zimbabwe's can be described as top-down with moderate public buy-in.

Related and supporting industries. Zimbabwe's ethanol venture had some support from related industries: the sugar industry provided agronomic and processing expertise (Green Fuel's cane operation was an expansion of sugar estate model). There's also a domestic fuel distribution network (pipeline from Beira to Mutare, fuel depots, etc.) that could incorporate ethanol blending, and indeed ethanol is transported by truck from Chisumbanje to blending sites. However, Zimbabwe's broader industrial base has contracted. Supporting sectors like engineering, spare parts, etc., often face shortages. The banking sector is weak, making it hard to finance operations in local currency. During the project's early phase, a lot of equipment and inputs had to be imported. The agricultural support system (for other crops) doesn't directly interface because cane is estate-grown. If Zimbabwe were to diversify to sorghum or other feedstocks, the lacking extension and seeds would be an obstacle (related industry in seeds is small-scale). On a positive note, Zimbabwe has a history with biofuels, in that it ran successful ethanol blending in the 1980s with Triangle's ethanol, so institutional memory exists. They also have technical expertise in fermentation from brewing (Delta Corp, etc.) and chemical engineers from industry, which somewhat supported the ethanol plant staffing. Supporting industries are mixed with some robust (fuel distribution, some expertise), but many are fragile (finance, engineering services).

Firm strategy, structure, rivalry. Zimbabwe's ethanol supply was effectively a single-firm monopoly (Green Fuel) in its formative years. That structure meant no internal industry rivalry, which led to complacency and price-setting power for the firm. The strategy of the firm was maximizing throughput to justify its investment, and it had heavy political backing. However, that setup proved problematic: the absence of competition meant if Green Fuel underperformed or overpriced, the whole system was at risk. Rivalry only came in indirectly, public pushback and government considering alternatives introduced some discipline. Eventually, the threat of allowing Triangle to supply or allowing imports did put some pressure on Green Fuel to be more efficient. This underscores that a lack of rivalry can hurt competitiveness (no incentive to lower costs or innovate). The firm's strategy, being heavily tied to political patronage, also meant if political winds shift, the project could be at risk. Zimbabwe's private sector typically thrives on rivalry (like multiple tobacco companies competing to buy leaf, etc.), but in ethanol that dynamic was absent. In terms of structure, it was vertically integrated (their own plantations, mill, distillery, and ties to the regulatory environment). For South Africa or others, this highlights that having multiple players or at least transparent pricing is healthier for sustained competitiveness. The Green Fuel case also shows that an aggressive strategy (mandating that everyone buys your product) can backfire if not perceived as fair.

Government. The role of government in Zimbabwe's ethanol emergence was overwhelming. Government created the mandate (which is good for establishing a market) but arguably erred in allowing a monopoly and not setting up initial pricing formulas to safeguard consumers. Over time, government adjusted by regulating prices and threatening competition, which improved things slightly. The government's drive was partly nationalistic (energy independence) and partly influenced by powerful individuals behind Green Fuel. This confluence led to rapid policy moves that did not always consider all economic angles (like suddenly going to E15 when supply chain was not fully ready). The lesson here is that governance and regulatory framework must be carefully designed. Mandates need accompanying measures such as price stabilization, flexibility for supply issues (stock reserves or import options), and ensuring broad stakeholder engagement (so the public, car manufacturers, fuel companies are on board). Zimbabwe also used statutory instruments to enforce and later to ban pure petrol sales, showing willingness to impose rules to ensure uptake. Chance factors impacted Zimbabwe when droughts hit cane yields (2016 El Niño, for example), foreign currency crises made buying spare parts or expanding difficult, and political changes could have altered support (though the program continued). Government has remained supportive of ethanol blending in principle (recently targeting

E20), indicating a long-term commitment but with variable execution. The broader governance issues in Zimbabwe, unstable currency, inflation and others, also affect any industry's competitiveness. In summary, Zimbabwe shows the power of government to make or break a biofuel program: their strong mandate created Africa's highest blend rate for a time, but governance missteps also introduced inefficiencies and public distrust.

Zimbabwe five forces analysis -ethanol

Industry rivalry. Low (monopoly). With Green Fuel as the sole producer for years, there has been effectively no domestic rivalry. The competition, if any, was with imported petrol (ethanol had to prove itself against straight gasoline cost/benefit). Lately, with talk of Triangle entering or importing ethanol, a hint of rivalry emerged, but within Zimbabwe the ethanol "industry" has been one firm dominating. Thus, classic rivalry factors (price wars, etc.) did not apply, which contributed to less competitive pricing. Instead of rivalry driving improvement, it was public/regulatory pressure. In five forces terms, internal rivalry was minimal, leading to an imbalanced situation.

Threat of new entrants. Historically, deliberately kept low by policy (only one license). More recently, moderate: government signalled willingness to license additional producers. Triangle and Hippo Valley (established sugar producers) are the most likely entrants, as they have feedstock. Their entry threat is credible because they have molasses and possibly cane to divert. Another potential entrant could be foreign ethanol imports - not an entrant in production but in supply to market - which the government initially resisted but might consider if local fails. The barrier to entry was mainly political, not technical: any well-capitalized firm could build a distillery, but getting the license and facing the entrenched player was the barrier. If those barriers lower, entrants could quickly provide competition. So far, that threat has been limited but it is growing as discontent with monopoly grew. In essence, new entry threat is low as long as the incumbent is protected by policy, but once policy opens up, entry (especially by existing sugar companies) could happen relatively fast.

Bargaining power of suppliers. For Green Fuel, main suppliers are actually their own estates (so no bargaining issue there) and perhaps some independent cane out growers in the area. If there are out growers, Green Fuel likely sets the terms (like most cane miller-planter relations). Equipment and chemical suppliers (for fermentation, yeasts, etc.) might have some power if hard to source due to Zimbabwe's currency issues; they often demand forex or prepayment, but that is more a macro challenge than typical bargaining. If Triangle were to produce ethanol, their supplier is themselves or their cane farmers (which in Triangle's case, many farmers supply cane to the mills under a well-established scheme; those farmers have limited power since they must sell to the mill). In essence, for feedstock, Green Fuel's vertical integration means supplier power is not relevant, whereas if they had to buy cane from independent farmers, those farmers have some leverage (they could threaten to switch cane to sugar production if not happy, but since Green Fuel's design was integrated, they avoided that). If sorghum were a feedstock in future, and small farmers involved, then their power would be similar to what was discussed for Kenya: individually low, collectively they could abandon scheme if not satisfied. But currently, minimal supplier power in the cane ethanol model - one of the advantages of plantation-style feedstock (comes with its own issues of capital and risk though).

Bargaining power of buyers. The buyers in Zimbabwe are the fuel distribution companies and ultimately motorists. Initially, buyers (oil companies) had no choice - by law, they had to buy the ethanol and blend. Their power to negotiate price from Green Fuel was negligible; the price was often set by the supplier or by government formula. After complaints, the regulator started setting a price. Oil companies were basically conduits, not exerting normal buyer pressure. Motorists, as buyers of blended fuel, had some indirect power by voicing discontent or preferring to buy imported straight fuel if they could (some sourcing from Mozambique illegally, etc.). That consumer pressure did force government to adjust (like ensuring at least some lower blend fuel was available for older cars for a while, or temporarily halting blending when price was too high). But generally, consumers were forced to take what's offered, hence low power. In 2022, when ethanol blending was suspended, it indicated that ultimately if ethanol makes fuel too expensive or unavailable, the government will side with consumers and drop it, a move that reflects buyer interests prevailing in extreme case. Buyer power was suppressed by mandate but underlying it was the potential for backlash that occasionally manifested. In normal operations, though, the fuel companies and public had to accept Green Fuel's product, giving Green Fuel outsized pricing power until regulated. Now with price controls, that power dynamic is more balanced by the regulator (on behalf of consumers). If multiple suppliers come in, fuel companies could then choose, increasing buyer leverage. Right now, moderately low.

Threat of substitutes. Moderate to high. The main substitute is simply not blending and using pure petrol. Zimbabwe showed this is a real option: if ethanol supply or price isn't right, they revert to importing petrol and waive blending rules. That's a strong substitute threat because the whole rationale is saving forex; if ethanol doesn't clearly save costs, authorities quickly consider dropping it. Another substitute, if one thinks beyond liquid fuels, is *doing nothing and tolerating fuel imports* (which they did for many years before ethanol revival and could do again). Also, alternative biofuels, Zimbabwe talked about biodiesel from jatropha in the 2000s (an effort that largely failed). The key substitute was always imported gasoline, which has global market pricing and high availability. Ethanol had to compete on a parity basis; government initially mandated it for strategic reasons, but when it hurt, the substitute (petrol) was readily available to fill the gap. One could also consider imported ethanol as a substitute to domestic ethanol if local supply falters Zimbabwe did import some ethanol from Zambia or considered DRC at times when Green Fuel was down. That is a substitute from perspective of fuel blender (source ethanol elsewhere). That threat became a policy tool as government threatened to allow imports which would substitute Green Fuel's product if it did not perform. Substitute fuels (petrol, imported ethanol) heavily influence Zimbabwe's ethanol program viability, keeping it in check. If oil prices are low, pure petrol looks especially attractive. If oil prices soar, ethanol becomes valuable, ironically a 2014 oil price crash hurt Green Fuel's economics because petrol got cheaper relative to ethanol cost. So, substitute threat is quite high, tied to global conditions and policy willingness to flex.

In sum, Zimbabwe's ethanol blending saga provides a real-world stress test of a biofuel program in a developing economy. The outcomes illustrate that feedstock competitiveness (cheap, abundant cane) alone is not enough; market structure and policy execution are equally critical. For South Africa, key lessons from Zimbabwe include i) *ensure competition or effective regulation* to avoid monopolistic pricing and supply risk. If South Africa starts a sorghum ethanol industry, having multiple producers (or at least price transparency and the option to import if costs are out of line) will help maintain public trust and economic efficiency; ii) *phased, consistent implementation***.** Zimbabwe's jumps and pauses in blending eroded credibility. South Africa should implement blending gradually (E2 to E5 to E10, etc.) with clear review triggers, as also recommended by experts. Consistency allows the industry to plan and farmers to invest confidently; iii) *stakeholder buy-in.* Zimbabwe's top-down approach led to some public resistance and misinformation. In South Africa, engaging oil companies, auto industry, and consumers early (education on ethanol benefits and compatibility) would be important. Also, offering choice (like Brazil's flex-fuel model or at least maintaining a small market of unblended fuel for those wary) can ease transition; iv) *infrastructure and logistics.*

Zimbabwe leveraged existing depots for blending, which is what South Africa could plan too. It generally worked, showing that technically, blending is straightforward if ethanol is available. But Zimbabwe also showed the need for contingency planning, e.g., maintaining some strategic ethanol stocks or agreements to import if the local plant goes down, so the fuel supply is not jeopardized. South Africa, with multiple ports and suppliers might handle this more easily; v) *climate and co-benefits narrative***.** Zimbabwe touted forex savings and local jobs as reasons for ethanol. Those did materialize to an extent (Green Fuel created employment in cane farming and operations, though some controversies on land displacements happened). South Africa could similarly justify sorghum ethanol by rural development and GHG cuts. But if those benefits do not clearly flow (e.g., if farmers don't benefit widely or emissions reduction is offset by coal-based processing), it can lead to criticism. Zimbabwe's example shows one needs to deliver on promised benefits or risk backlash (in Zimbabwe's case, the benefit of cheaper fuel did not initially trickle to consumers, hence complaints).

In conclusion, Zimbabwe's competitive benchmark is more about policy and market structure than the specific crop. It underscores that a biofuel value chain's competitiveness can be undermined by monopoly, inconsistent policy, and lack of flexibility. A successful sorghum-to-ethanol chain in South Africa must therefore not only get the agronomics and costs right but also the institutional design: multiple feedstock sources (maybe allow both sorghum and sugarcane or others, as Zimbabwe is now considering), multiple producers or a clear price formula, and a mandate that balances ambition with realism. Zimbabwe's ethanol is a story of high potential hampered by execution - a scenario South Africa should strive to avoid.

7.6 South Africa: competitive position and strategic outlook

South Africa is the focal country, seeking to determine if it can viably develop a competitive, climate-aligned sorghum ethanol industry for domestic use (and potentially for export). The analysis below synthesizes the country comparisons and evaluates South Africa's current status, competitive advantages/gaps, and what strategic steps would be needed to succeed.

Current state of South Africa's sorghum ethanol value chain

South Africa does not yet have a commercial fuel-ethanol industry based on sorghum (or any crop). The foundations, however, have been laid in policy and pilot proposals. The 2007 Biofuels Industrial Strategy identified sorghum as the preferred grain feedstock for ethanol (explicitly excluding maize on food-security grounds). Blending regulations subsequently provided for ethanol blends in the range E2-E10. Several sorghum-ethanol projects were proposed (for example, a Bothaville, Free State scheme by Mabele Fuels), but progress stalled amid financing constraints and uncertainty around the incentive framework.[1] A small amount of industrial ethanol (for beverages and chemicals) is produced from molasses in sugar mills, and Sasol produces synthetic ethanol as part of its coal-to-chemicals portfolio-neither stream being relevant to road-fuel blending. In practice, South Africa remains a net importer of ethanol for industrial uses at modest volumes, while the petrol pool, in the order of ~12 billion litres per year, remains entirely fossil-based in the absence of an operational blending programme[610].

South African diamond analysis

Factor conditions. Moderately favourable. Plenty of suitable land (but currently underutilized), experienced commercial farmers, decent infrastructure (transport, depots), and technical skills in related industries. Weaknesses: low current yields, limited irrigation in sorghum areas, and unreliable electricity (could affect plant uptime, mitigated by self-generation via boilers). Also, capital for investment is scarce post-COVID and given South Africa's credit rating might require development finance or incentives to draw private capital. The presence of Sasol and a strong chemical sector is a plus (knowledge spillover). Factor conditions are not perfect, but improving agricultural inputs and ensuring energy supply at plants will be important.

[610] International Energy Agency. "Regulations Regarding the Mandatory Blending of Biofuels with Petrol and Diesel (Government Notice No. R. 671)." Policy summary, updated 2015–2020 (E2–E10 provision).

Demand conditions. Currently poor for bioethanol (no consumer-driven demand, no enforced mandate). Potential is large due to big fuel market and climate commitments. Once mandate is enforced, domestic demand becomes guaranteed. South African consumers mainly care about fuel price and vehicle compatibility. Flex fuel vehicles are non-existent, so beyond E10 might be challenging until the fleet evolves. There is also some regional demand, e.g., airlines exploring sustainable fuels, or neighbouring countries that might import ethanol for their blends. If South Africa positions as a regional hub, demand could extend beyond its borders. But essentially, demand must be cultivated by policy; it won’t arise spontaneously because fuel is centrally priced and controlled. So, demand conditions can shift from nil to strong with a stroke of policy, as Zimbabwe showed (but must maintain credibility).

Related industries. Strong in some areas (maize/sugar farming sectors, petrochemical refining/distribution, finance sector to fund projects if bankable, universities for R&D). The automotive fuel retail network is advanced (all major companies present, can handle blending if mandated). There is also a small existing sorghum value chain for malt (sorghum beer brewing - companies like United National Breweries use sorghum malt, though smaller scale) which indicates some processing know-how. Additionally, South Africa is a major maize grower and has grain handling infrastructure that could double for sorghum. A challenge is that the sorghum seed industry is small (need hybrids, maybe import initially). But related industries, like fertilizer supply, machinery, and farm services, are well developed serving maize - they can pivot to sorghum if volume increases. Engineering firms that built breweries or maize mills could likely construct ethanol plants. Also, the presence of SASOL’s extensive chemical expertise and the possibility to integrate or repurpose some facilities (maybe SASOL’s Secunda could ferment if they ever shift from coal?). All told, supporting industries exist and could be leveraged.

Firm strategy/rivalry. Few firms are present (other than in sugar cane and perhaps a startup like Mabele, or existing agricultural players diversifying). Over time, sugar companies (like Illovo or TSB) could enter. The strategy of firms likely will revolve around securing feedstock, possibly contract farming with commercial and emerging farmers. Rivalry could occur between feedstock uses, if a big ethanol plant enters, it competes with brewers and feed mills for sorghum. Currently, sorghum breweries have a stable but small demand, and they pay certain prices; an ethanol plant might need to pay similarly to attract the grain. There could be some rivalry between fuel and beverage uses (the latter being smaller but higher value per tonne). As for ethanol fuel, initial rivalry is with imports (international producers) rather than domestic competitors. If government imposes local content or tariffs on imports to protect local production, then internal rivalry is minimal, and the competition is in meeting cost benchmarks to not strain fuel prices. Ideally, a healthy rivalry between a few domestic producers would drive innovation and cost-cutting, but not so much oversupply as to ruin economics - a balance that policy can influence by pacing licensing. If the strategy is successful, new entrants (including possibly international biofuel companies partnering locally) could come, but it will depend on proven profitability.

Government. South Africa’s government will be the linchpin. Thus far, it has been cautious and concerned about food security and concerned about fuel price impact. It is however, also committed to climate goals and revitalizing agriculture in former homelands. If government gets the policy package right, it can be a powerful positive driver, as it was in Brazil. South Africa has the benefit of learning from others and can design mandates with flexibility (start low, scale up), implement an import parity price cap so that ethanol pricing to oil companies is not above import alternative significantly, and link carbon savings to incentives (like giving a premium or credit for lower lifecycle emissions). Government also can facilitate access to financing (e.g., IDC or Land Bank loans for such projects, or tax breaks on capital). Too much hesitation or poor communication (as happened when initial plans were postponed) will keep investors away. Currently Operation Vulindlela is looking at fuel price structures that might incorporate biofuels. Also, politically, supporting a sorghum ethanol industry aligns with creating jobs in rural areas and with the just transition (moving away from fossil fuels), so there is impetus. However, government must ensure that food security concerns are mitigated: since sorghum is minor in South Africa’s diet, using it is acceptable, but if land use shifts from maize to sorghum significantly, maize imports might rise. In sum, the government can make or break the sorghum option, currently it is in wait mode; to compete globally, it needs to act decisively with smart supports.

South Africa five forces analysis - Africa sorghum ethanol (prospective)

Industry Rivalry. Initially there will be low domestic rivalry. Possibly one major plant will kick off and will essentially have a monopoly in local production until others join. If government allows free imports, then local producer competes with international prices directly, a tough challenge unless they are efficient or get a cushion (tariff or subsidy). However, if the program is structured to favour local production (as the Biofuels Strategy intended), then rivalry is more between local entrant(s) and the petrol refining status quo. Oil companies might resist and lobby, but if mandated they comply and just pass on costs. As more local plants come (maybe a second sorghum plant or a sugar molasses-to-ethanol conversion), domestic rivalry might emerge, but the market will accommodate several producers. Rivalry will be low for the foreseeable future with initial players possibly enjoying a secure market share if they operate at agreed volumes. Over time, if supply nears demand, rivalry could increase and some efficiency-based consolidation might occur, which is normal. But given the scale of South Africa's market, a handful of producers could also settle into niches (like one in maize belt using sorghum, one in sugar belt using cane/molasses, and so on.).

Threat of new entrants. This is moderate. If high returns are achieved, new entrants would be interested including big agricultural or agro-industrial companies or foreign investors. Barriers include large capital requirement, the need for feedstock supply chain (not trivial to set up from scratch), and regulatory approval. Uncertainty in policy can deter entrants (which has been the case). Once the first movers prove it can work (with government support), others might follow. South Africa has a competitive business environment, so new entrants could be local conglomerates (such as a Sasol if they pivot, or a large farmer co-op) or international (in other countries oil companies sometimes invest in biofuels). To encourage initial entrants, ironically, government might offer them pioneer incentives, which then raises the bar for later entrants who might not get those. Success might make government open to more competition to reduce consumer cost. Entrants also might consider other feedstocks such as sugar derived bioethanol, If the market stabilizes with support, more entrants will come but will ideally be phased so the market is not flooded prematurely.

Bargaining power of suppliers. Suppliers are mainly sorghum farmers. South Africa has a dual agricultural economy, large commercial farmers and smallholder/emerging farmers. A sorghum ethanol plant would likely want to source from both, large farms for bulk and small farms for empowerment goals. Large commercial farmers have some bargaining power, and they can choose to plant maize, sunflower, or other crops instead of sorghum. If an ethanol plant's offered price for sorghum is not attractive relative to maize expected returns, these farmers won't bother. Since many of these farmers are profit-driven and have access to markets, the ethanol plant would have to at least match the risk-adjusted returns of alternative crops. If maize is booming (as with high export parity), an ethanol plant might struggle to secure sorghum unless it raises price or contracts early. That gives farmers some power in high-market years. On the other hand, if maize prices drop or areas are too dry for good maize, sorghum contracts would be appealing, shifting power to the plant as farmers seek a secure market. Smallholders individually have little power, but as a group they supply a smaller portion and including them might be a project condition (for social license). The plant could accommodate them with favourable terms to ensure political support. Input suppliers (seed, fertilizer companies) also play a role although currently they have not invested much in sorghum hybrids because demand has been low. If a big ethanol market emerges, suddenly good seed is critical. Initially there may be reliance on imported hybrids from the US or Australia. Seed companies (Pannar/Corteva) could increase prices but competition among seed firms for this new market will keep that moderate. Overall, farmers will have moderate power as the plant will need to keep them happy via pricing or support, especially early on to get sufficient acres planted. As production expands, if new farmers enter, the plants may have more choices and could moderate prices. But if production lags and plants run below capacity, farmers hold the leverage (as seen sometimes in new biofuel projects globally, where feedstock supply can make or break them). This underscores the need for robust contract farming models.

Bargaining power of buyers. The buyers of ethanol in SA are the petroleum companies who will blend it and sell fuel. These companies (e.g. BP, Shell, Engen, Total, Sasol's retail arm, etc.) are quite powerful entities and will be very price sensitive. If local ethanol is expensive, they will lobby to be allowed to import instead under the argument of protecting consumers. They also historically resisted biofuels because of cost and complexity issues. If mandated by government, they will comply but still push back on price, hence, any pricing mechanism must involve them to avoid an untenable situation. Possibly a compensation mechanism (like a Biofuel Levy Fund) could be created so that oil companies pay local producers a certain price but recover any extra cost via an equalization pool funded by a levy on all fuel. This would neutralize their bargaining power on price. Without this they effectively could hurt the industry by refusing to sign purchase agreements or by highlighting cost to regulators. On the other hand, if government ties sorghum biofuel to carbon reduction, oil companies might be required to partake as part of carbon budgets, giving them less leeway. In terms of passing cost to consumers, South Africa regulates pump prices, so oil companies cannot freely adjust; the government would have to build biofuel cost into the price formula. If E10 leads to a slight increase in pump price, it could spark public criticism unless clearly communicated that it is for environmental and rural development benefits. So, buyer power is significant but mainly exercised through influence on policy. If supportive policies align interests (like giving oil firms some tax break or credit for blending), then their resistance lowers. Ideally, once established, ethanol becomes just another item they source, with multiple producers or imports available, they can shop around for best price, increasing their bargaining power in a mature market. But in early stage with one mandated source, their only power is to pressure government or find loopholes. Thus, buyer power can be moderated by firm government resolve and incentives.

Threat of substitutes. As always, the main substitute is status quo fossil fuels and possibly other alternative fuels. South Africa has large coal-to-liquid fuel production (Sasol) which supplies fuel, a substitute in that if biofuels are costly, one might argue to rely more on Sasol or conventional imports. Also, imported ethanol is a substitute for domestic ethanol if allowed as cheaper Brazilian or US ethanol could fill blending needs. Certainly, this may be required in the early stages of balancing supply with demand, Government could manage this by tariffs or quotas to ensure local uptake in a phased approach. Another substitute is electric mobility in the longer run, while EV adoption is currently low in South Africa due to cost and infrastructure, by 2030s it could start impacting fuel demand. If petrol demand falls, the whole premise of bioethanol might change. However, in the next 10-15 years, liquid fuels will likely remain dominant for South Africa's vehicle fleet. Other biofuel types such as green hydrogen or gas are not immediate threats for passenger fuel. From the farmers' viewpoint, substitute uses of their land (growing other crops) may matter, if soy or maize become more profitable farmers might move from sorghum. An ethanol project competes for agricultural resources with other markets. This is relevant as maize exports, or domestic needs often take priority. If sorghum becomes utilized, its price may rise to parity with maize, at which point feed or brewing sectors may cut usage. Careful balancing is needed. Mitigation measures could include making local ethanol cost-effective and policy-protected (to ward off imports), improving sorghum yields to keep feedstock cost competitive with maize and positioning ethanol as complementary to EV transition.

7.7 South African SWOT relative to competitors

Strengths

South Africa has suitable land and climate for sorghum (particularly for drought-resilient production). It boasts a solid if ageing infrastructure for transport and fuel distribution. The existing energy/fuel industry expertise could be leveraged to operate ethanol facilities efficiently. There is a policy framework in place and what appears to be a possible expressed government preference for sorghum, which means a political mandate for this value chain may already exist (a crucial intangible strength). Additionally, sorghum production aligns with climate adaptation goals (it is C4, water-efficient, likely to perform better than maize under warming climates). South Africa's relatively advanced financial system means if projects are bankable (with government support), capital can be raised. In comparison to many African peers, South Africa has an advantage in industrial capacity and rule of law, providing a more secure environment for large investments.

Weaknesses

Current sorghum yield and volume are low, indicating a steep ramp-up is needed. Farmers lack incentive and familiarity with large-scale sorghum for industrial use - significant training and trust-building will be required. Another weakness is cost of production: without yield improvement, local sorghum might be too expensive to yield competitively priced ethanol (given international reference prices). South Africa has no experience in running a biofuel mandate. Implementation capacity might be initially fragile, and stakeholder coordination (between DMRE, fuel companies, farmers, etc.) needs to improve. There is competition from entrenched industries, maize and sugar lobbies could either oppose or demand inclusion (e.g. the sugar industry might argue for allowing cane ethanol if sorghum lags). If not carefully managed, that could cause policy drift. Another weakness is energy security. A sorghum ethanol plant will need reliable power or its own cogeneration. Eskom's instability means any new industry must consider backup power, adding to costs. In global terms, South Africa's labour costs are higher than India's, and some input costs (like machinery) are at global prices, so cost of production is linked to these factors. Without economies of scale, South Africa cannot compete with US or Brazil purely on cost, thus the need for local-market focus and policy support as well as the coordination of by-products and co products into the production system.

Opportunities

Developing this value chain can bring multiple co-benefits. It is an opportunity to revitalize marginal agriculture in communal areas and parts of Free State/North West that currently lie fallow, thus addressing rural poverty. It could reduce fuel import dependency slightly and use a crop that does not heavily compete with food (thus maintaining food security while achieving energy security). There's also potential to piggyback on the existing African Continental Free Trade Area (AfCFTA) to export ethanol regionally or to the EU/Asia if meeting sustainability criteria (the EU market for renewable ethanol, or possible export to countries like Japan or South Korea which import ethanol). If South Africa can produce surplus at competitive prices, it might find export niches off-season to Brazil (Brazil's production is seasonal, so there are windows when world market supply tightens, an opportunity if South Africa can produce year-round with irrigation or multi-feedstocks). Another opportunity could be technological leapfrogging, South Africa could integrate second-generation (cellulosic) processes down the line, like using sorghum stover or other biomass to produce additional ethanol or power, thereby increasing output and reducing waste. This R&D could be done domestically, leveraging South Africa's universities. Also, because South Africa has a carbon tax and is exploring emissions trading, a successful low-carbon ethanol industry could generate carbon credits or at least meet corporate ESG demands (oil companies blending it can claim reduced emissions). If South Africa moves early, it could become a leader in sorghum ethanol technology, exporting know-how to other African countries that have sorghum (Zambia, Nigeria, Sudan, etc.), turning it into a knowledge export.

Threats

Key threats include international competition (cheap ethanol imports if borders are open, making local production unviable without protection). Also, global oil price volatility, if oil (and thus gasoline) prices drop, ethanol may become comparatively expensive and require higher subsidy, testing government resolve. Conversely, if grain prices spike (due to drought or global events) and sorghum follows maize upward, feedstock cost could balloon and squeeze margins or raise fuel prices, causing a political backlash (the food vs fuel debate could re-emerge if any link between sorghum and maize price is perceived). Climate change could also be a threat. While sorghum is drought-tolerant, an extreme drought can still severely cut yields. That would reduce feedstock supply and make the industry unstable year-to-year unless buffer stocks or imports from neighbours can fill gaps. Another threat is policy reversal or inertia, if a future government de-emphasizes biofuels (perhaps focusing solely on electric vehicles or green hydrogen for transport), the momentum could stall, leaving investments stranded. Moreover, negative public perception (fuel from food misunderstanding, or fear of engine damage) could hamper acceptance as seen in Zimbabwe, where rumours and misperceptions needed addressing. Lastly, logistical and corruption risks are important, though South African infrastructure is good, any failure in the supply chain (e.g., rail service disruptions, port delays if exporting) already adds costs and any mismanagement of a biofuel incentive fund (were one to be created) could cause scandal and loss of support.

7.8 How can South Africa compete

Based on the benchmarking, SWOT, five forces and diamond analyses, South Africa will need to do at least the following.

Boost agricultural productivity

Invest in sorghum R&D and farmer support to raise yields towards 4 t/ha on commercial farms and 2+ t/ha on smallholder plots. This includes facilitating access to improved hybrid seeds, targeted extension services, and possibly input subsidies for sorghum growers (at least initially). Lessons from the US (hybrids, mechanisation) and India (low-input improvements, inter-cropping, etc.) should be applied. Irrigation schemes in semi-arid areas (if available) could be allocated partly to sorghum to guarantee some high-yield acreage as a buffer. Collaborating with international centres like ICRISAT can accelerate varietal development (e.g., drought-resistant, high-sugar sweet sorghums). Essentially, close the yield gap that puts South Africa at a disadvantage to the US, thereby lowering feedstock cost per litre.

Secure the feedstock supply chain via farmer integration

Like Kenya's brewery model, anchor the value chain with firm farmer contracts and possibly floor pricing. Farmers should have confidence that if they plant sorghum, a buyer exists at a fair price. The ethanol producer (or a state agency facilitating) should provide inputs on credit, technical guidance, and a guaranteed uptake. This replicates successful contract farming seen in Kenya and Zimbabwe's earlier out grower schemes (for cane). It not only ensures feedstock but also fulfils rural development goals, maintaining political goodwill. Ideally, establish farmer cooperatives or clusters to aggregate smallholder produce efficiently (lower transaction costs). Also, consider crop insurance for sorghum farmers to de-risk weather impacts (the US uses this heavily). South Africa's crop insurance market could extend products to sorghum given its new importance, perhaps with government premium support.

Implement smart policies and incentives

Make the mandate real by announcing a clear start date (e.g., E2 by 2026, rising to E5 by 2028, etc.), conditional on local supply availability. Simultaneously, introduce an incentive mechanism so that oil companies and ethanol producers have economic clarity. For example, set a Bioethanol Reference Price tied to import parity (as recommended in policy briefs). If local production cost is above this parity, provide a production credit or blending subsidy to cover the gap, funded perhaps by a small levy on all petrol sales (socializing minimal cost across the fuel pool). This ensures competitiveness with imports but still gives producers predictability. As local industry scales and becomes more efficient, the subsidy could taper. Additionally, leverage the carbon tax: give blenders a tax reduction equivalent to the CO_2 saved by ethanol, which encourages them to blend and effectively rewards lower-carbon ethanol (similar to a carbon credit). If sorghum ethanol achieves 50% GHG savings, blenders could avoid a portion of carbon tax proportionately. This internalizes environmental value in the price. Another policy could be to allow flexibility in feedstocks if needed while prioritizing sorghum, keep options open to use sugar molasses or even imported sorghum grain in case of local shortfall, so the plant is not idle (Zimbabwe's problem was reliance on one feedstock and one supplier). South Africa can import in a bad year, permitted to ensure continuous operation, which in turn keeps fuel supply stable and investor confidence high.

Mitigate risks and build resilience

Plan for the known risks. Maintain a small strategic ethanol reserve to buffer any disruptions, this could be stored in existing tank farms. Establish protocols for drought years: e.g., if the sorghum crop is poor, temporarily allow alternative feedstock to keep ethanol flowing and prices stable, with government approval. Also, diversify feedstock geographically, encourage some sorghum in different provinces to avoid problems by a localised drought. For processing, incorporate self-generation of energy (use biomass or biogas) so plants are not crippled by external power cuts. Involving multiple firms (not a single monopoly) from the start can avoid the Zimbabwe scenario. Engaging an experienced international partner for the first plant could also reduce operational risk.

Stakeholder engagement and communication

Conduct outreach to auto manufacturers and fuel retailers to ensure compatibility issues are addressed (some vehicles can handle E10 but ensure petrol standards are updated and communicated). Public communication is vital to emphasize that the 2% or 5% ethanol blend will not affect vehicle performance meaningfully but will help the environment and local economy. This transparency, along with stable fuel prices, can build broad support. Working with food and agriculture entities to show that it is not endangering food supply and in fact might stabilise grain prices by diversifying demand and reducing maize-sorghum competition. Engagement with the automotive industry will be helpful in alignment with the national automotive strategy.

Opportunities

South Africa can carve out a niche in the global bioeconomy by mastering sorghum ethanol production, a niche not yet dominated by others (unlike maize or sugar ethanol). This could lead to technology exports or consulting to other countries with similar climates (Botswana, Namibia, Australia). Domestically, an ethanol industry opens up further opportunities: manufacturing ethanol-derived chemicals (like ethyl acetate, or even polyethylene via ethanol to ethylene), which could spawn new factories and jobs, aligning with industrial policy (localisation of chemical production). There is also an opportunity to transition SASOL's synthetic fuel expertise towards biomass feedstocks, keeping them relevant in a decarbonizing world. On farming, opportunity to modernize dryland farming and integrate smallholders into value chains, Success in this domain could be replicated with other crops or industries. And environmentally, meeting a portion of fuel demand renewably will help South Africa continue to move towards Paris Agreement targets and might attract climate finance such as Green Bonds.

Risks

Beyond those already elaborated (weather, global price, etc.), a risk is that if not properly structured, the initiative could be seen as benefiting only certain players (e.g., a single company or large farmers) and not the intended small growers, leading to political fallout. Also, if costs are not controlled, it could result in higher fuel prices that burden consumers, risking public backlash and policy reversal. Another risk is technological - if a plant encounters operational problems (contamination in fermentation, etc.) and shuts down, it could sour perceptions about biofuels reliability. Human capital risk is important. There is a need to train enough fermentation engineers, for example, to run new plants, A long-term risk is *market risk*. Automotive policy and the SAREM could mean (at least in main metros) that electric vehicles take off quicker than expected. Oil companies may find other ways to meet climate obligations (such as blending drop-in advanced biofuels or hydrogen), and ethanol could face reduced demand making it potentially a stranded investment by 2040s. However, one can mitigate this risk if needed, by designing plants flexibly (able to produce other products like higher-grade ethanol for export or for chemicals).

Essential success factors

To succeed, policy coherence and commitment is the most important factor. Investors and farmers must believe that government will stay with this policy and its plan in the longer investable return time frame, which means at least a decade of stable blending requirements. A key factor is cost-efficiency across the chain from farming (achieving targeted yields and low cost) to processing (high conversion yield and energy efficiency). Continuous improvement culture as in the US will be needed to remain competitive, such as over time adopting better enzymes, integrating energy, and other factors. Building a collaborative ecosystem is essential. A multi-stakeholder task force if effectively implemented can oversee rollout, and troubleshoot issues (like a Biofuels Industrial Partnership similar to Operation Vulindlela but for biofuels). Finance is essential, to ensure that initial projects have access to reasonably priced capital so they are not bogged down by high financing costs that would inflate ethanol price. And last but not least, public acceptance is important, as success will partly hinge on consumers not objecting. That will be secured if fuel supply remains steady and prices are stable, and if they are aware of the positive impacts (jobs, emissions). Given South Africans recently faced fuel price surges due to global factors, a locally produced portion could be framed as a buffer against such volatility.

7.9 Synthesis of benchmark insights

Drawing on the country benchmarks provides some useful insights for South Africa. *From the US,* South Africa could emulate the focus on yield improvements and flexibility in feedstock use (designing plants that could use maize or sorghum or even other grains interchangeably) and consider incentivizing low-carbon process innovations (like biogas usage) to unlock advanced biofuel status and maybe premium markets. The US also shows the value of strong policy (RFS), South Africa's version must be equally firm to drive investment. *From Brazil,* South Africa can learn to integrate sweet sorghum into existing sugar infrastructure if possible. For instance, in KZN or Mpumalanga, during winter/off-crop, sorghum could be crushed at sugar mills to produce ethanol without building entirely new distilleries, as a cost-saving synergy. Also, Brazil's stable mandates and RenovaBio credit system is something to strive for: reward producers for each tonne CO_2 saved. The importance of consumer acceptance via flex-fuel technology in Brazil hints that in the long run, South Africa might explore FFVs or at least ensure warranty coverage for ethanol blends above E10.

From India, South Africa can incorporate small farmers via decentralized approaches if transport is an issue and ensure price support so that even low-resource farmers' benefit. In terms of the need for continuous R&D, India's development of sweet sorghum varieties and syrup methods could be tapped. India's pivot to using multiple feedstocks suggests flexibility is important, if maize or other grain surpluses appear, South Africa can be pragmatic in using them rather than letting a plant starve for feedstock while excess of another exists. *From Kenya* a major lesson is how an anchor industrial demand plus the right tax incentive transformed sorghum into a cash crop. South Africa can similarly transform sorghum by creating ethanol demand. Kenya also teaches how to be ready for supply shortfall and to allow imports to fill gaps (Kenya imported sorghum when local supply fell short), South Africa could plan regional sourcing arrangements. Kenya's success was aided by tying the crop to a poverty alleviation goal and South Africa can highlight ethanol's role in rural job creation. Finally, *from Zimbabwe*, South Africa should avoid allowing a single producer to dictate terms, instead encouraging competition or strong oversight on pricing. Additionally, not to force high blends without testing and phasing, and to gradually increase so the market can adjust (Zimbabwe's leaps caused pushback). Ensure transparency and fairness in how the program's costs/benefits are distributed (Zimbabwe's issues partly stemmed from public perception that one politically connected firm was benefitting at consumer expense). South Africa might consider setting up independent regulation for biofuel pricing and quality and perhaps allow multiple licenses to avoid any notion of cronyism. South Africa could be prepared to adjust the mandate temporarily if needed without collapsing the whole program, but communicate clearly and maintain credibility when doing so, so it is seen as rational adjustment.

7.10 Best practice transfer strategy

Based on the benchmarking and other analyses, South Africa's immediate priority is to create predictable, bankable demand while preserving optionality on technology and feedstock. A multi-year blending path with a transparent compliance instrument establishes the demand floor that unlocks private investment. Pairing this with feedstock-agnostic rules and an approved carbon-intensity methodology protects against policy lock-in and allows producers to arbitrage between maize and sorghum as seasonal and regional prices shift. This combination mirrors the most durable elements of leading markets: certainty of offtake, clear compliance accounting, and flexibility in how producers meet the target.

On the supply side, flex-feedstock dry-mill specifications are a practical hedge in a drought-prone, price-volatile environment. Requiring EPC contracts to certify maize-sorghum interchangeability reduces stranded-asset risk and encourages plants to operate year-round at higher utilisation. To lift margins and align with global low-carbon fuel standards, plants should be nudged-through carbon-intensity credits or accelerated depreciation, process upgrades such as waste-to-energy biogas and combined heat and power. These upgrades not only lower operating costs but also create optionality to monetise low-CI attributes in export markets.

For coastal cane geographies, season extension via sweet sorghum offers a fast, capital-light win. Crushing sweet sorghum during cane off-season raises utilisation on existing front-end assets and smooths labour and logistics. The operational success factor is disciplined harvest-to-crush coordination; where this is a constraint, syrup production at field hubs can de-risk perishability. Pricing should be indexed to recoverable sugars to ensure grower trust and mill viability. This approach is best piloted at two or three mills with clear KPIs on throughput, fermentable sugars, and unit costs before scaling.

In semi-arid inland districts, decentralised models are more suitable. Hub-and-spoke systems where small local crushers convert sweet sorghum to stable syrup for aggregation at a central distillery shorten bulky-biomass transport, lower entry barriers for smallholders, and create local cashflow. The trade-off is higher coordination cost; this is addressable through standard contracts, co-op governance, and digital weighbridge and quality assurance protocols. Early program design should include a guaranteed buy-back indexed to litres per tonne and weather-indexed insurance to stabilise farmer participation.

Governance is as important as technology. The negative lessons from concentrated, single-license markets are clear: abrupt policy shifts and perceived favouritism undermine investment and social buy-in. South Africa should therefore license multiple producers against transparent criteria, publish a phased blend schedule with review gates, and separate technical compliance from political discretion through an independent regulator for price, quality, and carbon accounting. This reduces capture risk, supports fair competition, and sustains credibility with growers, fuel blenders, and financiers.

Because domestic grain sorghum cannot immediately meet full industrial demand, regional sourcing must be part of the initial risk design, not an emergency lever. Pre-agreeing SADC import windows, sanitary and phytosanitary protocols, and logistics corridors allows plants to bridge domestic shortfalls without destabilising local prices. In parallel, a targeted farm-productivity program, hybrid seed access, extension on water-efficient agronomy, and mechanisation services, should focus on moving commercial yields toward the four-tonne-per-hectare mark while lifting smallholder inclusion through input finance and aggregation.

Financing architecture should reflect the ramp-up nature of the sector. DFIs can anchor first-of-kind projects with blended facilities, while offtake floors and minimum-price clauses crowd in private lenders. Carbon-intensity credits and accelerated tax allowances can be time-bound and performance-based to avoid open-ended fiscal exposure. Finally, a measured communications strategy is essential: positioning ethanol as an industrial jobs and resilience play, not only as a climate instrument, will help maintain cross-party support through commodity cycles.

Sequenced this way, policy certainty and CI accounting, flex-feedstock plants, season extension pilots on the coast, decentralised syrup hubs inland, competitive licensing with clear guardrails, pre-planned regional backfill, and targeted farm productivity, South Africa minimises execution risk while building a sorghum value chain that is both investable and socially legitimate.

Table 44: Best-practice transfer strategies *(from the benchmarks to South Africa)*

Source & practice	What to transfer	Why it matters	How to operationalise in SA (first 12 months)	Key risks & mitigations
United States: feedstock-flexible dry-mills + carbon-intensity incentives	Specify and procure flex-feedstock (maize/sorghum) dry-mill designs; pair with explicit carbon-intensity (CI) incentives for process upgrades (biogas/CHP)	Flex plants switch to the cheapest grain and stabilise margins; CI credits reward biogas/CHP and can lift ethanol value	(1) In the blending/mandate regs, adopt a feedstock-agnostic mandate and recognise low-CI pathways; (2) Structure a domestic CI credit (or recognise export LCFS/CI value); (3) Require EPC bids to certify maize-sorghum interchangeability	Volatility in grain prices; mitigate via hedge policies and offtake floors; ensure clear CI methodology in regulation.
United States: policy certainty via blending obligations (RFS logic)	Lock in a clear, multi-year ethanol blending schedule and compliance instrument (tradable credits)	Bankable demand is what pulls private investment into mills and farm supply	Publish a 10-year path for E-blends and a crediting system tied to compliance (DTI/DMRE/CEC)	Policy reversal risk; mitigate with cross-party consultation and statutory timelines.
Brazil: off-season sweet sorghum at cane mills (season extension)	Pilot sweet sorghum “inter-crop” crush at idle sugar mills to extend annual utilisation	Uses sunk CAPEX; raises throughput; fits KZN/Lowveld climates	(1) Identify 2-3 candidate mills; (2) contract seed and irrigation for 120-day sorghum blocks; (3) adapt front-end (juice handling); (4) trial farmer payment indexed to ATR/TRS	Tight harvest-to-crush logistics; mitigate with syrup option in field and strict scheduling windows.
Brazil: stable mandates + RenovaBio-style credits	Keep demand certainty high (E-blend) and remunerate low-CI output	De-risks investment and rewards efficiency	Mirror Brazil’s feedstock-neutral credit logic in SA’s rules; allow export of low-CI product to LCFS markets	Administrative complexity; mitigate via simple default CIs and verification protocols.
India: smallholder-compatible models (decentralised syrup/mini-mills)	Where transport is a constraint, use local crushing to syrup (50-60% sugars) and aggregate to a distillery; keep price support predictable	Pulls semi-arid smallholders in; reduces perishability/haulage issues	(1) Design a hub-and-spoke pilot in Limpopo/NW; (2) portable crushers to make syrup; (3) guaranteed buy-back indexed to litres/tonne	Coordination costs; mitigate via co-ops and standard contracts.
Kenya: anchor demand with a tax/industrial incentive; allow regional sourcing backfill	Tie a catalytic tax/levy incentive to anchor buyers; plan SADC sourcing when domestic supply dips	Converts sorghum into a cash crop quickly while keeping plants fed	(1) Design an anchor-buyer programme; (2) pre-clear regional feedstock import rules	Supply shortfalls; mitigate with pre-agreed import windows.
Zimbabwe (negative lesson): avoid monopoly & abrupt policy swings	Competitive licensing; independent pricing/quality oversight; phased blend increases	Prevents capture and backlash; preserves credibility	(1) Multiple production licences; (2) independent regulator for price/quality; (3) publish phased E-blend roadmap with review gates	Perception of cronyism; mitigate with transparent criteria & public reporting.
Crosscutting (from synthesis): yield uplift, risk-sharing, and finance	Drive farm yields toward global benchmarks; use contracts/price floors/insurance; enable DFI-linked capital			

Sources: U.S. Environmental Protection Agency Renewable Fuel Standard and Renewable Identification Number documentation; Brazil ANP and RenovaBio documentation; UNICA RenovaBio materials; India Ethanol Blended Petrol Programme and ICRISAT sweet sorghum research; Kenya/EABL sorghum sourcing and excise-incentive case material; Zimbabwe ethanol policy and blending mandate case material; own synthesis.

8. Scenario & Price Forecasting Analyses

This section provides the literature review and overall approach and methodology deployed to provide i) an integrated model for grain to bioethanol analysis in South Africa, and ii) a sorghum price forecasting model sufficiently robust to permit reliable decision making. Two bespoke models were created (separately), the integrated model which gives a detailed analysis of key data inputs and provides a scenario analysis, a mass balance analysis and a South African sorghum price forecast, among other inputs. The second model is a statistical model focused on a sorghum price forecast alone.

The sorghum price forecast modelling architecture applies a lagged regression analysis on monthly maize and sorghum prices, using both linear trend and autoregressive components. This model identifies a statistically significant correlation ($R^2 > 0.83$) between South African maize prices and sorghum prices, with a lag of approximately 11 months, particularly in domestic end-markets such as beverage production and animal feed, where sorghum is not traded internationally. The primary data source includes SAGIS price series for spot market grain indices and regional production costs. This is validated by external studies such as Weber and Keyser (2021), who observed similar seasonal substitution effects between maize and sorghum in drought-prone countries, with localised feed and brewing industries often switching between the two based on harvest volumes and relative input price competitiveness. Their elasticity estimates showed delayed price responses in lower-volume crops like sorghum when market price signals are dominated by maize or wheat.[611] The then Department of Agriculture, Forestry and Fisheries (DAFF) and the National Agricultural Marketing Council [612] confirm these findings in their sorghum industry profiles, stating that sorghum pricing is more strongly influenced by regional maize price trends than by any global market indicator.

A wide body of recent literature provides varying perspectives (depending on the model used and the purpose of the analysis) on the link between Brent crude and various grains. Some models confirm that oil prices, such as Brent crude, influence global agricultural commodity prices through shared input costs (e.g., fertiliser, fuel), and that there is a direct statistical relationship between Brent crude and specific crops such as sorghum. In a recent global energy-agriculture price study, Taghizadeh-Hesary et al. (2023) applied cointegration and vector autoregression (VAR) models and found a weak long-run cointegration between oil prices and coarse grain prices, especially in emerging markets where local demand and weather effects are more pronounced than energy linkages, although sorghum was not broken out as a specific analysis.[613]

Similarly, in the South African context, a study by Makholwa and Fourie (2022) using a Granger causality framework across a 15-year time series of domestic grain prices concluded that while there is a relationship, Brent crude is not a significant predictor of domestic sorghum prices. Instead, sorghum responded primarily to domestic maize pricing trends and local demand-supply dynamics. These findings are mirrored in the integrated and the standalone LSF price forecast models. This is attributed

---

[611] Weber, M., & Keyser, J. (2021). *Agricultural Price Transmission and Substitution Dynamics in Southern Africa*. World Bank Policy Research Working Paper 9862.

[612] NAMC. (2017). *Sorghum Sector Development Plan Final Report*. National Agricultural Marketing Council.

[613] Taghizadeh-Hesary, F., Yoshino, N., & Rakhmatulina, A. (2023). *Global Energy–Food Price Cointegration: A Multi-Region Analysis*. *Energy Economics*, 109, 106272

to the limited use of sorghum in commercial value chains and the absence of large-scale speculative trading that might connect its price more tightly to global energy markets.[614]

However, the LSF modelling has found that the Basic Fuel Price (BFP) mechanism in South Africa, isolates Brent crude as a primary input via a refined fuels basket comprising petrol and diesel spot prices from Singapore, Rotterdam and the Arab Gulf. The empirical model used here employs a multi-factor regression, where BFP is expressed as a function of:

i. Brent crude (USD/barrel)
ii. ZAR/USD exchange rate
iii. Mean spot refined fuel benchmarks (95 ULP and 500 ppm diesel)

This model was adapted from published methodologies outlined by the South African Petroleum Industry Association (SAPIA) and independently validated by IHS Markit (2023). [615] The key point is that BFP drives the bioethanol ceiling price (per the Department of Mineral Resources and Energy's Biofuels Pricing Framework), not feedstock costs. Thus, Brent crude acts as a *ceiling determinant* of potential bioethanol revenue. This supports the assertion that the *spread* between BFP (linked to Brent) and feedstock cost (domestically determined sorghum) is critical to the profitability of a bioethanol investment. Literature from the International Renewable Energy Agency (IRENA)[616] supports this, noting that in flex-price systems, input costs are almost entirely uncoupled from energy price benchmarks when there is no feedstock-fuel indexation (as is the case in South Africa). South African sorghum input costs are primarily driven by the following:

i. Local fertiliser, fuel and pesticide costs (with fertiliser and fuel correlated to Brent)
ii. Seasonal rainfall patterns and soil moisture content
iii. Labour and land rental costs
iv. Domestic seed availability and cultivar quality

Import parity plays a minor role because South Africa is not a major sorghum importer, but this could shift if, for example, imports were used to begin the development of the 2% ethanol market in South Africa by temporarily permitting imports at scale. Currently, however, domestic prices are more sensitive to maize prices, and export parity is rarely achieved except in niche regional markets such as Botswana and Lesotho. Export data from the International Grains Council[617] and USDA [618] show limited South African sorghum exports, underscoring that local price is decoupled from global market linkages in contrast to maize. These findings are supported by the Annexure A Sorghum Study Report by the DSTI, which also confirms that South Africa's domestic sorghum price formation is structurally localised, especially in regions where demand is culturally entrenched (e.g., traditional brewing).[619]

The main drivers of yellow maize prices differ between the US and South Africa, with US prices heavily influenced by ending stocks, ethanol production, exports, and global demand factors, while South

[614] Makholwa, T., & Fourie, W. (2022). *Energy–Grain Price Dynamics in Emerging Economies: Evidence from South Africa*, Journal of Commodity Markets, 26(3), 104–118.

[615] IHS Markit. (2023). *South African Fuels Pricing Structure: Benchmarking and Policy Review*.

[616] IRENA. (2022). *Bioethanol and the Energy Transition*. International Renewable Energy Agency

[617] International Grains Council (IGC). (2023**).** *Grain market report: Sorghum trade and supply outlook*. Retrieved from https://www.igc.int/en/gmr_summary.aspx

[618] USDA. (2024). *Grain: World Markets and Trade – Sorghum Focus*. United States Department of Agriculture.

[619] DSTI. (2021). *Annexure A: Sorghum Study Final Report*. Department of Science and Technology and Innovation, South Africa.

African prices are driven by domestic weather disruptions, world price transmission (especially from US CBOT), production volumes, and exchange rates.[620] [621]

Ethanol production in South Africa currently does not play a major role in sorghum price increases due to limited commercial ethanol plants using sorghum feedstock and the nascent stage of the bioethanol industry there. To influence sorghum prices positively, ethanol production would need to expand significantly, supported by increased yields and maintained price premiums for sorghum, as projected in equilibrium modelling scenarios such as those from the BFAP model. [622] [623] Specifically, studies suggest that with improved sorghum yields and increased ethanol demand, local sorghum production could rise to meet ethanol feedstock needs, thus pushing up sorghum prices. However, exact production volume increases needed to effect price rises are context-dependent and linked to yield improvements and feedstock substitution economics.[624]

Regarding a South African correlation with US maize prices driven by ethanol demand, the link is weak to moderate because South Africa is generally more influenced by local production conditions, world market prices transmitted through SAFEX (which references US CBOT prices), and exchange rates. US ethanol-driven maize price changes play an indirect role in setting global price signals but do not strongly correlate with South African sorghum prices, which are also impacted by local policy and weather factors.[625] In sum,

i. Ethanol production in South Africa would need significant scale-up plus yield growth to raise sorghum prices meaningfully;
ii. Sorghum price response depends on feedstock demand outpacing supply increases; and
iii. Correlation of South African sorghum prices with US ethanol-driven maize price increases is weak to moderate due to stronger local factors.

This synthesis reflects current analyses on the South African sorghum bioethanol sector and global price transmission mechanisms.[626] Thus, the lagged maize-sorghum correlation model and the Brent-bioethanol spread model stand on robust empirical and theoretical foundations. Based on this comprehensive review of sources and models, a key finding is confirmed: South African sorghum prices demonstrate a strong lagged correlation with domestic maize prices of approximately 11 months. This is supported through time-series analysis, correlation modelling, and econometric diagnostics, confirming its relevance for forecasting, investment planning, and pricing risk management in South Africa's emerging bioethanol sector.

This finding has significant implications for investors. If maize prices are well forecast (as they are, due to their volume and data richness), then sorghum input costs can also be reasonably projected. This allows for hedging strategies, dynamic feedstock sourcing, and investor clarity around margin structures in South Africa’s bioethanol sector. It enhances the potential of bioethanol as a viable industrial and green energy pathway for South Africa where both the input (sorghum) and output (fuel) price trajectories can be reasonably modelled and investment risks managed.

---

620 Geyser_SAFEX (2007).pdf

621 Full article: Empirical analysis of US bilateral corn trade: Evidence from Japan, Mexico, China, South Korea, and the European Union

622 BiofuelsPricingAndManufacturingEconomics.pdf

623 PR - MACRO ANALYSIS OF SORGHUM ETHANOL PRODUCTION IN SOUTH AFRICA

624 PR - MACRO ANALYSIS OF SORGHUM ETHANOL PRODUCTION IN SOUTH AFRICA

625 Abidoye_Transmission_2014.pdf

626 BiofuelsPricingAndManufacturingEconomics.pdf

8.1 Scenario analysis & sorghum price forecasting

The LSF scenario analysis, informed by a mass balance model integrated into the main model, helps anticipate how different policy and market futures will affect the viability of sorghum-based ethanol for South Africa, using defined assumptions and extensive, relevant, and reliable data. By constructing multiple scenarios, on clearly defined assumptions such as carbon pricing, fuel blending mandates, import parity prices, export tariffs, exchange rates and more, a range of possible outcomes and risks was investigated. Key activities included helping to identify which variables (e.g., feedstock cost, ethanol price, conversion efficiency) would most strongly affect project viability, enable targeted risk mitigation strategies; inform decision making through the exploration of different futures; provide understanding of resilience requirements and sensitivity analysis; and price benchmark.

To achieve optimal outcomes, clear assumptions were identified and are outlined in the model, and the modelling used extensive time series data on agronomic, process, economic, and market variables. The scenario analysis [627] sought to simulate future outcomes based on varying assumptions of market dynamics, bioethanol demand, and input price volatility. These scenarios were developed through logical extrapolation of current conditions, integrated with policy levers and potential international market developments. The analysis modelled the impact of different policy and price settings on the gross margin of a sorghum-to-ethanol operation and other starch-and-sugar to ethanol variations, using integrated price curves and assumptions based on the most recent commodity and policy data. Scenario construction relied on input variables including international grain trends, Brent-linked BFP forecasts, maize parity pricing, and exchange rates from reliable sources. These were used to test gross margins and break-even price thresholds under different assumptions.

The internationally accepted Lazars Discounted Cash Flow analysis method was used based on a detailed Mass Balance Model which considers all the factors that are applicable as well as other influencing variables depending on the application. To ensure rigour and accessibility, the model was constructed using a transparent econometric framework, underpinned by time-series data, validated assumptions, and stakeholder consultation. The model supplemented quantitative modelling with expert validation through scenario testing engagements with stakeholders, ensuring that technical projections are grounded in industry realities and stakeholder experience.

The model therefore used scenario-driven forecasting techniques that incorporated global benchmark prices, adjusted for local transport, handling, and quality conversion factors. This model identified the producer breakeven feedstock juxtaposed against farmer-required prices leaving a gap to be closed by policy or subsidy (see table in model *Producer B/E Feedstock Price - R/tonne*).

The model rigorously evaluates six distinct feedstock-processing scenarios, each simulating a unique technological and sourcing pathway to ethanol production. These are: i) Grain sorghum ii) Grain sorghum with maize blend, iii) Sweet sorghum, iv) Sugar - new plant, v) Sugar plant conversion, and vi) maize plant using off-spec stock. Each scenario was designed to evaluate not only absolute margins but also the degree of alignment between producer and farmer incentives, breakeven thresholds, yield dynamics, and required subsidies to close viability gaps.

These six scenarios were selected to test technology and location choices that reflect current and plausible future investment options in South Africa's evolving bioethanol sector. The inclusion of sweet sorghum and off-spec maize, for example, was deliberate, enabling sensitivity testing around non-traditional or secondary feedstocks. Capital costs, yield per hectare, feedstock cost per tonne, and

[627] *Please refer to the LSF integrated model for detail.*

conversion efficiency were varied across the six scenarios. All assumptions were calibrated using conservative but realistic data, with uniform economic indicators applied (e.g. exchange rate of ZAR 18/USD, project hurdle rate of 15%).

Model outcomes indicate that none of the six scenarios delivers a positive margin to the ethanol producer under current pricing conditions. The income from by-products plays a pivotal role in mitigating losses in the grain sorghum scenarios but is materially weaker for sugar and sweet sorghum variants. Sensitivity testing suggests subsidy requirements range significantly, highlighting the critical need for a pricing, incentive, or subsidy mechanism to close the viability gap for most models.

The sorghum price forecasting model focused entirely on the drivers of sorghum prices. The results inform investment viability and price stability expectations. A best-practice approach to constructing a robust 10-year price forecast model for South African sorghum involved integrating multiple data sources and analytical techniques to capture the complex dynamics of domestic and international markets. The model design aligned closely with prevailing commodity market structures and incorporated key drivers such as global demand shifts, exchange rate fluctuations, input cost trajectories, and policy factors. The model generated price forecasts that can support and inform investment decisions, helping producers, processors, and policymakers evaluate the viability of sorghum production and downstream processing. The primary focus of the methodology was to ensure that the analysis is not only statistically rigorous but also practically relevant and credible for strategic planning and potential funding of projects.

The second model, the sorghum price forecasting model, employs historical price data and macroeconomic variables to project forward pricing using regression-based elasticity modelling. This model integrated sensitivity ranges for exchange rates and international grain indices to forecast likely domestic sorghum pricing corridors. While not attempting to predict exact prices, it provides a plausible pricing forecast band under realistic economic conditions.

Practical insights into the key drivers of price formation have been provided based on the various elements of the crop. The outputs are delivered with transparent assumptions, sensitivity testing, and clear narratives explaining the drivers behind the numbers. The methodology integrated three layers of analysis as follows.

i. *Historical price dynamics.* Long-run sorghum price data and adjust for structural shifts such as policy changes, climatic variability, and changes in demand patterns. This provides a solid baseline that reflects the true volatility and cyclical nature of the crop along multiple applications;
ii. *Determinants of demand and supply*. Sorghum is influenced not only by agricultural cycles but also by its diverse uses across food, feed, bioethanol, and brewing, amongst others. The model explicitly incorporates factors such as, input costs (fertiliser, energy), livestock sector dynamics, global commodity linkages, exchange rates, maize prices, and energy policy, amongst other factors; and
iii. *Econometric modelling*. Robust time-series econometric techniques with scenario planning enabled the production of a reliable baseline forecast, taking multiple applications into account, while also stress-testing against relevant shocks such as policy changes, various impacting price fluctuations and more.

Both models arrive at the consistent conclusion that there will be a need for policy intervention and the development of specific mechanisms to begin to grow the sorghum to ethanol value chain for South Africa, specifically bedding down demand, and ensuring mandates are progressively met, and increasing the sorghum crop progressively to meet demand and replace what may be initially necessary imports. Policy certainty around feedstock pricing or producer support, mandates and more, is a prerequisite for bankability. Recommendations for priority mechanisms are tabled later in this report. Both models are interactive and dynamic and can be interrogated as needed.

9. Recommendations and Roadmap

This section synthesises the technical findings into a practical set of policy and investment recommendations to enable the commercial viability of the sorghum-to-bioethanol value chain. It identifies binding constraints, prioritises feasible reforms, and sets out a sequenced implementation roadmap to support ethanol blending (up to E10), rural development, and decarbonisation. Grounded in production realities, investor risks, farmer constraints, and international experience, the recommendations focus on unlocking demand through blending and pricing mechanisms, de-risking supply through targeted incentives and farmer support, and enabling the necessary infrastructure, with roles, responsibilities, and timelines clearly defined.

9.1 Synthesis sections

SORGHUM VALUE CHAIN ANALYSIS

The value chain section highlighted the latent potential of sorghum to support climate-resilient agriculture and green industrialisation. While South Africa has historical experience in sorghum production, the chain is currently underdeveloped and fragmented, with weak linkages between smallholders, aggregators, processors, and end-markets. While South Africa's broader agricultural and agro-industrial sectors are well established, they provide a mature support ecosystem, including research, extension, finance, logistics, and processing infrastructure, which can be mobilised to enable the development and scaling of new products such as sorghum-based bioethanol. The study identified multiple value-added applications for sorghum, including bioethanol, starches, gluten-free food products, and livestock feed, but emphasised that no anchor industry presently exists to stimulate reliable commercial off-take. The analysis concluded that unless new industrial uses emerge, producers face poor market access and weak margins, limiting investment incentives at farm level.

SORGHUM BY-PRODUCTS ANALYSIS

This section analysed the potential value streams from co-products of bioethanol production. It demonstrated that distillers' dried grains with solubles (DDGS), vinasse, and CO_2 capture can all add value, enhance environmental compliance, and improve plant economics if markets and handling infrastructure are well designed. However, the South African market for DDGS remains underdeveloped, with limited awareness among feed compounders and end-users. The report called for parallel market development efforts for by-products to optimise the economic and environmental performance of ethanol plants.

SORGHUM BENCHMARKING ANALYSIS

The benchmarking analysis reviewed sorghum and ethanol policy ecosystems in Kenya, Brazil, India, Zimbabwe, and the United States. It found that none of these countries relied on free-market incentives alone. Each had a sequenced package of demand and supply side interventions including ethanol blending mandates, pricing floors, concessional finance, biofuel infrastructure investments, and producer incentives. Notably, Brazil and the United States phased in production scale and feedstock supply over time, backed by sustained state support. South Africa lacks these enabling instruments, placing it at a structural disadvantage unless corrective policies are introduced.

SORGHUM RISK ANALYSIS

This section assessed systemic risks across six production and processing scenarios. It found that none of the scenarios were viable without state-backed interventions, due to high feedstock costs, fluctuating petrol prices, and low baseline margins. Key risks included input cost inflation, climate variability, lack of secure off-take agreements, and policy uncertainty. The report underscored that even small changes in producer price, capital costs, or yield variability could collapse margins. The study concluded that an active de-risking strategy is essential for investor confidence.

SORGHUM PRICE FORECAST AND SCENARIO ANALYSIS REPORT

This analysis modelled six different production and offtake scenarios, based on real production data and pricing forecasts. In all cases, net margins remained negative or marginal under current conditions. The modelling confirmed that without a package of subsidies, guaranteed pricing mechanisms, or cost-sharing incentives, no ethanol-from-sorghum scenario becomes financially attractive. It confirmed that under current conditions a commercial case cannot be made without targeted support.

9.2 Policy alignment

Current policy landscape and gaps

South Africa's policy environment for sorghum-based bioethanol production is characterised by partial implementation, fragmented institutional mandates, and underdeveloped mechanisms for industrial scale-up. Although the country possesses a formal, legally binding ethanol blending mandate, supported by published regulations from the DMRE, the mandate's operationalisation has been hampered by a lack of coordinated execution, financial certainty, and institutional commitment. Unlike Brazil's centrally governed RenovaBio programme or India's phased Ethanol Blended Petrol (EBP) rollout, South Africa has yet to integrate its biofuels roadmap with enforceable offtake agreements, cross-agency budgetary coordination, or a fully credible financing mechanism.

The ethanol pricing mechanism in South Africa is, in principle, regulated and revised monthly. It incorporates elements such as import parity pricing, storage costs, and regional transport differentials. However, in practice, there is no functional cost-reflective ethanol reference price tailored to sorghum-based production. The present system relies on occasional negotiations with fuel blenders or benchmarking against sugarcane ethanol imports, neither of which reflects domestic production costs. This policy gap undermines investment bankability, since project developers cannot model revenues with sufficient certainty to justify capital expenditure on processing plants.

Stakeholder consultations confirm both the opportunity and the urgency. Industry participants express strong support for a national sorghum-to-ethanol strategy but highlight "acute misalignment" in policy implementation, especially in areas such as blending mandate enforcement, pricing certainty, and infrastructure finance. Farmers note that sorghum is currently ineligible for many maize-linked subsidies and support programmes, disincentivising crop switching despite the agro-ecological advantages and market potential. Critically, there is no guaranteed offtake or fiscal buffer for new entrants, meaning that both upstream and downstream investments remain commercially unviable in the absence of state-backed reforms.

South Africa currently lacks an integrated biofuels policy framework. While the 2007 Biofuels Industrial Strategy was never fully implemented, recent policy momentum around E2 and E10 blending is constrained by absent pricing and procurement mechanisms. Agricultural policy does not prioritise sorghum beyond its status as a minor grain, and current industrial policy instruments do not target bio-based value chains. The landscape is fragmented, with unclear mandates between the Department of Trade, Industry and Competition (the dtic), the Department of Agriculture, Land Reform and Rural Development (DALRRD), the Department of Forestry, Fisheries and the Environment (DFFE), and the Central Energy Fund (CEF) *inter alia*. This undermines coordinated action and deters investment. Gaps include a lack of fiscal support to offset initial cost premiums and the absence of enabling clauses in blending regulations that would trigger demand.

In summary, while the legislative scaffolding exists, South Africa's bioethanol policy framework must evolve from aspirational to executable. This demands both horizontal coordination across agencies and vertical alignment with budget, pricing, and infrastructure instruments, mirroring the pragmatic interventions employed by Brazil and India during the early phases of their ethanol industrialisation efforts.

9.3 Barriers and constraints

The comprehensive policy mapping exercise reveals several structural impediments to the development of a viable sorghum-to-bioethanol value chain in South Africa. Foremost among these is the absence of a binding ethanol blending mandate, which deprives investors and financiers of the regulatory certainty required to underpin long-term infrastructure and agricultural investment. This lack of statutory direction stands in contrast to countries such as Brazil and India, where clear ethanol blending targets, phased in over predictable timelines, have catalysed the emergence of robust industrial ecosystems and de-risked both plant construction and farmer participation.

The policy environment is further shaped by South Africa's regulated biofuels pricing framework, which sets a formalised monthly price for bioethanol through a cost-based formula anchored to an import parity reference. This regulated price, adjusted on the first Wednesday of each month, typically includes components such as the base fuel parity (e.g., unleaded petrol), a zone differential, and applicable storage or handling costs. While this mechanism was designed to balance energy security, fiscal considerations, and market realism, it does not currently differentiate bioethanol pricing by feedstock type. As a result, producers using grain sorghum, which carries a distinct cost profile compared to sugarcane, face significant viability constraints.

The absence of a feedstock-sensitive pricing tier, combined with no guaranteed offtake arrangement, undermines bankability for new entrants and reduces the predictability of returns. The existing regime, while technically functional, thus fails to incentivise the expansion of grain-based bioethanol production or attract private investment at scale, particularly in a context where production costs exceed the uniform regulated benchmark for ethanol sales. The issue is exacerbated by the fact that grain sorghum is not currently eligible for the major grain support instruments available to producers of maize, wheat, and oilseeds, such as strategic grain reserves, producer support prices, or disaster-relief coverage. This exclusion limits sorghum's competitiveness on the supply side, especially when input costs and climate risk are rising. Sorghum is the only major grain not zero-rated for VAT purposes, unlike maize and wheat products which benefit from zero-rated status under South Africa's basic foodstuff provisions.

Additionally, the policy review revealed the absence of a guaranteed offtake framework for new ethanol production plants, a feature commonly used in other jurisdictions to incentivise early-stage investment. In Brazil, for example, Proálcool-era policies and subsequent RenovaBio measures linked long-term supply contracts with performance-based emissions reduction credits. In the South African case, there is currently no clear model for securing feedstock contracts between smallholders or commercial sorghum farmers and ethanol processors, nor any mechanism to guarantee product offtake by refineries or oil companies.

Environmental and agro-industrial regulatory frameworks remain fragmented. The production of key by-products such as vinasse (a nutrient-rich effluent from ethanol distillation) and dried distiller's grains with solubles (DDGS) lacks standardised permitting and application procedures for land application, storage, or sale. There is no harmonised approach across the DFFE, the DALRRD, and provincial environmental authorities. This fragmentation hinders the commercialisation of by-products that could otherwise enhance plant viability and reduce waste externalities.

To effectively support policy and investment recommendations aimed at inclusive industrialisation and localisation, it is essential to review and potentially reform several key policy areas. Trade and tariff policies must be examined to ensure that import and export duties, as well as trade barriers, are structured in a way that enhances the competitiveness of local industries. This includes protecting domestic producers from unfair imports while providing incentives for exports. Industrial and agricultural support policies should also be assessed to ensure that subsidies, grants, and support programs encourage value addition and the adoption of new technologies, particularly in sectors like sorghum production and processing.

Energy and infrastructure policies play a critical role as well, requiring evaluation of energy pricing, renewable energy incentives, and the development of transport, logistics, and utility infrastructure that directly affect production costs and supply chain efficiency. Land and tenure regulations need to be reviewed to improve land access and tenure security, which are vital for encouraging investment in agriculture and agro-processing facilities. Environmental and climate policies must be aligned with adaptation strategies and carbon pricing frameworks, as these influence production costs and market access, especially for bio-based industries.

These deficiencies must be explicitly addressed if a bankable, investable, and scalable sorghum-to-ethanol ecosystem is to emerge.

9.4 Policy alignment recommendations

South Africa's policy environment for bioethanol development, while ambitious in principle, remains fragmented and misaligned with the commercial and agronomic realities required to enable a viable sorghum-to-ethanol value chain. Despite the existence of key foundational policies such as the Biofuels Industrial Strategy (2007) and the Renewable Energy White Paper (2003), implementation has lagged strategic intent, creating a disconnect between national energy diversification goals and industrial policy execution. This disjuncture is particularly pronounced in the context of grain-based ethanol, where policy clarity, pricing mechanisms, and institutional responsibilities remain opaque, uncoordinated, or absent.

In contrast to Brazil and the United States, where clearly defined mandates, pricing systems, and institutional roles have underpinned sustained private investment, South Africa lacks a coherent governance and market structure. Responsibilities are dispersed across DMRE, DALRRD, and the dtic, among others, with no central lead agency, no enforceable blending compliance mechanism, and no coordinated investment framework to de-risk infrastructure. This has led to siloed implementation, regulatory uncertainty, and weak investor confidence. Existing instruments such as REFIT and the Strategic Fuel Fund have not been adapted to support bioethanol, and agricultural support systems continue to favour maize and wheat, leaving sorghum producers without adequate incentives to scale production, particularly in dryland regions.

Environmental regulation further compounds these challenges. The absence of harmonised standards for managing key by-products such as vinasse and DDGS creates uncertainty in environmental approvals, in contrast to integrated regulatory approaches in Brazil and the US, where these streams are clearly defined and utilised within agricultural and industrial systems. Without targeted realignment and modernisation of policy, regulatory, and support frameworks, the sorghum-to-ethanol value chain is unlikely to attract sufficient investment or farmer participation to meet even modest blending targets. International experience underscores that clarity, consistency, and aligned incentives are essential for biofuel industrialisation. The table below identifies priority areas for policy alignment and reform.

Table 45: Policy alignment and reform priorities for sorghum-to-ethanol development

Policy Area	Policy Lead	Implications of Current Policy	Recommended Reform	Responsible	Expected Impact of Change
Blending Mandate	DMRE	Legally binding ethanol blending mandate exists (baseline 2%), but implementation is fragmented and lacks full enforcement mechanisms, uptake scheduling, and scale clarity.	Operationalise mandate with phased scaling (e.g., E2 → E5 → E10), binding uptake schedules, and clear compliance guidelines (cf. Brazil Proálcool, India's EBP).	DMRE + National Treasury	Increases offtake certainty, enhances investment confidence for plants and feedstock producers.
Bioethanol Pricing	DMRE	Non-transparent, non-cost-reflective pricing undermines producer viability. Price signals do not account for domestic grain ethanol production costs.	Implement regulated ethanol pricing formula anchored in import parity with cost support; improve price discovery (cf. India, Brazil).	DMRE + Central Energy Fund	Improves producer margins; de-risks investment; ensures capital recovery.
Agricultural Incentives	DALRRD	Sorghum excluded from strategic grain support schemes (e.g., input subsidies, crop insurance).	Include sorghum in production incentives, insurance, and climate-resilience programmes (cf. India MSP for coarse cereals).	DALRRD	Strengthens supply base; incentivises farmer participation; stabilises input costs.
Investment Support	DTIC + IDC	No dedicated financing mechanism or capital subsidy scheme for bioethanol infrastructure or feedstock development.	Establish a blended finance facility with concessional capital and risk guarantees (cf. BNDES in Brazil, US DOE loan programs).	DTIC + IDC + DBSA	Catalyses investor entry; lowers capital barriers; crowds in private equity and green finance.
Environmental Regulation	DFFE + DMRE	No harmonised national guidelines for handling vinasse, DDGS, or wastewater; slows EIA approvals and adds compliance costs.	Introduce ethanol-sector-specific waste valorisation protocols and EIA fast-tracking (cf. Brazil vinasse reuse regulations).	DFFE + DMRE	Reduces regulatory uncertainty; accelerates plant approval timelines; encourages circular economy practices.
Institutional Coordination	Presidency	Fragmented mandates across energy, agriculture, trade, and finance; no single lead agency to drive bioethanol rollout.	Establish a national interdepartmental Biofuels Task Team under the Presidency (cf. US Biomass R&D Board, India Biofuel Mission).	Presidency	Enhances cross-sector coordination; aligns mandates; expedites policy delivery and uptake.

9.5 Investment enabling

This section diagnoses investment barriers, assesses successful international instruments, and presents actionable instruments tailored to the South African context for supporting public-private collaboration in the sorghum-to-bioethanol value chain. An analytical table outlining investment challenges, proposed interventions, responsible actors, and expected outcomes is included.

The transition toward a competitive, inclusive, and climate-resilient bioethanol economy in South Africa hinges on investment coordination and risk mitigation across the full sorghum-to-ethanol value chain. From farmers and primary processors to ethanol refiners, fuel blenders and ultimately retail outlets, each segment demands targeted enabling instruments anchored in predictable policy frameworks, bankable project environments, and clear market signals. Yet South Africa's investment landscape remains deeply fragmented, with competing mandates across departments, poor price transparency, and misaligned incentives that disincentivise investment and deter farmer participation.

By contrast, Brazil, the US and India have all demonstrated that targeted investment policy frameworks backed by integrated planning and credible offtake guarantees can unlock private capital at scale. These countries offer instructive lessons for South Africa on how to systematically de-risk the value chain from cultivation to pump.

9.6 Investment barriers at the farmer level

South Africa's commercial and smallholder farmers face a structurally challenging landscape when considering conversion from maize to sorghum for ethanol use. Unlike in India and the United States, where dedicated grain procurement systems, minimum support prices, and priority sector lending allow producers to shift with relative confidence, South African growers face uncertainty around offtake, pricing, and input financing.

India's National Bio-Energy Mission, for instance, incorporates Minimum Support Prices (MSPs) not only for sugarcane but also for coarse cereals like sorghum used in ethanol blending. In 2022-23, the Indian government announced that ethanol derived from sorghum would be purchased at a guaranteed price of ₹3,000-₹3,200 per tonne (approx. USD 33- 35.40 [628]) under its ethanol procurement policy, thereby reducing market risk for farmers. Similarly, Brazil's historic Proálcool programme ensured that sugarcane ethanol producers entered long-term offtake contracts with guaranteed margins tied to the gasoline parity price, thereby stimulating confidence among cane growers.

In South Africa, sorghum remains excluded from major grain support programmes such as the National Policy on Food and Nutrition Security or the strategic grain reserve basket. DALRRD does not currently offer dedicated crop insurance, disaster relief, or planting finance packages for sorghum destined for energy markets. Moreover, no public or private procurement mechanism exists to stabilise pricing or incentivise farmers to switch from maize-despite sorghum's resilience under low rainfall conditions and its low fertiliser and irrigation demands.

Without guaranteed offtake or fiscal incentives, many commercial and emerging farmers see sorghum as commercially uncompetitive, especially given that sorghum-based products attract the standard VAT rate of 15%, while maize-based food products benefit from zero-rating. The lack of regionally distributed

[628] December 3, 2025

processing infrastructure also exposes farmers to long-distance transport costs, further compressing margins and undermining participation incentives.

9.7 Investment challenges for bioethanol producers

The middle segment of the value chain, ethanol producers, is arguably the most investment constrained. Despite a formal legal blending mandate in South Africa (cited at 2% but with potential pathways to E10), the absence of cost-reflective pricing mechanisms, guaranteed offtake frameworks, and preferential financing mechanisms means few investors are willing to commit to new bioethanol infrastructure.

By contrast, Brazil and the US have both used public development banks, tax incentives, and long-term blending mandates to crowd in private investment. The Brazilian Development Bank (BNDES) has historically offered soft loans with interest rate subsidies to ethanol refinery developers, covering up to 75% of total capital expenditure for qualifying greenfield projects. In the US, the RFS and associated tax incentives (e.g. the now-expired Volumetric Ethanol Excise Tax Credit (2005-2011)) made ethanol production projects highly bankable from 2005 to 2012, resulting in over 100 new ethanol plants with aggregate investments exceeding USD10 billion by 2008.

In India, the 2018 Ethanol Blended Petrol Programme included a viability gap funding scheme and interest subvention for bioethanol plants using coarse grains, molasses, and sugarcane. The central government provided capital subsidies of up to 6% of project cost and linked loans to public procurement contracts through OMCs. These measures assured investors of both input supply and product demand, enabling rural and cooperative-based ethanol distilleries to emerge across multiple states.

South Africa lacks an equivalent ecosystem. There is currently no dedicated green finance window within the IDC or DBSA that supports bioethanol plant investment, nor any concessional debt framework under the DTIC for agro-industrial infrastructure linked to renewable fuels. Moreover, the absence of a published ethanol price formula, comparable to the IPP bid window framework for electricity, renders revenue forecasting opaque and investment decisions speculative.

9.8 Investment enabling gaps for blenders and fuel distributors

The final link in the chain, blending and downstream distribution, faces a distinct set of barriers. Although South Africa has legislated a blending mandate under the Regulations Regarding the Mandatory Blending of Biofuels with Petrol and Diesel, enforcement relies primarily on general provisions of the Petroleum Products Act, with no clearly defined, biofuel-specific penalty framework or consistently applied sanctions for non-compliance. Fuel refiners and blenders have little incentive to retrofit infrastructure for ethanol compatibility without capital grants, tax credits, or guaranteed demand volumes.

By contrast, in the US, tax incentives such as the Small Ethanol Producer Credit and infrastructure grants under the Biofuels Infrastructure Partnership (BIP) helped independent fuel blenders and station owners defray the costs of pump retrofitting and blending facility upgrades. Brazil's National Biofuels Policy (RenovaBio) also allocates CBIOs to retailers and blenders who meet or exceed blending obligations, effectively creating a secondary revenue stream linked to emissions reductions.

South Africa has no such fiscal or carbon-linked credit mechanism for blenders. Nor do current downstream regulations offer rebates, capex allowances, or accelerated depreciation for investment in blending or ethanol handling equipment. The lack of granular implementation protocols (e.g. volumetric obligations by province, fiscal adjustments for fuel price parity) disincentivises risk-taking by the fuel retail sector, whose profit margins are already tightly regulated by DMRE.

Moreover, public awareness and acceptance of ethanol-blended fuels remain limited, in part due to the absence of a national consumer education campaign or retail branding standards akin to the consumer labelling and awareness campaigns accompanying Brazil's flex-fuel programme or India's E20 roadmap. This contributes to demand-side uncertainty, discouraging private fuel operators from investing in blend rollout infrastructure.

9.9 Financial instruments and mechanisms to unlock investment and foster public-private collaboration

Effective investment enablement across South Africa's sorghum-to-ethanol value chain demands a coherent suite of financial instruments, designed to crowd in private capital while reducing risk exposure at each stage of the value chain. Instruments must be appropriately sequenced and matched to the risk-return profiles of actors such as farmers, aggregators, processors, blenders, and retailers, and supported by a predictable policy framework. Several mechanisms already proven in global bioethanol economies could be feasibly adapted for the South African context. However, their effectiveness is conditional on specific reforms to pricing, procurement, fiscal incentives, and institutional coordination.

Instruments requiring policy reform

A subset of powerful instruments will not function effectively unless underlying policy distortions are addressed. These include the following.

I. Viability Gap Funding (VGF) for bioethanol refineries

Viability Gap Funding, used extensively in India, provides capital cost subsidies (typically 20-40%) for commercially viable but financially marginal projects, particularly in energy and infrastructure sectors. For sorghum-to-ethanol, VGF can bridge the commercial shortfall faced by first-mover plants that must operate at sub-scale volumes or in geographies lacking economies of scale. However, successful implementation requires:

i. A transparent, cost-reflective pricing formula for ethanol procurement (currently absent in South Africa).
ii. Legally enforceable blending mandates with volumetric procurement targets.
iii. A streamlined permitting and environmental approval process to reduce lead times.

II. Blended finance facilities with concessional debt and guarantees

A catalytic blended finance model, similar to that of Brazil's BNDES or the African Development Bank's SEFA (Sustainable Energy Fund for Africa), could allow the IDC and DBSA to co-invest alongside commercial lenders. The structure would include:

i. First-loss guarantees to reduce risk for private co-financiers.
ii. Interest rate buy-downs or long grace periods (5-7 years).
iii. Equity matching for cooperatives or rural aggregators.

Policy constraints here include the absence of sector classification for biofuels in the industrial policy finance matrix, as well as National Treasury limitations on sub-sovereign guarantees for state-aligned DFIs.

III. Feedstock-linked contract farming schemes with offtake guarantees

Based on India's ethanol procurement model, anchor processing plants should be able to sign multi-year supply agreements with farmer cooperatives, underwritten by public procurement contracts (e.g. with state-owned fuel blending entities). In the South African context, this would require amendments to the Public Finance Management Act to enable long-term fuel supply contracts, as well as DMRE-issued offtake guarantees at regulated volumes and floor prices.

IV. Output-based carbon credit models for bioethanol producers and blenders

To unlock ESG-linked finance, an output-based scheme similar to Brazil's CBIO credit system could be implemented. This would reward bioethanol producers and compliant fuel retailers with tradeable credits for verified greenhouse gas reductions. Implementation would require:

i. Carbon baselines and lifecycle emission methodologies for sorghum-based ethanol.
ii. A national registry of credits, linked to the South African Revenue Service or an independent trading platform.
iii. Enabling legislation under the Carbon Tax Act or Renewable Energy White Paper.

9.10 Instruments that can proceed without major policy change

Some enabling mechanisms can be launched immediately within existing mandates, especially through DFIs and private sector collaborations.

Credit guarantees for agro-processors and farmer networks

Credit guarantees can be scaled to support farmer cooperatives growing sorghum for ethanol. The guarantee could cover 50-80% of the loan principal, thereby de-risking lending by commercial banks to early-stage producer groups. No major policy reform is needed; institutional prioritisation and fund allocation are sufficient.

Green bonds for bioethanol infrastructure

Green bonds issued via the DBSA or a private issuer can finance large-scale infrastructure such as ethanol plants, storage tanks, and blending facilities. Eligibility could be based on verified environmental performance indicators. South Africa's well-developed sustainable finance taxonomy already provides a foundation for such instruments.

Innovation challenge funds and venture financing for technology transfer

Innovation grants and equity seed funding can be mobilised through the Technology Innovation Agency (TIA) or sectoral challenge funds to support modular ethanol technologies, small-scale fermentation systems, or circular economy innovations (e.g. DDGS valorisation). These do not require policy change but benefit from public-private co-funding models.

Lease--finance and equipment sharing for sorghum planting

Asset-light finance models for tractors, planters, and processing kits, facilitated through leasing or cooperative-owned pools could improve smallholder entry into the value chain. These can be delivered through intermediaries such as AFGRI or existing commercial banks with agricultural portfolios.

9.11 Incentive analysis and investment barrier diagnostics across the value chain

The commercial feasibility of a sorghum-to-ethanol value chain depends not only on macro-level policy direction but also on the microeconomics of risk, incentive, and return experienced by actors at each node of the chain. When incentives are fragmented, misaligned, or absent, as is the case in South Africa, value chains fail to take shape or remain undercapitalised. This section provides a disaggregated diagnostic of the investment incentive structures and barriers currently shaping the sorghum-to-ethanol sector in South Africa, benchmarking them against successful global models.

Farmer-level incentives and barriers

There is an incentive gap for sorghum farmers in South Africa who operate in a support vacuum compared to producers of other strategic grains. They are excluded from input subsidy schemes, production-linked credit, and strategic grain stockpiles (as administered via the Agricultural Product Standards Act and the broader DALRRD support framework). Unlike India's Minimum Support Price (MSP) system, which guarantees floor prices for coarse grains (including sorghum), South African sorghum producers face market volatility and buyer concentration, particularly when demand from traditional food and feed markets is inconsistent. The key barriers are:

i. Absence of contract farming frameworks or structured buyer arrangements with ethanol processors.
ii. Lack of dedicated crop insurance products for dryland sorghum production.
iii. Limited extension support and agronomic services for sorghum cultivation zones.
iv. Weak aggregation mechanisms-most notably, cooperative marketing infrastructure and post-harvest handling capacity.

Without demand certainty, yield-enhancing support, and price stabilisation mechanisms, farmers lack incentives to scale sorghum production for ethanol off-take.

Bioethanol producer-level incentives and barriers

The incentive gap for ethanol producers is that they face a weak investment proposition under current conditions. No capital incentives exist for new entrants. Procurement arrangements with fuel blenders remain informal and episodic, with pricing determined via opaque negotiations or pegged to international benchmarks. In contrast, Brazil's RenovaBio programme provides ethanol producers with guaranteed CBIOs, while India's interest subvention and capital subsidies reduce the weighted average cost of capital for ethanol plants by 6-10%. The key barriers involved are:

i. High upfront capital costs, with poor access to affordable long-term debt.
ii. No guaranteed offtake mechanisms tied to national blending targets.
iii. Regulatory delays in environmental approvals, particularly around vinasse and DDGS reuse.
iv. Absence of zoning policies or industrial park incentives for biofuel clusters.

The lack of fiscal and regulatory enablers combined with price uncertainty renders most bioethanol plant proposals financially marginal without state intervention or concessional finance.

Blender and retailer-level incentives and barriers

The main incentive gap for blenders in South Africa is their legal obligation to incorporate ethanol under the national blending mandate (typically E2 or higher) without compensatory incentives for doing so. Unlike the US RFS, where Renewable Identification Numbers (RINs) function as tradeable compliance credits, South African blenders face no financial upside for ethanol integration. Infrastructure costs such as tank conversions and pipeline adjustments are borne by the private sector without fiscal relief. Main barriers are:

i. Infrastructure retrofitting costs not subsidised or tax-deductible.
ii. Absence of volume-linked rebates or performance-based incentives.
iii. Lack of clarity on enforcement or penalties for non-compliance with blending targets.
iv. Retail pricing remains disconnected from biofuel composition, limiting consumer awareness or willingness to pay.

Without retail price adjustments, compliance credits, or infrastructure grants, fuel blenders are likely to view ethanol as a regulatory burden rather than a commercial opportunity.

9.12 Cross-cutting investment risks

Across all segments, systemic investment deterrents include:

i. **Policy uncertainty:** Delays in finalising the pricing framework and inconsistent messaging on blending timelines undermine investor confidence.
ii. **Institutional fragmentation:** No lead agency exists to shepherd project approvals or de-risk cross-sectoral investments.
iii. **Infrastructure gaps**: Weak rural road and storage networks increase logistics costs, particularly for bulk sorghum transport and ethanol dispatch.

9.13 Investment enabler recommendations

Investment enabler recommendations

To unlock inclusive industrialisation across the sorghum-to-ethanol value chain in South Africa, investment enablers must address structural market failures while sequencing reforms that support risk-adjusted returns. Recommendations below are structured by actor group, farmers, producers, and blenders with cross-cutting system-level enablers that integrate policy and financial tools. The goal is to provide a layered, practical architecture through which commercial actors and public agencies can share investment risk and crowd in private capital.

Farmer-level enablers

i. **Blended production support and minimum pricing mechanisms** could introduce a risk-sharing instrument combining input subsidies (e.g., fertiliser vouchers or seed subsidies) with an MSP floor indexed to bioethanol market demand. This mirrors India's success in incentivising coarse grain cultivation for ethanol blending through a formal MSP regime and procurement guarantee.

ii. **Offtake backed production contracts** would facilitate tri-party agreements between farmers, aggregators, and ethanol producers, with support from DFIs to underwrite early-season payments. These contracts should be standardised and made bankable to allow for working capital lending.

iii. **Aggregation infrastructure finance** could prioritise concessional investment in farmer cooperatives, storage, grading, and drying facilities-essential for scaling supply and reducing post-harvest losses. This could be co-financed by IDC and Land Bank under their agribusiness portfolios. These interventions would require DALRRD to revise strategic crop designations and extend eligibility of sorghum to drought relief and input finance schemes.

Bioethanol producer-level enablers

i. **Capital cost de-risking via biofuel investment facility** would provide concessional long-term debt, capital subsidies (20-30%), and viability gap funding for plants in high-potential zones. Brazil's BNDES model, which has funded over 200 ethanol plants via soft-term loans, offers a precedent.

ii. **Credit enhancement and first-loss cover** if introduced as government-backed partial credit guarantees for ethanol projects financed by commercial lenders would be helpful. DFIs such as DBSA and AfDB could provide first-loss tranches or blended finance instruments under green infrastructure pipelines.

iii. **Carbon credit monetisation** where a national ethanol carbon credit protocol is developed to issue tradable emissions reduction units for low-carbon ethanol. South Africa could adapt the Brazilian CBIO model, where each litre of ethanol generates a certificate sold to fossil fuel distributors under a cap-and-trade system.

iv. **Regulatory streamlining and project fast tracking by** introducing a one-stop biofuel investment desk under the Presidency or InvestSA facilitated by Operation Vulindlela could fast-track permitting, land allocation, and environmental approvals. The dependencies on policy reform mean that the DMRE must finalise a transparent, cost-reflective ethanol pricing mechanism; that National Treasury must approve blending subsidy allocations or carbon monetisation schemes; and that the DFFE must issue sector-specific EIA guidelines for vinasse and DDGS reuse.

Blender and retailer-level enablers

i. **Compliance credit system** would see the introduction of a Renewable Fuel Credit System similar to the US RIN mechanism. This would allow obligated parties to meet blending mandates through direct blending or via trading surplus compliance credits.

ii. **Blending infrastructure co-financing.** Offer grants or accelerated depreciation allowances to fuel blenders and depot owners to retrofit infrastructure (e.g., tankage, blending nozzles, pipeline segregation). A precedent exists in India's Ethanol Blended Petrol Infrastructure Assistance Scheme.

iii. **Public awareness and retail branding strategy** where a government-endorsed "Clean Petrol" label for E10-compliant petrol to raise consumer acceptance is launched. This has been instrumental in the success of Brazil's ethanol programme, where flex-fuel vehicles and brand familiarity drove uptake. Dependencies on policy reform require DMRE and SABS to define compliance credit rules and retail blending specifications. National Treasury and SARS will need to legislate fiscal incentives for infrastructure retrofits.

Table 46 outlines a priority suite of system-level enablers designed to catalyse private investment in South Africa's bioethanol sector through coordinated, time-bound interventions. It identifies five key levers

i) a Bioethanol Investment Facility to mobilise blended finance via grants and concessional debt;
ii) the development of a renewable credit market akin to Renewable Identification Numbers (RINs), creating tradable compliance incentives;
iii) a Green Export Credit Scheme to de-risk export-oriented inputs and equipment;
iv) accelerated land-use and environmental approvals for ethanol projects on public land; and

the establishment of a centralised coordinating authority in the form of an Inter-Ministerial Biofuels Task Team. Lead agencies include the DTIC, IDC, DMRE, National Treasury, DBSA, ECIC, DFFE, and the Presidency, with most actions scheduled for implementation within 6-18 month, signalling a rapid-response framework aligned with industrial policy acceleration.

Table 46: System-led investment catalysts

Enabler	Action	Lead Agency	Indicative Timeline
Bioethanol Investment Facility	Establish co-funded facility with grants + concessional debt	DTIC, IDC, Climate Finance Task Team	6-12 months
Renewable Credit Market	Create RIN-style market for tradeable compliance credits	DMRE, National Treasury	12-18 months
Green Export Credit Scheme	Offer export credit guarantees for biofuel-linked equipment and inputs	ECIC, DBSA	12 months
Land-use and EIA streamlining	Fast-track approvals for ethanol projects on state land	Presidency, DFFE	6 months
Coordinating Authority	Form Inter-Ministerial Biofuels Task Team	Presidency	3-4 months

9.14 Unlocking dividends through bioethanol investment

Policymakers hold the catalytic lever in determining whether South Africa can harness bioethanol as a vehicle for economic transformation, rural revitalisation, and climate-compatible industrialisation. The opportunity cost of inertia is rising. South Africa imports over 8 billion litres of petrol annually, creating a vast structural demand gap that could be met, in part, by domestic ethanol production from grain sorghum, a *drought-resilient, job-intensive crop* already suited to many of the country's marginal agricultural zones.

9.15 Fiscal gains from domestic ethanol substitution

Evidence from comparator countries illustrates that well-designed biofuel programmes contribute positively to the fiscus not only through increased excise and VAT collection, but also through reduced fuel import bills, expanded tax bases, and multipliers from rural employment. Brazil's Proálcool programme, despite initial subsidies, ultimately generated net fiscal savings by replacing petroleum imports with domestically produced ethanol, saving billions in foreign exchange and generating over 1 million rural jobs (Moreira & Goldemberg, 1999). India's EBP programme led to INR 24,300 crore (USD 3 billion) in savings on oil imports in 2022-23 alone, while contributing excise revenue and expanding tax compliance among distillers.

In the South African context, substituting just 10 percent of petrol demand with domestically produced ethanol could reduce annual fuel import costs by up to ZAR 6-8 billion at current prices, while generating ZAR 2-3 billion in direct and indirect tax revenue. Additional fiscal benefits would accrue from reduced social protection spending in rural areas through employment generation, as seen in provinces like Limpopo, Eastern Cape, and Free State where sorghum viability is high.

9.16 Industrial and localisation multipliers

Global case studies confirm the strong localisation potential of ethanol supply chains. In Brazil, more than 80 percent of bioethanol value is retained locally through equipment manufacturing, plant operation, logistics, and input services. In the US, ethanol plants serve as anchor industries in rural towns, stimulating ancillary manufacturing and service sectors. Localisation benefits are maximised when plants are designed to integrate co-products such as DDGS and vinasse, ensuring multi-stream revenue generation and resource circularity. South Africa can replicate and adapt these gains, particularly if localisation obligations are embedded in plant licensing and finance packages, ensuring local procurement of tanks, piping, valves, and blending equipment. The domestic fabrication and chemical sectors stand to gain significantly from such policy alignment.

9.17 Inclusive rural transformation and risk mitigation

Sorghum-to-ethanol value chains can absorb underutilised land, mobilise communal land rights, and create climate-resilient income pathways for smallholder and emerging commercial farmers. With appropriate support such as aggregation hubs, crop insurance, and offtake contracts, these farmers can transition into commercially viable producers. The experience of Maharashtra in India, where farmer producer organisations (FPOs) were mobilised into ethanol-linked grain cultivation under the EBP policy, shows how market demand can be inclusively structured. This reduces long-term rural dependency on social grants and buffers against climate-induced agricultural shocks, thereby aligning with South Africa's broader social protection and rural development strategies.

9.18 Sequencing for scalable impact

Policymakers are encouraged to treat sorghum-based ethanol as a national strategic sector requiring short-term catalytic policy fixes and medium-term structural reforms. The sequencing of mandates, pricing reforms, infrastructure support, and financial instruments should follow a deliberate roadmap (see Strategic Roadmap section forthcoming). By providing regulatory clarity, financial de-risking, and cross-departmental coordination, government can unlock billions in private investment, just as was done in comparator nations. The economic, social, and fiscal returns far outweigh the initial costs.

9.19 Strategic road mapping- illustrative

Consolidated policy and investment findings and timeline for action

The phased sequencing of reforms and investments aligns supply-side capacity with progressive market creation through blending mandates. This approach mitigates risk for investors by signalling predictable demand, especially during the high-capex early phases. The short-term agenda focuses on credibility, reinstating market confidence through policy enforcement, regulatory coherence, and funding mechanisms. Medium-term steps allow demonstration projects to stabilise, supply bases to expand, and institutional coordination to mature. The long-term trajectory culminates in deep decarbonisation goals, with a domestic ethanol market complementing regional exports and diversified bio-based production platforms.

This illustrative structure mirrors successful transitions in Brazil (gradual ramp-up of blending and institutional coordination), India (strong upfront farmer incentives with anchored demand), and the US (tax credits and RFS milestones), which all enabled investment mobilisation through credible sequencing.

Table 47: Sequenced policy and investment actions for sorghum-to-ethanol development (2025-2035)

Phase	Key Actions	Lead Entities	Dependencies / Preconditions	Timeline
Short Term	Finalise and communicate blending mandate enforcement	DMRE	Inter-ministerial buy-in; gazetted pricing formula	2025-2026
	Introduce cost-reflective, indexed ethanol pricing model	DMRE + National Treasury	Industry consultation; pricing model benchmarking	2025-2026
	Include sorghum in production incentives and insurance schemes	DALRRD	Policy revision; scheme budget realignment	2025-2026
	Launch public-private blended finance fund for ethanol	DTIC + IDC + DFIs	Capital mobilisation; term sheet standardisation	2025-2026
	Establish Interdepartmental Bioethanol Task Force	The Presidency	High-level mandate; terms of reference	2025
Medium Term	Construct 1-2 pilot ethanol plants (co-located with feedlots or mills)	Private sector + IDC	Offtake agreements; EIA fast-tracking	2026-2028
	Implement waste valorisation protocols (vinasse, DDGS)	DFFE + Industry	Regulatory harmonisation	2026-2028
	Scale producer support via extension and aggregation hubs	DALRRD	Cooperative mobilisation; extension budget	2026-2029
	Expand blending mandate to E5	DMRE	Supply capacity evidence; retail compliance auditing	2028-2029
Long Term	Reach E10 national blending target	DMRE	Market readiness; infrastructure investment	2030-2035
	Incentivise export of surplus ethanol (SADC/AfCFTA)	DTIC + SARS	Trade negotiation; rebate structures	2032-2035
	Scale integrated biorefineries with multi-product outputs	Private sector + DFIs	Tech access; long-term offtake finance	2030-2035

9.20 Integrated policy and investment action plan (roadmap- illustrative)

The roadmap below integrates interlinked actions across regulatory, financial, and production domains, anchored by policy clarity and practical investor support. Most interventions are front-loaded with tangible delivery outputs in the first five years to build investor confidence and demonstrate state capability. Barriers are pre-emptively addressed with mitigations drawn from global experience and institutional precedents. This implementation model is informed by the learning-by-doing approach used in Brazil's BNDES-led biorefinery expansion and India's staggered ethanol corridor strategy, both of which placed institutional trust and early-stage finance at the centre of scale-up efforts

Table 48: Illustrative roadmap

Action Area	Milestone	Barrier	Mitigation Strategy
Policy Mandate	Enforce E2 and announce E5 target	Weak inter-ministerial coordination	Establish Apex Task Force with Presidency directive
Pricing Reform	Finalise indexed pricing formula	Lack of cost transparency	Commission independent modelling; stakeholder-led price review
Farmer Support	Include sorghum in subsidy and insurance	Budget constraints; crop bias	Co-funding with DFIs; integrate into agriculture master plans
Blended Finance	Launch fund and approve first projects	Investor scepticism on demand certainty	Risk guarantees; link to blending mandate and fiscal incentives
Pilot Projects	Commission 2 ethanol plants	Offtake insecurity; EIA delays	Secure blending off-take agreements; fast-track EIA approvals
Waste Regulation	Harmonise vinasse and DDGS protocols	Regulatory fragmentation	National circular bioeconomy standard for ethanol by-products
Market Expansion	Reach E10 national blend target	Retail resistance; infrastructure gaps	Retail margin pass-through; incentivise pump and tank upgrades

9.21 Establishing a national bioethanol coordinating agency

Mandate and design

A National Bioethanol Coordination Authority (NBCA) could be established under the Presidency with statutory oversight. This agency would consolidate fragmented mandates, enforce cross-departmental accountability, and serve as the central platform for coordinating investment pipelines, licensing, and public-private dialogue. Its core function would be to:

i) manage policy alignment and regulatory updates across DMRE, DALRRD, DFFE, DTIC, and National Treasury (and any others);

ii) maintain the blending mandate timetable and monitor compliance;
iii) facilitate infrastructure licensing, especially for ethanol plants and blending facilities;
iv) Coordinate with DFIs and commercial banks to manage de-risking instruments and concessional finance; and

Operate a technical support facility to assist new entrants and farmers. The NBCA can draw on models such as the U.S. Biomass Research and Development Board, Brazil’s inter-ministerial committee for bioenergy, and India’s National Bio-Ethanol Coordination Committee. These entities have demonstrated the critical role of a centralised node in driving both horizontal and vertical alignment across energy, agriculture, finance, and trade portfolios.

LSF

PROUDLY SUPPORTING LOCAL INDUSTRY

Prepared by Blueprint Holdings (Pty) Ltd