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AN ANALYSIS OF SOUTH AFRICA'S PETROCHEMICALS AND BASIC CHEMICALS IN THE CONTEXT OF SOUTH AFRICA'S ENERGY TRANSITION FOCUSING ON SASOL'S SECUNDA COAL-TO-CHEMICALS-AND-LIQUIDS FACILITY

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EXECUTIVE SUMMARY

The central question addressed by this paper is: what is the future of the South African petrochemicals and plastics, ammonia, fertiliser, explosives and other chemical value chains of the Secunda petrochemical complex in the light of Sasol's stated greenhouse gas emission reduction plans and other assessed business constraints?

Sasol's Secunda operations are the heart of its inextricably interdependent liquid fuels and petrochemicals manufacturing activities, which make a considerable contribution to South Africa's GDP and employment that will be difficult to replace. It is effectively the sole supplier of basic petrochemicals and chemicals such as plastics. Essentially it adds immense direct and indirect value to a stranded natural asset, low-grade South African coal. To do this Secunda uses 70-year-old coal-to-liquids Fischer Tropsch technology in a process that today is used in very few countries. Despite some modifications and supplementary natural gas feedstock, it cannot easily escape its basic requirement for coal feedstock as a carbon and energy source. This results in a large environmental footprint, including very large greenhouse gas emissions. In particular, in the period approaching 2030, tightening regulation of sulphur emissions and carbon taxation represent a significant local hurdle for Sasol. This hurdle could be raised by carbon border taxes in export markets. Alternative feedstock and abatement technologies such as biomass, green hydrogen and carbon capture are analysed and found to be impractical and not commercially viable in the transition to a net zero world. Consequently, Sasol Secunda is intrinsically poorly placed to deal with global and domestic transition commitments to a lower emissions future particularly for a company in distress.

Sasol is currently a company in distress for several reasons. A feedstock analysis reveals that Sasol Secunda faces significant challenges in the supply of suitable quality coal at an affordable price. Low-cost piped natural gas from Mozambique is in decline and imported liquified natural gas is unaffordable. The implications of output reductions for key petrochemical value chains are analysed. Plant maintenance expenditure appears somewhat low, which can be a leading indicator of reduced reliability. The Lake Charles investment, although dramatically over budget, but finally completed, has not contributed materially to Sasol's financial resources thus far and leaves Sasol with a substantial debt overhang.

Shareholder value concerns are analysed and the share price decline over the last decade, coupled with increasing debt levels, forced asset sales, cultural issues identified in an independent review, and a risky future vision and strategy has been harshly judged by the market.

Following an analysis of Secunda's key value drivers, economic modelling identified six key risks: low oil prices (<US$70/bbl); an increase in carbon taxes to US$30/ton CO_2e by 2030; unsuccessful capital projects potentially affecting production and operating costs, some involving pioneering technologies; coal feedstock prices and natural gas shortages; increased capital requirements for environmental compliance; and the potential need to repay debt incurred for the large Lake Charles petrochemicals project in the United States.

This study found that surmounting the hurdles confronting it will be extremely difficult for Secunda in the light of Sasol's current financial position and other capabilities. All things being equal, the duration of Secunda's sunset phase appears to lie partly in the government's hands with its remaining life being shortened or lengthened according to the degree of environmental pressure on it. The duration also lies partly in Sasol's own hands and how it meets the challenges confronting it.

Given the risks that a declining Secunda output pose to the South African economy, several possible economic development substitutes are identified and roughly compared against policy objectives as possible targets for further detailed quantitative and financial analysis.

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ABBREVIATIONS AND ACRONYMS

BEE	Black Economic Empowerment
Bbl	Barrel of oil (159 litres)
Bpd	Barrels per day (of oil)
Bscf	Billion standard cubic feet
BTX	Benzene, toluene and xylene
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CEF	Central Energy Fund
CO_2	Carbon dioxide. Often substituted for CO_2e albeit not technically correct
CO_2e	Term for describing different greenhouse gases including CO_2 in a common unit.
COP	Crude Oil Pipeline
CNG	Compressed natural gas
CTL	Coal to liquids
DAC	Direct air capture
DRI	Direct reduced iron
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortisation
ENH	Empresa Nacional de Hidrocarbonetos – the Mozambican state oil company
EU	European Union
EU ETS	EU Emissions Trading Scheme for GHGs
EV	Electric vehicle
FCEV	Fuel cell electric vehicles
FID	Final investment decision
FY	Financial year
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
GJ	Gigajoule
GTL	Gas to liquids
GTP	Gas to power
HTFT	High-temperature Fischer Tropsch process
ICE	Internal Combustion Engine
IEA	International Energy Agency
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
ISPT	Institute for Sustainable Process Technology
kton	Kilo tonnes
LCCP	Lake Charles Cracker Project
LPG	Liquified petroleum gas
LTFT	Low-temperature Fischer Tropsch process
MRG	Methane-rich gas – a natural gas substitute sold by Secunda into external market
mtpa	Million tonnes per annum

NERSA	The National Energy Regulator of South Africa
NDC	Nationally Determined Contribution
NG	Natural gas
NGO	Non-Governmental Organisation
PE	Polyethylene
PEM	Proton exchange membrane
PJ	Petajoule
PP	Polypropylene
PV	Photo voltaic
PVC	Polyvinyl Chloride
REIPPPP	The Renewable Energy Independent Power Producer Procurement Programme
ROMPCO	The Republic of Mozambique Pipeline Company
RSA	Republic of South Africa
SAF	Sustainable aviation fuel
SANEDI	South African National Energy Development Institute
SDAC	Synthetic direct air capture
SSLNG	Small-scale LNG
tcf	Trillion cubic feet
TCTC	Thermal Crude-oil-to-chemicals
TIC	Total installed costs
tpa	Tonnes per annum
WEO	World Energy Outlook

GLOSSARY

BEE	Black Economic Empowerment (BEE) is a policy framework implemented in South Africa aimed at addressing the economic inequalities and disparities created by apartheid. It seeks to increase the participation of Black South Africans – particularly Africans, Coloureds, and Indians – in the economy by promoting ownership, management, and control of businesses by previously disadvantaged groups.
CBAM	CBAM stands for the Carbon Border Adjustment Mechanism, a policy tool introduced by the European Union (EU) to reduce carbon leakage and support global climate action. The CBAM is set to be introduced in its transitional phase starting in 2023, with full implementation planned for 2026. Initially, it will apply to carbon-intensive products such as steel, aluminum, cement, fertilisers, electricity, and some chemical sectors. The goal is to place a carbon price on imports of goods from countries with less stringent climate policies or carbon pricing, ensuring that EU companies, subject to stricter environmental regulations, are not at a competitive disadvantage compared to foreign producers. For chemicals, the mechanism is expected to be gradually expanded to cover certain carbon-intensive chemical products, although the exact scope is still being determined. It will apply a carbon price based on the greenhouse gas emissions associated with the production of these chemicals. The inclusion of chemicals will ensure that high-emission sectors are incentivised to adopt cleaner technologies and align with the EU's climate goals, thereby preventing the outsourcing of carbon-intensive production to countries with weaker environmental regulations.
CCS	Carbon Capture and Storage (CCS) is a technology designed to reduce carbon dioxide (CO_2) emissions from industrial processes and power generation by capturing the CO_2 at its source, transporting it to a storage site, and securely storing it underground. This process prevents the CO_2 from entering the atmosphere, thereby mitigating its contribution to global warming.
CDM	CDM stands for the Clean Development Mechanism, which is one of the flexible mechanisms defined under the Kyoto Protocol, an international treaty aimed at reducing greenhouse gas emissions. The CDM allows industrialised countries (known as Annex I countries) to invest in emission-reduction projects in developing countries (non-Annex I countries) as a way to meet their own emission reduction targets. In exchange, the investing country or company earns Certified Emission Reductions (CERs), which can be traded or used to offset part of their own emissions.
CNG	CNG stands for Compressed Natural Gas, which is a form of natural gas that has been compressed to less than 1% of its volume at standard atmospheric pressure. It is primarily composed of methane and is used as a cleaner alternative to gasoline, diesel, and other fossil fuels in transportation, industrial applications, and power generation.
COP26	COP26 refers to the 26th annual United Nations Climate Change Conference, which was held in Glasgow, Scotland, from October 31 to November 13, 2021. The COP conferences are annual meetings where countries that are parties to the United Nations Framework Convention on Climate Change (UNFCCC) come together to discuss and negotiate international climate policies and actions to combat global warming.
CTL	Coal-to-Liquids (CTL) is a technology that converts coal into liquid hydrocarbons, such as synthetic fuels, and chemicals, which can be used as a substitute for petroleum-derived fuels and chemicals. The CTL process typically involves two main steps: gasification and Fischer-Tropsch (FT) synthesis.
DRI	Direct Reduced Iron (DRI) using hydrogen, especially green hydrogen, is an innovative and environmentally friendly method of producing iron. In this process, hydrogen gas

	is used as the reducing agent to convert iron ore into sponge iron (DRI) without melting the ore, significantly reducing the carbon footprint compared to traditional methods that rely on natural gas or coal.
EBITDA	EBITDA is a financial metric used to assess a company's operating performance by calculating earnings before the impact of interest, taxes, depreciation, and amortization. It provides a clearer view of a company's profitability by focusing on the core business operations and excluding the effects of financing and accounting decisions.
ETS	An Emissions Trading System (ETS), also known as a cap-and-trade system, is a market-based approach used to control and reduce greenhouse gas (GHG) emissions by setting a limit (cap) on the total amount of emissions that can be produced by all participating entities. The goal of an ETS is to incentivize companies to reduce their carbon emissions by allowing them to trade emission allowances within the set cap.
EV	An Electric Vehicle (EV) is a type of vehicle that is powered entirely or partially by electricity instead of traditional internal combustion engines that use gasoline or diesel. EVs use electric motors and are powered by energy stored in batteries, which are recharged by plugging into an external power source, such as a charging station or a home outlet.
FCEV	FCEV stands for Fuel Cell Electric Vehicle, which is a type of electric vehicle that uses a fuel cell, usually powered by hydrogen, to generate electricity for driving the vehicle. Unlike battery electric vehicles (BEVs), which store electricity in a battery, FCEVs generate electricity on demand through a chemical reaction in the fuel cell.
FID	FID stands for Final Investment Decision, a term commonly used in industries such as energy, infrastructure, and large-scale project development. FID refers to the point at which a company or organization formally commits to proceed with a major capital investment, after all the necessary feasibility studies, planning, regulatory approvals, and financing arrangements have been completed.
FT	The Fischer-Tropsch (FT) process is a chemical reaction that converts a mixture of carbon monoxide (CO) and hydrogen (H_2), known as synthesis gas or syngas, into liquid hydrocarbons. These hydrocarbons can be refined into synthetic fuels, such as diesel, gasoline, and jet fuel, as well as other chemical products. The FT process is named after German chemists Franz Fischer and Hans Tropsch, who developed it in the 1920s.
GTL	GTL stands for Gas-to-Liquids, which is a technology used to convert natural gas into liquid fuels such as diesel, gasoline, and jet fuel. The GTL process transforms natural gas, primarily methane, into longer-chain hydrocarbons that resemble those found in traditional petroleum-based fuels using Fischer Tropsch (FT) technology
IGUA-SA	The Industrial Gas Users Association of Southern Africa (IGUA-SA) is an organisation that represents the interests of large industrial consumers of gas in Southern Africa. These industries rely heavily on natural gas for their operations, and IGUA-SA serves as a collective voice to advocate on issues related to gas supply, pricing, and regulation.
JET	The term Just Energy Transition (JET) refers to a comprehensive strategy aimed at shifting from fossil fuel-based energy production to renewable energy sources while ensuring that the transition is equitable, inclusive, and socially just. The concept recognises that the transition to a low-carbon economy should not come at the expense of workers, communities, or vulnerable populations who are currently dependent on fossil fuel industries.
LCCP	The Lake Charles Chemicals Project (LCCP) is a large-scale multibillion dollar chemical complex developed by Sasol in Lake Charles, Louisiana, in the United States. The project, which represents one of Sasol's most significant investments outside of South

	Africa, focuses on the production of specialty chemicals and polyethylene derived from ethane, a natural gas liquid.
LNG	Liquefied Natural Gas (LNG) is natural gas that has been cooled to a liquid state at approximately -162°C. This process reduces its volume by about 600 times, making it easier and more efficient to store and ship, particularly across long distances where pipelines are not feasible.
NERSA	The National Energy Regulator of South Africa (NERSA) is a regulatory authority responsible for overseeing the electricity, piped gas, and petroleum pipeline industries in South Africa. Established under the National Energy Regulator Act No. 40 of 2004, NERSA's mandate is to ensure that these energy sectors operate efficiently, sustainably, and in the public interest. Its decisions on tariffs, licensing, and regulations directly affect energy prices, infrastructure investment, and the transition to more sustainable energy sources.
PVC	Polyvinyl Chloride (PVC) is one of the most widely used synthetic plastic polymers in the world. It is a versatile material that comes in two basic forms: rigid (often referred to as "uPVC" or unplasticised PVC) and flexible (plasticised PVC). PVC is produced through the polymerisation of vinyl chloride monomers, and it can be made softer and more flexible by adding plasticisers, making it suitable for a wide range of applications.
REIPPPP	The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) is a South African government initiative aimed at increasing the country's renewable energy capacity by attracting private sector investment in wind, solar, biomass, and other renewable energy projects. Launched in 2011 by the Department of Energy (now the Department of Mineral Resources and Energy), REIPPPP is designed to help South Africa transition to a low-carbon economy, reduce greenhouse gas emissions, and ensure energy security.
ROMPCO	The Republic of Mozambique Pipeline Company (ROMPCO) is a joint venture responsible for the ownership and operation of the natural gas pipeline that runs from Mozambique's Pande and Temane gas fields to South Africa. The pipeline is a critical piece of infrastructure that facilitates the transportation of natural gas, primarily to industrial users in South Africa, and plays a significant role in the energy cooperation between South Africa and Mozambique.
SMMEs	In South Africa, Small, Medium, and Micro Enterprises (SMMEs) play a crucial role in the economy. Micro Enterprises: Typically, these businesses have 1-10 employees, with a turnover of up to R10 million. Small Enterprises: These businesses have 11-50 employees, with a turnover ranging between R10 million and R50 million. Medium Enterprises: These businesses employ 51-250 people and have a turnover between R50 million and R220 million
SAF	SAF stands for Sustainable Aviation Fuel, a type of aviation fuel produced from renewable or sustainable resources designed to reduce the carbon footprint of aviation. SAF can be produced from various feedstocks, including biofuels, synthetic fuels, and waste-derived fuels. The two main types of SAF are bio-based SAF, made from renewable biomass sources like waste oils, agricultural residues, and non-food crops, and synthetic SAF, created using renewable electricity to convert CO_2 and hydrogen into liquid fuels through processes like Power-to-Liquid (PtL). SAF can be blended with traditional jet fuel and used in existing aircraft without modifications, making it a viable option for reducing emissions in the aviation sector.
SANEDI	SANEDI stands for the South African National Energy Development Institute, a state-owned entity responsible for driving innovation and research in energy technologies to support South Africa's transition to a sustainable energy future. SANEDI plays a key role in promoting energy efficiency, renewable energy, and cleaner energy

	technologies, aligning with the country's broader goals of reducing greenhouse gas emissions and ensuring energy security.
SDAC	Synthetic Direct Air Capture (SDAC) refers to a technology designed to capture carbon dioxide (CO_2) directly from the atmosphere using synthetic or engineered methods. The process involves using chemical solutions or solid sorbents to absorb or adsorb CO_2 from ambient air, allowing for the removal of greenhouse gases from the atmosphere, which can then be either stored or utilized in other processes.
TCTC	Thermal Crude to Chemicals (TCTC) is a process in the petrochemical industry that converts crude oil directly into chemicals rather than traditional fuels like gasoline, diesel, and jet fuel. This approach is designed to maximise the yield of valuable petrochemicals such as ethylene, propylene, and other olefins, which are the building blocks for plastics, synthetic fibres, and a variety of chemical products.

1. INTRODUCTION

This report deals with South Africa's basic chemicals, petrochemicals and plastic value chains, without which modern industrial societies could not exist, and how they are positioned for a transition to a lower carbon future. It confronts a key, but frequently neglected, question: What is the future of the South African petrochemicals and plastics, ammonia, fertiliser and explosives value chains in the light of Sasol's stated greenhouse gas emission reduction plans and other assessed business constraints? Although South Africa's chemical industry is deeply interconnected with the manufacturing sector, the strategic importance of such products is often overlooked, and this is the case in South Africa's discourse on a lower emissions future. For example, the Presidency's Just Energy Transition Investment Plan (PCC, 2022) does not fully deal with the petrochemicals sector despite recognising its economic importance.

Because Sasol is the sole manufacturer of most of South Africa's petrochemicals and plastic raw materials as well as other key commodity base chemicals, such as ammonia, fertiliser and explosives, it is the key focus of the report. It is also a major emitter of greenhouse gasses. Consequently, its transition to a lower emissions future is a national concern and occupies the central place in this report.

The transition to a lower carbon intensity energy future in South Africa faces a particular challenge in the basic chemicals, petrochemicals and plastic value chains. This is because these value chains are largely dependent on Sasol's coal and gas-based Secunda operations with its associated very high CO_2 emissions intensity. The coal feedstock is supplemented by approximately 10% of piped natural gas imported from Mozambique which, although of lower GHG intensity than coal, still results in significant CO_2 emissions compared to conventional manufacturing routes.

The technologies[1] used by Sasol Secunda produce liquid fuels and petrochemicals simultaneously and inextricably. This co-production complicates efforts to understand Sasol's large role in South Africa's industrial fabric and the government interventions intended to drive Sasol to a lower emissions future. It is hoped that this document will, *inter alia,* clarify some of the confusion stemming from Sasol's interrelated co-production of key economic and industrial inputs in South Africa.

Sasol's main manufacturing site in South Africa is located at Secunda in the Mpumalanga province with a secondary site in Sasolburg. Sasolburg processes some of the Secunda chemical intermediates as well as producing basic and more specialty type chemicals from natural gas and is thus integrated with the Secunda site.

Mpumalanga's coal fields are occupied by both Sasol Secunda and several Eskom coal-fired power stations all of which have substantial emissions, and which makes emissions attribution challenging. It also complicates their defence against environmental activists.

In addition to CO_2-related challenges, Sasol Secunda also faces significant feedstock challenges. In recent years the Secunda plant has been struggling to keep up with historical production targets due to coal production problems. In addition, Sasol has reported that its gas fields in Mozambique are reaching the end of their lifespans and will start rapidly declining in the next decade. Dealing with these feedstock challenges while at the same time transitioning to a lower emissions future is a daunting challenge for Sasol in South Africa. This report examines these challenges in some detail and considers possible options for Sasol and South Africa.

As a manufacturer of commodity products, the economic viability of the Secunda and Sasolburg plants is very sensitive to production volumes and oil prices. A combination of a period of lower oil prices

[1] High-temperature and low-temperature Fischer Tropsch (HTFT and LTFT) technologies as well as low temperature coal gasification.

(<US$70/bbl), lower production volumes, and the threat of a dramatically increasing cost of emission taxes and obligations is likely to prove very challenging. This report interrogates some of these challenges and how they are expected to influence Sasol in future.

Consequently, market interventions by the government intended to incentivise and or forcefully change corporate behaviour towards a lower carbon future require a very clear, correct and detailed understanding of the petrochemicals, base chemicals and synfuels value chains as well as the socio-economic impacts of these value chains. The intersection of climate change and economic prosperity is complex with a high risk of unintended policy outcomes and consequences. It is hoped that this report may contribute to better-informed and nuanced interventions yielding better outcomes.

TIPS has commenced work in this area with a straightforward factual report that outlined Sasol's current position and some of its history – see Bergh et al. (2022). The research proposed in this report will not duplicate that work. This research will expand on that work and offer policy options for South Africa. It will also not seek to duplicate work on Sasol's earlier history that may be found in, for example, Rustomjee et al., 2007, and Sparks, 2016.

To ease the burden placed on readers of complexity and data-driven analysis, much of this is relegated to Annexures.

2. HISTORICAL CONTEXT OF SECUNDA CHEMICALS PRODUCTION

South Africa's manufacturing development has been underpinned by an import substitution industrialisation strategy from the early 1900s. In the post-World War II period, state intervention played an increasing role until the 1990s. In this period the chemical industry was dominated by three large firms, AECI (linked to Imperial Chemical Industries of the United Kingdom), Sasol, and Sentrachem. The latter two emerged as a result of state interventions.

Synthetic fuels manufacture in South Africa began with a 1932 joint venture between Anglovaal and the British Burmah Oil Company called South African Torbanite Mining and Refining (Satmar) that was set up to process torbanite (Encyclopaedia Britannica, n.d.) oil shale for fuel, a substitute for imported oil. In the post-war period, the rest of the world moved to oil and gas as feedstocks for commodity chemicals. South Africa went in the opposite direction – towards increasing reliance on its bountiful reserves of coal given its lack of other hydrocarbons.

In a significant market intervention, the government established the South African Coal, Oil and Gas Corporation in 1950, which subsequently became Sasol. The basis for the company was a licence Anglovaal had obtained from the German company Ruhrchemie AG for Fischer Tropsch (oil from coal) technology[2] (Government Gazette, 1937). State capital via the Industrial Development Corporation (IDC) was added and by 1955 Sasol One in Sasolburg began producing petrol from coal. Standard Oil commenced building South Africa's first oil refinery in 1954 in Durban (later owned by Mobil and then Engen).

The 1973 oil crisis triggered radical changes in the South African liquid fuels industry as the price of crude oil rose from US$3 to US$12 per barrel. At this time South Africa's international political position was deteriorating as a result of the apartheid policies being pursued. In 1974 a resolution went before the United Nations Security Council calling for mandatory sanctions against South Africa. Although the United States, Britain and France rallied to defend apartheid and used their veto to block this

[2] Fischer Tropsch technology is an indirect liquefaction of the coal route. First the coal is reduced to its constituent gases and then in a second stage the desired gasses are synthesised into the raw materials for liquid fuels.

resolution it must nevertheless have weighed heavily on the minds of apartheid state planners, confronted as they were by not only rising oil prices but also dwindling access to oil supplies as well.

On December 5, 1974, the cabinet announced that a second synfuels plant, Sasol 2, much larger than the first, would be built in Secunda. This decision, made for military/strategic reasons, marked a major turning point in South Africa's liquid fuels history.

The fall of the government of the Shah of Iran in 1979 precipitated a second oil crisis during which oil prices leapt from US$12.5 to US$36 per barrel, further concentrating the minds of apartheid planners. The decision to build Sasol Three (a mirror image of Sasol Two) was made in 1979. These two Sasol plants cost R31 500 million in 1991 Rands (Sasol Facts, Undated:13) or roughly R242 billion in 2023 Rands (Bergh et al., 2022)[3], a very large investment for the South African economy at the time. Continuing international pressure contributed to a 1987 decision to embark on yet another synfuels scheme, Mossgas (today PetroSA, a small 32 000 bpd gas-to-liquids refinery at Mossel Bay) at a final cost of about R12 billion (approximately R157 billion in 2023 Rands), equivalent to the cost of replacing the country's entire existing refinery capacity (Financial Times 13-12-91). The dovetail fit between the ongoing Import Substitution Industrialisation policies and the strategic energy security decisions to invest massively in the manufacture of liquid fuels from local resources is clearly evident.

South Africa's real entry into petrochemical production took place in 1965 when the state, through its ownership of Sasol, built a small naphtha cracker at Sasolburg. Naphtha feedstock was imported and carried inland from Durban by pipeline. This plant's original design capacity was 30 000 tpa of ethylene, which was later expanded to 135 000 tpa. Market growth exposed the scale constraints of this cracker and in 1976 AECI and Sentrachem built Coalplex at Sasolburg, reinforcing Import Substitution Industrialisation and coal dependency. The decision to relocate this naphtha-based petrochemical complex inland from Richards Bay was made "with Government backing for strategic reasons" (AECI/Sentrachem, Coalplex, undated, p1). Later, these PVC and other plants were absorbed by Sasol and are still in service in 2023.

All of these coal-based synfuels and petrochemical investments represented an unconventional step, technologically speaking, as the rest of the world was moving to oil and natural gas based feedstocks with processing plants that were less capital intensive than coal-based plants. The synfuels decisions also represent turning points in South Africa's petrochemical history. SASOL Two and Three turned the industry back to coal-based feedstocks at a time when the economics of production over the preceding two decades had been turning international producers away from coal towards oil-based feedstocks. The need for funding for Sasol Two and Three led to Sasol being privatised by Government and subsequently being listed on the Johannesburg Stock Exchange in 1979 (Sparks, 2017). In 1992, Mossgas (now PetroSA) changed the focus towards natural gas as a feedstock for liquid fuels in a world first gas-to-liquids facility (Offshore Technology, n.d.).

The lack of domestic petrochemicals manufacture can in part at least be explained by the lack of economies of scale. The advent of Sasol 2 and 3 in the early 1980s led to the co-production (at then) world-scale levels of ethylene, propylene and other light gases from the high-temperature Fischer Tropsch chemistry. This quickly led to the closure of the Sasolburg naphtha cracker and some of its downstream derivative plants. The unfortunate consequence of this was to narrow the slate of petrochemical feedstocks available. The Fischer Tropsch technology does not produce benzene, toluene and xylene (BTX) in the amounts and concentration that the Sasolburg cracker had produced. As these molecules are the precursors to certain commodity plastics such as polystyrene, as well as many of the more sophisticated engineering plastics, this opportunity for local manufacturing capability was lost.

3 Bergh et al. (2022) estimate the investment to be approximately US$19 billion in 2022 monetary value.

The early 1990s saw a period of very low crude oil prices and rapidly declining Sasol profitability. To address this, Sasol started to focus on the exploitation of the chemical molecules within the Secunda fuel environment as a means to add incremental value over fuels. This was termed the "Secunda treasure chest" (Wikipedia, n.d.-a). This drive led to many base chemical production facilities being constructed that transformed Secunda into the petrochemical complex that it is today. These projects included hexene, octene, detergent alcohols, high-purity ethanol and ethyl acetate, and high-purity propanol in Secunda and also led to the manufacture of butanol and acrylic acid (and ester derivatives) in Sasolburg. These projects redirected many hundreds of thousands of tons of feedstocks away from fuels into higher value adding chemical products. The unique nature of the high-temperature Fischer Tropsch feed streams meant that these projects were mostly based on first-of-a-kind, innovative separations and reaction-based technologies that were developed in-house. Later, significant additional ethylene and propylene production capacity and downstream polymer plants were constructed in the 2005 period when Sasol constructed a new naphtha cracker in Secunda as part of the Clean Fuels 1 program (Sasol, 2005). This period of concentrated construction including the conversion of Sasolburg to natural gas, the upgrading of the Secunda FT reactors to more advanced SAS technology (Sasol, 2007), and export-orientated chemical facilities ended around the late 2000s.

This period resulted in Sasol developing core competencies in technology development and scale-up, project construction and execution, new business development and global marketing skills as a significant portion of the chemicals were exported. Such institutional capacity, competencies and institutional memory cannot easily be retained if they are not constantly put to use.

Over this period a substantial restructuring of the domestic chemical industry occurred. The other two large firms in the local commodity chemicals industry all but disappeared. Sentrachem disappeared completely and much of AECI's activities were absorbed by Sasol (via Polifin) or closed. AECI survives in 2023 as a mere shadow of its former self.

In 2006 the Minister of Finance appointed a Windfall Tax Task Team "to investigate whether windfall profits were being generated by the liquid fuels industry, in particular the synthetic fuels industry, and whether a windfall tax should be imposed if such profits existed". It recommended "an additional special fuel levy on existing synfuel producer's volumes" and "a progressive investment incentive dispensation for the manufacture of liquid fuels from indigenous raw materials" (National Treasury, 2007a). The Government concluded that the windfall gains were not structural and decided not to introduce a windfall tax on synthetic fuels producers firmly putting an end to that notion (National Treasury, 2007b).

The consequences of the state decisions to intervene in the market and to build Sasol 2 and 3 have not, in the subsequent 50 years, worked themselves out of South Africa's liquid fuels nor its petrochemical industries, but may do so in the next decade or so, depending upon Sasol's fortunes. What began as a modest market intervention by the state with the investment in Sasol One blossomed into a massive market intervention in the form of Sasol Two and Three in Secunda. This brief history and the balance of this report seek, in part, to illustrate the intended and unintended consequences of massive industrial policy interventions, some of consequences of which endure which long after the initial decision makers have passed. The balance of this report paints a picture of the current challenges faced by the state as a consequence of its initial market intervention and Sasol's subsequent development which raise the prospect of further large policy interventions that may be necessary to aid Sasol Secunda through its twilight years, something which the initial industrial policy architects and their successors appear to have given little thought to. This cautionary tale about the consequences of large market interventions and their long-terms consequences is particularly relevant in today's energy sector which is undergoing rapid technological change.

Sasol Secunda's historical development trajectory gives rise to other, related concerns. There has recently been limited large-scale and/or new business project activity in Sasol South Africa except for the multi-year FT Wax Expansion Project in Sasolburg (orientated to the export of hard wax). While the second phase was completed in 2018 (Sasol, 2018a) , accounting impairments (partial) had already started in 2013 suggesting perhaps that some of this business and technical decision making acumen was already in decline (Sasol, 2013a).

The present state of Sasol's South African new business and project execution capabilities, given the very limited number of South African mega projects executed in recent years, is unknown. However, business development and project execution skills benefit considerably from continuous practice and exposure.

3. GLOBAL CONTEXT

3.1. The energy transition – A South African view and Sasol history

South Africa's formal recognition of climate change dates back to its ratification of the United Nations Framework Convention on Climate Change (UNFCCC) Convention in 1997. South Africa hosted the Johannesburg World Summit on Sustainable Development in 2002 and recognised climate change as a concern in the White Paper on the Renewable Energy Policy of the Republic of South Africa published in 2003. The abundance of coal as a cheap source of energy combined with the demand created by the opportunity to beneficiate its mineral heritage meant that South Africa had a carbon footprint amongst the top 15 globally (Statistica, 2023) of around 450 million tons per annum in 2008. Numerous references to climate change exist in the Industrial Policy Action Plan of 2011-2013 including references to future carbon taxes and the threats presented by "border adjustment mechanisms" (the dti, 2011).

An abundance of coal and the need for energy security led to the construction of Sasol's coal-to-liquids facility in Secunda in the early 1980s. This process is very carbon and energy intensive and contributes around 50 mtpa of direct CO_2 emissions. Sasol's recognition of climate change dates back to 2008 with more than 60 references to it in its Sustainable Development Report of the same year. Climate change was recognised in the section under "material sustainability challenges" (Sasol, 2008) and the report recognises the need to develop targets to manage greenhouse gas emissions. In the same year, Sasol established a New Energy Business Unit.

Sasol South Africa appears to have initiated its first climate change specific project, a nitrous oxide reduction project in Sasolburg, in 2007. This project abated around 1 000 000 tons per annum CO_2e (Sasol, 2008) and was in part funded by the Clean Development Mechanism (CDM) (Sasol 2011a) credits available to developing countries under the Kyoto Protocol. In the 2014 Sasol restructuring exercise, dubbed project Phoenix, the New Energy Business Unit appears to have been shut down.

A high-level summary of key international, South African and Sasol events through the lens of climate change is in Appendix A.

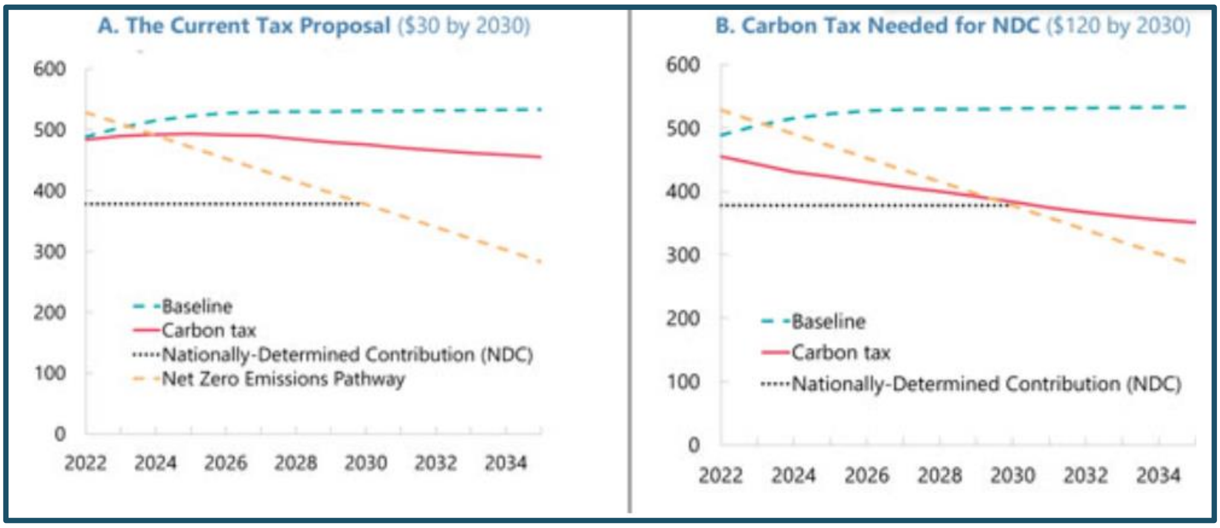
3.2. South Africa's environmental commitments

Formal climate change action has principally evolved along the lines of developed and developing countries within the United Nations. As such, South African commitments become a key driver for Sasol commitments. In 2021, South Africa updated its Nationally Determined Contribution (NDC) under the Paris Accord to achieve greenhouse gas emissions levels of 398-510 $MtCO_2e$ by 2025, and 350-420 $MtCO_2e$ by 2030 under a peak, plateau and decline model. The implementation of these objectives will be achieved through such policy mechanisms as a carbon tax (Carbon Tax Act No. 15 of 2019) under National Treasury, and carbon budgets (Climate Change Bill (B9-2022) under the

Department of Environmental Affairs (Parliamentary Monitoring Group, 2021). While the Carbon Act set the price of CO_2 at R120/ton, the opportunity for tax-free allowances substantially reduces the effective carbon price. According to the International Monetary Fund (IMF), the estimated effective rate was less than R7 per ton of CO_2e during the FY2021–22 (less than 0.5 US$/ton CO_2). In 2024, the South African government increased its carbon tax from R159 to R190 (US$10) per tonne of CO_2 equivalent from 1 January. (Climate Neutral Group, 2024)

According to the Climate Action Tracker (n.d.) South Africa's NDC is deemed to be "almost sufficient", although its current policies and actions are rated as "insufficient". The IMF estimates that a carbon price of R2196 (US$120) per ton CO_2 in 2030 would be required in South Africa to achieve its NDC commitment, as is evident in Figure 1.

Figure 1: IMF estimation of carbon price on South African emissions trajectories



Source: IMF, 2023.

Any premature closure of Eskom coal fired power stations would substantially ease reaching the NDC targets, notwithstanding Eskom's recent "return to service" announcements for three old power stations (Bloomberg, 2024). This, however, would not ameliorate the effects of measures like the European Union Carbon Border Tax as this is based on relative taxation rates as opposed to achievement of an NDC.

3.3. The chemicals transition

Introduction

The modern petrochemical industry emerged in the late 19th century because of the oil boom. Early developments in the oil sector led to the extraction of various by-products, including naphtha, which was found to have valuable chemical properties.

In the early 20th century, with the development of the Haber-Bosch process by Fritz Haber, the large-scale synthesis of ammonia from atmospheric nitrogen and anthropogenically derived hydrogen commenced. This process revolutionised agriculture by enabling the mass production of synthetic fertilisers and played a pivotal role in the Green Revolution of the mid-20th century. Ammonia-based fertiliser is now an essential requirement of commercial agriculture that is required to feed the eight billion people on the planet. The energy expert, Vaclav Smil, is quoted as saying, "*Without ammonia, there would be no inorganic fertilisers, and nearly half the world would go hungry. Of all the century's technological marvels, the Haber-Bosch process has made the most difference to our survival*" (Smil, 1999).

Also in the early 20th century, the production of synthetic materials like plastics and synthetic rubber began to take off. World War II played a pivotal role in the expansion of petrochemicals, as they were crucial for military applications. Post-war, the industry saw significant growth as the demand for consumer goods surged.

The 1950s and 1960s marked a period of rapid petrochemical expansion. The advent of new catalytic "cracking" processes circa 1940 (IvyPanda, n.d.) enabling the production of light olefins at scale together with the discovery of vast hydrocarbon reserves fuelled growth. Petrochemicals became a cornerstone of modern industry, contributing to sectors like automotive, construction, and packaging.

In the latter half of the 20th century, the industry diversified, developing a wide range of products such as detergents and cleaning chemicals, agrochemicals, plastics, and synthetic fibres, among others. It also expanded globally, with production centres in the Middle East, Asia, and other regions.

Today, the petrochemical industry is a multi-trillion-dollar global sector producing hundreds of millions of tons of products essential to numerous industries and modern life. Chemicals are essential to modern life, playing a pivotal role in almost every aspect of our daily existence. This includes healthcare, agriculture, food packaging, clean water, transportation, construction, and consumer goods, among others. However, it also faces challenges related to sustainability and environmental concerns, driving research into alternative, more eco-friendly materials, and processes.

Demand for plastics – the most familiar of petrochemical products, has outpaced all other bulk materials (such as steel, aluminium, or cement), nearly doubling since the start of the millennium. The United States, Europe, and other advanced economies currently use up to 20 times as much plastic and up to 10 times as much fertiliser as India, Indonesia, and other developing economies on a per capita basis, underscoring the huge potential for growth worldwide.

Economies of scale in the production of commodity chemical feedstocks like ammonia, ethylene, and propylene have played a pivotal role in shaping the industry. These chemicals are produced on a massive scale, benefiting from several key factors.

First, larger production facilities benefit from lower average production costs per unit. As the scale of production increases, the fixed costs, like infrastructure and labour, are spread over a larger volume of output, resulting in cost savings. This is particularly true for the energy-intensive processes used in ammonia, ethylene, and propylene production.

Second, access to feedstock and the geography of feedstock sources are critical. Proximity to cheap raw materials, such as natural gas for ammonia or ethane for ethylene and naphtha for propylene, significantly impacts production costs. Regions with abundant and low-cost feedstock supplies, like the Middle East, North America, and Russia with their vast oil and gas reserves, enjoy a competitive advantage. Transporting raw materials over long distances incurs additional costs and makes regions like Europe and South Africa less competitive for commodity chemical manufacture.

The South African context

While South Africa is not the most appealing destination for commodity chemical manufacturing, it does reap the benefits of Sasol Secunda's legacy coal-based high-temperature Fischer-Tropsch process. This unconventional process, constructed in the early 1980s, yields essential commodity chemical feedstocks like ammonia, ethylene, and propylene at around world scale. Initially conceived as a coal-to-liquid fuels facility, the Secunda process now generates a wide range of valuable chemical components. In the two decades following Secunda's commissioning in the early 1980s, Sasol's engineers and scientists pioneered novel and innovative technologies for the extraction, purification, and beneficiation of these valuable chemicals over and above ammonia and sulphur production that is intrinsic in the coal gasification process. Consequently, Sasol also produces co-monomers, oxygenated solvents, detergent alcohols, and phenolics. This period, stretching up to around 2000 earned the moniker "the chemical treasure chest" era for Sasol. However, this era ended as all economically viable chemicals were exhausted from the Secunda product slate. Consequently, the Secunda plant operates as an integrated fuels and chemicals facility, with liquid fuels comprising about 60% of production and chemicals constituting the remaining 40%. Since chemicals command higher values than fuels and often track crude oil prices, the revenues generated from fuels and chemicals are roughly equal.

The production of fuels and chemicals from coal has a significantly higher carbon footprint than the conventional routes from oil and gas. This means that Secunda is inordinately more sensitive to carbon taxes and carbon border taxes than conventional plants.

Decarbonisation of petrochemicals

Petrochemical feedstock accounts for 12% of global oil demand, a share that is expected to increase driven by increasing demand for plastics, fertilisers and other products. Despite its size, the sector continues to take a back seat in the global energy debate (IEA, 2018).

The combination of a growing global economy, rising population, and technological development will translate into an increasing demand for petrochemical products. Although substantial increases in recycling and efforts to curb single-use plastics are taking place, especially led by Europe, Japan and Korea, these efforts will be far outweighed by the sharp increase in demand of plastic consumption from developing economies. The difficulty in finding cost-competitive and environmentally superior alternatives is another factor underpinning the robust overall demand growth for petrochemical products. For example, a driver for plastic demand has been its superior performance relative to other materials and its contribution to energy efficiency. It many cases, these substitutions also have a lower GHG emissions profile, e.g. plastic used for reducing the weight of vehicles and packaging. Petrochemicals have a significant role to play in meeting climate change challenges.

While it is possible to use bio-based feedstocks to partially replace petrochemical feedstocks in the production of polyethylene and other petrochemicals, completely replacing petrochemical feedstocks with bio-based alternatives presents several challenges. The primary challenge is the availability of bio-based feedstocks in sufficient quantities The production of petrochemicals on a global scale requires a vast amount of raw materials, and securing a consistent and abundant supply of bio-based feedstocks is not feasible. The production of bio-based feedstocks can also raise environmental, water and land use concerns, including deforestation and competition with food crops.

Bearing in mind that many chemicals such as plastic polymers are not burned like fuels, their carbon footprint is determined by the emissions associated with their production processes and the resultant emissions associated with their products such as plastics. Traditionally the energy requirements for chemical production processes are supplied by the burning of fossil fuels. The direct use of renewable electricity to supply process energy is an emerging approach to the first stage of decarbonisation of the chemical industry (BASF, 2022).

Given that most petrochemical production is integrated with fossil fuel refining, the decline of demand for gasoline and diesel as decarbonisation progresses poses unresolved issues for how petrochemicals will be produced as the world decarbonises. New, direct crude-oil-to-chemicals process routes may also come into play, offering alternatives to traditional refining/petrochemical operations although the technology remains challenging for now (see Section 13.2 for further details).

In the South African context, it is not likely to be feasible to decarbonise the existing Secunda HTFT coal to fuels and chemicals complex given the large quantum of CO_2 produced. Although chemicals constitute about 40% of Secunda's production, the remaining 60% are fuels with the majority of this being petrol. As the transition to BEVs continues to gather pace, the demand for petrol is likely to start declining (RMI, 2021a). The decarbonisation of heavy-duty trucks which use diesel is lagging the passenger car market where electric vehicles are rapidly gaining market share. Given that refineries produce both petrol and diesel in a relatively inflexible ratio, this could cause supply imbalances that could affect the petrol price negatively. The future of the Secunda complex is thus inextricably tied up with the future of petrol.

4. SASOL IN THE CONTEXT OF SOUTH AFRICA'S BASIC CHEMICAL INDUSTRY AND FUELS INDUSTRY

4.1. Introduction

Sasol employs 30 100 people worldwide and has operations in 33 countries. The vast majority of these employees are located in South Africa. It is the largest corporate taxpayer in South Africa and the seventh-largest coal mining company in the world. Sasol has established itself as a large liquid fuel petrochemicals, and natural gas supplier in South Africa. It produces a wide range of fuels, oils and chemicals ranging from conventional petrol and diesel to more specialised chemicals.

This section dimensions the role that Sasol has played in the South African economy, by identifying key information such as the revenue share of South African manufacturing, tax, gross domestic product (GDP), and employment contributions, as well as its role in the chemical economy of the country.

4.2. Outline of Sasol's Southern African production 2022/2023

Sasol South Africa has diversified its revenue streams which span across mining, gas, chemicals, and liquid fuels. A more in-depth analysis can be found in the subsequent section, which was sourced from Sasol's 2022 and 2023 annual production metrics.

Mining

In 2023, Sasol produced 30.8 million tons of coal internally and purchased 9.4 million tons of coal from external sources. Both fuels and chemicals were sold to the mining sector and accounted for 23.1 and 14.9 million tons respectively. In addition, it sold two mm tons of coal to the international market (Sasol, 2023a). To put these numbers into perspective, South Africa in 2022 produced 231.2 million tonnes of coal of which 70% was used domestically, while the rest was exported (Minerals Council, n.d.). These figures highlight Sasol as a significant stakeholder in this space.

Sasol Secunda uses coal for gasification to produce syngas as well as to produce steam and power for its boiler fleet. Various strategic initiatives such as coal briquetting are being considered to improve efficiency and enable boiler turndown (fine coal management) together with a coal destoning project.

Gas

Since 2000, Sasol has owned a 70% stake in a natural gas production facility in Mozambique and all figures provided represent this stake. In 2023, the entity produced 113.8 bscf and externally procured 43.3 bscf. Sasol South Africa used this natural gas in its operations, for fuels and chemicals, ultimately utilising 45.2 and 59.1 bscf respectively (Sasol, 2023a). Sasol also sold natural gas and methane-rich gas to industrial customers in South Africa with a volumetric flow of 36.2 and 22.6 bscf respectively (Sasol, 2023a). These figures are significant, but in broader terms, Sasol is a relatively small natural gas producer. Some other significant global petrochemical players in this space include BP, Exxon Mobil, and Shell, with annual production figures of 2900, 3070, and 2600 bscf p.a. respectively (Investopedia, n.d.). QatarEnergy in 2022 produced approximately 405[4] bscf, however, the company is also a significant producer of LNG with an annual production capacity of 77 Mtons (QatarEnergy, n.d.). These figures show that Sasol is a small-scale natural gas producer relative to some other global players, yet despite this, it plays a pivotal role in the South African economy.

Chemicals

In 2023, Sasol's South African facilities produced advanced materials (3%), base chemicals (64%), essential care chemicals (1%), and performance solutions (32%). Sasol's African operations generated 3434 kilotons of sales, supporting a significant portion of the downstream value chain within South Africa's chemical economy (Sasol, 2023a). To contextualise Sasol's South African and international[5] revenue figures within the global market, a high-level comparison was made with larger competitors, BASF and Dow[6]. Production volumes for both BASF and Dow were unavailable in their annual reports. Instead, annual revenues were compared as a proxy for their production volumes – see Table 1.

Table 1: Comparison between BASF, Dow, and Sasol Chemical production and revenues (2023)

	PRODUCTION VOLUME (KTON)	ANNUAL REVENUE (USD BILLION)	COMMENTS
BASF	N/A	77*	BASF is the largest chemical producer globally and has extensive operations across the globe in various chemical sectors.
Dow	N/A	45**	Dow is a major player in global chemicals with a focus on plastics, chemicals and performance materials.
Sasol South Africa Chemicals	3 430	3.8	For more detailed information, refer to Section 6 of this report.
Sasol Global Chemicals	2 710	5.2	Chemical production comprises of advanced materials, base and essential care chemicals, as well as performance solutions.
Sasol Chemicals Total	6 140	9	

Note: *BASF, 2023; **Dow, 2023.

In conclusion, BASF and Dow operate at a much higher scale than Sasol in terms of chemical production volume and revenue generation. Sasol, however, has a unique position in the market due to its specialisation in coal-to-liquids and gas-to-liquids technology, setting it apart from the others and reflected in the difference in revenue.

Fuels

In South Africa, Sasol produces liquid fuels at Secunda and the Natref crude oil refinery in Sasolburg in which it has a 64% share. Its Secunda operations accounted for the production of 6935 kton

[4] Authors calculations based on QatarEnergy, 2022
[5] This includes Sasol Eurasia and American operations, but detailed analysis of these operations falls beyond the scope of the report and is provided for comparison purposes only.
[6] Information was sourced from 2023 annual reports and other investor reports across different institutions.

comprising refined products, heating fuels, alcohols/ketones, other chemicals and gasification products. Overall Secunda produced a total of 29.9 mm bbl of refined fuel products.

Natref processed 17.8 mm bbl of crude in 2023 with a white product yield and total yields of 88.1% and 96.5% respectively. Overall production of refined product was 17.2 mm bbl for Sasol's 60% share of the refinery.

Sasol South Africa also externally purchased 6 mm bbl of white products in 2023 for resale. Overall sales of white and black products respectively were 51.2 and 2.7 mm bbl.

4.3. Sasol's South African economic contribution

Sasol is a major participant in the South African economy, contributing an estimated 1.2% to GDP directly and 2.9% if indirect impacts are included.[7] A study done by FTI Consulting for Sasol for 2021 found its direct contribution to GDP to be higher at 2.6% and 5.23% if a broader range of impacts are included (Sasol, 2022a).

In the fiscal year of 2023, Sasol's global chemical sales reached R166 Billion (Sasol, 2023a), a decrease in the previous year's revenue. The South African operations were responsible for around 43% of these chemical sales, amounting to R70.6 billion. Chemicals exports from Secunda also contribute to South Africa's balance of trade.

Sasol's tax contributions come in various forms, including corporate income taxes and fuel levies. Sasol's study found its contribution to government revenue in South Africa in 2021 to be R51 billion, and including all indirect contributions to be R151.6 billion. (Sasol, 2022a)

In terms of Broad-Based Black Economic Empowerment (B-BBEE), skills development and social investment spending, Sasol achieved Level 3 BEE status and contributed around R1.4 billion and R857 million respectively in 2023 (Sasol, 2023b). Additional contributions include investments in research and development and skills development, which was R1.4 billion.

In 2019, the petrochemicals sector contributed approximately R232 billion (6.22%) to GDP and accounted for approximately 169 000 direct and 693 000 indirect jobs, with a quarter of the direct jobs linked to Sasol (~28 000) (NBI, 2021). In additional, wages and benefits accounted for R35 billion in expenditure (Sasol, 2023b). Sasol's study found that in 2021 Sasol South Africa employed 24 841 people and that its total impact on employment was 457 563 jobs or 3.1% of total employment. (Sasol, 2022a)

South Africa exported a total of R224.2 billion (US$11.8 billion @ R19/US$) worth of mineral fuels, oils and distillate fuels. South Africa is the main supplier of all other liquid fuels to Botswana, Namibia, Lesotho and Swaziland.

A dedicated town, Secunda was built 50 years ago for the employees of Sasol Two and Three. Sasol's announcement of potentially reducing Secunda production will raise a question mark over the future of the town which has 40 000 inhabitants, 80% of whom work for Sasol in one way or another. (Burkhardt, 2024)

[7] Confidential source.

4.4. Sasol's contribution to local chemical manufacturing

Sasol has cemented itself as a major producer of diverse chemical feedstocks for the South African economy. The company accounts for approximately 30% of the local South African liquid fuels production volume when all refineries are in operation. In recent times however, production volumes of liquid fuels by other refiners have declined, thereby increasing Sasol's share of local fuel production to around 52%. It also manufactures chemicals such as reagents for mining, minerals processing and other industries mainly bulk chemicals but also waxes. Its products include diesel, petrol (gasoline), naphtha, kerosene (jet fuel), liquid petroleum gas (LPG), olefins, alcohols, polymers, solvents, surfactants (detergent alcohols and oil-field chemicals), co-monomers, ammonia, methanol, various phenolics, sulphur, illuminating paraffin, bitumen, acrylates, and fuel oil. The 2022 (Sasol, 2022b) and 2023 (Sasol, 2023a) annual production volumes have been summarised in Table 2, Table 3 and Table 4.

Table 2: Sasol Secunda liquids

	2022 SYNFUEL PRODUCTION (KTON)	2023 SYNFUEL PRODUCTION (KTON)
Refining Product	3 276	3 375
Heating Fuels	691	652
Alcohols/Ketones	571	570
Other Chemicals	1 707	1 645
Gasification	522	693
Other	114	

Table 3: Sasol Secunda chemical manufacturing

	2022 CHEMICAL VOLUME (KTON)	2023 CHEMICAL VOLUME (KTON)
Advanced Materials	114	104
Base Chemicals	2 127	2 202
Essential Care Chemicals	43	38
Performance Solutions	1 127	1 090

Table 4: Sasol production capacities at 30 June 2022

LOCATION	C2-3 OLEFINS	C5-8 ALPHA OLEFINS	POLYOLEFINS	C1-5 ALCOHOLS, KETONES, ACRYLATES	C6+ ALCOHOLS	WAX	OTHER	OTHER DESCRIPTION
Secunda	x	x	x	X	X		x	Ammonia, Carbon
Sasolburg	x		x	X		X	x	Ammonia, aromatics
Durban						X		
	1600	400	1200	1000	100	300	900	

Note: Production capacities are rounded to the nearest 100kt. X indicates that the location produces the specific product grouping. *Source*: Sasol Limited Form 20-F for 2020 (Sasol, 2022d).

4.5. Downstream industries served

Most of Sasol's South African products are so called "intermediates" and are used to make other products and are thus "hidden" from ordinary consumers. Key amongst such end-use products are fertilizers for agriculture and explosives for mining and construction. Sasol is a large producer of plastics pellets that are converted into many types of end-use products containing low density polyethylene, linear low density polyethylene, high density polyethylene and polypropylene.

These plastic feedstocks serve a wide range of markets – see Table 5.

Table 5: Plastic market sectors

SECTOR	SOUTH AFRICA	GLOBAL
Packaging	49%	44%
Building and Construction	14%	18%
Other	13%	12%
Agriculture	8%	4%
Automotive	6%	8%
Electric and Electronic	6%	7%
Household, Leisure and Sports	4%	7%

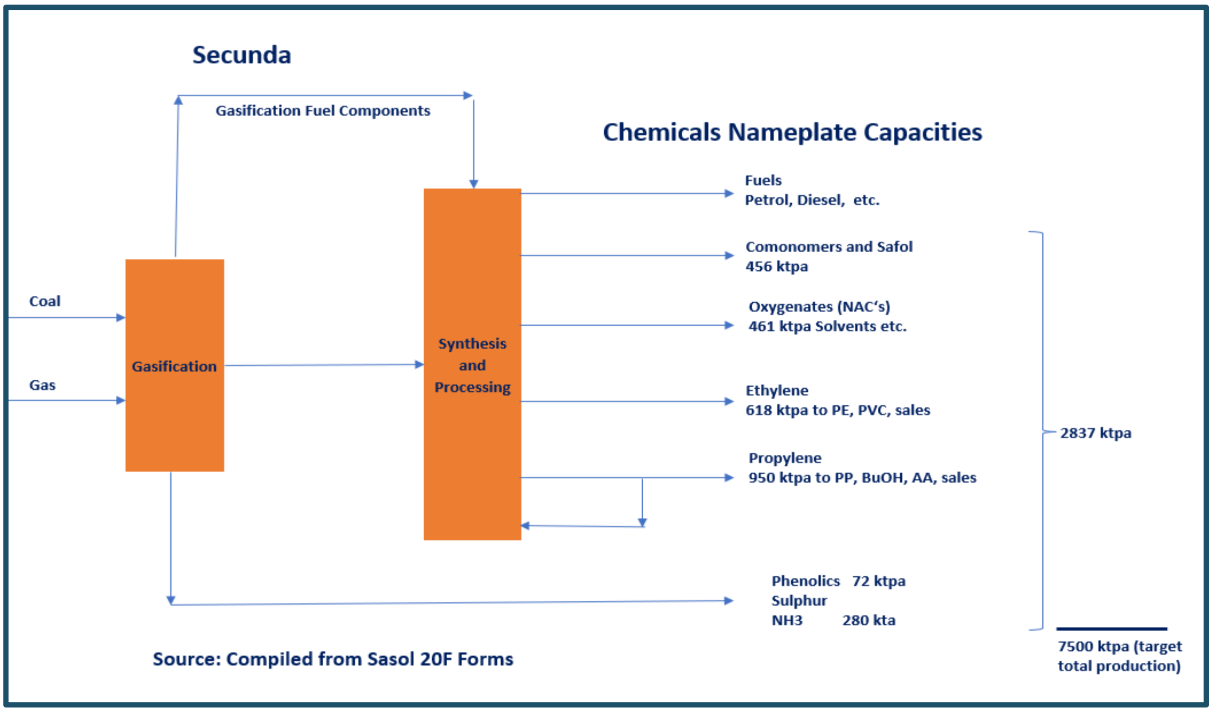
Source: Plastics SA. 2022. An analysis of the South African plastics industry data. July.
Note: percentages have been rounded.

5. SECUNDA MASS BALANCE

5.1. Overall high-level mass balance

A high-level schematic overview of the Secunda production process showing the chemicals and chemical feedstocks produced by Secunda is shown in Figure 2.

Figure 2: Schematic overview of Secunda Chemicals production



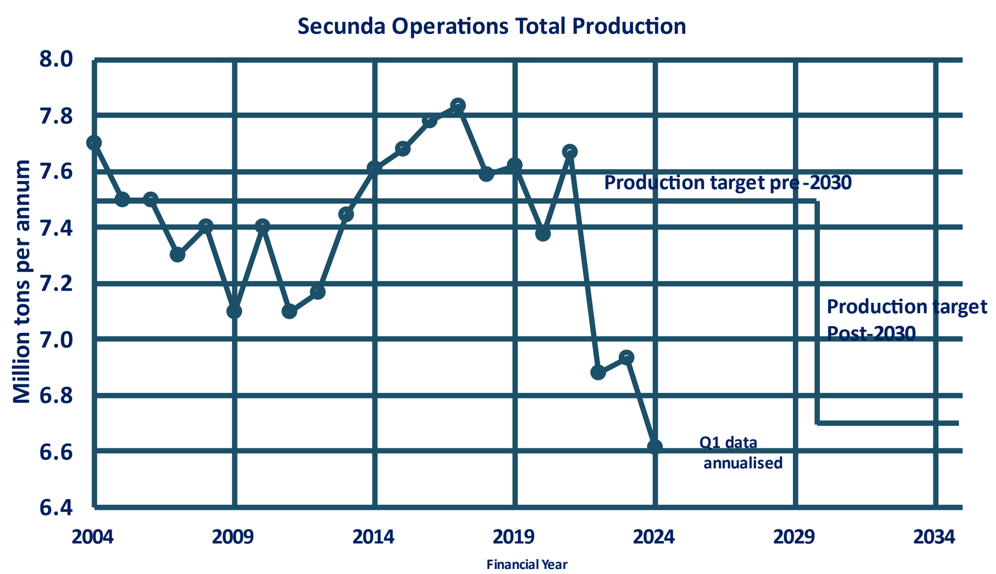
Although the total production of fuels and chemicals[8] varies from year to year an overall production guidance of 7.5 mtpa (including Secunda ammonia and sulphur) has been in place for over two decades. The Secunda gasification and high-temperature Fischer Tropsch (HTFT) process produces a product slate which can be considered to be fixed in composition so that the proportion of fuels and

[8] This includes both solid and liquid products derived mainly from the Fischer Tropsch reactors but also includes gasification products (ammonia, sulphur)

chemicals shown in Figure 2 are fixed. Thus, as the total production rate of Secunda varies the production rate of chemicals will vary in proportion to the total production rate.

The historical Secunda operation's total production rate is shown in Figure 3.

Figure 3: History of Secunda operations total production rate



Source: Compiled from Sasol 20F Forms and Production Reports

Historically Secunda has sometimes achieved or exceeded the 7.5 mtpa production target. It is, however, worth noting that since 2022 production has declined below 7 mtpa owing to coal supply and operational issues (Steyn, 2021). Chemical production has declined in tandem with overall production.

Sasol is endeavouring to increase production back to historical levels in the region of 7.5 mtpa but it is worth mentioning that Sasol has indicated to the market that post 2030 yearly production guidance will be lowered to 6.7 mtpa as part of Sasol's commitment to reduce greenhouse gas emissions by 30% by 2030. (Creamer, 2023a) This represents an 11% reduction in production and chemical production from Secunda will also decline by 11%.

5.2. Feedstocks

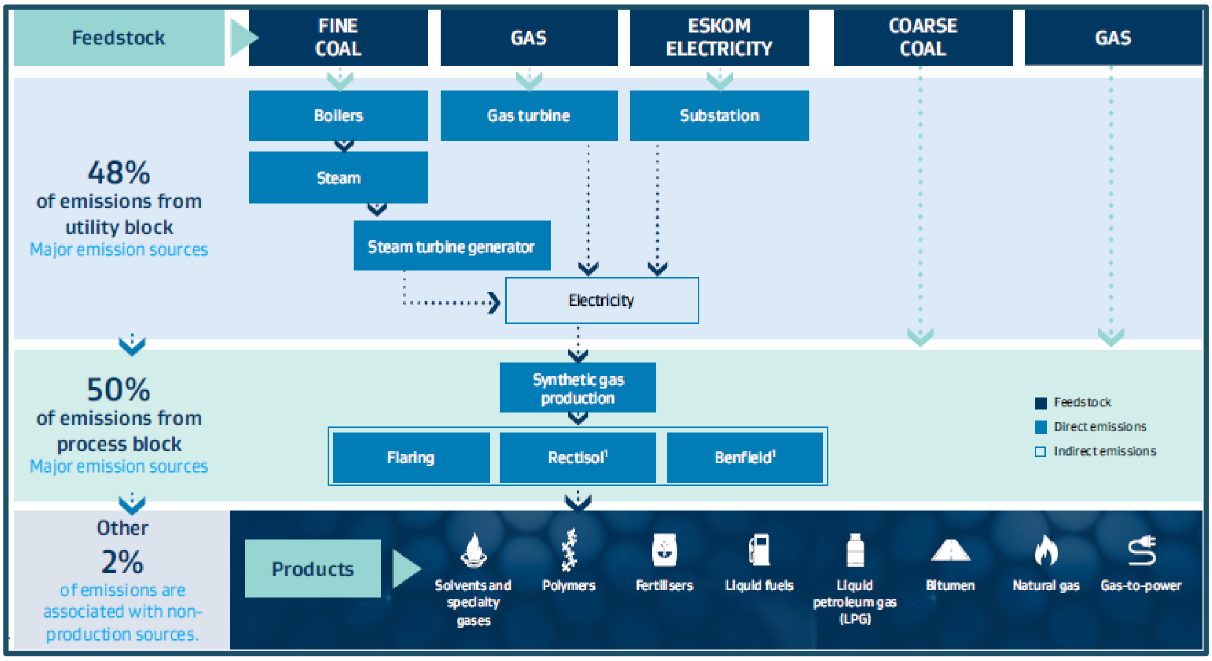
An overview of the Secunda feedstock and carbon emissions picture for 2017 is shown in Figure 4. The primary inputs to the Secunda process are coal, natural gas, water and electricity.

Coal: The coal consists of coarse coal, which is fed to the gasifiers as a source of carbon, and fine coal which is fed to steam boilers. The ratio of fine coal to coarse coal is a product of the mining process. Fine coal is not a suitable feed for the gasifiers. Maintaining a balance between the use of fine coal and coarse coal is an important feature of Secunda operations.

Water: Steam is used throughout the complex both as a process feedstock (most notably in gasification and reforming as a source of hydrogen) as well as to generate electricity. The complex is net short on power generation capacity thus (substantial) additional electricity is purchased from Eskom to supply the remainder of the complex's needs. These additional purchases from Eskom have the additional benefit of easing start-ups and increasing the stability of the system.

Natural gas is used to generate electricity and is also reformed into syngas to supplement coal gasification.

Figure 4: Secunda operations feedstocks and emissions

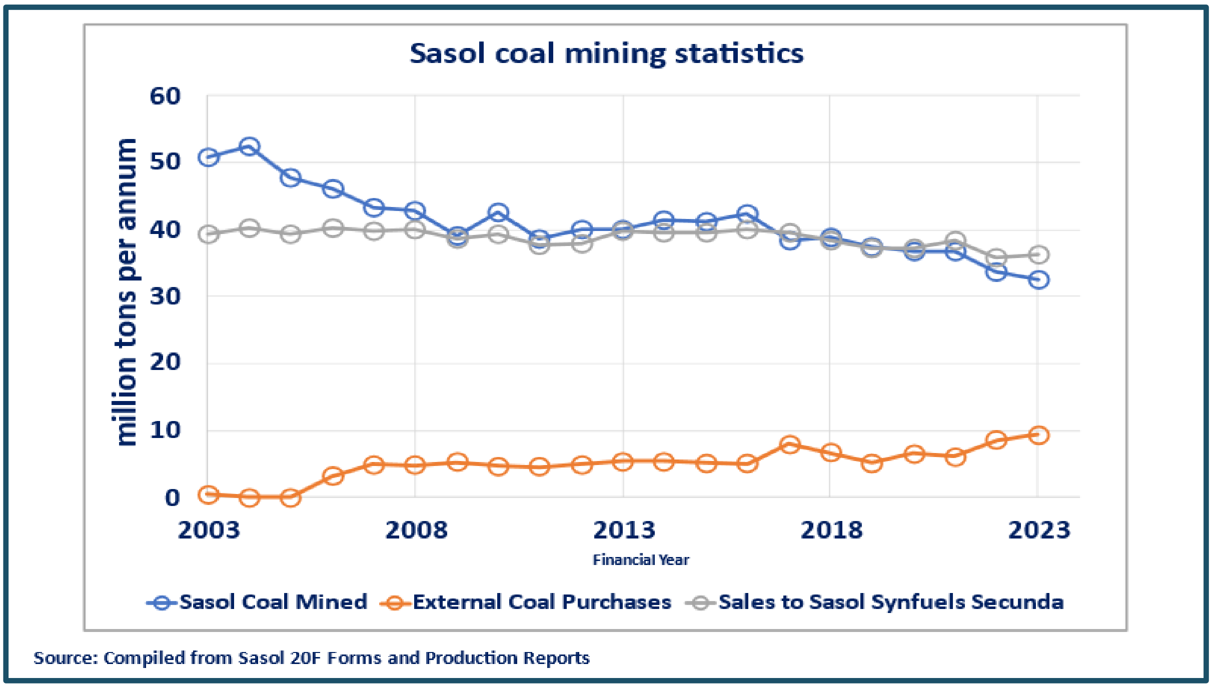


Source: Sasol Climate Change Report 2023 (Sasol, 2023c).

5.2.1. Coal

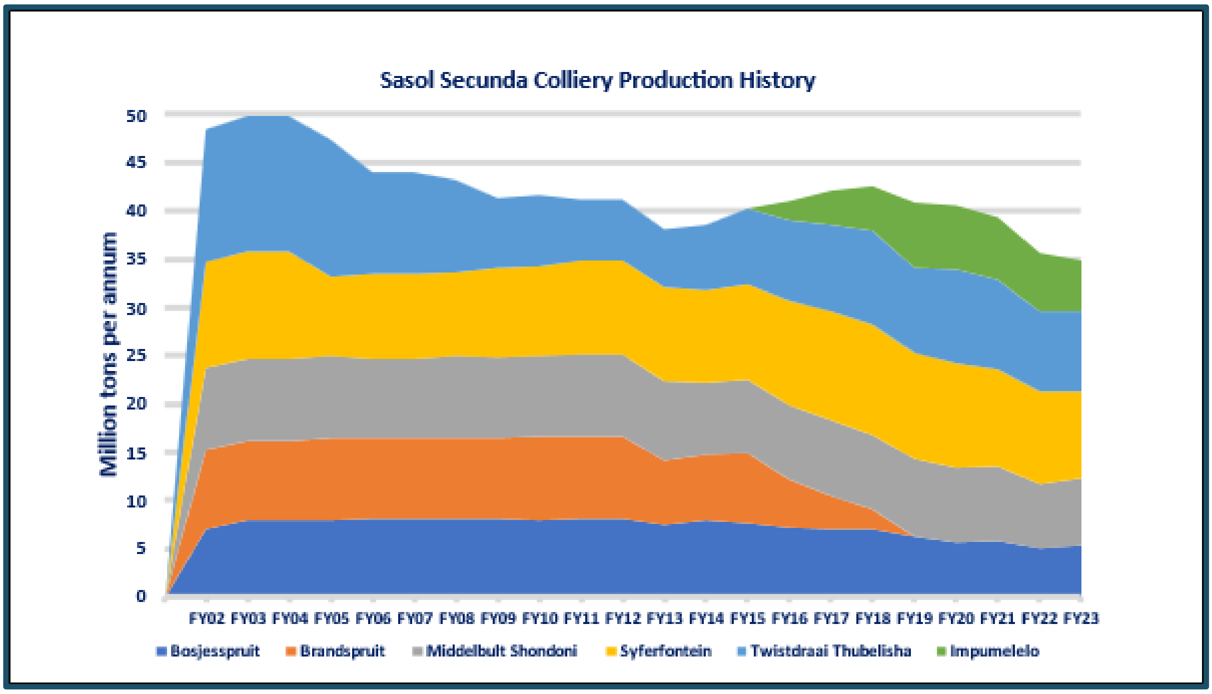
The historical production of coal from Secunda is shown in Figure 5. In the early 2000's, Sasol's coal production was in the region of 50 million tons per annum (mtpa) before Sasolburg was converted to natural gas followed to a smaller extent by Secunda. Coal production then declined to about 40 mtpa and then from 2016 steadily declined further to about 33 mtpa by 2023. The decline in Sasol coal production has necessitated increasing external coal purchases.

Figure 5: History of Secunda coal production



The history of Sasol coal production from its six collieries is shown in Figure 6. This figure also shows the overall declining coal production from the Secunda collieries as well as the impact of the Brandspruit colliery reaching the end of its useful life. In 2015, the new Impumelelo colliery was commissioned to supplement the declining production. This illustrates the need for constant replenishment of coal supply and that it is becoming increasingly challenging to maintain internal supply as the physically closest and highest quality resources tend to be mined out first.

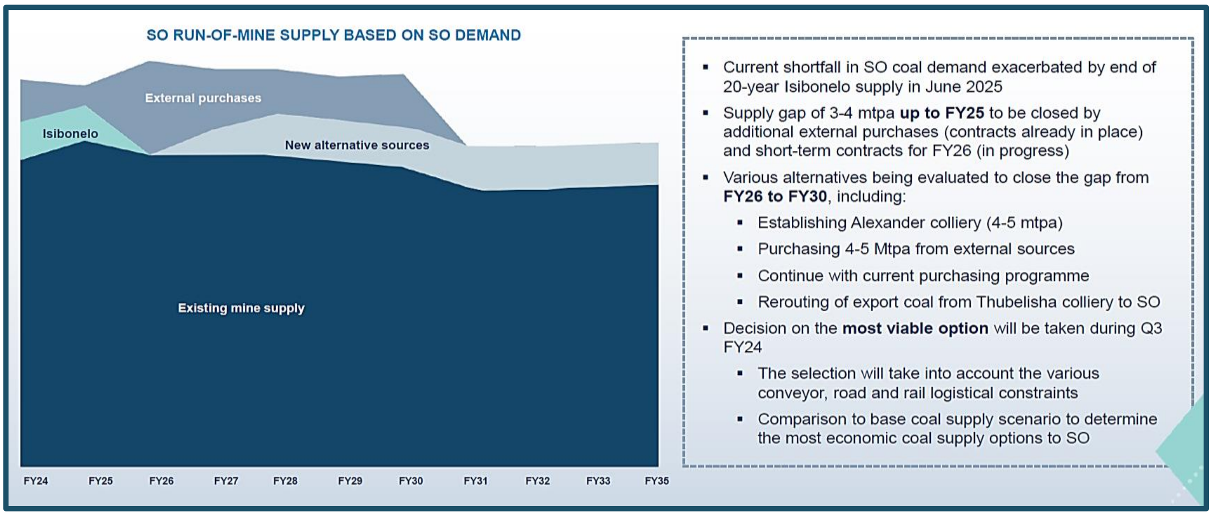
Figure 6: History of coal production from Sasol Secunda Collieries



Source: Sasol 20F Forms, various years.

The outlook for coal supply to Secunda is shown in Figure 7 which shows the increasing need for external coal purchases. In 2005 Anglo coal commissioned the Isibonelo Colliery to supply five million tons per annum of coal to Secunda by conveyor. A 20-year supply contract was signed and is due to expire in 2025/6 when all the recoverable coal is expected to have been depleted (Thungela, n.d.). Isibonelo and other Anglo coal mines were unbundled from Anglo in 2021 (Anglo American, 2021).

Figure 7: Outlook for Sasol coal supply



Source: Sasol 2023k.

Sasol's mining business has experienced operational challenges and a deterioration in the quality of coal, which have led to a reduction in mining productivity. Uneconomic productivity levels could hasten the closure of some mines.

Isibonelo Colliery will need to be replaced with coal from alternative external sources. These will most likely be located further away from the Secunda facility as typically the closest coal gets depleted first. This will likely be beyond the range of conveyors and thus will involve the increasing use of coal delivery by road. In South Africa, 34-ton side tipper trucks are often used for this purpose. To replace the five mtpa from the Isibonelo Colliery would thus require over 400 coal truck deliveries per day. Given that Sasol coal external purchases are in the region of 10 mtpa, it is possible that 800 coal truck deliveries per day will be required in future. This is about one truck every two minutes, 24 hours a day, a significant logistical challenge should this route be pursued.

In recent years, racketeering by coal mafias has threatened Eskom, while law enforcement agencies struggle to contain this growing problem. Coal deliveries are intercepted and replaced with poor quality coal (Naidoo, 2022). Maintaining quality control when receiving hundreds of coal deliveries per day can become a significant challenge, particularly in an environment of criminality and poor law enforcement. This will impose significant additional management challenges and add additional costs.

Sasol Secunda is also busy with two critical coal projects which are viewed as essential to halt the decline in coal quality and ensure environmental compliance. The first is a coal destoning project coupled with improved mining practices and an integrated quality management system (Parker, 2023a). This destoning project is in the feasibility phase with a final investment decision (FID) expected in the second half of 2024. The purpose of this project is to improve coal quality.

The second project is a coal briquetting project. With the announced phased closure of six of the 17 coal boilers in Secunda by 2030, an imbalance between fine and coarse coal production will be created. Apart from the economic ramifications, it is not deemed environmentally acceptable to dispose of fine coal by dumping. An innovative fine coal briquetting technology developed by EESTech Inc Ltd has been selected by Sasol as the most promising technology. Coal briquetting is a process in which fine coal is moulded into briquettes for effective consumption in the gasifiers, in this way optimising feedstock usage. Sasol has yet to approve the Basic Engineering phase for this project (Sasol, 2023c).

It is believed that finding a solution to the fine coal problem has been a perennial problem for Sasol Secunda. It is assumed that stockpiling of fine coal is not environmentally acceptable.[9] The successful implementation of a coal briquetting solution is an essential component of Sasol's commitment to reduce greenhouse gas emissions by 2030. It should be emphasised that the successful implementation and commissioning of an innovative and pioneering briquetting technology involving solids handling, which is a specific risk for pioneering process projects (Merrow et al., 1988), represents a significant challenge for Sasol. Delays or the briquetting process not performing as per design imposes a significant risk for Sasol to be able to meet its environmental commitments by 2030. No briquetting facilities at or near this scale appear to be in operation globally in 2023, making benchmarking difficult. An extreme comparison of a comparatively small-scale yet commercialised technology might be braai briquettes. These retail at an equivalent of R8000/ton with manufacturers claiming capacities around 10 000 tpa (Bosveld Charcoal, n.d.). While the benefits of on-site processing

[9] It is believed that coal fines cannot merely be "dumped" as under the National Environmental Management Waste Act of 2008 , as coal fines are likely classified as a hazardous waste and would be subject to the waste management hierarchy which is potentially (financially) onerous. Sasol does not appear to be storing fine coal and its concomitant interest in coal briquetting gives credence to this regulatory interpretation.

at scale will no doubt be large, and Sasol would be paying effectively wholesale prices less logistic and other costs, this would perhaps reduce the cost to R5000/ton. It is, however, difficult to imagine supply chain benefits and economies of scale reducing prices by up to a factor of 10 to bring briquette costs into the range of conventional coal. In addition, this analysis makes many other significant assumptions including that the resulting briquette properties are suitable for the unique environment inside a Sasol low-temperature gasifier, thus maintaining an operational status quo and that a suitable binder material is economically available at the quantities required.

In light of the risks involved in the execution of this project, Sasol is understandably quite cautious about committing to firm intermediate deadlines until projects are more advanced. Some investors are becoming increasingly frustrated about the lack of clear targets for emission reduction (Bloomberg, 2023). Given increasing pressure globally and in South Africa, Sasol is also facing increasing criticism in the media for what is perceived to be delaying tactics relating to greenhouse gas emission reduction (Rose, 2022). The reality is more nuanced than mainstream media articles portray as the targets that Sasol has committed to are extremely challenging and require the completion of several complex and ambitious projects. However, Sasol has set itself bold emission reduction targets by 2030 and it is now increasingly being held to account for its promises. This is likely to create significant pressure for Sasol in the coming years.

In summary, Sasol Secunda is facing significant challenges in the supply of appropriate quality coal at an affordable price while also meeting environmental commitments within agreed timeframes for emission reduction.

5.2.2. Natural gas

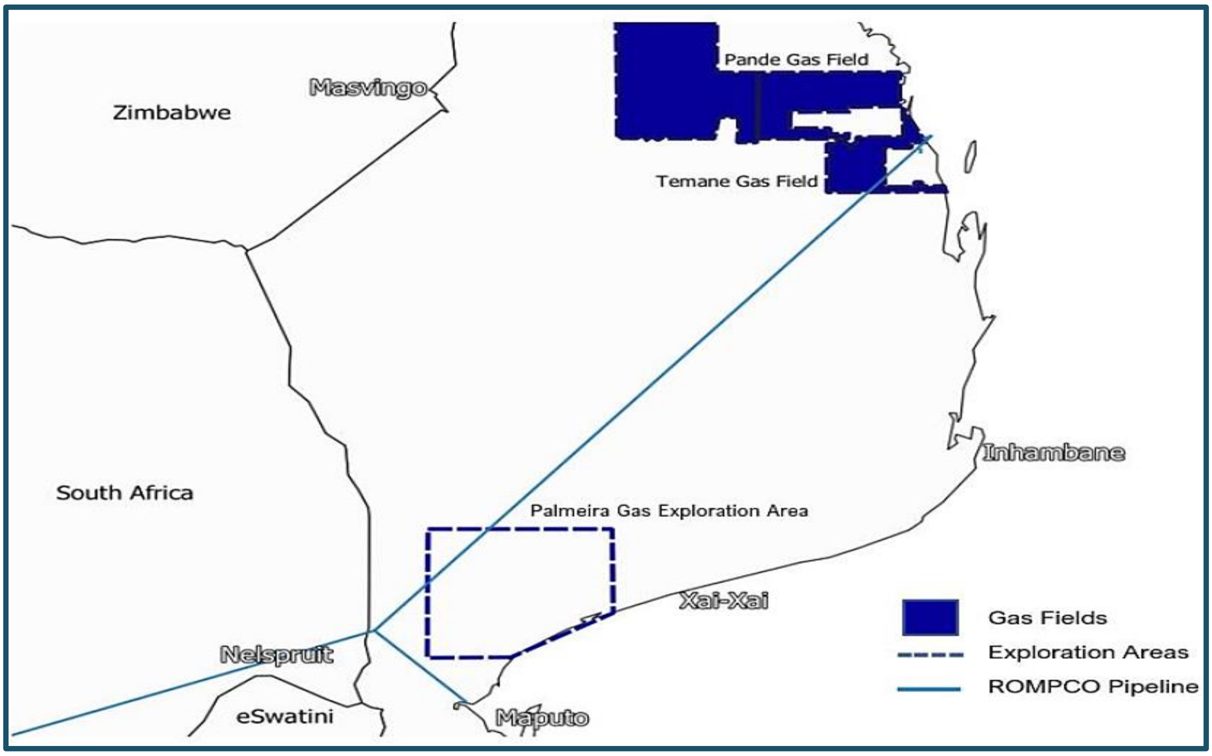
Current gas supplied to South Africa comes from the Pande and Temane fields in southern Mozambique. The Temane field was discovered in 1957 and the Pande field in 1961 by Gulf Oil. (National Petroleum Institute, n.d.) These gas rights were acquired by Enron in 1994, which intended to construct a pipeline to deliver the gas to South Africa. However, Sasol, as the baseload customer did not want such a strategic feedstock to be controlled by another entity and eventually frustrated Enron into relinquishing its gas field rights in 2000. (World Bank, 2016) Sasol acquired the rights in 2000 which were commercially developed by Sasol in collaboration with its partners, including the Mozambican state oil company, Empresa Nacional de Hidrocarbonetos (ENH) supported by World Bank funding, in the early 2000s.

Simultaneously Sasol commenced negotiations with the Government of South Africa on a regulatory dispensation as the Gas Act No. 48 of 2001 did not exist at the time. This framework resulted in a Regulatory Agreement and a Commercial Agreement.[10] The former gave Sasol up to a 10-year monopoly in the local market depending on proven gas reserves, with some supply obligations and pricing constraints. The latter gave ENH and iGas (South African state-owned gas company) one quarter of the shares each in the Republic of Mozambique Pipeline Investments Company (ROMPCO) which was to own the gas transmission pipeline from the gas fields to Secunda. This is one of the rare public-private partnerships in the post-democratic energy sector that has been successful. Sasol remained the majority shareholder of ROMPCO until it sold a 30% share in 2021.

Sasol, along with ENH, invested in the development of the gas fields, and the construction of a central gas processing facility and infrastructure necessary for extracting and transporting natural gas into South Africa. This trans-national project was completed in the early 2000s. Gas first flowed in 2004.

[10] Both signed on 26 September 2001.

Figure 8: Overview of ROMPCO gas supply to South Africa from Southern Mozambique

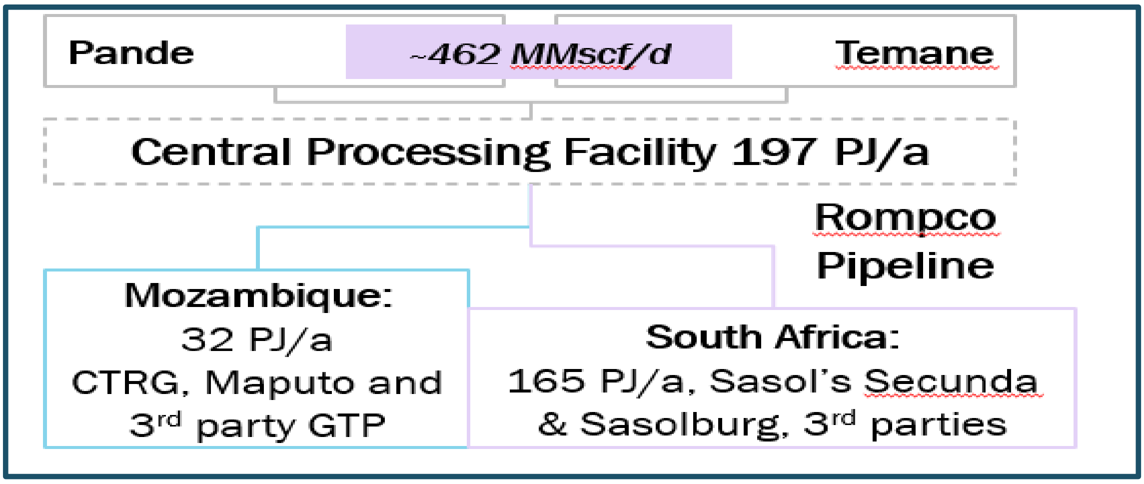


Source: Africa International Advisors (AIA).

A schematic overview of the Southern Mozambique gas supply to South Africa is shown in Figure 8. The gas supplied was intended for both industrial and domestic use in South Africa. An overview of the gas supply capacity and split of the gas between South Africa and Mozambique is shown in Figure 8. The central processing facility is designed to supply up to 197 PJ/annum of gas to Mozambique and South Africa.

Of the 197 PJ/annum production capacity, 32 PJ/annum is reserved for Mozambique for gas to power. This leaves 165 PJ/annum for South African use – see Figure 9. This supplies Secunda and Sasolburg with gas as well as external third parties. External users of gas include Arcelor Mittal, the food and beverage industry, the ceramics industry, the packaging industry and glass manufacture. The external gas users are represented by an industry body called the Industrial Gas Users Association of Southern Africa (IGUA-SA) which provides a list of large industrial users on its website (IGUA-SA, n.d.).

Figure 9: Overview of gas supply from Pande and Temane



Source: Author calculations.

In both Secunda and Sasolburg, natural gas is used primarily as a process feed as well as to generate electricity. In Secunda, gas is used to supplement coal as a feedstock to the high-temperature Fischer Tropsch process. In Sasolburg, gas is used to feed the integrated low-temperature Fischer Tropsch gas loop which is used to make FT waxes, ammonia, and methanol as well as to generate some electricity. The consumption figures for the last few years are shown in Table 6.

Table 6: Sasol natural gas (NG) usage

Financial Year	NG into Secunda reformers	NG into Secunda electricity	NG External Sales	NG to Sasolburg Process	NG to Sasolburg Electricity	Total South African NG consumption
PJ/annum						
2017	62	18				
2018	59	19				
2019	61	19				
2020	57	19	32	33	17	157
2021	59	19	38	33	15	163
2022	57	10	37	31	19	154
2023	59	15	36	32	19	160

Source: Sasol 20F Forms, production updates Sasol releases.[11]

When the Mozambique natural gas project was approved in the early 2000s with a gas reserve of 2.5-3.2 trillion cubic feet (tcf) it was expected to have a lifetime of 25 years (AfDB, 2002).

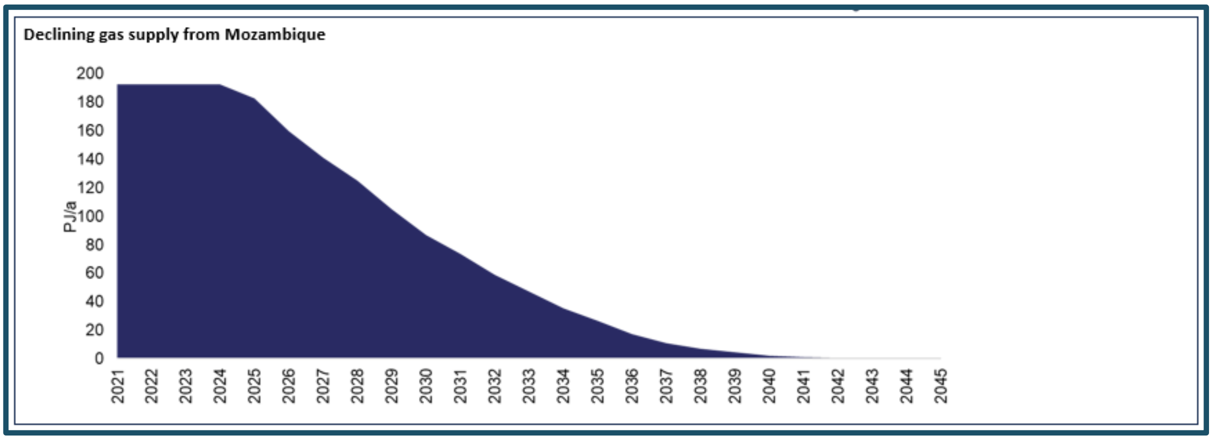
However, Sasol began signalling in its Section 20-F forms as early as 2018 that continued long-term gas supply from Southern Mozambique was a risk and that the gas fields faced depletion in the 2020s (Sasol, 20218b). The following was stated, "*During 2018 it was determined that production will nevertheless begin to decline during 2023 and we will no longer be able to supply at currently contracted rates. Technical and commercial options are under consideration to address the matter*". Sasol recognised that the gas fields at Pande and Temane were reaching the end of their expected life.

Based on a reconstruction of data from Sasol 20F forms and production and sales metrics, a forecast for gas supply from southern Mozambique is shown in Figure 10. This shows gas supply declining from 2026 and then falling off rapidly after that and by the mid-2030s, the gas will be depleted.

In Sasol's 2023 Climate Change Report (Sasol, 2023c) the Sasol CEO, Fleetwood Grobler, says, "*We have implemented mechanisms to extend our Mozambique gas plateau from 2026 to 2028, and potentially further, while continuing to investigate alternative gas sources.*" This seems more optimistic than Sasol's 20-F form for 2023 where it was reported that "*Production from proved reserves is expected to commence declining in 2024*" (Sasol 2023-h, p.58) (The SASOL integrated report for the year ended June 2023 does not mention this). The exact timing of when the gas supply from Mozambique will start declining is thus uncertain, but the fact that it will decline is not in dispute.

[11] This table excludes another approximately 30 PJ of mainly gasification based gas sold by Secunda as a natural gas substitute, called Methane Rich Gas.

Figure 10: Schematic forecast gas decline from Southern Mozambique



Source: Africa International Advisors reconstructed from Sasol 20F forms and production and sales metrics.

To deal with declining gas from Mozambique, Sasol considered importing liquified natural gas (LNG) into Mozambique by mostly using the existing ROMPCO pipeline infrastructure to deliver it to Secunda. However, in Sasol's 2023 Climate Change Report (Sasol, 2023c) it was stated that "*The supply of re-gasified LNG had been considered possible to top up further gas requirements and to use this as a substitute for coal. However, LNG has become unaffordable at prevailing levels. Substantial investment in additional gas reforming capacity was also included in our roadmap to further recover production through gas. Given the increase in capital cost and affordability of LNG, Sasol Energy decided to place on hold expenditure on additional gas reforming capacity.*" Bearing in mind the capital investment requirements for LNG infrastructure which typically requires up to a 15-year operational window to be commercially viable, it is debatable as to whether importing LNG will become viable at some point. A working assumption is thus that Sasol cannot afford to import LNG[12]. The easiest option would be to discover more gas in Southern Mozambique and indeed Sasol is pursuing a "promising new discovery" in block PT5-C. (Steyn, 2023a)

If gas supplies are going to start declining later in this decade, then the question becomes how this decline will be managed across the five gas-user categories shown in Table 6.

At the August 2023 Sasol results presentation, Priscilla Mabelane, executive vice president of the Sasol energy business said, "*So, we've been in discussions with customers explicitly to indicate that Sasol gas which has been investing in the PPA is not able to extend and afford gas supply from FY26 onwards. At the same time, previously, we've also communicated to our customers that the methane-rich gas will actually be phased out by FY26 because we need that gas for the decarbonization of our own operations"*[13]. Sasol has thus commenced discussions with external gas customers regarding the phase-out of their gas supply as Mozambique natural gas declines, as well as the phase-out of their coal-based equivalent "methane-rich gas" due to own needs. Although the exact timing of the Mozambique gas decline is uncertain, it is apparent that it is not a question of if gas from Southern Mozambique will decline but rather a question of when.

The price of gas to external customers is regulated by the National Energy Regulator of South Africa (NERSA). Sasol maintains that, apart from operational cost increases, NERSA should also consider the

[12] As a rule of thumb, 10 times the gas price in US$/GJ provides a quick estimate of the gas feedstock variable cost to a gas-to-liquids facility. As an example, if LNG is delivered to Secunda at US$6/GJ, then an oil price of US$60/bbl is required to cover just the variable cost of the gas.

[13] Sasol may be able to use methane rich gas in Sasolburg if the technical nature of their facility permits this. However, the reference to decarbonisation implies that it will be used in Secunda (as Sasolburg already uses natural gas). It might also be concluded that some significant technical modifications may be required else Sasol might also have already used this gas internally to some extent to offset its own declining coal production volumes.

risk associated with extensive investments which Sasol is currently making to try and extend supply and the incentives to develop new resources (Bubulia, 2023). Moreover, Sasol Gas posits that the alternative value for Sasol is that it can convert gas into other value-added products in its South African facilities, as an alternative to selling this gas to third-party customers. In addition to this, the Competition Commission has referred a complaint of excessive pricing of piped natural gas against Sasol Gas to the Competition Tribunal (Burger, 2023). The referral stems from three complaints against Sasol Gas that were lodged with the Commission in early 2022 by Egoli Gas, IGUA-SA and Spring Lights Gas.

Sasol Gas has challenged the commission's jurisdiction to investigate gas pricing complaints based on the National Energy Regulator of South Africa's regulatory powers under the Gas Act. There is thus confusion regarding whether NERSA or the Competition Commission has jurisdiction regarding gas pricing to external gas customers. These two government agencies appear to be pursuing different agendas, increasing regulatory uncertainty for Sasol and its gas customers.

Sasol's 2026 gas cliff for industrial customers[14]

External gas customers, having converted to gas from mostly coal in the early 2000s, are now facing a potential gas supply crisis in 2026. In August 2023, Sasol warned its natural gas customers in South Africa that it would not be able to provide them with gas from the 2026 financial year onwards (Steyn, 2023a). This notice period appears generous given that Sasol reports that "Production from Proved Reserves is expected to commence declining in 2024". (2023 Form 20-F – Sasol, 2023-h, p.58).

Of immediate concern is the economic impact of the termination of gas supply to industrial customers in 2026. In November 2023, James Mackay, chief executive officer of the Energy Council of South Africa, warned that "We have a supply cliff coming", and that "There isn't currently a supply alternative that will readily be available in the time frames needed." He estimated that 300 000 to 400 000 jobs at firms that use gas may be at risk (Squazzin, 2023a). The impact on taxable revenue may be more than R450 billion. (Swart, 2024) There has been a deafening silence from the government on this looming crisis for manufacturing in South Africa.

Apart from Sasol's declining gas reserves in Mozambique, Sasol may have had additional reasons for giving notice to exit the industrial gas market (and to leave stranded its network of pipeline assets that supplies its customers). These reasons stem from the regulatory regime and the state of the economy and may include the fact that Sasol reported lower natural gas and methane-rich gas sales volumes in South Africa, by 3% and 1% respectively for the year ending June 2023 (2023 Form 20-F – Sasol, 2023-h, p.67). This was despite Sasol keeping prices constant at R68.60/GJ for two years (Sasol, 2023b, p.58). Also, on 18 May 2023, the Competition Tribunal interdicted Sasol Gas from increasing the price of its piped natural gas above R68.39/GJ for the next six months in response to an application by IGUA-SA (Competition Tribunal, 2023). This price freeze did not deter the Competition Commission from referring complaints regarding excessive pricing from certain Sasol Gas customers to the Competition Tribunal on 11 July 2023, a matter that is still under dispute according to the Sasol Integrated Report (2023b, p.58). The Sasol CEO is reported to have said regarding a gas supply "day zero" in 2026 that "because of Sasol's calculation that it would be unable to recover the cost of its exploration and development investments under the **current regulated pricing formula**" (emphasis added). (Creamer,2024) There is thus sufficient evidence to suggest that the regulatory dispensation governing Sasol's gas pricing to industrial customers is a significant contributory factor in its decision to terminate gas supplies to industrial customers in 2026.

[14] As this report was being finalised Sasol announced that it had extended its 2026 deadline to June 2027.

The alternatives for industrial customers are conventional LNG imports, small scale LNG, liquified petroleum gas (LPG), compressed natural gas (CNG) or renewable electricity, each with its own cost and supply implications. The French energy company TotalEnergies is performing a feasibility study for a new (LNG) import terminal at Mozambique's Matola port and is scheduled to consider a FID by September 2024 (Reuters, 2023a). This would present a possible substitute for Sasol gas supply but will reflect international LNG pricing, which is expected to be higher than Sasol's historical gas pricing and may not be affordable for some of the users, resulting in some demand destruction. It remains to be seen whether large gas users such as ArcelorMittal and Consol Glass will be able to afford these higher costs.

However, alternative gas supplies using imported LNG do not seem to be a viable alternative because Sasol has ruled out LNG as too costly for it, and without Sasol there is no baseload customer which means that there is unlikely to be sufficient gas demand to meet the economies of scale requirements of the costly LNG terminal and regasification infrastructure that would be needed. It is estimated that the industrial customers account for about 40 PJ of demand and that an additional demand of approximately 60 PJ would be needed to justify LNG import infrastructure. (Erasmus, 2024)

Small-scale LNG (SSLNG) may be an option for some stranded industrial customers depending on their price appetites. Rough estimates suggest that SSLNG will be considerably more costly than Sasol's historic gas prices and LPG. Another option may be CNG delivered by road from the Renergen gas wells in Virginia in the Free State Province, again depending on price appetites.

A further gas supply option may emerge from prospecting work being carried out by Kinetiko Energy Ltd. In proximity to Secunda. Kinetiko is focused on commercialising advanced shallow conventional gas and coal bed methane projects and has reported maiden gas reserves of 3.1 bcf and net contingent gas resources (2C) of 6.0 tcf.[15] Talks with Sasol were reported to be at a very early stage in August 2023. (Reuters, 2023b) If the 6 tcf of gas resources claimed by Kinetiko are proven to be reserves and are available at a price that Sasol can afford, it could be a game changer for Sasol as it is roughly twice the reserves that it needed to justify the ROMPCO pipeline. Unfortunately, this will only be known after several years of exploration and drilling.

Once customers have moved to an alternate energy carrier it is not likely that Sasol will be able to re-enter this market even if further gas is found in southern Mozambique.

Sasol gas cliff for own use

When Sasol exits the external gas supply market the question then becomes how will the internal Sasol gas users will be prioritised as the gas supply continues to decline?

A potential scenario for the use of remaining gas within Sasol is presented below.

(i) **Secunda and Sasolburg gas to electricity:** Sasol is facing increasing pressure to reduce GHG emissions (Davies, 2023) and the procurement of 600MW of renewable electricity from IPPs by way of wheeling is imminent and expected to come online in 2025 (Green Building Africa, 2023). A further 600MW is planned by 2030. As the gas supply from Mozambique declines there will be ongoing pressure to reduce GHG emissions even further and replacing gas to power with more renewable electricity will most likely be the easiest place to start. This could mean that the existing Sasolburg gas-to-power asset is used for load following or potentially becomes stranded and is sold as used equipment. The fate of the Secunda open-cycle gas turbines is unknown given their integration into the Secunda process through steam production (Bloomberg, 2010)

[15] Kinetiko Announcement 21 August 2023.

(ii) **Gas to Sasolburg process:** The Sasolburg gas loop produces Fischer Tropsch (FT) waxes, ammonia and methanol with FT waxes being the higher value product. Historically, Sasol and to a lesser extent Shell produced FT waxes used in several different applications (Shell, n.d.). However, in the last decade, the global FT wax market experienced substantial capacity additions. Chinese FT wax suppliers, including Inner Mongolia Yitai CTO Co. Ltd., Shanxi Lu'an Coal-To-Liquid Co. Ltd., and Shenhua Group Co. Ltd. expanded production capacities to fill the void left by the global petroleum wax deficit. New players like Shaanxi Future Energy Chemical Co. Ltd. have also entered the market and are rapidly expanding. Many of these suppliers have plans to continue increasing FT wax supply over the next five years (Kline Group, 2023). This increase in supply has served to increase competition, commoditise FT wax and reduce margins. It is therefore speculated that the Sasolburg gas loop will be the next process to face closure pressure after gas to power.

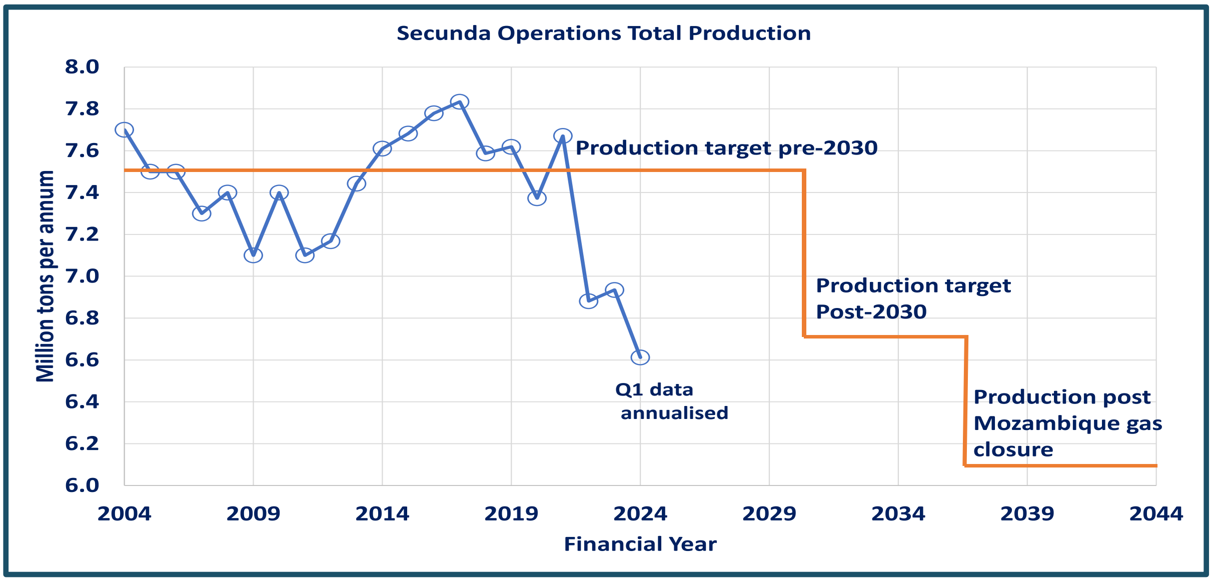
(iii) Gas to Secunda reformers: With Secunda being the main cash generator for Sasol South Africa it is speculated that the gas to the Secunda reformers will be retained for as long as possible but ultimately in the mid to late 2030s these are expected to start shutting down.

Approximately 60 PJ/annum of gas is fed to the Secunda reformers. This represents 1.43 million tons per annum of feed and, assuming an overall conversion efficiency of 60%, this represents a production loss of 0.57 million tons per annum of production. This means that Secunda's total production will decline from 6.7 million tons per annum to about 6.1 million tons per annum[16] in the mid to late 2030s when the gas supply runs out (see Figure 11).

Total production is already forecast to decline from 7.5 million tons per annum to 6.7 million tons per annum by 2030 to meet GHG reduction targets. It then drops further to 6.1 million tons per annum by the mid to late 2030s as Mozambique gas runs out. This represents a 19% reduction in the production of fuels and chemicals from Secunda.

The ramifications of this reduced production for the operation of Secunda and its economics are complex but without significant fixed cost reductions Secunda margins will be squeezed, and the breakeven oil price required for Secunda will increase significantly.

Figure 11: Secunda total production history and long-term forecast



Source: Compiled from Sasol Limited, Form 20-F, various years and Sasol Production Reports.

[16] Author's calculation.

6. HIGH-LEVEL PRODUCTS OVERVIEW

A schematic overview of Secunda production is provided in Figure 2, giving a high-level overview of chemicals production from Secunda.

In this section, more detail will be provided regarding chemicals production from Secunda as well as a perspective regarding what the declining production from Secunda will mean for these chemicals.

Ethylene value chain

The production capacities for ethylene and its derivatives are shown in Table 7.

Table 7: Production capacities for ethylene and its derivatives

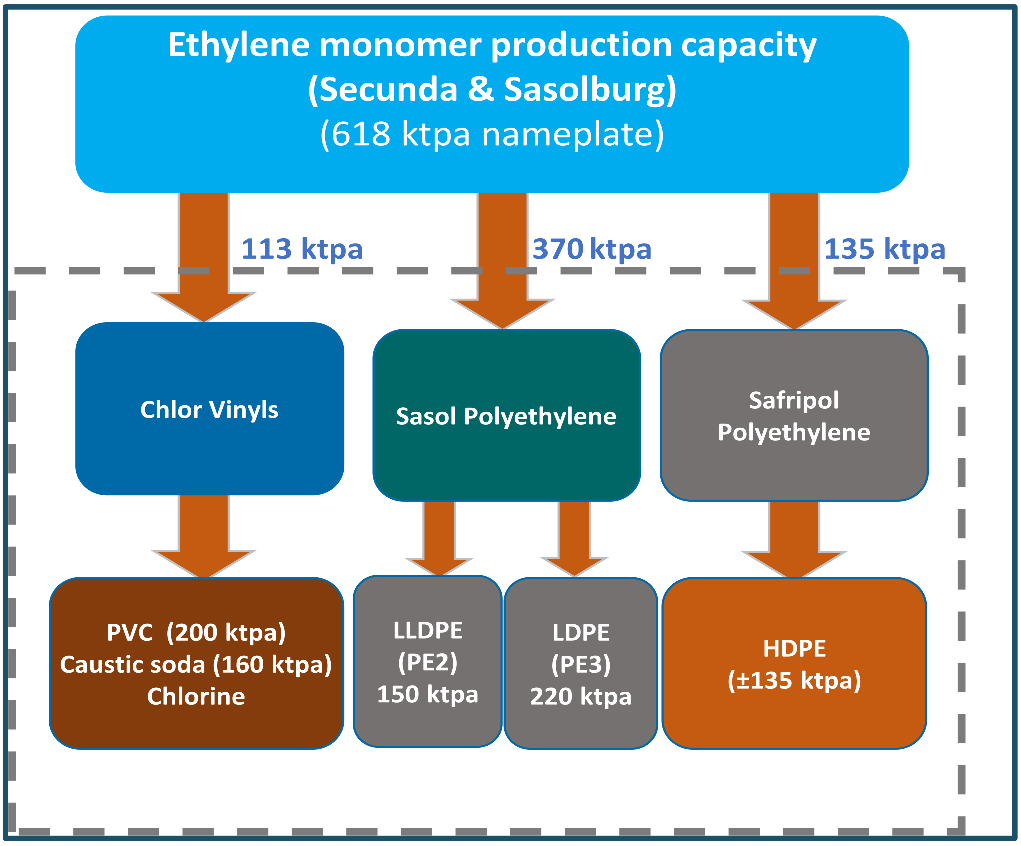
	Production Capacity (kilo tons per annum)	Ethylene Derivatives, ethylene consumption (production capacity)	Ethylene derivatives production capacity	Location	Ownership	Estimated maximum production post 2030	Estimated maximum production post Mozambique gas decline
Ethylene	618			Secunda	Sasol	552	503
LDPE		220	220	Sasolburg	Sasol	197	179
HDPE		135	135	Sasolburg	Safripol	121	110
LLDPE		150	150	Sasolburg	Sasol	134	122
PVC		113	200	Sasolburg	Sasol	179	163
Caustic Soda			160	Sasolburg	Sasol	143	130
Total		**618**	**865**				

The production capacities for ethylene and its derivatives were sourced from the 2015 Sasol 20F forms as Sasol did not subsequently publish actual production figures for ethylene derivatives on an annual basis. Actual production figures will generally be lower than nameplate capacities. In addition, Sasol will optimise the use of ethylene across its derivative options to maximise profitability.

Sasol also has a contractual obligation to supply ethylene and propylene to Safripol that makes high-density polyethylene and polypropylene from Sasol produced ethylene and propylene. With Sasol Secunda being the monopoly supplier of ethylene and propylene in South Africa the pricing and other supply conditions are subject to regulatory scrutiny from the Competition Commission and Competition Tribunal. (SAFLII, 2011)

A schematic overview of the ethylene value chain is shown in Figure 12.

Figure 12: Schematic overview of the ethylene value chain



Based on the future declines in Secunda production shown in Figure 12, the production capacity of ethylene will decline from its current 618 ktpa to 552 ktpa post 2030 and then 503 ktpa when Mozambique gas supply runs out. This means that the ethylene derivative plants in South Africa will be feedstock constrained. The maximum capacity figures for ethylene derivatives are shown in Figure 12 assuming a proportional reduction in all ethylene derivatives based on an equal misery assumption. This is not likely to play out in practice. Given that Safripol is entirely dependent on Sasol Secunda for its feedstock and that Sasol is subject to regulatory scrutiny it is unknown if Sasol Secunda will be able to reduce or terminate the supply of ethylene to Safripol.

As with the declining gas situation, Sasol will need to make difficult choices regarding how to deal with its declining ethylene supply. It is speculated, for example, that the old PVC production facility which requires significant maintenance could provide a worse business case than the Sasol polyethylene plants. It is therefore possible that the chlor-alkali and PVC production plants could face closure as ethylene production declines. The potential consequences of this closure are briefly explored.

South Africa will need to import more than 160 ktpa of PVC and 140 ktpa of caustic soda, the net impact of which will be to increase the trade deficit by > R3.5 billion p.a. Movement of this material through South Africa's congested and deteriorating ports will result in a daily increase of more than 100 trucks on South African roads.

Caustic soda is a basic industrial chemical co-produced with chlorine (Wikipedia, n.d.-b) and the ramifications of Sasol's local production[17] (Vula UCT, n.d.) being closed will be complex and could be

[17] South Africa's second largest producer of chlor-alkali products is NCP Chlorchem with around 90 ktpa production.

yet another contributing factor to the current deindustrialisation trend in South Africa. Current estimated caustic soda markets served by Sasol South Africa are set out in Table 8.

Table 8: SASOL's caustic soda market estimate

Market	ktpa
Paper manufacture	70
Sasol manufacture of cyanide for gold recovery	>20
Sasol Secunda refinery	20
Platinum mining industry	30
Other chemicals	no data
TOTAL	140

Source: Authors estimates.

Sasol and or others would therefore need to set up an import value chain and infrastructure for ±140 ktpa of caustic soda. This could entail the tripling of onsite storage to ensure that the Secunda operations and the gold mining industry are not affected by any port or road congestion issues in Durban and or the N3 toll highway. Other markets for Sasol's caustic soda are not known but it has widespread use in the manufacturing sector and could include:

- soaps
- degreasers
- drain unblockers
- processing wood pulp
- construction materials
- automobile manufacture
- food packaging
- beverage cans
- pharmaceuticals like blood thinners and cholesterol medication
- water treatment
- manufacture of sodium hypochlorite a water disinfectant water

The caustic soda value chain is just one example of the complex consequences of declining commodity chemical production from Secunda. Another example is chlorine, a toxic chemical for which only limited quantities are traded internationally (it is sufficiently toxic that it was used in World War 1 and the Iran-Iraq war in 2007 as a poison gas weapon). It is estimated that approximately 90% of the chlorine produced by Sasol is used in its PVC plant with the balance going into liquefied chlorine gas for the water treatment industry.

Global exports of chlorine in 2021 were just 600 000 tonnes, valued at R3 .6 billion (US$200 million,) of which South Africa exported 4 835 tonnes and imported 178 tonnes (World Bank, 2021) suggesting that imports are an option. Another option to meet local demand if the PVC plant were to close would be to continue to operate some of the chlorine manufacturing cells as the plant is configured in a modular configuration, if that were commercially attractive for Sasol. This could be important as chlorine is used in several important manufacturing markets, such as disinfectants to treat drinking water and swimming pool water, hundreds of consumer products from paper to paints, and from textiles to insecticides, solvents, pharmaceuticals, and the manufacturing of paper and pulp. There are also other chlorine manufacturers in South Africa such as NCP Chlorchem which may be able to expand production to meet a Sasol supply shortfall.

Propylene value chain

The production capacity estimates for propylene and its derivatives are shown in Table 9.

Table 9: Propylene and propylene derivatives production capacity estimates

	Production Capacity (kilo tons per annum)	Propylene Derivatives, propylene consumption (production capacity	Propylene derivatives production capacity	Location	Ownership	Estimated maximum production capacity post 2030	Estimated maximum production capacity post Mozambique gas decline
Propylene	950			Secunda	Sasol	849	773
Polypropylene 1		220	220	Secunda	Sasol	197	179
Polypropylene 2		300	300	Secunda	Sasol	268	244
Butanol		85	150	Sasolburg	Sasol	134	122
Isobutanol		9	15	Sasolburg	Sasol	13	12
Polypropylene		120	120	Sasolburg	Safripol	107	98
Ethyl Acrylate		15	35	Sasolburg	Sasol	31	28
Butyl Acrylate		26	80	Sasolburg	Sasol	71	65
Acrylic acid		6	10	Sasolburg	Sasol	9	8
Liquid fuels		169	169	Secunda	Sasol	151	138
Total		**950**	**1099**			**981**	**894**

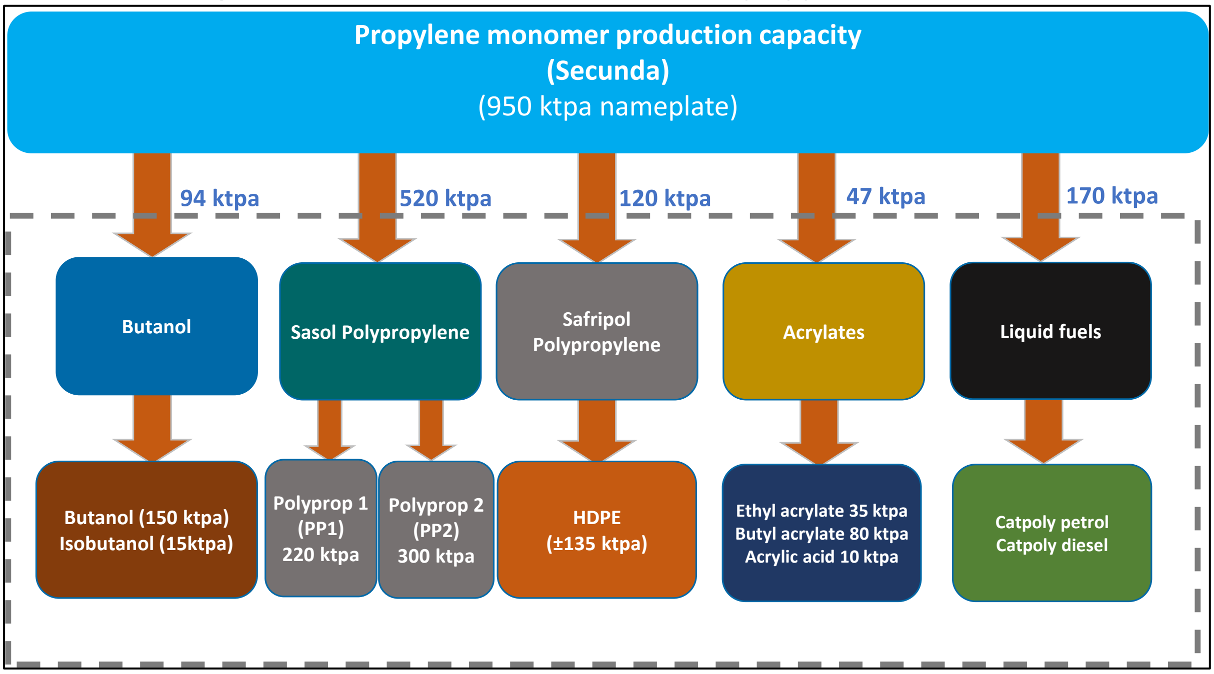
Source: Sasol Limited, Form 20-F for 2015 and authors estimates.

The production capacities for propylene and its derivatives were sourced from the earlier 2015 Sasol 20F forms as Sasol has not subsequently published actual production figures for propylene derivatives on an annual basis. Actual production figures will generally be lower than nameplate capacities. The production capacity of propylene is expected to decline from its current 950 ktpa to 849 ktpa post 2030 and then to 773 ktpa when Mozambique gas supply runs out. This means that the propylene derivative plants in South Africa will be feedstock constrained. The maximum capacity figures for propylene derivatives shown in Figure 13 assume a proportional reduction in all ethylene derivatives based on an equal misery assumption. This is not likely to play out in practice and one or more of the derivative plants may be shut down. The conversion of propylene into fuels is the lowest margin propylene derivative and this may be minimized as production declines.

The amount of polypropylene produced in South Africa exceeds demand and thus the balance is exported. Most of the butanol, isobutanol, and acrylates are also exported.

A schematic overview of the propylene value chain is shown in Figure 13.

Figure 13: Schematic overview of the in-land propylene value chain



Source: Sasol Limited, Form 20-F various years. *Note:* Supply and demand numbers do not necessarily balance as actual operating levels may differ in various units compared to nameplate.

In a similar fashion to the ethylene derivatives, as propylene supply declines choices will need to be made regarding which derivatives are prioritized and whether Safripol will be supplied with propylene or not. The future of Safripol will hang in the balance depending on the supply of ethylene and propylene to its polymer plants.

Non-acid chemicals (solvents) value chain

The Secunda HTFT process also produces water and oxygenated hydrocarbons (e.g. alcohols and ketones). The shorter chain oxygenates (less than four carbon atoms) are highly soluble in water and report to the water stream. These oxygenates are valuable chemicals and are separated from the water stream in the chemical workup process in Secunda before the remaining water is sent to the water treatment plant to convert to process water for recycling. Some of these oxygenates have been used as feedstock to make other higher value oxygenates, ethyl acetate and acrylates.

The solvents portfolio also includes products made in Sasolburg derived from the reforming of natural gas into synthesis gas (hydrogen and carbon monoxide) in a complementary ecosystem. Thus, in addition to the low-temperature Fischer Tropsch waxes, Sasolburg also produces methanol as well as butanol (from Secunda propylene via the so-called hydroformylation process with Sasolburg carbon monoxide).

The industrial solvents products Sasol markets include alcohols and ketones including ethyl-acetate, n-propanol, acetone, methyl ethyl ketone, methyl isobutyl ketone, and mixed alcohols used in coatings, printing, packaging and plastics. Methanol, methyl isobutyl ketone and blends are used in aerosol paint and adhesive industries, polish, cosmetics, agriculture, and mining. N-Butanol, glacial acrylic acid, butyl acrylate and ethyl acrylate are used in inks, adhesives, solvents and polymers (for example, superabsorbent polymers). Butyl glycol ethers and acetates are used in chemical intermediates.

An overview of the solvents production capacities is shown in Table 10. Based on the future declines in Secunda production shown in Figure 11, the production capacity of the solvent's portfolio will decline from its current 1160 ktpa to 1051 ktpa post 2030 and then 830 ktpa when Mozambique gas supply runs out. This means that the solvents plants in South Africa will be feedstock constrained. It is also assumed that as Mozambique's gas supply dwindles, the Sasolburg gas loop will be shut down which means the methanol plant will also be shut down.

Table 10: Solvents portfolio production capacities and estimated future production

	Production Capacity (kilo tons per annum)	Location	Estimated maximum production post 2030	Estimated maximum production post Mozambique gas decline
Acetone	175	Secunda	156	142
Methyl Ethyl Ketone (MIBK)	60	Secunda	54	49
Methyl Isobutyl Ketone (MIBK)	58	Secunda	52	47
Ethyl Acetate	54	Sasolburg	48	44
Mixed alcohols	215	Secunda	192	175
Methanol	140	Sasolburg	140	0
Ethanol	114	Secunda	102	93
n-Propanol	54	Secunda	48	44
n-Butanol	150	Sasolburg	134	122
Isobutanol	15	Sasolburg	13	12
Ethyl Acrylate	35	Sasolburg	31	28
Butyl Acrylate	80	Sasolburg	71	65
Glacial Acrylic Acid	10	Sasolburg	9	8
Total	**1160**		**1051**	**830**

Sources: Sasol Limited Form 20-F for 2015 and authors estimates.

It is also important to note that the solvents plants are located in both Sasolburg and Secunda which serves to emphasise the integrated nature of Secunda and Sasolburg.

In most cases, the production of solvents by Sasol exceeds local demand and most of the solvents are exported to customers worldwide.

Alpha olefins and detergent alcohols value chain

A feature of the Secunda HTFT process is that it produces a light synthetic crude oil stream with a very different composition from conventional crude oil. The HTFT process produces a syncrude, which is rich in alpha olefins. Alpha olefins are a type of unsaturated hydrocarbon with a specific chemical structure. They are characterised by having a double bond between the first and second carbon atoms from the end of the carbon chain. The term "alpha" indicates the position of the double bond, which is at the beginning (alpha position) of the "carbon" chain.

Alpha olefins are a valuable chemical feedstock used as comonomers (shorter chain molecules) and to make detergent alcohols, among other applications. Comonomers are monomers that are used in the polymerisation process along with the main monomer (for example ethylene to make polyethylene) to form copolymers. The inclusion of comonomers in the polymerisation process can introduce specific properties or characteristics to the copolymer that differ from those of homopolymers (polymers derived from a single type of monomer). The incorporation of comonomers allows for the tailoring of the copolymer's properties such as flexibility, toughness, chemical resistance, and other desired attributes. Sasol Secunda produces world-scale amounts of the comonomers 1-pentene, 1-hexene and 1-octene.

Longer chain alpha olefins (C10-C14) can be hydroformylated to produce detergent alcohols, which are a chemical intermediate used to make a range of detergents and surfactants.

Conventionally alpha olefins are manufactured by oligomerising (relatively expensive) ethylene and the extraction of the naturally occurring alpha olefins from a lower value fuel stream provides Sasol with a competitive advantage compared to the conventional process.

The processes required to extract and purify the alpha olefins from the Secunda syncrude are complex and unique in the world. They were researched, developed, piloted, and commercialised by Sasol in the 1990s. As is common with pioneering processes, there were many challenges and difficulties when the plants were commissioned but these problems were ultimately solved, and the processes were successfully commercialised.

An overview of the alpha-olefins production capacities is shown in Table 11. Based on the future declines in Secunda production shown in Figure 11, the production capacity of the alpha olefins portfolio of products is estimated to decline from its current 476 ktpa to 425 ktpa post 2030 and then to 387 ktpa when Mozambique gas supply runs out. This means that the alpha-olefins plants in South Africa will be feedstock constrained.

Table 11: Production capacities for alpha olefins and derivatives and estimated future production

	Production Capacity (kilo tons per annum)	Location	Estimated maximum production post 2030	Estimated maximum production post Mozambique gas decline
Comonomers	356	Secunda	318	290
1-pentene		Secunda		
1-hexene		Secunda		
1-octene		Secunda		
Detergent alcohols	120	Secunda	107	98
Total	**476**		**425**	**387**

Source: Sasol Limited, 2011, Form 20-F; Stephens, 2000.

Almost all of the alpha olefins and detergent alcohols produced in Secunda are exported.

Other chemicals produced by Sasol in South Africa

In addition to the chemicals already discussed the following additional chemicals need to be considered to complete Sasol's South African chemicals portfolio and will be discussed in turn:

(i) Gasification byproducts in Secunda
  a. Ammonia
  b. Phenolics (Tar acids)
  c. Sulphur
(ii) Cyanide

Ammonia

Ammonia is a byproduct of the Secunda coal gasification process. In addition, ammonia is produced on demand from natural gas in Sasolburg. The combined capacity is 660 ktpa which will reduce post 2030 as both coal gasification and natural gas supply decline. About half of the ammonia production comes from Secunda. As coal consumption for gasification declines and the Sasolburg gas loop is potentially shut down, a significant decline in ammonia production can be expected. Sasol does not produce enough ammonia for the South African market and, consequently, ammonia is also imported into South Africa. These imports will need to significantly increase as Sasol production declines. This will require more investment in ammonia import infrastructure as well as putting further pressure on South Africa's congested port, rail, and road infrastructure. Ammonia is an extremely hazardous and poisonous chemical and road transportation has significant safety concerns.

Ammonia is used for the manufacture of ammonium nitrate, most of which is used for fertilisers with the remainder being used for mining and industrial explosives.

South Africa is somewhat unusual in using ammonium nitrate as a fertiliser rather than urea, which is the conventional nitrogen source for fertiliser used globally. Insufficient ammonium nitrate for South Africa's fertiliser requirements is produced in South Africa and, in 2022, 867 ktpa of urea was imported into South Africa (IndexBox, 2024). It would need to be evaluated as to whether the importation of ammonia for fertiliser manufacture or increased imports of urea would be the optimal route if ammonia production in South Africa declined.

An emerging carbon-neutral route to produce ammonia is to use green hydrogen to make green ammonia, and a pre-feasibility study is in progress to make green hydrogen in Nelson Mandela Bay to produce green ammonia (CNN, 2022). This project is, however, at the pre-feasibility level and green hydrogen requires substantial subsidies if it is to compete with conventional ammonia production (Bhashyan, 2023). It is doubtful that South Africa would be able to afford significant subsidies, and it is not known if this project will achieve financial closure. Urea manufacture requires a large amount of pure CO_2 as feedstock which may also be challenging to obtain in South Africa.

The future supply of ammonia and fertiliser for South Africa is of strategic importance.

Phenolics

A byproduct of the Secunda gasification process is a tar acid stream which is purified to produce 35 ktpa of phenol, ortho, meta and para cresol and xylenols with a total production capacity of 72 ktpa. Phenol is a commodity chemical, but meta and para cresols are speciality chemicals. Almost all the phenolics are exported.

The production rate of raw phenolics is determined by the amount of coal gasified and the coal composition. As Sasol Secunda reduces gasification the production of phenolics will decline.

Cyanide

Sasol has a plant on the Sasolburg Midlands site to make sodium cyanide with a production capacity of 40 kpta. Cyanide 1 was built in 1962 by AECI supplying 16 ktpa of sodium cyanide to the booming gold industry. Cyanide 2 was commissioned in 1984 with an additional production capacity of 26 ktpa. Sasol acquired the cyanide business from AECI in 2000. Both plants use the Shawnigan process which uses natural gas, ammonia, and caustic soda as feed.

The cyanide plant can be viewed as a standalone plant using commodity chemical feedstocks. The natural gas requirement for the cyanide plant is relatively small at 1 PJ/annum and continued supply of natural gas is important for the continued operation of the plant.

Sodium cyanide is predominantly used for the extraction of precious metals (gold and silver) from ore bodies. As gold ore bodies are depleting on the highveld and underground gold mining is declining, demand for cyanide for underground mining is declining. However, despite this, cyanide demand has continued to grow, and the plant is sold out. This is because of a move from underground mining (using approximately 5 kg cyanide per ounce of gold) to tailings recovery (50 kg/oz).

There are still a significant number of gold tailings which can be reprocessed, and demand for cyanide is likely to be robust for the next 20 years. The economics of gold tailings reprocessing is sensitive to the gold price, but at prices greater than US$1400/oz is attractive.

In 2020 when Sasol needed to sell assets to reduce its gearing it attempted to sell the cyanide business. The business was provisionally sold to the Czech company Draslovka for R1.3 billion subject to regulatory approval. Draslovka intended to refurbish the plant, increase its capacity, and invest in downstream speciality chemicals based on cyanide chemistry. After a protracted process, the Competition Tribunal blocked the sale. (Steyn, 2023b) Sasol has a sodium cyanide market share exceeding 90% in South Africa

The Sasol cyanide process produces a liquid solution. Sasol sells this solution to the mines and it is delivered directly into their tanks. Imported sodium cyanide comes in the form of sodium cyanide pellets and needs to be dissolved before it can be used in the mines. This requires a dissolving plant and very careful process and Ph control to ensure there is no release of highly toxic cyanide gas.

Most of the mines do not have dissolving facilities and are thus completely dependent on Sasol as a single source of supply for their cyanide. Any major disruption in the supply of liquid sodium cyanide by Sasol has the potential to create a significant short-term crisis for the gold mining industry. This represents a strategic risk for South Africa.

7. KEY VALUE DRIVERS FOR THE SECUNDA VALUE CHAIN

7.1. Product prices

Secunda at its heart is a liquid fuels facility producing about 60% petrol, jet and diesel together with about 40% of commodity chemicals. Globally the pricing of most petrochemicals is inextricably linked to crude oil through the conversion of crude oil fractions into petrochemicals via naphtha cracking. Secunda, unlike naphtha cracking, “assembles” longer chain hydrocarbons using Fischer Tropsch technology and produces large volumes of ethylene, propylene and other light olefins. Extraction of these other light olefins from the Fischer Tropsch fuel streams also links Secunda into the middle of the chemicals value chain.

Naphtha cracking often represents the economics of the marginal commodity chemical producer, and the production costs of marginal producers are the dominant driver of product prices. As such, any changes in crude oil pricing rapidly follow through into the commodity chemicals markets (spot pricing) and generally in a somewhat more delayed fashion into contract prices. The timing of these pass-through effects for the various Secunda products is expected to be in the order of one to three months and two to six months respectively (McKinsey & Company, 2023).

Given the above, the use of crude pricing together with crude pricing plus an adder (representing the increased variable cost of commodity chemical manufacturing together with some capital return) represents a reasonable proxy for the Secunda ex-gate sales prices.

7.2. Feedstock prices

Initially, almost all of Secunda's "energy" was provided in the form of coal both for use as a carbon source for gasification (to produce products) as well as the energy needed to operate the facility (steam and electricity).

In 2004, piped natural gas from Southern Mozambique began to be supplied to South Africa including Secunda. Natural gas is not only commonly used as an energy source but it is also a valued process feedstock in a CTL facility as it provides a rich source of the hydrogen that is also needed in the Fischer Tropsch reaction. While this hydrogen can be produced from coal via the so-called "shift" reaction, it comes at the cost of increased CO_2 emissions as well as reduced final product production.

It is estimated that around 11% of energy in the Secunda Fischer Tropsch process is derived from natural gas. The price of piped natural gas sold by Sasol in South Africa has undergone numerous regulatory and legal challenges. Using a recent price quoted by IGUA) of R68/GJ (Competition Tribunal, 2023) suggests that, on an arm's length basis, Secunda is paying roughly R4 billion for natural gas feedstock compared to around R15 billion for coal[18] (XMP Consulting, 2010). On this basis, natural gas thus represents roughly 20% of Secunda's feedstock costs.

7.3. Production volumes

Secunda, as a very large manufacturing facility, has an economic value proposition similar to other large-scale, capital-intensive facilities. As such, there is a large, fixed-cost base comprising of such things as labour and maintenance which has to be recovered from the (sometimes small) contribution margin derived from the difference between product selling prices (such as petrol and diesel chemicals) and its natural gas and coal feedstock prices.

These types of facilities are often economically delicately balanced, making large profits when production volumes are high and experiencing economic difficulties should volumes decline (FasterCapital, n.d.). While it is tempting to compare the economic dynamics of Secunda to a classical oil refinery, it is probably better thought of as a crude refinery backward integrated into a cheap crude oil source. Oil refineries have a generally very large input cost (crude oil) and economically operate in the generally small pricing space between crude oil and white product prices due to the competitive nature of global refining. Backward integration into the oil well locks in a primary feedstock cost advantage similar to Secunda's coal.

7.4. Carbon tax

Secunda is well recognised for its substantial carbon footprint comprising both Scope 1 (around 50 mtpa) and Scope 2 (10 mtpa) of CO_2. South Africa's carbon tax in 2024 was R190 (US$10) per tonne of CO_2 equivalent but was in effect much lower after "tax-free allowances" have been taken into account.

In dollar terms, even R190 per ton (for every ton) of CO_2 (around US$10/ton CO_2) is a very low carbon price compared with Sasol's European customers under European Union Emissions Trading Scheme

[18] Author calculations corrected for inflation at 5.5% per annum

(EU ETS) (Wikipedia, n.d.-c). The South African nominal price level is such that it is unlikely to result in a behaviour change. The potential expansion of the EU Carbon Border Adjustment Mechanism (CBAM) will have a dramatic effect on Sasol exports if and when it includes chemicals.

Sasol's FY2023 financials (Sasol, 2023 – a,b,c,d) reported that in FY23, it paid R1.7 billion in carbon taxes. From this, it can be estimated that for its South African operations:

- FY23 effective CO_2 price is around R29/ton on scope 1+2 emissions basis.
- Operating profit becomes zero at a carbon price of around R650/ton CO_2 Scope 1 emissions.

When compared on a dollar basis to European carbon prices, these amounts are very low at around 1.9 and 36 US$/ton CO_2 respectively[19]. Although EU ETS) prices are volatile by nature, they have moved in the range between US$45 and US$110/ton CO_2 since 2021 (Statista, 2024).

As such, current South African carbon taxes (in this form of carbon risk) under Phase 1 of the South African Carbon Act are only a small part of Sasol's FY2023 operating expenses.

Notwithstanding this, Sasol's challenge is that on a per ton basis, Secunda's products generate around 7.8 tons of CO_2/ton of carbon to manufacture. This creates a substantial GHG cost leveraging effect compared to many conventional analogues.

This places Secunda, all other things being equal, at a relative disadvantage to classical crude oil and gas-based production routes which are multiples lower at around 1.8 and 1.2 tons CO_2/ton respectively (using ethylene as a product proxy) (S&P Global, 2021).

Table 12 shows the standalone CO_2 emissions for Secunda since 2019. Earlier data is not published by Sasol.

Table 12: Secunda Scope 1 and 2 CO_2 emissions

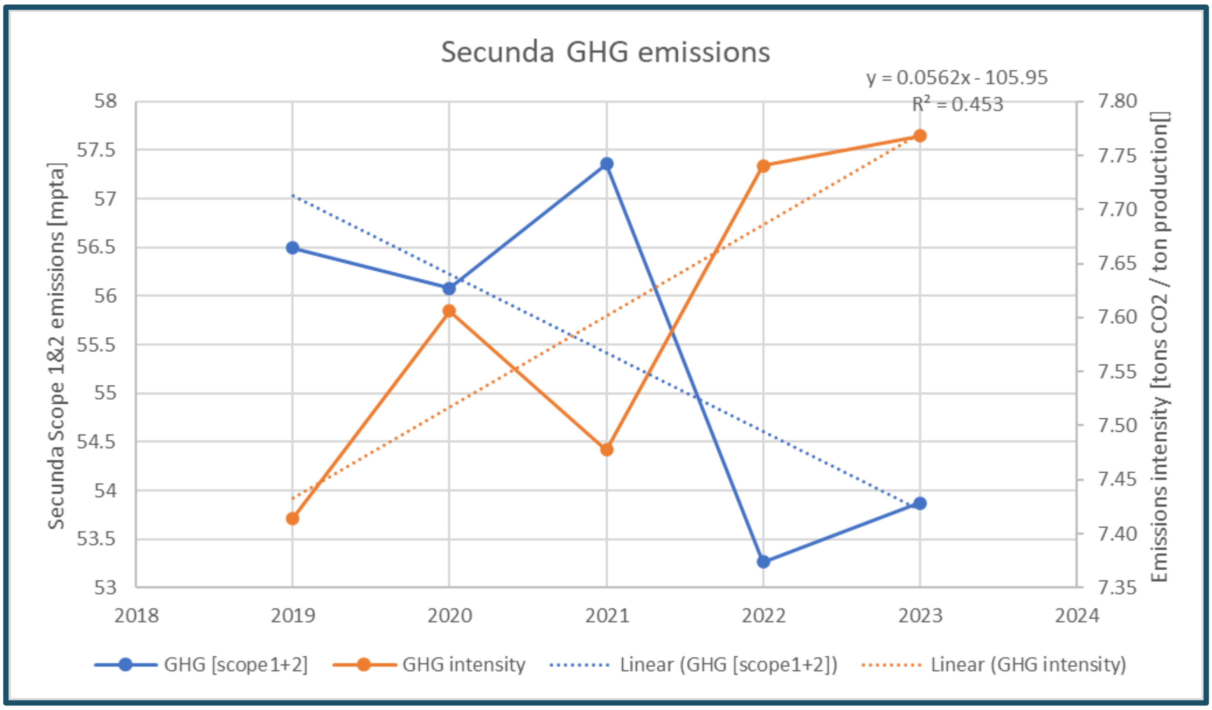
FINANCIAL YEAR ENDING IN JUNE	SECUNDA CO_2 EMISSIONS [MTPA]	SECUNDA CO_2 EMISSIONS/ TON PRODUCTION
2023	53.9	7.63
2022	53.3	7.75
2021	57.3	7.47
2020	56.1	7.61
2019	56.5	7.42

Source: Sasol, 2023c *Note:* Sasol's appears to only publish Secunda specific CO_2 emissions data from 2019 onwards in its annual Climate Change Reports.

While noisy, the recent data in Figure 14 suggest that while Secunda's absolute emissions may be declining, the intensity is actually increasing at just over 4% per year. (Sasol, 2023c) Sasol has not provided an explanation for these trends but it is possible that any deviation from stable operation starts resulting in inefficiencies.

[19] R/US$ exchange rate of 18.0 and €/US$ exchange rate of 1.1 used as basis.

Figure 14: Secunda GHG emissions and emissions intensity



Source: Authors calculations.

7.5. Fixed costs and maintenance

Controlling fixed costs is one of the corner stones of a successful commodity business, particularly so when the almost inevitable downturn in the commodity cycle arrives. Sasol's Secunda plant is almost 45 years old and could be expected to be approaching a state of needing almost "continuous replacement". As such, maintenance costs could be expected to be at the higher end of typical norms notwithstanding the nature of their process.

Generically, maintenance costs are expected to be between 2% and 4% of replacement capital (Eti et al., 2006; Rosenthal, n.d.). Valuing Secunda at around US$30 billion (Climate Policy Initiative, n.d.) suggests expected maintenance costs of between US$600 and US1200 million per annum(around R11 to R22 billion) covering reactive, predictive and preventative maintenance .

Sasol South Africa's financial results for FY2023 report (as a line item) maintenance expenditure of around R7.2 billion (Sasol, 2023d) for all its South African assets (not just Secunda). Accounting treatment may result in a reporting split in maintenance between expenses (routine actions to keep an asset in its original condition) and capital expenditures (e.g. increase an asset's useful life). As such, further capital expenditure information is provided in the 2023 Analyst's Book (Sasol, 2023e) covering the South African Fuels and Chemicals Africa value chains of amounts of R8.9 billion and R8.2 billion respectively. While reference is made to Secunda maintenance activities, these amounts also include other environmental capital projects as well as non-Secunda related scope. Assuming 50% of these amounts are Secunda maintenance related translates into a maintenance being roughly between 1.2%-2.7% of replacement value.

Given the age, nature and complexity of the Secunda operations, there is an expectation that maintenance will be on the higher end of industry norms. Maintenance is a critical component of a business as low maintenance is correlated to low productive capacity with impacts reported in the range of 5%-20% (Deloitte, 2017).

Maintenance budgets are an easy target in times of cash conservation, but this is often not a sustainable practice and comes, *ceteris paribus*, perhaps at an almost inevitable cost of lower production in future.

Sasol recently started reporting Secunda CO_2 emissions on a site basis as opposed to incorporating them in other larger metrics (regional or value chain). It would be useful if a similar approach would be adopted for the Secunda facility given its criticality in the South African value chain.

8. SIMPLIFIED ECONOMIC MODEL

A simplified techno-economic model for the Secunda site was developed by integrating and reconciling data from *inter alia* the following Sasol sources:

- Sasol Limited Annual Financial Statements for the year ended 30 June 2023
- Sasol South Africa Limited Annual Financial Statements for the year ended 30 June 2023
- Sasol Limited Production and Sales metrics for the year ended 30 June 2023
- Sasol Limited Additional Information for Analysts for the year ended 30 June 2023
- Sasol Limited Climate Change Report for the year ended 30 June 2023

The purpose of this simplified model is to capture Secunda's techno-economic performance at almost the highest possible level, while still being meaningful but without being drowned in superfluous detail that can dilute insight. The strength of this approach is that it allows for the exploration of scenarios in a manner that allows for clear traceability back to the root cause of changes. Conversely, the model has limited extrapolative powers in certain areas as many metrics are indexed off FY2023 techno-economic performance. Furthermore, in many places, information descriptors in the documentation do not fully define the legal, business or other boundaries of a "number" being presented, leading to potential double or under accounting across reference sources. See Appendix B for further details on the modelling approach.

Operationally, FY2023 appears to have been a difficult year for Sasol as it needed to import substantial amounts of coal to maximise Secunda operations. Notwithstanding this, production was materially below long-term norms and significant additional material white product[20] appears to have been purchased from the wholesale market. To somewhat normalise FY23, the effect of coal imports, white product transactions and other was reversed out of the financials to create a more meaningful operational cost baseline.

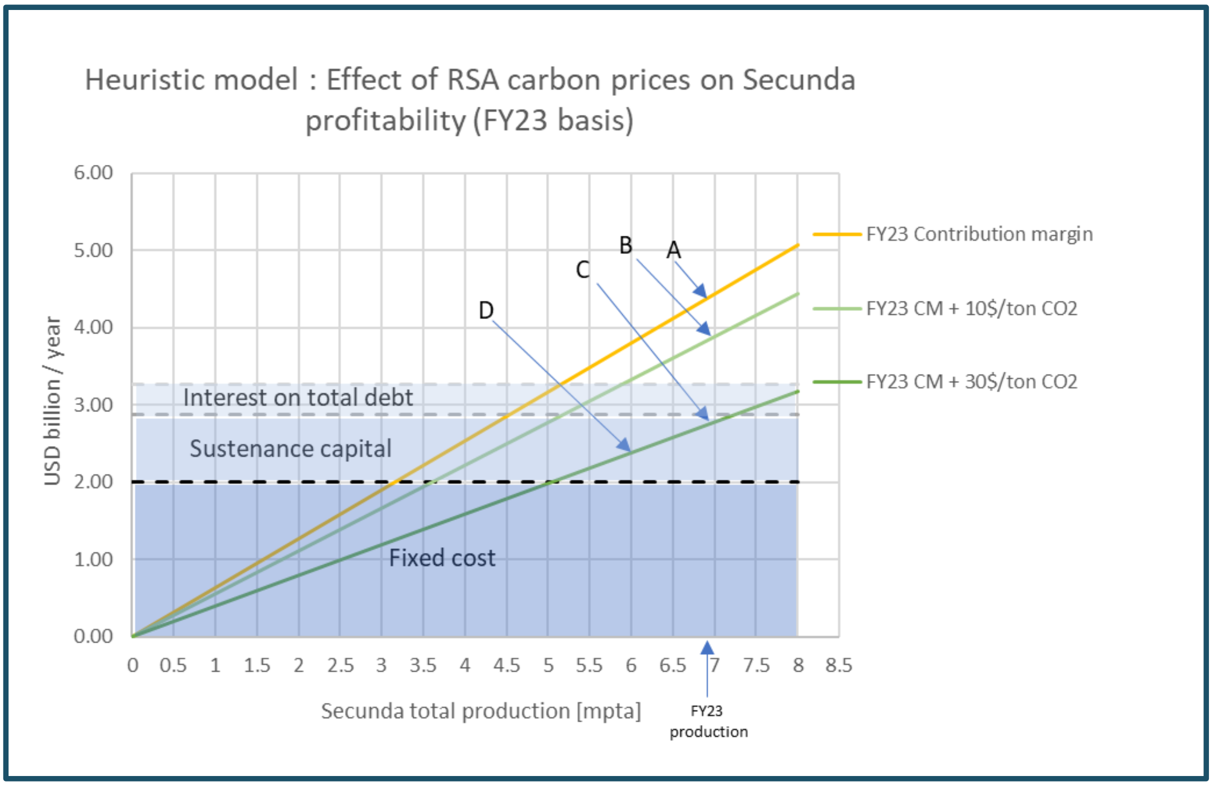
From a market perspective, is FY2023 a reasonable year against which to benchmark Sasol's economic performance? The share prices of other publicly traded integrated petrochemical companies were considered including (Shell, BP and Chevron). From this, the general outlook appears to be improving post-COVID, as would be expected. Sasol JV partner, LyondellBasell's share price is broadly flat over the same period although trending slowly upward over the FY2023 period. BASF is perhaps an exception in that its share price fell dramatically and almost immediately after the Russian invasion of the Ukraine, further exacerbated by extended decline in the level of the Rhine River hampering operations. It's share price too has been drifting upwards over the FY2023 period. Based on this, FY2023 is assessed to be a reasonable, if not slightly generous, year from which to assess Sasol from a product pricing perspective. The relevant share price information is available in Appendix D.

[20] Typically petrol and diesel.

8.1. Carbon pricing risk

The economic modelling suggests that the Secunda operation is economically vulnerable not only to increased carbon pricing but also to the more classical business risks. The effect of carbon pricing and its relation to production volumes is shown in Figure 15.

Figure 15: Effect of RSA carbon prices on Secunda profitability



Source: Authors calculations. *Note:* RSA = Republic of South Africa.

The FY23 contribution margin (represented by location A in Figure 15) includes the present day Sasol effective South African carbon price of around US$1.7/ton CO_2. At an absolute US$10/ton CO_2 price (represented by location B), Secunda is quite resilient. A US$30/ton CO_2 price highlights the South African government's target price for 2030 (represented by location C). This would place Secunda under significant financial pressure despite the (unusually) favourable tailwinds provided by crude oil prices of around US$85/bbl and crack spreads of well over US$20/bbl in the FY23 period. Secunda is breakeven on a standalone basis and would be unable to financially contribute elsewhere in the Sasol Group.

Location D is a scenario in which Sasol has reduced production by 15% relative to FY23 production levels (in support of their absolute CO_2 reduction targets) together with the target price of US$30 /ton CO_2 in in effect. Under these conditions, Secunda is cash negative even before considering additional project capital that would be required to enable a green transition.

It can also be seen that Secunda has a substantial fixed cost base assessed to be nearly US$3 billion per annum. From Graph 15, it can be calculated that Secunda needs to produce almost five million tons before reaching breakeven. This was achieved 70% through FY23. In a sense, Secunda only starts making a profit in September of every calendar year. High production is a critical factor for driving Secunda's profitability, as would be expected for a commodity business.

8.2. Other risks

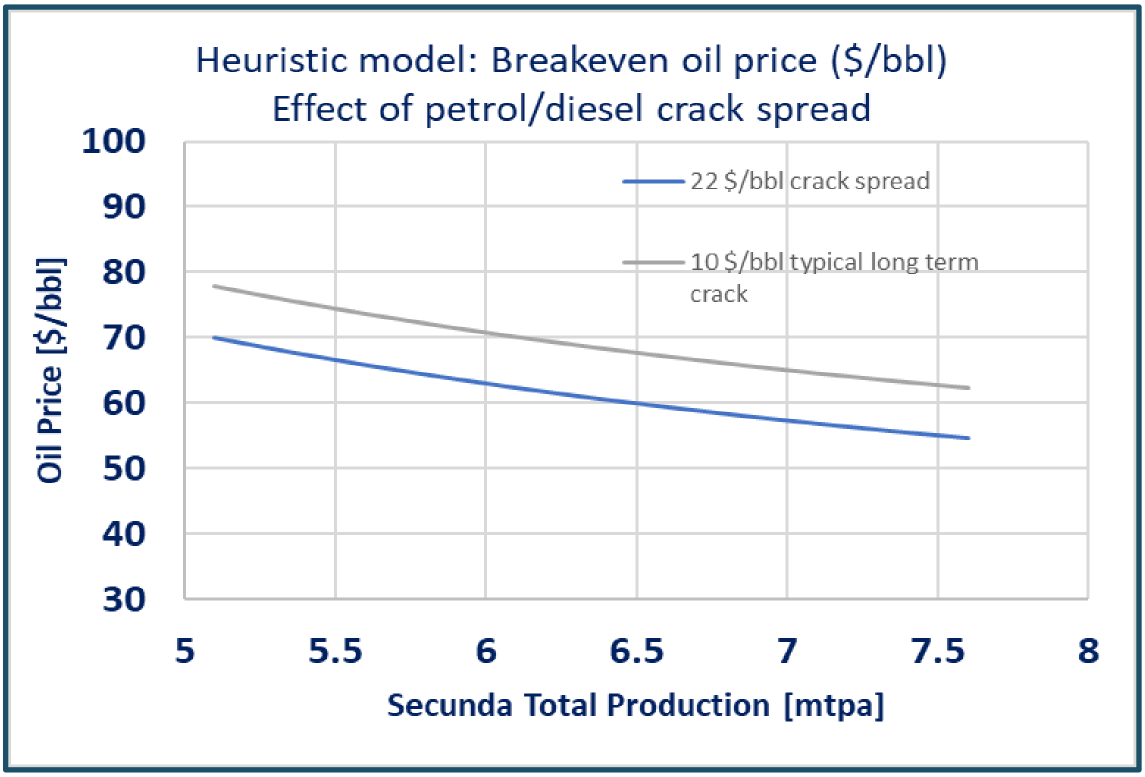
Some other potential significant economic risks that emerge from the modelling include:

- A period of lower oil prices (<70/bbl) and/or a decrease in the white product crack spread to levels closer to the cost of refinery marginal manufacture.
- Capital projects such as the pioneering coal briquetting project not performing according to plan leading to increased costs, potential commissioning and operational problems potentially affecting production and operating costs.
- Further increases in variable costs for example caused by increasing costs for additional external coal supply as outlined in the feedstock section.
- Increased capital requirements for more non-GHG related environmental compliance, for instance, sulphur abatement.
- Potential need to pay back corporate debt incurred as part of the Lake Charles Cracker Project (LCCP) given the poor financial performance of the international chemicals portion of the company.

It is also possible that some of these risk factors may occur concurrently. It is therefore not inconceivable that Secunda may face significant economic distress in the coming decade.

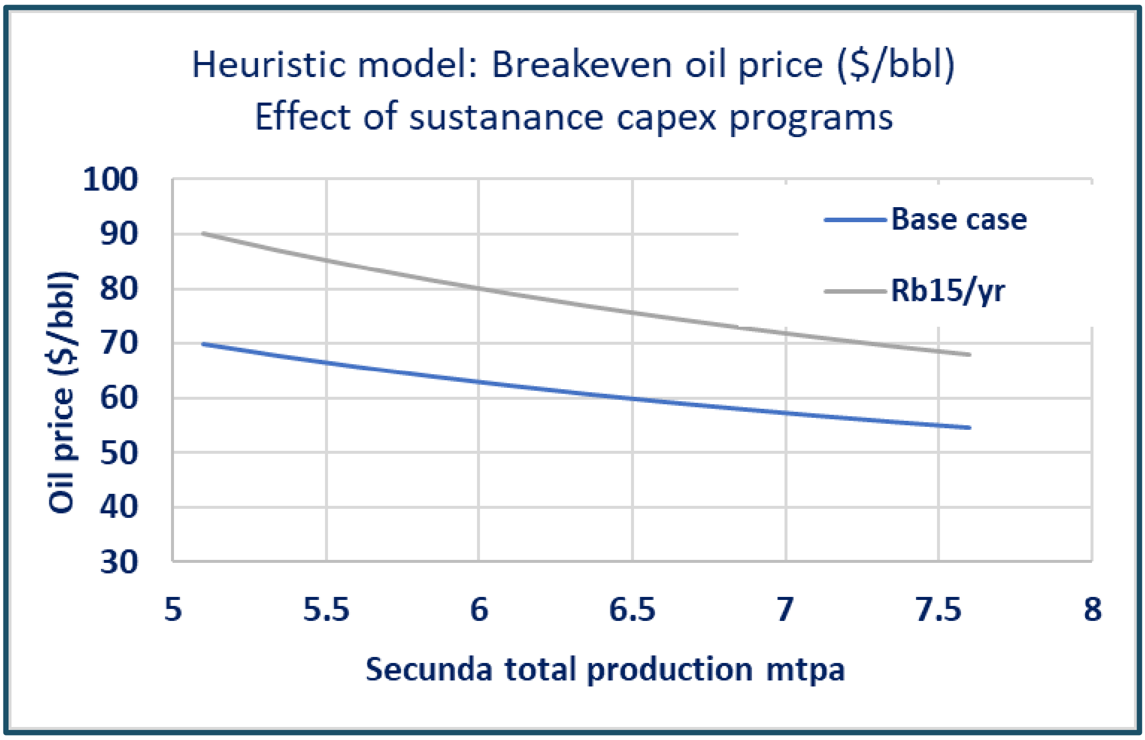
The economic model can be mathematically solved in different ways. Another interesting view is to solve for a breakeven crude oil price while varying up to two different parameters. An example of the effect of varying total Secunda production at different crude oil prices and crack spreads is shown in Figure 16.

Figure 16: Effect of varying production volumes and crack spread on Secunda breakeven oil price



Increased capital spending on new projects needed to implement the green transition program has a material effect on the breakeven crude price as can be seen in Figure 17.

Figure 17: Effect of varying production volumes and annual capital project spend on Secunda breakeven oil price



9. SASOL'S FINANCIAL CONSTRAINTS

9.1. Share price history

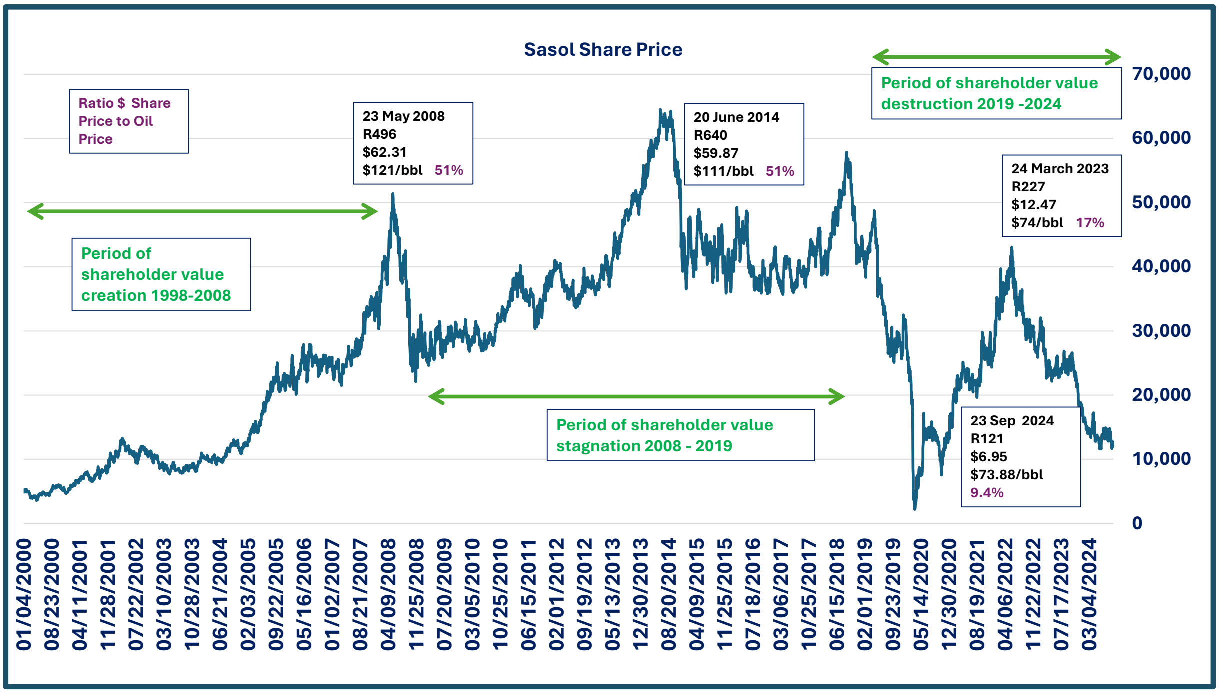
Much of this report focuses on bottom-up type analyses of Sasol's performance. Integrating this type of analysis in an appropriately weighted manner can be difficult. The share price is, however, a wide ranging top-down metric that covers all metrics that may have a financial impact (such as recent operations and market conditions) together with market sentiment (a view that oil will increase in the near future based on expectation of a war) or for strategic investors, a longer-term outlook (copper will be in demand as demand for electric vehicles increase, alternately, carbon prices will increase as awareness of the real world effects of climate change become more commonly accepted and acted on).

Over the longer run, the share price reflects the strength of a company and its ability to internally adapt to changing external circumstances with the short-term noise dissipating.

Sasol's share price is in the first order dominated by the crude oil price. To fairly assess a company's internal strength and adaptability effects it is necessary to reverse out this effect.

This has been achieved in Figure 18 by plotting both the share price as well as share price divided by the oil price. This ratio is a historically recognised heuristic metric that 50% of the oil price represents a reasonable approximation of the Sasol share price.

Figure 18: Sasol share price history



Source: Authors' analysis.

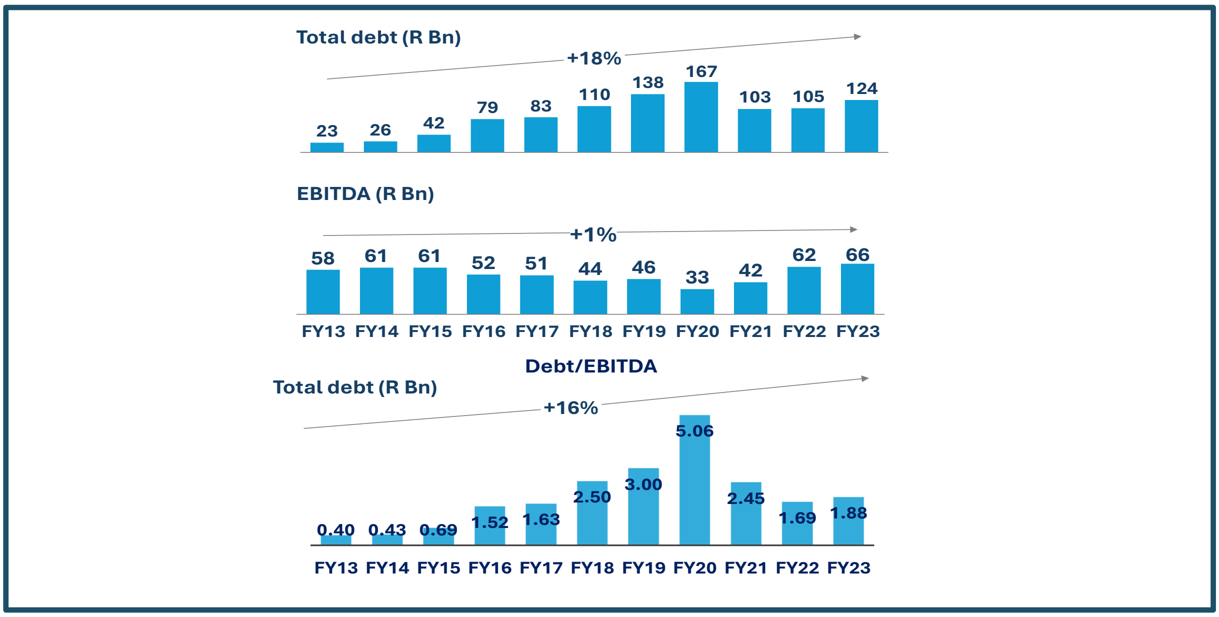
Figure 18 shows that, in recent years, this metric has been weakening from its historic 50% value down to 16% in August 2023 and to below 10% today (September 2024), continuing its precipitous decline.

It is the authors' view that, on this basis, Sasol has very limited capacity to undertake the business, economic and technical transformations needed to align Secunda with a future highly carbon constrained world. This view is discussed in more detail in Appendix D.

9.2. Sasol's debt and earnings position

In addition to exploring the Sasol share price history and narrative, it is also instructive to evaluate Sasol's debt and earnings position. The position is summarised in Figure 19.

Figure 19: Sasol's earnings and debt position



Source: Authors' analysis.

Over the last 10 years, Sasol's dollar earnings have declined by an average of 5.5% per year while debt has increased by an average of 10.4%. In 2013 Sasol had a "lazy" balance sheet with very low debt levels but the rapid increase in debt precipitated a crisis in 2020 when debt to EBITDA exceeded 5 and the sale of assets was required.

Although debt to earnings declined on completion of the asset sale programme, it has recently started increasing again. Given that Secunda production is set to decline post 2030 and further when the Mozambique gas is exhausted, this raises questions regarding Sasol's ability to pay off its debt burden while at the same time funding a green transformation. As production in Secunda declines, there will be significant pressure on margins potentially leading to further earnings declines. The declining financial position of Sasol explains the destruction of shareholder value of Sasol.

It is also worth reflecting on research on cultural issues that evolve as companies face financial distress (Finkelstein, 2012). One common feature is that a company creates an unwavering vision of what it is doing, and the vision takes on a momentum of its own. After a while, the company will tend to do things, not because they make any business sense, but because they carry out the vision. Kodak is a well-documented (University of Cambridge, 2021) and perfect example of this unrealistic vision. Although Kodak dominated film for decades, when the world shifted from analogue to digital, Kodak initially denied that there was a problem and later fell behind the innovation curve. Sadly, Kodak invented the digital camera, but the company couldn't make it work for them because the culture was first and foremost about film. Sasol is a global leader in Fischer Tropsch technology; however, FT technology has been a fringe technology in the global petrochemical scene that relies on access to cheap feedstocks and cheap capital and or subsidies for viability. The fact that none have been recently built outside South Africa, China, Qatar and Uzbekistan suggests that cheap feedstocks alone are not enough to generate an investment case. The potential production of sustainable aviation fuel (SAF) using green hydrogen and sustainable carbon presents a potential ray of hope for the survival of FT technology and a resurgence of Sasol. Sasol is doubling down on FT technology confident that it will prevail in the future. Will renewable carbon and hydrogen become cheap enough to support a renaissance? This appears to be a very risky strategy as has been outlined elsewhere in this report.

In summary, the shareholder value destruction over the last decade, coupled with increasing debt levels, forced asset sales, cultural issues identified in an independent review, and a risky future vision and strategy has been very harshly judged by the market. It remains to be seen if Sasol will be able to turn this around.

The share price embodies information about the overall health of a company and by this metric, Sasol is in its weakest position in over a decade to deal with the challenges lying ahead.

10. EXTERNAL PRESSURES ON SASOL

The external pressures being exerted on Sasol have their origins in growing global concerns about the natural environment and global warming. These have caused Sasol to adopt greenhouse gas reduction targets which has widened its risk profile:

> "The primary risks associated with achieving the 2030 and 2050 greenhouse gas reduction targets and ambition are the unavailability and unaffordability of gas as feedstock, the potentially prohibitive costs of green hydrogen, electrolysers, the lack of enabling policy and legal frameworks and the ability to access markets in the jurisdictions within which we operate and trade to enable the transition". (Sasol Limited, 2023 Form 20-F, p. 32).

10.1. Threats to local markets

Environmental concerns are expected to put Secunda's major product, petrol, at risk. This is because globally there is a shift in vehicle markets from internal combustion engines (ICE) to other forms of propulsion such as electric (EV) and hydrogen-powered vehicles. Even South Africa is offering tax incentives to those who invest in electric vehicle manufacture. (Godongwana, 2024) Electric vehicle manufacturers appear to be targeting the light motor vehicles (up to 3500 kg GVM) market, which in many countries is dominated by petrol engines. As EVs replace petrol vehicles, it is expected to result in a decline in global petrol demand and prices which will translate into a lower Basic Fuels Price in South Africa's regulated petrol prices. This will naturally impact Sasol's revenue and possibly the South African demand for petrol.

10.2. Threats to export markets

The most immediate threat to Sasol's South African exports to international markets is the EU's introduction of carbon border taxes or CBAM. Simply put, this mechanism is intended to adjust upwards (usually) the carbon tax on the product to be imported by the difference needed to match the level of tax applicable in the EU. The intent is to create a level playing field between South African producers of a chemical and a European producer in terms of the carbon taxes paid.

Secunda's use of mainly coal as a feedstock and its very large scale give the facility the dubious distinction of being the largest single-point emitter of GHGs on the planet. Some 90% of emissions from the petrochemicals and chemicals sector are caused by Sasol's Secunda and Sasolburg operations (NBI, 2021). This CBAM risk is exacerbated by South Africa's mainly coal-fired power generation (as Sasol purchases a large amount of electricity from Eskom) and its relatively low carbon taxes.

The CBAM transitional period started on October 1, 2023. South African exporters to the EU must submit onerous quarterly CBAM reports, stating their imports of the designated CBAM products, as well as the emissions "embedded" in those products. In its transitional phase, CBAM will only apply to imports of cement, iron and steel, aluminium, fertilisers, electricity and hydrogen. These reporting requirements will create a significant additional administrative burden for exporters as accurately quantifying emissions to the satisfaction of EU regulatory standards and approved independent third-party verifiers will not be a straightforward task. Rerouting of exports to other jurisdictions with less onerous requirements will be an ongoing optimisation exercise.

The transitional CBAM reporting period is scheduled to end in January 2027, after which the carbon levy under the CBAM tax must be paid. The emissions are proposed to include direct and indirect emissions occurring during the production process of the imported goods. Although CBAM does not currently apply to the export of organic chemicals to the EU, the intent is to expand its scope in future to a wider range of products as the procedural wrinkles get ironed out.

Several other countries outside the EU are considering introducing similar carbon border taxes. Countries with low domestic carbon taxes, like China, Japan, the United States and South Africa may be tempted to increase their local carbon taxes to protect their exports to those markets with carbon border adjustment taxes, creating some uncertainty for Sasol's potential investment plans. While this approach may serve to retain tax money locally in South Africa, it could have a devastating effect on companies like Sasol in the absence of some sort of carbon-tax recycling mechanism.

Looking to the future, Sasol South Africa is securing renewable energy power supplies and may be able to source additional renewable power locally. It could be argued that such power was used to manufacture their affected export products thus reducing their exposure to border taxes, but this -intensive nature of the coal-based HTFT process.

10.3. Water

10.3.1. Availability

Climate change is expected to change rainfall patterns and provinces within South Africa which are expected to experience both increasing and decreasing amounts of rainfall as well as increased extreme rainfall events (SciELO, 2012). Sasol Secunda is in an area where water availability is recognised as "stressed" or "extremely" stressed by the Aqueduct Water Atlas (World Resources Institute, n.d.). Secunda consumes roughly 87 million m^3 of water annually, which is extracted from the Vaal River system. (Sasol, 2023f)[21] This is roughly equivalent to 5% of the annual supply of Rand Water (Rand Water, 2022). Threats related to physical water supply are recognised by Sasol. Despite this large water consumption, we believe that there have not been any Secunda operational curtailments due to physical water availability constraints to date. Sasol recognises water as a key resource.

10.3.2. Quality

Of concern though, is that water quality appears to be highly variable. In its 2023 Sustainability Report Sasol reports using 13.9% less water in Secunda than FY22 being "largely attributed to an improved river water quality following favourable rains resulting in less water use per volumes of steam generated". (Sasol, 2023g)

10.3.3. Regulatory

It was recently reported that Sasol had its water use licence for its largest colliery, the 10.5 mtpa Syferfontein coal mine, rejected (Khumalo, 2023). This licence for nearly 1 000 000 m3/annum (small by Sasol standards) was reportedly rejected on the basis that "technical reports submitted by the energy major do not meet the standards for protection of resources" (Jones & Wagener, n.d.). The extent to which this reflects an updated approach by the Department of Water and Sanitation is unknown.

10.4. Other threats

Sasol's lists of risks cover over 20 pages in its 2023 Form 20-F submission to the SEC (Sasol, 2023h). This is probably a response to the litigious nature of the US business environment. Unfortunately, in line with this business environment, the ranking of these risks for financial impact and associated probability is left to the reader. This makes a practical ranking challenging and is beyond the scope of this document. Nevertheless, drawing from the South African press, common themes not already explicitly addressed in this report can be easily extracted.

These include the performance of State-Owned Entities including:

- Transnet Freight Rail (product logistics to coast).
- Transnet National Ports Authority (outbound logistics).
- Eskom (electricity supply reliability and cost).

Regulatory risk for Sasol in South Africa is significant as both petrol prices and natural gas prices are heavily regulated. Sasol's challenges with NERSA and the Competition authorities are referred to elsewhere in this document (see page 355).

A growing risk is the increasing theft and vandalism of network infrastructure such as water, electricity and liquid fuel pipelines, all of which are important to Sasol's business operations in South Africa.

[21] Assuming 7.5 mtpa Secunda production.

10.5. Conclusions on external pressures

The external pressures confronting Sasol in South Africa are collectively a daunting prospect. In the short term, Sasol may be able to reduce its dependence on Eskom's unreliable electricity supply to some extent but the rail and port risks to its exports depend on a Transnet turnaround and collaboration with Transnet where feasible. A recent Sasol announcement of collaboration with Transnet for dedicated ammonia rail cars holds the prospect of better things to come.

In the medium term, most of the pressures are related to the natural environment and send a strong message that Sasol, and Secunda in particular, need to change their technologies used in production and change their product range if they are to find environmental acceptance. Given the nature of the fixed investment in machinery and equipment, the lack of a reinvestment case (dealt with elsewhere in this report), and the unattractive economics of hydrogen and other cleaner feedstocks, these problems appear insurmountable.

11. PROSPECTS AND OPPORTUNITIES FOR SASOL SECUNDA

The National Business Initiative has stated that "The ability to decarbonise the petrochemicals and chemicals sector will depend on access to key technologies and feedstocks: Full decarbonisation of the existing synfuels production requires access to green H2 at scale below a price of USUSD2/kg and sustainable carbon feedstocks, supplied via, for example, biomass and potentially in the long-term, Direct Air Carbon Capture (DACC). For gas to support the decarbonisation as a transition feedstock, gas prices would need to be secured at an economically-viable level" (National Business Initiative, 2022:19). This section considers *inter alia* this possibility for Sasol and Secunda in particular.

11.1. Sasol's high-level response to changing business conditions

South Africa's updated Nationally Determined Contribution span an emissions range of between 350-420 Mt CO_2e by 2030. This range was submitted to the United Nations Framework Convention on Climate Change as part of the country's obligations under the Paris Agreement for the 26th Conference of the Parties, held in November 2021. Nationally Determined Contribution refers to a climate change action plan to cut emissions and adapt to climate change. Sasol's emission reduction target and roadmaps broadly support the national effort and are in line with South Africa's fair share contribution to the Paris Agreement. Sasol is targeting a 30% Scope 1 and Scope 2 greenhouse gas emission reduction by 2030, off a 2017 baseline. Scope 2 greenhouse gas emissions are defined broadly as emissions attributable to Sasol's use of purchased energy to conduct its operations.

Sasol's statement on emissions

> "We have developed plans to reduce emissions towards our targets through known, available technologies and with additional improvements in technology, efficiencies in our processes and the introduction of lower-carbon feedstocks. We set a 20% emission reduction on scope 3 Category 11: Use of Sold Energy Products by 2030, off a 2019 baseline, and a net zero ambition by 2050 for these emissions. Category 11 accounts for ~80% of Sasol's total scope 3 emissions. We have an energy efficiency improvement target of 30% by 2030, which supports our overall emission reduction efforts, by 2030 off a 2005 baseline. By 2050, we aspire to achieve net zero emissions." (Sasol, 2022d, p.16)

Sasol intends to replace coal with natural gas, sustainable biomass, and green hydrogen as sustainable feedstocks for their operations in Secunda, but it concedes that this is likely to increase the cost of production and reduce its profitability significantly. (Sasol, 2023h, p.33)

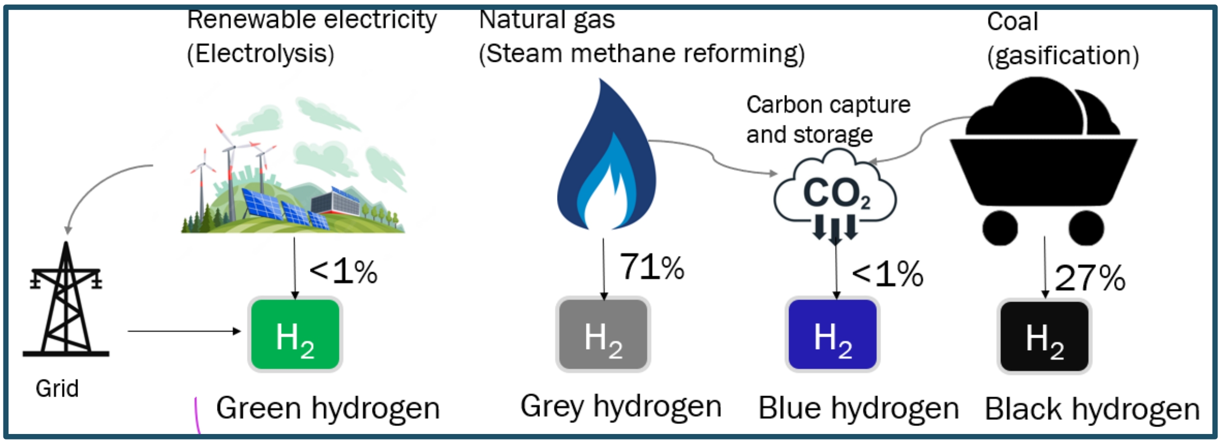
In the following sections, those options are reviewed.

11.2. Hydrogen, grey to green?

The Secunda site is one of the largest producers of hydrogen in the world. Traditionally hydrogen is produced by reforming natural gas or gasifying coal. The Secunda process produces both hydrogen and carbon monoxide, collectively termed syngas, which is the feed to the HTFT process. Hydrogen produced from natural gas is termed grey hydrogen and that produced from coal is termed black hydrogen. Both the coal and natural gas process routes produce substantial carbon dioxide emissions that contribute to anthropogenic global warming. As mentioned elsewhere in this report, Sasol is facing increasing pressure to reduce its greenhouse gas emissions and alternative carbon neutral routes to produce syngas (hydrogen and carbon monoxide) are being explored.

Recently the concepts of green and blue hydrogen have emerged. The infographic in Figure 20 shows current hydrogen production routes globally. Green hydrogen uses renewable electricity to split water into hydrogen and oxygen by electrolysis and no carbon dioxide is directly produced in this process. Blue hydrogen uses conventional gasification or reforming processes to produce hydrogen, but the carbon dioxide is captured and sequestered underground using a process called carbon capture and storage (CCS) thus avoiding carbon emissions to the atmosphere. It is important to note that almost all hydrogen currently produced is grey or black. Green and blue hydrogen, while broadly commercially proven, are not practised at scale as, in the absence of some form of a subsidy or carbon price, are not economically competitive today.

Figure 20: Infographic showing hydrogen production routes



Green Hydrogen Production

There is a developing consensus from COP26 (RMI, 2021b) and the oil and gas industry (The National, 2021) that green hydrogen will play a pivotal role in the Just Energy Transition (JET). The EU has announced that by 2030 it intends to produce 10 million tons per annum (tpa) of green hydrogen and import a further 10 million tpa. (Recharge News, 2023)

Sasol, for its part, is pursuing several green hydrogen related opportunities. It has commissioned an approximately 3MW solar photovoltaic power station enabling the production of its first commercial-scale green hydrogen from its existing assets at its Sasolburg facility (Sasol , 2023b, p.7), and has signed a 69MW 20-year wind energy power purchase agreement with the Msenge Emoyeni project (currently under construction) for the Sasolburg green hydrogen pilot project. It is also pursuing a power-to-x green hydrogen and SAF agenda through collaborative partnerships and innovation

(Sasol, 2023, p.41.) and is carrying out a prefeasibility study for a Boegoebaai green hydrogen export hub project.

The current global wave of interest in green hydrogen is the third wave, with earlier waves in the 1970s and early 2000s (Bardi, 2021). It is also important to note that industry consensus is not necessarily an accurate predictor of what will happen in the energy industry. For example, in 1970 General Electric predicted that by 2000 about 90% of the United States's electricity would come from fast breeder nuclear reactors. Only two were ever built and fast breeder reactors were a costly failure (Smil, 2021).

11.3. Conversion of the Secunda HTFT Process to Green Feedstocks

To explore the potential conversion of the Secunda HTFT process to green hydrogen, some simplified high-level technical and economic calculations will be performed as a thought experiment to explore the viability of this option. This starts with the simplified overall stoichiometry of the FT reaction as follows:

$$CO + 2H_2 \rightarrow CH_2 + H_2O$$

Equation 1: Simplified Fischer Tropsch Reaction

One mol of carbon monoxide plus two moles of hydrogen provide one mol of hydrocarbon product and one mol of water. It is worth noting at the outset that only half of the feed hydrogen is converted to useful products with the other half being converted to water which has no commercial value. This is an inherent inefficiency where you start with water and convert half of the valuable green hydrogen back to water. If one takes the total output of hydrocarbons from Secunda as 7.5 million tpa then the hydrogen required for this is 1.07 million tpa. This needs to be doubled to consider the water production so an absolute minimum of 2.14 million tpa of hydrogen is required (as process inefficiencies are not included).

It is useful to obtain a rough estimate of what the capital costs for producing this amount of green hydrogen would be. A report by the Institute for Sustainable Process Technology (ISPT) for the total installed costs (TIC) for a gigawatt scale green hydrogen in the Netherlands is a valuable reference (ISPT, 2020). A TIC cost is used to make a FID for a capital project in the petrochemical industry and includes all the offsites, balance of plant, utilities and infrastructure to deliver a fully functioning and operational plant.

As technology development relating to optimal electrolyser technology is still in progress, the ISPT considered the two most commercially advanced technologies: alkaline electrolysers and proton exchange membrane (PEM) electrolysers. ISPT prepared a cost estimate within a –25%/+40% range (complying with the Class IV level of the Association for the Advancement of Cost Engineering). The estimated cost intensities and production figures are shown in Table 13.

Table 13: Capital cost estimates for total installed costs for a 1GW green hydrogen plant

	Alkaline Technology	PEM Technology
Hydrogen production capacity (tpa)	165 000	150 000
Capital Cost (€ billion)	1.4	1.8
Capital intensity (€/kW)	1400	1800
Capital Intensity (€/kg/day) hydrogen)	3100	4400

Source: ISPT, 2020.

The International Renewable Energy Agency (IRENA) has also estimated capital costs for green hydrogen production (IRENA, 2020). IRENA has used a capital intensity assumption of US$1000/kW for a green hydrogen plant which is significantly lower than the estimated €1400-1800 of ISPT. ISPT acknowledges that its capital figures are higher than usually reported figures because of different definitions, such as direct costs for system supply and installations and owners' costs. ISPT comprehensively estimates total installed costs, which are the correct basis for final investment decisions. It is also worth noting that these capital estimates were performed in 2020 and costs will likely have increased with inflation. For this simple analysis, this inflation will be ignored.

Although alkaline technology is better from a capital intensity perspective, PEM technology has other potential advantages. For this simple analysis, alkaline technology will be assumed as the cheaper alternative. Given the modular nature of electrolysers, it is assumed there will be no meaningful economy of scale in the capital cost of the green hydrogen plant and the costs are scaled linearly. The capital cost estimate for the required 2.14 million tpa of green hydrogen is €18 billion and will require 18.2GW of renewable electricity continuously. Even if an economy of scale exponent of 0.8 (Newnan, et al, n.d.) is assumed. the capital cost is €11 billion (R220 billion). These are sobering figures. The capital cost is more than three times Sasol's market capitalisation.

The 18.2GW of renewable electricity needs to be supplied on a continuous basis. The Secunda HTFT complex cannot be run on an intermittent basis and takes many days to start up and shut down safely. If one considers that South Africa's current electricity demand is about 25GW, this represents more than 70% of current demand. The variable nature of renewable energy also needs to be considered, and if a conservative capacity factor of 25% is assumed then an installed capacity of 73GW will be required. Perhaps an electricity utility can be contracted to supply this, but it is worthwhile to consider the capital investment required for this. If one considers solar photo voltaic (PV) technology, the world's largest solar PV farm is in India and generates 2.25GW and costs US$1.3 billion (Ornate Solar, 2024). Assumings a capital intensity of US$1 million per megawatt (Coldwell Solar, n.d.), then a capital investment of US$32 billion (R640 billion) will be required. One may speculate to what extent solar PV costs may still come down but even if they do, the capital outlay will be very significant.

Alternately, there is the issue of electricity storage so that renewable electricity can be supplied when the sun is not shining, or the wind is not blowing. On a sunny day, 54 GWh of storage would be required. One could store hydrogen and operate hydrogen turbines and the cost of that would be evaluated. Pumped hydro is by far the most used electricity storage technology in the world and if you optimistically assumed a capital cost of US$400/kW (Galvan-Lopez, 2014) and an 80% efficiency for pumped hydro then an additional US$9 billion would be required for that. Transmission costs and infrastructure would also need to be considered.

Optimistically, more than US$50 billion (R1 trillion) of capital investment would be required to supply Secunda with 2.14 million tpa of green hydrogen on a continuous basis.

Quite apart from the enormous capital cost involved, it is useful to step back and consider the logic of using 18.2GW of electricity to make mainly petrol, whose main application is for passenger car vehicles. The HTFT process's main product is petrol, and a modern and efficient petrol vehicle has an efficiency of about 30% (Wikipedia, n.d.-d). Battery electric vehicles have an efficiency close to 80% (FuelEconomy.gov, n.d.). The question then needs to be asked if it is sensible to use renewable electricity to make petrol rather than using it directly to power a battery electric vehicle. Surely the US$50 billion of capital would be better placed incentivising electric vehicle demand?

The white hydrogen wildcard

White hydrogen, which is also known as natural hydrogen or gold hydrogen, is hydrogen that is formed by natural processes as opposed to hydrogen produced in an industrial process such as green, grey or blue hydrogen. It is non-polluting and potentially offers lower costs than industrial hydrogen. Natural hydrogen has been identified in many source rocks in areas beyond the sedimentary basins where oil companies typically operate (Deville and Prinzhofer, 2016).

Reserves have recently been identified in France (Paddison, 2023). In 2023 French researchers Jacques Pironon and Philippe de Donato announced the discovery of a deposit they estimated to be some 46 million to 260 million metric tons (several years' worth of 2020s production). This has generated significant excitement regarding potentially cheap and abundant white hydrogen. If this proves to be true it could be transformational.

However, caution is advised. White hydrogen extraction is a nascent technology and there are significant uncertainties. Even if white hydrogen turns out to be plentiful (which is a big if), it will be energy-intensive to extract, store and transport. In natural reservoirs, hydrogen is often mixed with other gases from which it must be separated. And it is also sometimes found dissolved in liquid and so must be extracted from the liquid after that liquid is pumped to the surface. What will the cost of getting at the pure hydrogen gas be? No one knows for sure because reservoir extraction has never been done on a large scale. Separating hydrogen from other gases would likely be done by liquefying the gases at very low temperatures and then distilling off each one. This is extremely energy intensive (Cobb, 2023). There is also the problem of storage and transport to the point of use. Almost all hydrogen used today is made on the site where it is used.

It is also uncertain whether there are white hydrogen reserves close to Secunda. White hydrogen in the Secunda context should therefore be viewed as very speculative and an improbable wildcard. Nevertheless, developments in white hydrogen development should be tracked.

Sustainable Carbon Supply

One now also needs to consider the carbon source. Currently, Secunda's carbon source is fossil-based natural gas and coal. In Sasol's journey to carbon emission reductions an alternative non-fossil-based sustainable carbon source is required. Two alternatives are currently being considered by Sasol biomass and carbon capture (Sasol, 2023b). Both options face considerable challenges and high costs.

Sustainable Biomass

First, let's consider sustainable biomass. The Secunda complex as well as the coal power stations in Mpumalanga were deliberately sited next to large coal fields. The ideal and most cost-effective means of coal supply is utilising a conveyer directly to the Secunda complex. In addition to cost effectiveness, coal quality control is significantly simplified if coal is delivered by conveyor. This is equally true for power stations. The Secunda coal supply situation is discussed in Section 5.2.1.

A great deal of attention is often paid to the pace of technical innovation needed for the shift from a world dominated by fossil fuel combustion to one relying increasingly on renewable energy conversions and the use of biomass. One also needs to consider the spatial dimension of replacing coal and gas with biomass. The energy scholar, Vaclav Smil, has studied this issue extensively (Smil, 2010).

Smil considers the amount of land required for electricity generation for a typical coal field. He estimates a coal field has a power density of about 4.8 kW/m^2. This means that each square metre of coal field can deliver 4.8 kW of electricity for the lifetime of the coal field.

Smil then considers what would be required for a wood-fired power station of 1GW. The best conversion rates for trees grown for energy can be achieved in intensively cultivated monocultural plantations. Using tree phytomass, extensive tree plantations would have to be established, which would require fertilisation, control of weeds and pests and, if needed, supplementary irrigation – and even then, harvests surpassing 20 t/ha could not be expected. Rates in less favourable locations are as low as 5-6 t/ha with the most common yields around 10 t/ha. Such a plantation would yield no more than 190 GJ/ha/yr, resulting in a harvest power density of 0.6 W/m2. This means that a land area 8000 times larger than a coal field of equivalent output is required.

A wood-fired power plant with an installed capacity of 1 GW, capacity factor of 70% and conversion efficiency of 35% would require an annual harvest of about 330 000 ha of plantation growth, an equivalent of a square nearly 58 x 58 km. Burning of wood for electricity is thus not feasible for large scale electricity generation. It is also important to consider the implications of setting up such a huge tree plantation and the time it would take for the trees to reach maturity, not to mention the harvesting and delivery costs.

The same logic applies to the use of wood as a sustainable carbon source for Secunda. Any form of biomass other than wood will be even less efficient. The use of biomass as a sustainable source of carbon for Secunda on a large scale is thus not feasible.

Sustainable carbon dioxide

Second, sustainable carbon dioxide for use as a feedstock. It is first necessary to examine what is meant by sustainable carbon dioxide. One option is to utilise carbon dioxide from other industrial processes, such as coal-fed power plants such as Kusile, or other power stations in Mpumalanga. Other industrial facilities such as cement factories could also be considered. Coal power stations produce flue gas. The carbon dioxide content of flue gas is typically in the range of 10%-15%. This needs to be captured and purified before Sasol can use it.

Purification of flue gas

Post-combustion capture of flue gas involves treating the flue gas with a solvent or absorbent to selectively capture CO_2. The most commonly used solvents are aqueous amines. The flue gas is typically passed through an absorber column where CO_2 is absorbed into the solvent, while other gases such as nitrogen (N_2) and oxygen (O_2) pass through unhindered. The CO_2-rich solvent is then regenerated in a separate column, releasing concentrated CO_2 for further processing or storage.

The energy requirements for post-combustion CO_2 purification primarily depend on the regeneration process, which typically involves heating the solvent to release the captured CO_2. Energy is also required for operating pumps, fans, and other auxiliary equipment. The energy demand for solvent regeneration can be significant and will negatively impact the overall efficiency of the purification system. Efficient heat integration and process optimisation can help minimise energy consumption. The source of the energy required needs to be considered and should ideally be a renewable energy source to avoid further CO_2 emissions.

An estimate of the capital costs for a purification plant retrofitted to a conventional steel mill is about US$65/ton CO_2/year (National Energy Technology Laboratory, 2022). Assuming a Secunda carbon requirement of 6.4 million tpa, this equates to a CO_2 requirement of 23.5 million tpa because of the weight of the oxygen molecules present in carbon dioxide. The capital cost can be approximated as US$1.53 billion x 8 years payback = US$12 billion (approximately R228 billion). This does not include the cost of piping the CO_2 to Secunda from a power station, which would add a significant further cost. This seems unaffordable for Secunda compared to eight years of Sasol's own coal costs at approximately R200 billion (Table 14), given the higher value of coal compared to CO_2.

Table 14: Estimate of Secunda costs of coal

	Mt p.a.	R/ton	Cost R mil
Own coal	30.8	R 560	R 17 248
Purchased coal	10	R770	R 7 700
			R 24 948
8 years			8
Cost of 8 years coal			R 199 584

Apart from the capital requirements for CO_2 purification from flue gas, there are two serious further concerns regarding this source of CO_2. First, recovery of CO_2 from flue gas is not sustainable as it ultimately involves sourcing carbon from fossil fuels and converting that to petrol and diesel in Secunda which then gets combusted releasing fossil-based CO_2 into the atmosphere. Thus, the use of flue gas-based anthropogenic CO_2 is not compatible with net zero ambitions and will also not be acceptable to climate activists who are already exerting significant pressure on Sasol.

Second is the need to consider the security of supply of this CO_2 source. As pressure builds to reduce CO_2 emissions and coal-based power stations reach the end of their lives this source of CO_2 will most likely decline. The security of supply of feed over at least 15 years of operation to justify the significant capital investment is inherently uncertain. It is thus concluded that flue gas capture and purification is not a viable or sustainable source of CO_2.[22]

Synthetic Direct Air Capture (SDAC)

Direct air capture (DAC) is a process of capturing carbon dioxide (CO_2) directly from the ambient air (as opposed to capturing from concentrated point sources, such as a cement factory or biomass power plant) and generating a near pure stream of CO_2 for sequestration or utilisation or production of carbon neutral fuel and chemicals. SDAC refers to a man-made chemical processing plant to remove carbon dioxide from the air.

Ambient air is sucked in through large fans and is then treated with a chemical sorbent (liquid or solid) to capture CO_2. Thereafter it is heated to extract CO_2 (Ozkan et al., 2022). This CO_2 could then be used as a feed for the Secunda plant. SDAC is an energy intensive and capital-intensive process vastly more difficult than capturing industrial (concentrated) CO_2 as dictated by the laws of thermodynamics. To be carbon neutral, it will be necessary to use renewable energy to operate these processes.

Theoretically and optimistically, DAC costs can potentially be reduced to US$150/ton CO_2 (WRI, 2023) although current costs are significantly higher. The Secunda CO_2 feed requirement is 23.5 million tpa. This equates to a cost of US$3.5 billion pa. If the Secunda product output is 7.5 million tpa, then this constitutes a CO_2 feedstock cost of US$470/ton. This equates to about US$56/bbl of oil equivalent on

[22] The newest coal-fired power stations (Medupi and Kusile) will only be completed in 2024/25 and have 50 year useful lives. In the emerging electricity market they are likely to be stranded assets. Captured carbon from those stations may give them another revenue stream that may reduce electricity costs for SA.

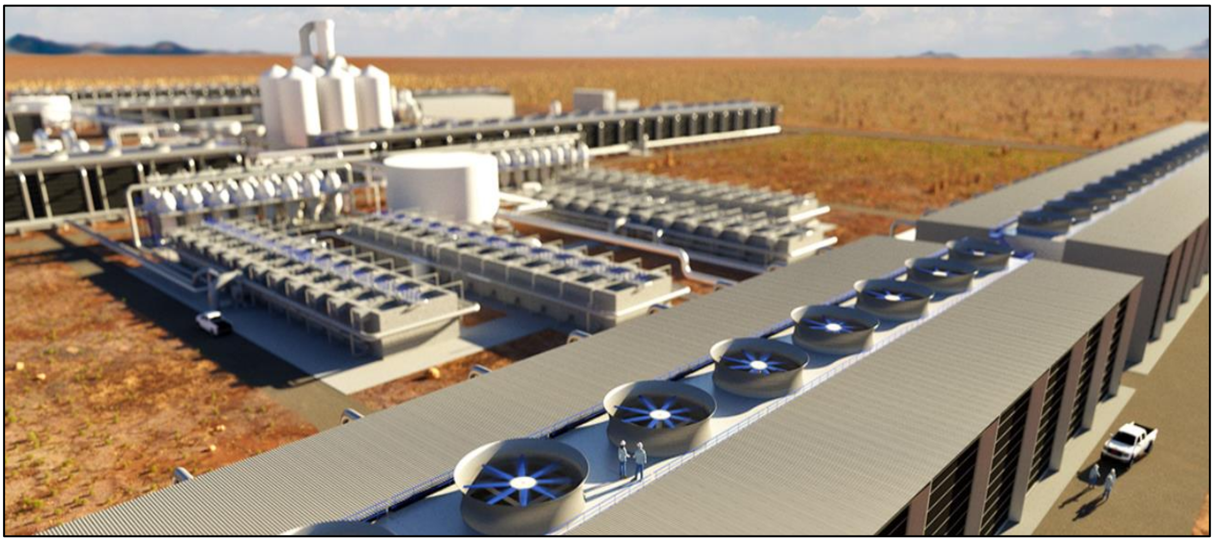
its own. This, on its own, illustrates that SDAC is not feasible for Secunda as the other production costs constitute an additional US$56/bbl.

The energy requirement for SDAC, depending on the technology used, is in the range of 180-500 MW per million tpa of CO_2. (CarbonPlan, n.d.) This equates to 4.3-11.8 GW of renewable energy required. Assuming a capacity factor of 25%, this translates to a renewable energy capacity requirement of 17-47 GW. This needs to be added to the 73 GW requirement for green hydrogen production.

Future carbon capture cost estimates for SDAC are wide-ranging and uncertain, reflecting the early stage of technology development, but are estimated at between US$125 and US$335 per ton per year of CO_2 for a large-scale plant built today (IEA, 2022). It is speculated that with deployment and innovation capture costs could fall to US$100 per ton per year. Based on this optimistic assumption a capital cost estimate of about US$2.35 x 8 years = US$18 billion (R324 billion) is proffered for SDAC for Secunda.

It is also worth stepping back and considering the basic thermodynamics of SDAC. In round numbers, the atmospheric CO_2 concentration is 420 parts per million (ppm) on a mass basis. This means that to recover one ton of CO_2 you need to process at least 2500 tons of air. An artistic rendering of what a large scale SDAC would look like is shown in Figure 21. The second law of thermodynamics is not a concept that is well understood among the non-technical fraternity, but it is one of the most basic laws of nature. The renowned Scottish physicist James Clerk Maxwell stated, "*the 2nd law of thermodynamics has the same degree of truth as the statement that if you throw a tumblerful of water into the sea, you cannot get the same tumblerful of water out again*". (Maxwell, 2024) Purifying anything from a very dilute stream is inherently difficult. Humans have been purifying gold from dilute ores for centuries and a reasonable ore grade is 4 g/ton or 4 ppm. Even after centuries of improvement in gold extraction technology, it remains expensive. The only reason it makes sense is that gold is very valuable. One gram of gold is worth US$56, which converts to US$56 million per ton. The SDAC problem is fundamentally difficult from a thermodynamic perspective and there is no cheap technology on the horizon. Also, the commodity nature of the products being replaced means that economic viability cannot be achieved through selling price either. SDAC is unlikely to be a viable option as a CO_2 source for Secunda.

Figure 21: Artistic rendering of a 1 million tpa scale SDAC plant



Source: Sustainable Ships, 2020.

The energy balance of CO_2 as a Secunda feedstock

One final thing that needs to be considered to complete the discussion on potential sustainable CO_2 for Secunda is the energy balance relating to using CO_2 as a feedstock. CO_2 is a combustion product and needs to be converted to CO via the water gas shift reaction before it can be fed into the Secunda HTFT process. This is an endothermic reaction which means that energy is required to drive this reaction.

The water gas shift reaction is shown in Equation 2.

$$CO_2 + H_2 \rightarrow CO + H_2O$$

Equation 2: Water gas shift reaction

This means that additional hydrogen (and capital) is required, over and above that required for the FT reaction to convert CO_2 to CO. Thus, to process 23.5 million tpa of CO_2 an additional 1.07 million tpa of green hydrogen production will be required. This needs to be added to the 2.14 million tpa of green hydrogen required for the FT reaction bringing the total green hydrogen requirement to 3.21 million tpa. The capital costs and energy requirements for green hydrogen production will need to be proportionately scaled up to account for this additional green hydrogen production.

Concluding remarks regarding the conversion of the Secunda HTFT process to green hydrogen and sustainable carbon

Although the analysis that has been performed is a high-level analysis in the form of a Fermi analysis (Wikipedia, n.d.-e) it is sufficient to illustrate the cost and complexity of converting Secunda to green hydrogen and sustainable carbon.

A Fermi analysis, named after the Italian-American physicist Enrico Fermi, is a method used to make rough estimates and approximate calculations for solving complex problems, often with limited information or data. Fermi analysis is particularly useful when precise measurements or detailed information are not available or when dealing with large uncertainties. It allows individuals to quickly arrive at reasonable estimates by making simplified assumptions and using basic principles. It helps individuals develop intuition, gain insights into complex systems, and make informed decisions even with incomplete information.

Further detailed technical and economic analysis is always possible and this can involve significant further work, time and cost. This analysis is just the beginning step of a more detailed analysis. More detailed analysis is beyond the scope of this work. Given the results presented in this report, and assuming that there are no significant mistakes in this analysis it does, however, beg the question as to whether a more detailed analysis is warranted.

This analysis casts significant doubt on the feasibility of converting the Secunda HTFT process to green hydrogen and sustainable carbon and the virtue of adding more detail and granularity utilising more detailed studies may be subject to question. If more detailed studies are performed, this analysis should serve as a useful check regarding the key parameters of the more detailed analysis.

11.4. Switch from HTFT to LTFT?

Sasol is also considering so-called e-kerosene for use as a SAF. In 2022 the launch of an FT catalyst research programme, entitled Catalyst Research for Sustainable Kerosene, to be funded by the German Federal Ministry of Education and Research and Sasol was announced (Sasol, 2022e). Unlike conventional kerosene derived from fossil feedstocks, e-kerosene SAF[23] can be made from green hydrogen and sustainable carbon dioxide sources using the Sasol low-temperature Fischer Tropsch (LTFT) process. The desire to produce sustainable aviation fuels stems from the fact that air transport has been identified as one of the "hard to abate" sectors in the global economy. This may provide Fischer-Tropsch-based processes with a competitive edge in this area as there are very few direct substitutes for aviation fuel.

The current Secunda HTFT process is not well suited to produce high yields of aviation kerosene (it favours the lighter petrol product), and it has already been concluded that it is not likely to be viable to convert the current HTFT plant to green hydrogen and sustainable carbon feedstocks.

However, the LTFT process is well suited to producing aviation kerosene. The Oryx gas-to-liquids (GTL) facility (in Qatar) using Sasol LTFT technology has also commercialised the use of GTL jet fuel for commercial aviation (Hydrocarbon Processing, 2013; Aviation Pros, 20099). GTL jet fuel has passed the stringent regulatory requirements for use in commercial aviation in blends of up to 50%.

Sasol's LTFT process has a jet fuel yield of more than 60% by mass (Google Patents, 2010) and ongoing research efforts are seeking to increase this yield. In its capital markets day presentation for the Energy business of 2021, it was proposed that a part of Secunda could be converted to LTFT to produce 20 000 bbl/day of SAF (Mabelane, 2021). It is then suggested that if suitable economic conditions prevail further transition to SAF may be possible.

The partial or complete conversion of Secunda to LTFT will have profound implications for the chemical value chain supported by the HTFT process and a further decline in chemical production could be expected.

To complete this analysis, it is instructive to illustrate the overall chemical equation for producing SAF from CO_2 and green hydrogen by adding Equations 1 and 2 together to provide the overall reaction for the process in Equation 3.

$$CO_2 + 3H_2 \rightarrow CH_2 + 2H_2O$$

Equation 3: Overall reaction for the production of SAF from hydrogen and CO_2

This shows that 3 moles of hydrogen is required for each mole of SAF produced and 2 moles of water is produced. An optimistic assumption for a CO_2 price is US$150/ton, and current indications for green hydrogen prices at the factory gate is about US$5000/ton, with hopes to reduce it to US$2000/ton in the coming decades as green hydrogen production improves with learning and scale (IRENA, 2020). The feedstock cost for SAF is shown in Table 15.

Table 15: Feedstock costs for sustainable aviation fuel

CO_2 PRICE US$/TON	HYDROGEN PRICE US$/TON	SAF FEEDSTOCK COST US$/TON	SAF FEEDSTOCK COST US$/BBL
150	2000	857	109
150	5000	2614	333

Thus, for current estimates of green hydrogen costs and CO_2 costs the feedstock cost for SAF is US$333/bbl. This does not include the requirement to add the operating costs and capital rewards

[23] Electrofuels, also known as e-fuels, a class of synthetic fuels, are a type of drop-in replacement fuel. They are manufactured using captured carbon dioxide or carbon monoxide, together with hydrogen obtained from water split by sustainable electricity sources such as wind, solar and nuclear power. e-kerosene refers to a subcategory of e-fuels suitable for aviation. Synthetic kerosene can mean e-kerosene, but can also refer to other means of producing kerosene, for example directly from coal as occurred during the second world war

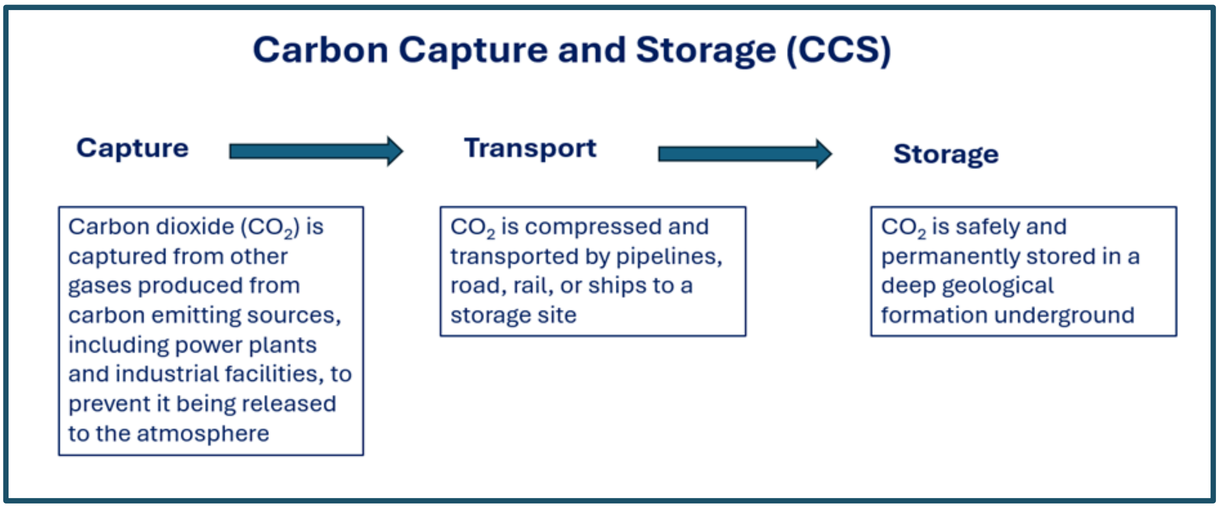
required for an LTFT plant. In addition, it has been assumed that the yield of the LTFT plant will be 100% (Fermi calculation) SAF whereas, in reality, the yield will at best be 65% with the remainder being a synthetic naphtha which will most likely have a much lower value than SAF. The full cost for SAF is thus likely to exceed US$500/bbl compared to the 3 March 2024 price of Jet A1 fuel in South Africa, US$83/bbl.

It is beyond the scope of this report to investigate the viability of Secunda-based SAF other than to emphasise that partial or complete conversion to LTFT will see a further decline in existing chemical production. A complete conversion of Secunda to green hydrogen, sustainable carbon, and SAF would entail a complete rebuild of the Secunda complex. Nearly all of the economic feedstock analysis that was applied to assessing the green conversion of an HTFT Secunda facility would apply. However, additional capital would be required to convert Secunda to a LTFT process; the existing SAS reactors can potentially be repurposed to LTFT which can save some capital.

11.5. The viability of carbon capture and storage (CCS)

CCS, often referred to as carbon capture and sequestration, is a suite of technologies and processes designed to capture carbon dioxide (CO_2) emissions from various sources, prevent them from being released into the atmosphere, and securely store or sequester the captured carbon in a way that prevents its contribution to climate change. An infographic summarising the technology is shown in Figure 22.

Figure 22: Schematic infographic of carbon capture and storage



CCS has been touted as a potential route to decarbonisation, but the technology is challenging and costly. CCS is an old technology, first developed in the 1970s. Despite its long history, carbon capture is a problematic technology. An Institute for Energy Economics and Financial Analysis study reviewed the capacity and performance of 13 flagship projects and found that 10 of the 13 failed or underperformed against their designed capacities, mostly by large margins (IEEFA, 2022).

From a South African government perspective, the management of CCS in South Africa was originally housed under the South African National Energy Development Institute (SANEDI). Interest in CCS appears to have started in 2004 with a study by the CSIR on theoretical CCS storage potential. This study was followed in 2010 by the publication of a Carbon Atlas, which indicated 1.5 Gigatons of storage capacity, 98% of which was offshore (and thus distant from the majority of CO_2 source centres). The next phase was identified as a small-scale CCS pilot project (PCSP) supported by World Bank funding in the Zululand basin area. (Global CCS Institute, 2023) A project document with a value of US$36.5 million was signed between the World Bank and the National Treasury in late 2017 targeting a completion date of December 2021. (World Bank, 2019)

In September 2020, responsibility for PCSP was transferred to the Council for Geosciences (Surridge, et al., 2021). The search for storage sites subsequently moved from the Zululand area to the Mpumalanga Province being physically closer to the source of emissions. A recent World Bank Implementation Status & Results Report (October 2023) indicates that the PCSP project completion date has been moved out by roughly three years and the project has substantially de-scoped. The overall project risk rating continues to be shown as high. (World Bank, 2023a)

Sasol identifies deploying affordable carbon capture, utilisation and storage as part of a set of potential post 2030 GHG reduction options (Sasol, 2021). It also acknowledges the risks: "CCS is in its infancy in South Africa. While Sasol has an advantage because our process CO_2 is already captured, we have yet to prove the viability of storage." (Sasol, 2021)

Irrespective of the viability of CCS technology storage requires deep saline aquifers or depleted oil and gas reservoirs to store the carbon dioxide (UNFCCC, n.d.a). Neither of these are available in proximity to Secunda.

The above discussion deals with the technical aspects of CCS. Overlaying this is the need for a legal and regulatory landscape to frame the implementation of a CCS project. The integration of CCS into an existing legal framework is a significant activity on its own (Glazewski et al., 2012; World Bank 2023b) and little progress appears to have been made in this area.

In light of the above 20 years of research and progress, the commercial implementation of CCS within South Africa may still only occur many years into the future and most likely not within a timeframe and scale to allow the Secunda site to meet its future CO_2 emissions targets.

11.6. Conclusions on Secunda's prospects and opportunities

While some progress will no doubt be made on incremental steps in the decarbonisation of Secunda, it is not readily apparent that deep decarbonisation of Secunda is economically viable. Secunda was located on a large coalfield as this was economically sensible at the time. While the manufacture of synfuels may be developed elsewhere in the world, the new locations under consideration have access to low-cost natural gas, geology suitable for CCS opportunities, large biomass concentrations, and excess renewable power in addition to a favourable investment environment. Consequently, the South African government needs to carefully consider what medium-term alternatives are available to it.

12. GOVERNMENT POLICY OPTIONS

12.1. Policy conundrums and contradictions

Secunda's capacity to add significant economic value is derived from the fact that it significantly upgrades the value of South African coal. From a South African perspective, this coal effectively comes at a zero cost (leaving aside for a moment consequential effects such as air emissions). The minerals mining industry is perhaps another excellent example of an industry in this category. An opposite example would perhaps be conventional crude oil refining in that in today's terms, US$80/bbl of cost has to be imported and only US$10/bbl of in-country value add is created through local refining. While US$10/bbl of in-country value add (if achieved economically) is no doubt better than importing fully refined white product, it is a far cry from creating all the value in-country as is the case for Secunda.

This raises the question of whether a policy should replace the economic consequences of a Secunda sun-set (jobs, tax, balance of payment effects) or alternately look to replace the functional role of Secunda in the fuel and chemicals space in South Africa (create more fuels and chemicals import facilities)?

The options presented below reflect a blend of these considerations, in part aligned with the theme of climate change robustness. Ultimately a careful cost-benefit analysis of options is required to ensure informed decision making at a macroeconomic level.

Successfully navigating the energy transition will involve, *inter alia*, coping with the current situation and navigating through future policy conundrums and contradictions. At the current time the government's *de facto,* and contradictory, policy is to simultaneously subsidise both fossil fuels and renewable energy. For example, Eskom has been receiving substantial bailouts from the government, (essentially because many customers are non-paying and thus it effectively sells electricity at below cost) thus subsidising the coal value chain. At the same time, the government has been giving 20-year power purchase and tariff guarantees for renewable power generation through its Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), thus subsidising renewable energy value chains by derisking such projects. It has also offered tax incentives to investors in renewable power generation.

Coping in the medium term with a declining role in the economy for Sasol's coal-to-liquids-and-chemicals technology may require a similarly contradictory approach during a transitional period. For example, Sasol's Secunda operations may require government support of some kind at the same time that government supports a transition to electric vehicles. The art of astute governance will lie in getting the balance "right" between such apparently contradictory incentives and in the ability of politicians to explain this to the electorate.

12.2. Leave it to market forces

Government doing nothing is one of the easiest options for it. The obvious implication is that imports will be needed to substitute for those products no longer produced in Secunda. In this case "Ports and import facilities will need to be modified/upgraded to handle a changed liquid fuel import product mix and increased volumes" (Republic of South Africa, 2022, p. 77). The same will apply to petrochemicals and some of their derivatives given that, in the Secunda operations, the manufacture of liquid fuels and petrochemicals are inextricably interlinked.

12.3. Exemption for Sasol on carbon emissions

Sasol faces current and emerging pressures on various fronts to address its carbon emissions. These include (i) South African government carbon taxes and national carbon budgets, (ii) institutional shareholder demands relating to investment mandates (iii) customer requirements for greener products (iv) border taxes[24] as well as (v) environmental activists and NGO groups.

The South African government has the flexibility to soften or delay effective costs to Sasol as witnessed by the extension of Phase 1 of its carbon tax plan (Bloomberg and Omarjee, 2022). This will delay what is potentially the most immediate threat to the Secunda site although it will, however, come at the risk of negatively impacting the government's international climate change reputation and potentially also trigger litigation from NGOs.

[24] Such as the EU's Carbon Border Adjustment Mechanism (CBAM).

It will not, however, change the expectations of other stakeholders. Indeed, it may have the opposite effect of increasing pressure from some stakeholders, given the expectations that have been created by Sasol's widely acclaimed announcement of achieving a 30% carbon emission reduction by 2030 (Omarjee, 2021).

An example of this growing frustration is reflected in the actions of shareholder activism organisation Just Share (Just Share, n.d.) To create additional climate change pressure, Just Share summarised what it claims is Sasol's continuously changing and confusing approach to climate change targets (Davies, 2023). Just Share has also opposed Sasol's proposed "integrated approach" to achieving GHG and air pollution laws legislation on principally legal grounds. At face value, Sasol's proposed integrated approach appears to offer a very similar and potentially improved outcome while optimising costs. Similar to the article on climate change targets, Just Share highlights, in its view, Sasol's long-term non-performance in dealing with sulphur emissions (Just Share, 2023).

On 11 November 2023, barely a week ahead of the 2023 Sasol Annual General Meeting (AGM), Old Mutual took the unusual step of publicly calling on its investment peers to reject several Board resolutions proposed by Sasol because of its poor performance on achieving climate targets (Squazzin, 2023b). Sasol subsequently issued a rebuttal claiming that Old Mutual was basing its decisions "on inaccurate and, to some extent, misleading information" (Sasol, 2023i). The AGM, held on 17 November 2023, was subsequently cancelled after climate activists occupied the stage (Reuters, 2023c).

In April 2024, Sasol has been reported as being on the list of the 57 companies responsible for 80% of global Scope 1, 2 and 3 emissions (Human, 2024; Carbon Majors, 2024).

Sasol has not previously experienced this level of climate change awareness, activism, pressure and ongoing scrutiny.

13. LOOKING BEYOND THE COAL-BASED PETROCHEMICALS CUL DE SAC

What options does South Africa have beyond its apparent coal-based petrochemicals cul de sac? Assuming the cessation of petrochemical production at Sasol's Secunda facility, where do the possible options lie? Essential to any development is the availability of key feedstocks and raw materials at or below world market prices. These could include naphtha, LPG, ethane and propane as raw materials or a naphtha cracker which typically produces the key petrochemicals building blocks; ethylene, propylene, benzene, toluene and xylene.

The following options could be considered by the government. All will need to be researched and evaluated before any decisions are made but are offered as possible targets for future work.

13.1. Regional gas to Secunda

This option envisages further supply of natural gas to Secunda after the Pande/Temane gas fields are exhausted. To completely exit coal while maintaining economies of scale would require the import of nearly 10 times the amount of natural gas used today.

Sasol has stated that imported liquefied natural gas is not affordable as a substitute for coal in its process (Sasol, 2023b p.28). The remaining known other possible sources of natural gas are:

- Further gas finds in Mozambique in proximity to the Temane central processing facility that currently serves the Pande/Teman gas fields and or the ROMPCO pipeline. Sasol has invested US$530 million in Mozambique to extend its Mozambique gas plateau from 2026 to 2028 and reports a new gas discovery (PT5-C) close to its existing operations (Sasol 2023b, pp.18 and 57). It has reported that it is "investing US$1 billion over the next few years in Mozambique to ensure a stable supply of gas to South Africa" (Sasol, 2023b, p.58).
- Gas in proximity to Secunda (discussed in the section on Sasol's 2026 gas cliff for industrial customers (Section 5.2.2).

If significant of gas that are affordable to Sasol are found, they are expected to extend the life of the Secunda and Sasolburg facilities, assist in meeting emissions targets, and result in increased production volume forecasts; but such finds will not be able to directly substitute for coal as a primary feedstock for the existing plant and equipment without substantial additional capital investment.

In the context of the global energy transition, Sasol sees gas as a "transitionary feedstock" (Sasol, 2023, p.58) while it pins its hopes on hydrogen and other feedstocks. It nevertheless notes that such feedstocks are likely to reduce profitability significantly. (Sasol, 2023h, p.33).

13.2. Thermal crude-oil-to-chemicals

This is a newly emerging processing route for crude oil termed TCTC. Crude oil is pre-processed and a large portion of the resulting products (excluding heavy oil fractions) are fed to an advanced naphtha cracker where ethylene, propylene and other chemical building blocks are produced. The remaining heavy oil fraction is further processed into International Maritime Organization compliant low sulphur fuel oil for shipping applications. The advantage of this technology is that a conventional oil refinery producing liquid fuels (costing approximately US$10 billion) is not necessary, saving a substantial investment while providing a higher value product slate containing well over 50% chemical feedstocks (Lummus Technology, 2021). For example, Saudi Aramco and Saudi Basic Industries Corporation are constructing a large, crude-to-chemicals project of 400 000 bbl/day in South Korea with an initial project cost of US$5.2 billion and scheduled for completion in 2025 (Aramco, 2018). This is five times the size of the only existing facility in Singapore (Armaco, 2018). Commissioning of this plant is scheduled for 2025.

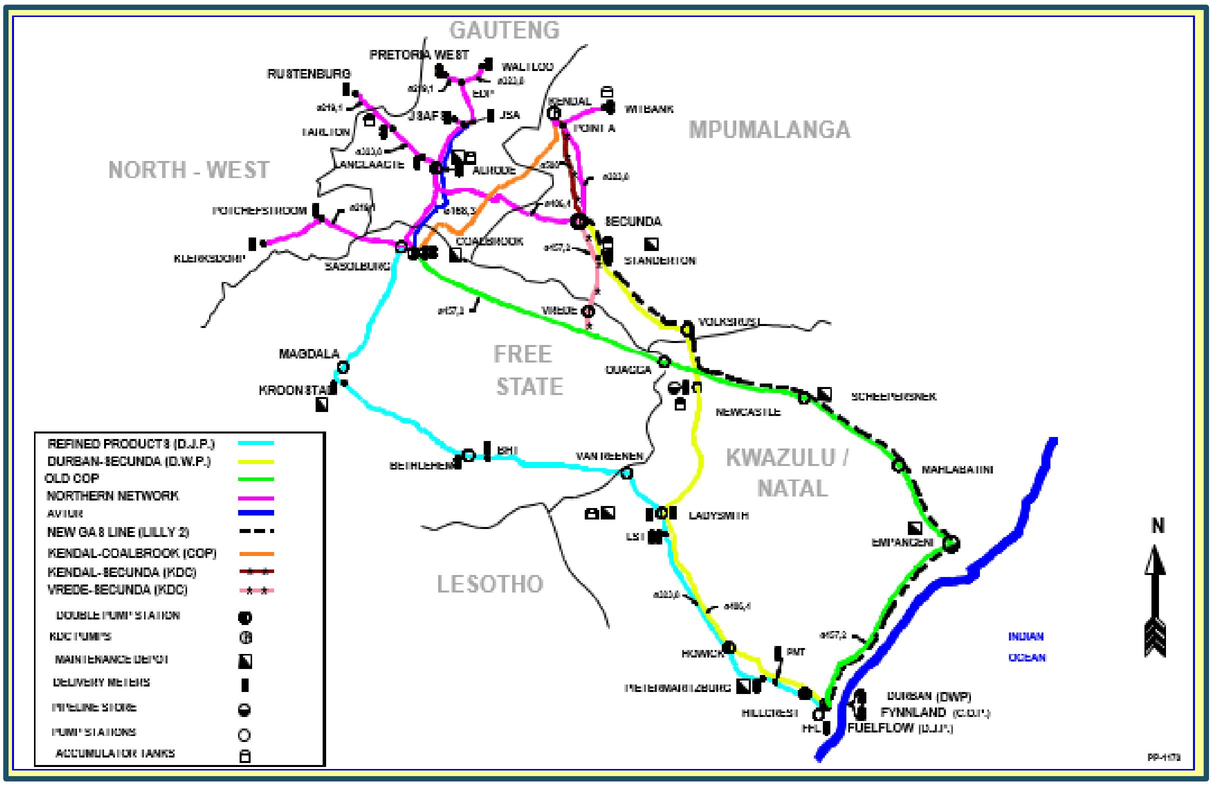
Three possible locations for such a facility could be considered:

a) **Sasolburg**: Sasolburg has several advantages. Sasol is the majority owner of the Natref crude oil refinery in Sasolburg. That site could be used even if the Natref refinery is still operating but may require the Crude Oil Pipeline (COP) capacity to be increased. Natref is connected to the COP (owned by Transnet Pipelines) and the coastal infrastructure[25] for off-loading and storing crude oil. Also, the downstream processing plants that manufacture polyethylene and polypropylene pellets are located in Sasolburg. Furthermore, the bulk of the plastic demand and thus converting industry is located in the inland market. The disadvantages of this location include possible COP volume constraints and potentially land availability.

[25] There is a Single Buoy Mooring (currently owned by Shell, BP, Sasol and TotalEnergies) and NAatcos crude tankage in Durban that are used to supply crude oil to Natref.

b) **Secunda**: Secunda has similar advantages to Sasolburg in the opportunity to utilise existing infrastructure. However, the crude oil would need to be transported from Durban to Secunda. Assuming that the Natref refinery was closed, the COP would be a stranded asset and could be utilised to transport the crude to Sasolburg or its capacity increased if Natref is still operating. Currently, there is a small 40 000bbl/day pipeline between Sasolburg and Secunda used to transport liquid fuel components between the two sites (NERSA, 2021). Possibly this pipeline could be converted to crude oil. If not, the Coalbrook (Sasolburg) to Kendal (Ogies) pipeline and then the Kendal to Secunda pipelines could be used. Alternatively, the old crude oil pipeline that was converted to natural gas, commonly known as the Lilly Pipeline, could be converted back to crude oil. This pipeline connects Durban to Secunda via Empangeni, see Figure 23.

Figure 23: Transnet Pipelines historical pipeline routes



Source: Petronet. *Notes:* (1) The dotted black line labelled 'New Gas & (Lilly 2)' could be converted back to crude oil. (2) Alternatively, the existing COP (not shown on this map) to Sasolburg could be used. From Sasolburg the Coalbrook to Kendal (Ogies) pipeline and then the Kendal to Secunda line could be used.

c) **Richards Bay**: This location would entail an all-new greenfield site requiring crude offloading facilities, crude storage facilities, the TCTC plus naphtha cracker plus the downstream processing plants – a substantial investment. It would avoid the need to transport crude to an inland site but would have to transport the manufactured polyethylene (PE), polypropylene (PP) and other plastic pellets inland where most of the plastic converting industry is located, as opposed to the presumably cheaper transportation of crude by pipeline.

13.3. Southern Namibia crude-oil-to-chemicals

A location in Southern Namibia could make use of the recent significant oil and gas finds offshore Southern Namibia. Shell and TotalEnergies have discovered 11 billion barrels of light oil and 8.7 tcf of gas offshore Southern Namibia (Upstream Online, 2024). Currently, these companies are proving up their finds. Production, if it goes ahead, is only expected from 2030. There is no information on the specifications of the gas or crude oil available, but assuming they are favourable and assuming that either gas or oil or both are brought onshore the feedstock for a crude-oil-to-chemicals complex could exist. Such a development would have the following challenges:

a) Need for greenfield site development in a remote location;
b) Means to transport plastic raw materials to South Africa's inland market, either by sea (necessitating the construction of a new port) or by rail (necessitating the construction of a rail link);
c) If a world-scale facility were to be constructed, production could exceed South African demand, necessitating the export of the surplus and therefore the construction of a deep sea port to reach export markets.

13.4. South African coastal crude oil refinery plus petrochemicals complex

The idea of building a new coastal refinery and petrochemicals complex is not a new one. In 1996 the Taiwanese Tuntex Group did a joint feasibility study with the Central Energy Fund (CEF) for a US$10 billion petrochemical project in South Africa (Oil & Gas Journal, 2023). It was abandoned after South Africa severed diplomatic ties with Taiwan. At the same time, Polifin[26] was also examining the *"possibility of investing about R6 billion in a new petrochemical complex"* (Mail & Guardian, 1996). The White Paper on Energy Policy (1998) paragraph 7.4.4 described *"The promotion of a coastal refining and petrochemicals hub for future investments*" as a cornerstone of Government policy. In 2018 the Minister of Minerals and Energy reported a meeting with the Minister of Energy, Industry and Mineral Resources of the Kingdom of Saudi Arabia His Excellency Khalid Al-Falih in which they discussed "the modalities for the proposed investment by Saudi Arabia in a new crude oil refinery and petrochemical plant in South Africa." (Government of South Africa, 2018) It was agreed that Saudi Aramco and the CEF will jointly conduct studies that will inform the next milestones in this endeavour. More recently, the Chemicals Master Plan (currently dormant within the Department of Trade Industry and Competition) recommends, *inter alia*, a New Greenfield Cracker and BTX facility associated with a new mega-refinery, possibly at Richards Bay (Laing, 2021). Such a development may be attractive to a large oil producer keen to secure off-take downstream markets for its output. Such a development would however have the following disadvantages:

a) It would only be sensible once all the existing crude oil refineries have been shut down to avoid completely swamping the local market.
b) It would be a very large greenfield investment, with the bulk of the funds needed for the oil refinery. Such a refinery would need to be world scale – there is some discussion about at what size the economies of scale become effective, but it is estimated that approximately 500 000 bpd could be commercially viable. According to the South African Petroleum Industry Association's (SAPIA's) 2021 Annual Report, South Africa had 718 000 bpd of refining capacity. By comparison, the Dangote refinery recently completed in Nigeria is 650 000 bpd and the Reliance refinery in India is 1 240 000 bpd (among the world's largest);
c) As EVs become more numerous in global markets, the demand for petrol will decline. As a result, there will initially be gasoline refining overcapacity and consequently lower liquid fuels gasoline crack spreads which would damage the profitability of a new large refinery;

[26] A Sasol AECI joint venture in which Sasol held a majority shareholding.

d) It would necessarily be located at the coast requiring the plastic raw materials to be transported to the inland converting industry (although this is probably a lessor transport burden than if all the final products were imported);

e) Such a refinery investment would require downstream outlets for its fuel products and, as the retail market for liquid fuels is already saturated with retail outlets, such an investor would need to acquire one or more of the major fuel brands and their sites and/or incentivise retailers to switch supply;

f) A Richards Bay location would require a pipeline to transport its liquid fuel output to the inland market (the largest liquid fuels market in South Africa). This would require either a new pipeline or at least a new pipeline that is interconnected with the new Transnet Pipelines Multi-product Pipeline at some point, increasing the capital outlay necessary.

g) Plastic raw materials would also need to be transported inland to the inland plastic converting industry.

14. POSSIBLE ALTERNATIVES TO SECUNDA'S ECONOMIC CONTRIBUTION

14.1. Green hydrogen/fertiliser/ammonia export hub

Green ammonia refers to ammonia produced through a process that utilises renewable energy sources and emits little to no carbon dioxide (CO_2) during its production. Traditional ammonia production relies heavily on fossil fuels, particularly natural gas, and is a significant contributor to greenhouse gas emissions.

Green ammonia is one of the potential applications for green hydrogen. The hydrogen is reacted with nitrogen using a conventional Haber Bosch ammonia synthesis process to produce green ammonia.

Green ammonia has several potential applications, including as a carbon-free fuel for transportation, a clean energy carrier for storing and transporting renewable energy, and a feedstock for sustainable fertiliser production.

The US$8.4 billion NOEM project is the only gigawatt scale development that has reached financial close (NEOM, 2023). Backed by ACWA Power and Air Products, the project will produce around 1.2 million tons per year of green ammonia (Bioenergy International, 2020). Globally several feasibility studies are underway to evaluate additional green ammonia production. In South Africa, Hive Energy is executing a feasibility study for a US$4.6 billion green ammonia plant in the Coega Special Economic Zone, alongside the Port of Ngqura (Hive Energy, n.d.). Southern Africa is one of the regions around the world with the very favourable wind and solar conditions technically required for green hydrogen and ammonia production and export.

Although there is significant global interest in green ammonia caution also needs to be advised. The cost of producing green hydrogen is significantly higher than conventional routes. In 2021 there was a consensus view that green hydrogen costs would be in the region of €3/kg. More recent and accurate estimates are now in the region of €5-8/kg. A green hydrogen price range of US$5-8/kg equates to an equivalent oil price range of US$250-400/bbl. Green hydrogen is thus considerably more expensive than conventionally produced hydrogen, which also makes green ammonia an expensive product. Many green hydrogen and ammonia projects will be reliant on regulatory support in the form of carbon pricing and/or significant subsidies.

There are also significant risks to being a pioneer in green ammonia production megaprojects. There is an increasing realisation that green hydrogen and thus green ammonia face hydrogen prices greater than US$5/kg, which is a significant impediment to the green ammonia market. (Boston Consulting Group, 2022) The possibility of further cost escalation as pioneering projects progress from feasibility studies to detailed design before a final investment decision is made is a distinct possibility.

Mitigating the risks associated with pioneering green ammonia as well as the classical mega-project risks will ultimately determine if any green ammonia plants will be constructed in South Africa.

14.2. Promote electric vehicle manufacturing

Crude oil and petroleum products are South Africa's single most costly import costing in the region of R400 billion per annum[27]. Most of the petroleum based products serve the liquid fuels market and most of that market consists of vehicle propulsion. Diesel and petrol are the major liquid fuels. South Africa has good solar and wind resources for the generation of renewable power and cheap coal for power generation albeit with comparatively high emissions. South Africa also has an established motor vehicle manufacturing industry and an emerging battery manufacturing industry. Electric vehicles, when charged from renewable sources and measured on a "well to wheel" basis, are more efficient and less polluting than internal combustion engine powered vehicles.

South Africa's transport sector is one of the largest in Africa. A large number of vehicles exist to cater for the country's logistics, linking major mineral and industrial hubs with ports. The main drivers of demand for liquid fuels in this regard are industrial trucking, rail, and commercial passenger vehicles. More efficient transport logistic network integration could improve the utilisation of liquid fuels in South Africa.

There is thus a good *prima facie* case for South Africa to switch vehicle propulsion from petroleum to electricity. Conveniently, such a switch would support South Africa's long-running basic industrial policy of import substitution industrialisation.

However, such change cannot be accomplished by the mere flick of a switch because, in addition to the expected obstacles facing new technologies, there are long-running energy systems and industrial policies that make such change difficult. The list of obstacles to a switch from ICE vehicles to EVs is considerable and includes the following:

1) The petroleum industry has a considerable vested interest in retaining ICE vehicles taking into account its investment in refineries, pipelines, storage, loading and distribution infrastructure as well as retail outlets.
2) A transition from ICE to an EV fleet increases the risk of road degradation (MyBroadband, 2023a) due to the higher vehicle mass particularly of trucks and busses (Read, 2022). This will result in the need for more frequent road repairs and higher upfront costs on future infrastructure.
3) Motor vehicles tend to be the second largest investment for many motorists. The average vehicle age in South Africa is older than in most developed economies, lengthening the period in which the vehicle pool can be replaced. Replacing an ICE vehicle fleet is no easy feat. It requires additional generation capacity, vast quantities of critical minerals, and a complex ecosystem of actors. A global assessment looking at a transition from fossil fuels to alternatives shows the complexities South Africa would have to face (Michaux, 2021).

[27] Assuming 700 000 bbl/day and 80 US$/bbl crude

4) South Africa has suffered extensive loadshedding since 2008, which is forecast by the government to end between 2028 and 2030 according to its draft Integrated Resources Plan 2023. This can, of course, be relatively easily and quickly overcome by solar photo voltaic (PV) power generation. Nevertheless, it requires additional energy systems and infrastructure to be developed. Private investors have established EV charging stations along the major national roads and some EV manufacturers also offer recharging facilities. Some even include a small PV power station with the vehicle purchase.
5) Battery theft. South African cellphone companies already suffer wide-scale theft of batteries from cellphone towers (MyBroadband, 2023b). EVs may present an irresistible target reducing the desirability of EVs for consumers and concomitantly increasing insurance costs.
6) South Africa has had a long-running incentive scheme for the local manufacture of ICE vehicles. This includes a higher import tariff on EVs than ICE vehicles. This has had the effect of increasing the price of EV's locally and may actually delay EV uptake.
7) Approximately 60% of locally manufactured ICE vehicles are exported mainly to the EU in which many countries and cities have pro-EV and anti-ICE policies, thus threatening the local industry's export markets. Despite public statements by several local ICE manufacturers calling on the government to put in place a supportive suite of policies, the Department of Trade, Industry and Competition had by March 2024 failed to adjust its ICE vehicle incentive scheme (Automotive Production and Development Programme). Despite this, the Minister of Finance in his budget speech on 21 February 2024 announced a tax incentive for EVs[28] suggesting that some parts of government see the advantage of a switch to EVs.
8) There is consumer reluctance to EVs based on "range anxiety" and the comparatively high upfront cost of EVs, even if they are lower cost over their useful lives.
9) Batteries constitute between 40% and 50% of the total cost of an EV (Montmassen-Clair et al., 2021) Consequently, local battery manufacture would be an important part of substituting for imported petroleum. South Africa has an established mining industry and resources of many of the minerals required to manufacture batteries. Battery manufacture could add to the local "minerals beneficiation"' mantra. It is beyond the scope of this report to consider the complexities of local battery manufacture but an emerging literature can be found at this reference (TIPS, 2021).

Some additional opportunities and points for consideration are:

- EVs can support and improve the reliability of the electricity grid through potential Vehicle-2-Grid (V2G) electricity transfers. Significant infrastructure upgrades and institutional restructuring are necessary to support this, including smart meters and revision of revenue generation, among others. South African V2G capability can help enhance distributed generation and improve peak demand trends. V2G provides consumers with an opportunity to recover some of their investment if a flexible electricity and feed-in tariff is implemented.
- Sodium-ion battery manufacturing capability coupled with industrial desalination can improve water security and develop cost-effective stationary storage solutions in industrially strategic water-scarce areas. Such demand could incentivise the manufacturing of batteries that incorporate rare earth metals for more specialised purposes, such as EVs which come with their

[28] This will allow producers to claim 150% of qualifying investment spending on electric and hydrogen-powered vehicles in the first year.

own considerations and environmental impacts. However, they hold better synergies with a green economy if implemented correctly.

- Hybrid vehicles are expected to play a more versatile role in South Africa's economy due to existing infrastructure, more reliable range, and synergies with existing manufacturing capability.
- The transition to EVs already has significant momentum elsewhere. In China for instance, battery electric vehicles already represent nearly 50% (Autovista24, 2024) of new car sales, making a significant contribution to both GHG reduction potential as well as local air quality, particularly in cities.
- EVs would only replace ICE vehicles and will not increase the demand for vehicles unless EVs become cheaper than ICE vehicles.

There is nevertheless a promising prospect for an EV and battery manufacturing industry to replace the existing ICE refuelling and support industry.

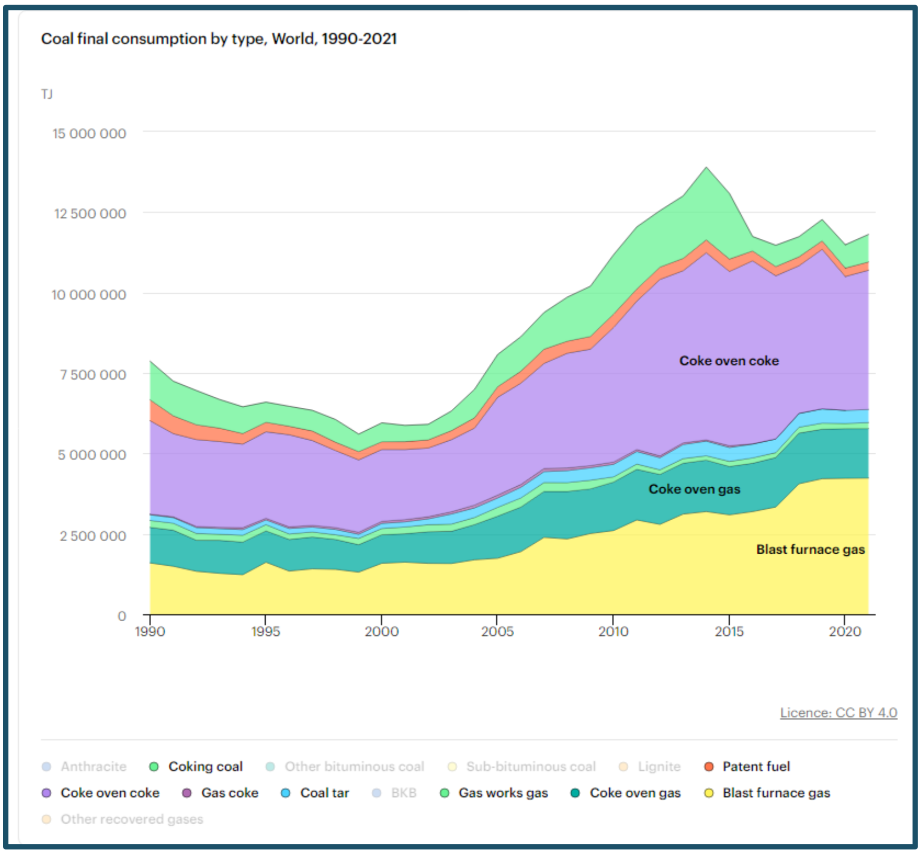
14.3. Green steel DRI using green hydrogen

Conventional steel manufacturing typically takes two processing routes namely Blast Furnace – Basic Oxygen Furnace and the Electric Arc Furnace. Both processes require significant amounts of energy that conventionally are derived from fossil fuels such as coal and natural gas (Visual Capitalist, 2022). Green steel is made from direct reduced iron (DRI) created using hydrogen instead of coal or natural gas. When green hydrogen is used as the reducing gas there are no greenhouse gases produced.

Steel manufacturing has a rich history across different industries and economies. Historically, this bulk material has played a pivotal role in the development of economies, particularly through its use in infrastructure development and manufacturing. Across multiple geographies, steel industries are prone to global trade dynamics, global growth rates, and availability of raw/recycled material at both domestic and international levels.

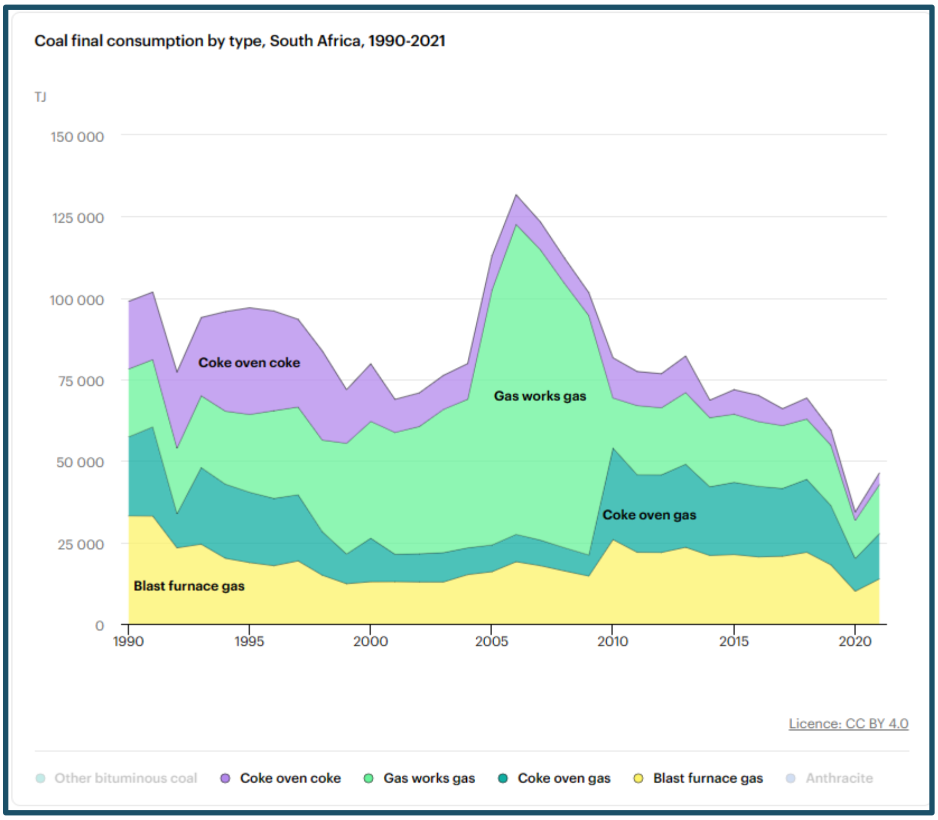
Coal plays a vital role in steel manufacturing, primarily through its use in the form of coke. Coke is a high-carbon chemical obtained from the thermal distillation of coal in the absence of air, a process known as coking. The role of coal, specifically in the form of coke, in steel manufacturing is characterised by its use as a fuel and heating source, reducing agent, and support structure in blast furnaces. A global and South African overview of the final consumption of key coal and blast furnace gas consumption for iron and steel manufacturing is characterised in Figure 24 and Figure 25.

Figure 24: Coal final consumption by type, World, 1990-2021



Source: Adapted from IEA, 2024a and IEA 2024b.

Figure 25: Coal final consumption by type, South Africa, 1190-2021



Source: Adapted from IEA, 2024a and IEA 2024b.

South Africa by comparison has electric arc furnaces that cater more for the iron and steel scrap market but can have synergies with other metal reducing sources and renewable energy. The South African steel manufacturers have adopted technology and various recycling programmes have been encouraged. One of the major debates in the industry surrounds the ban on scrap metal exports which was instituted to reduce the theft of infrastructure by removing a market for stolen goods (Dludla, 2024).

Green hydrogen can play a role in producing sponge/pig iron through the Direct Reduced Iron (DRI) process. Conventionally the DRI process utilises a mixture of hydrogen and carbon monoxide (syngas) as a reducing agent to remove oxides, but this can be replaced with green hydrogen to produce sponge iron. This would require a hydrogen supply of around 47 – 68 kg of hydrogen per ton of DRI produced (MyBroadband, 2023b).

At a country level, South Africa produces 8.5 million tons of steel p.a. and assuming an optimistic ~50 kgH_2/ton, DRI would require significant amounts of green hydrogen and renewable electricity, approximately 425 ktons and 21.25 GWh respectively (assuming a hydrogen energy demand of 50 kWh/kg H_2).

Nonetheless, the promotion of a green steel industry is attractive for South Africa due to its renewable energy potential, mineral resources, and its strategic manufacturing sector catering to several global markets including the EU. Steel is a hard-to-abate sector targeted by the EU's CBAM and the development of green steel value chains can help protect South African steel exports against these regulations. This approach comes with its own set of obstacles such as the scale of investment needed and adoption of new technology as evident in the previous calculation.

Green steel comes with its own set of obstacles such as the scale of investment needed and the risk associated with the widespread adoption of this relatively new technology against a backdrop of steel producers announcing shutdowns of many of their current facilities (Kruger, 2024).

An assessment of the effects of the CBAM on Africa found that the continent's iron and steel exports to the EU could decrease by 8.2% and carbon tariffs would increase between 5%-11% (African Climate Foundation, 2023). Sasol entered a joint development agreement with ArcelorMittal South Africa in 2022 to develop a competitive green hydrogen hub and ecosystem within Saldanha Bay (Sasol, 2023j). These developments help to position the green steel industry in South Africa, however for the entire industry to convert to this new technology would require significant development in renewables and green hydrogen needs to be undertaken to make these pathways viable.

14.4. Rough comparison of development project options

The efficacy of any market intervention or policy can only be judged against its objectives, cost effectiveness as well as intended outcomes and unintended outcomes. In Table 16 the various possible government interventions considered above are assessed against typical industrial policy criteria. It is to be stressed that these are merely the author's rough estimates and are not based on any in-depth research as that is beyond the scope of this report.

Table 16: Development options against policy objectives

Project	Local value added	Employment	Forex generated	Environmental impact	Commercially proven Technology	Market opportunity (non-subsidised)	Economic viability
LOOKING BEYOND THE COAL-BASED PETROCHEMICALS CUL DE SAC							
Regional Gas to Secunda (not LNG)	✓	✓	✓	?	✓	✓	✓
Thermal crude-oil-to-chemicals	?	✓	?	?	x	✓	?
Southern Namibia crude-oil-to-chemicals	x	x	x	-	✓	✓	?
South African Coastal crude oil refinery plus petrochemicals complex	?	✓	?	x	✓	✓	?
ALTERNATIVES TO SECUNDA'S ECONOMIC CONTRIBUTION							
Green Hydrogen/Fertilizer Export Hub	✓	✓	✓	✓	x	?	?
Promote Electric Vehicle Manufacturing	✓	✓	✓	✓	✓	?	?
Green Steel DRI using green hydrogen	✓	✓	✓	✓	✓?	✓	?

According to this crude qualitative assessment, the more promising opportunities are Regional Gas to Secunda (not LNG), Green Steel DRI and promoting electric vehicles. None of these are mutually exclusive.

15. CONCLUSION

This report has focused on a key question in South Africa's transition to a lower carbon future, 'what is the future of the South African petrochemicals and plastics, ammonia, fertiliser and explosives value chains in the light of Sasol's stated greenhouse gas emission reduction plans and other assessed business constraints?' It has confirmed that the future of those value chains is inextricably bound up with Sasol's future and its Secunda operations in particular, at least in the short term.

This report has shown that Sasol, despite its origins in a period of oil sanctions, is currently a valuable asset in the South African economy. It adds significant value to a stranded resource (low-grade coal) and in the process it makes a significant contribution to GDP, tax revenues and the employment of tax-paying workers. It also makes a significant contribution to the balance of payments, both through substituting for imported liquid fuels and through exports of chemicals. Less obviously to the average observer, it is the only domestic source of petrochemicals that find their way into a myriad of applications that oil the wheels of the economy.

Sasol's plants were never planned to last indefinitely. Unfortunately, this statement of the obvious seems to be ignored in South Africa and society goes on pretending that this is not true. This report recognises this obvious fact and points out that the rosy picture painted above is unlikely to last in the medium term, let alone indefinitely.

It is unrealistic to expect pre-World War Two technology to remain competitive indefinitely, even if it has been tweaked and improved. Indeed, this report finds that Sasol is a company in distress. It simultaneously has high levels of debt, is struggling to find cash to pay dividends and yet it needs to make substantial investments to stave off growing environmental pressures. To compound matters, its raw material costs (coal) are rising and its supplementary raw material, natural gas from Mozambique, is running out. So much so, that it has announced a termination of gas supplies to industrial customers in 2026 and an 11% cutback in Secunda's production in 2030. For about the last 20 years most of its investment has been outside South Africa and for the most part, these forays have, thus far, not turned out well.

Sasol's Secunda operations are vulnerable to several risks. Because the prices of much of its product slate are roughly correlated with the oil price, it faces significant risk to low oil prices. Another major risk stems from compliance with emissions requirements and the increasing burden of a carbon tax, which may be the proverbial straw that breaks the camel's back. Sasol's (Secunda) facility depends principally on coal as a feedstock (even though some natural gas is added). In our view, it cannot easily avoid the fundamental challenge of transitioning to a future where coal is replaced by "green" feedstocks. Based on current knowledge, we believe that the prospects for green hydrogen and captured carbon sources (as substitutes for coal) are not commercial propositions for Secunda. The sheer volume of biomass required discounts that possibility of a substitute for coal. This is not to say that Sasol Secunda cannot improve its environmental impacts by using renewable electricity and hydrogen produced from renewable electricity to manufacture some new boutique products that may find markets in developed economies. Such developments will help its case but will not allow it to escape its coal fundamentals. At the same time, Sasol Secunda is facing significant challenges in the supply of suitable quality coal at an affordable price while also meeting environmental commitments within its targeted timeframes for emission reduction.

It is also important to realise that Sasol's (Secunda) technology and equipment were not designed in such a fashion that it can somehow be adjusted to lower its emissions incrementally. It is analogous to an old car with an old engine. The old engine will continue to produce the majority of its GHG (and other) emissions in-line with its design regardless of any tinkering with aerodynamics, tyres and so on. The only solution is to change the fuel source and often the engine (thus moving to an electric vehicle in this analogy). In Sasol's case, this report finds that 'changing the engine' is not a realistic proposition, there is no standalone commercial reinvestment case, even if Sasol had the funds. The 'engine' will have to run to the end of its useful life unless emission reduction obligations curtail that life.

Ultimately, this means that Sasol's South African future lies, to a large extent, in the South African government's hands. The Government can continue down its current path of increasing environmental pressure on Sasol, which has led to an announced cutback in production and in our view, the risk of incremental closure of various Sasol plants until final closure. In this case, several possible alternatives are sketched that the Government could pursue to try and fill the gap in the economy left by Sasol's exit.

Alternatively, the Government could recognise that coal is at the heart of Sasol Secunda and thus carefully moderate its environmental pressures on Sasol as Sasol invests to improve its emissions profile, and perhaps with other *quid pro quo* actions by Sasol, see out the approximately 20 years of remaining life. Whilst doing so, government could try to put in place other economic activities that could fill the gap left by the truncation of Secunda's current product slate. Such a path would have to be aligned with South Africa's Nationally Determined Contribution, which in effect means it would be partially dependent on the emissions allowed/created by the state-owned power utility, Eskom, which is also mainly a coal-based company with its own very high emissions. Unfortunately, like Sasol, it too is caught in a squeeze, in its case between ongoing load shedding, financial distress and the need to reduce its emissions. In short, this path will require an astute and coordinated state apparatus.

More optimistic outcomes may be possible if significant natural gas reserves are found in proximity to the ROMPCO pipeline and/or in proximity to Secunda and become available at prices Sasol South Africa can afford and in the requisite quantities.

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APPENDIX A: SUMMARY OF KEY INTERNATIONAL, SOUTH AFRICAN AND SASOL EVENTS RELATED TO CLIMATE CHANGE

DATE	LOCATION	EVENT
1988	Global	Intergovernmental Panel on Climate Change (IPCC) an intergovernmental body of the United Nations, was formed in 1988.
1992	Global	United Nations Framework Convention on Climate Change (UNFCCC), was signed in 1992 at the United Nations Conference on Environment and Development in Rio de Janeiro
1995	Global	First Conference of the Parties held in Berlin, Germany.
1997	Global	Kyoto protocol developed. Recognises "common but differentiated responsibility and respective capabilities", because it recognizes that they are largely responsible for the current high levels of GHG emissions in the atmosphere."
1997	RSA	RSA ratifies UNFCC Convention (Department of energy, n.d.-a)
1997	Global	Clean Development Mechanism (CDM) developed (not implemented) under Kyoto Protocol to support climate change projects in developing countries.
2002	Global	Kyoto Protocol ratified (Department of Energy, n.d.-b)
2002	RSA	Johannesburg World Summit on Sustainable Development
2003	RSA	White Paper on the Renewable Energy Policy of the Republic of South Africa
2004	RSA	South Africa issues its "National Climate Change Response strategy" (UNFCCC, 2004).
2005	Global RSA	Kyoto Protocol comes into force. Kyoto Protocol is binding on developed countries and places a heavier burden on them under the principle of "common but differentiated responsibility and respective capabilities" because it recognizes that they are largely responsible for the current high levels of GHG emissions in the atmosphere. CDM gains momentum and small number of RSA projects developed
2008	Sasol	Sasol's first Sustainable Development Report included reference to climate change. Recognised Sasol's first CDM project being approved for nitrous oxide emissions reduction (Sasol, 2008)[29].
2009	Global RSA	COP 15 held in Copenhagen. Copenhagen Accord drafted, not binding but united position as the BASIC countries (China, India, South Africa, and Brazil) (Wikipedia, n.d.-f) RSA outlining a timeline for the country's emissions to peak, plateau and decline, had made the first such commitment by a major developing nation. "South Africa will undertake mitigation actions which will result in a deviation below the current emissions baseline of around 34% by 2020 and by around 42 per cent by 2025. This level of effort enables South Africa's emissions to peak between 2020 and 2025, plateau for approximately a decade and decline in absolute terms thereafter." (SAnews, 2009)

[29] Only CDM projects are reported as these projects have as their primary intent, a verified GHG reduction, as opposed to other projects where GHG reductions may simply have been a collateral benefit and thus not demonstrating material GHG reduction commitment.

DATE	LOCATION	EVENT
	Sasol	The undertaking was conditional, however, on a fair, ambitious and effective agreement in the international climate change negotiations and the provision of support and finance from the international community.
	Sasol	Sasol "Sustainable Development Report" issued. Defined Sasol's energy efficiency targets as *"to improve the energy efficiency of our South African utilities by 15% per unit of production, by 2015 on the 2000 baseline."* (Sasol, 2009a) Sasol's "New Energy Business Unit" (SNE) created, *"an important goal of which is to investigate the implications for Sasol to reposition itself for a* carbon constrained future." (Sasol, 2009b)
2010	Sasol	Sasol "Sustainable Development Report" issued. Contains first GHG intensity targets "Target: to reduce our emissions intensity by 15% in all our operations by 2020 on the 2005 baseline." (Sasol, 2010a)
	Sasol	Sasol New Energy (SNE) was *"created to focus on new technologies that can be integrated with our core technologies to result in a lower greenhouse gas footprint. In an effort to reduce production of* CO_2 *in our operations and integrate new technologies into our Fischer-Tropsch processes, SNE will explore renewable and lower-carbon energy options such as solar, biofuels and biomass, as well as nuclear, hydro and natural gas. Carbon capture and storage (CCS) will be targeted to sequester the* CO_2 *produced through the Fischer-Tropsch process."* (Sasol, 2010b)
	Eskom	April 2010 Eskom Investment Support Project (EISP) was approved based on using supercritical (clean-coal) technology and flue gas desulphurisation, USD3,750 million is International Bank for Reconstruction and Development (IBRD) loan which included 700 mil USD for wind, battery and efficiency projects (World Bank, 2020)
2011	Global	COP 17 held in Durban South Africa. Limited progress
2013	RSA	South Africa implements Regulation 12L offering a tax deduction for taxpayers who implement energy efficiency saving measures (GreenCape, 2015).
2014	Sasol	Very limited and apparent last material reporting on activities of Sasol New Energy business unit. Appears disbanded (Sasol, 2013b)
2015	Global	IPCC Paris
2016	RSA	South Africa submitted its first Nationally Determined Contribution (NDC) in 2016. In summary *"moves from a "deviation from business-as-usual" form of commitment and takes the form of a peak, plateau and decline GHG emissions trajectory range. South Africa's emissions by 2025 and 2030 will be in a range between 398 and 614 Mt* CO_2*–eq"* (UNFCCC, n.d.-b)
2019	RSA	South African Carbon Tax Act signed into law. (Government of South Africa, 2019)
2020	RSA	Presidential Climate Commission was formed as "*an independent, multistakeholder body established by President Cyril Ramaphosa. Our purpose is to oversee and facilitate a just and equitable transition towards a low-emissions and climate-resilient economy."* (Climate Commission, n.d.)
2021	RSA	South Africa updates its NDC under the Paris Accord. (UNFCCC, 2021)

DATE	LOCATION	EVENT
2021	RSA Sasol	South Africa updates its NDC and *"commits to 31% reduction and a fixed target for greenhouse gas emissions levels of 398-510 MtCO_2e by 2025, and 350-420 MtCO_2e by 2030."* (NDC Partnership, n.d.) Sasol announces it is: *"Targeting a 30% reduction in absolute scope 1 and 2 emissions by 2030 for the Energy and International Chemicals Businesses Targeting a 20% reduction in absolute scope 3 emissions by 2030 for Category 11: Use of our sold energy products 1 200 MW renewable energy target for the Energy Business by 2030"* (Sasol, 2021*).*
2023	RSA Sasol	The National Climate Change Bill (NCCB) was passed by the National Assembly. Includes the implementation of a carbon budget in addition to a carbon tax (Deloitte, 2021). The NCCB would make NDC legally binding and allow for the allocation of carbon budgets to high emitting GHG companies (Climate Action Tracker, n.d.). South Africa's targets are assessed by "cliamteactiontracker.org" as: • Having NDC targets that are "almost sufficient" in achieving a < 2 deg C world • Having policies and actions that are "insufficient" in achieving a < 3 deg C world. On the basis that South Africa is committed to making a meaningful contribution to climate change then it can be reasonably assumed that more onerous polices and actions will need to be developed and implemented together with their associated increased costs to high GHG emitting business's. 600MW of renewable power jointly with procured between Air Liquide and Sasol (Sasol, 2023c)

APPENDIX B: SIMPLIFIED SECUNDA ECONOMIC MODEL

Explanation of the modelling approach

Before explaining and formulating the simple economic model used for this work it will be useful to explain the philosophy used for the model because it does not necessarily adhere to what may be perceived as the conventional wisdom regarding how one should model a very complex facility like the Secunda value chain.

Before presenting a modelling framework, this Appendix looks at the modelling approach concerning the topics of modelling, approximation, precision, and accuracy, all of which are relevant to the approach taken here. At its core, it is suggested that when modelling a complex system while also comprehending the key underlying processes involved, there is no substitute for employing a top-down iterative model development approach. This stands in contrast to a bottom-up model, which aims to achieve precise details from the start under the assumption that more complexity results in a model that is both accurate and precise.

By starting with simple approximate models that list and understand the shortcomings it is possible to start with models that are easy to understand. This starts with the most important input variables and output variables with as few adjustable parameters as possible. This initiates the modelling process. The following quote from George Box the famous British statistician is relevant (Wikipedia, n.d-g):

> *"Since all models are wrong, the scientist cannot obtain a "correct" one by excessive elaboration. On the contrary, following William of Occam he should seek an economical description of natural phenomena. Just as the ability to devise simple but evocative models is the signature of the great scientist so over-elaboration and over-parameterization is often the mark of mediocrity".*

In line with this thinking, the approach proposed is to attempt to create the simplest and most economical model which provides a useful description for the extended Secunda value chain. To the extent necessary, the model can be refined and made more elaborate later, but this can soon generate diminishing returns. Further elaboration of the model can form the subject of future studies should this be necessary.

The inherent unpredictability and volatility of the oil price

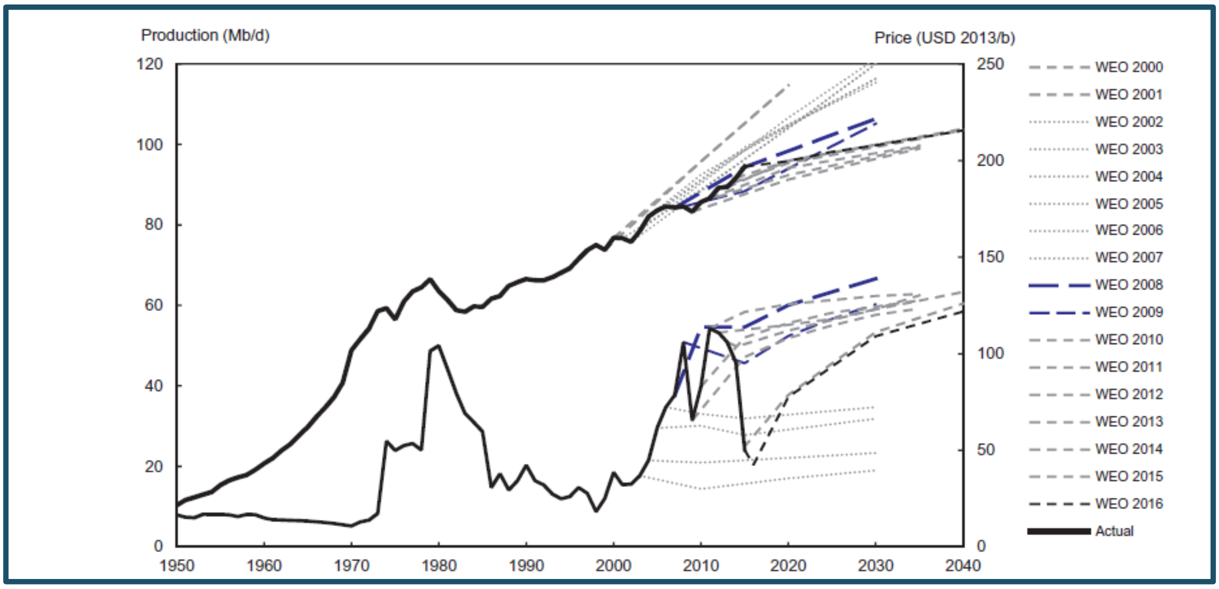
Given the importance of oil prices to Secunda, a short digression into oil price forecasts is warranted. For Sasol and other oil and petrochemical companies, the most important input variable is probably the oil price because the price of liquid fuels and many petrochemicals are correlated to the oil price. It is the case that for liquid fuels and many commodity petrochemicals that the oil related feedstock costs make up the bulk of variable costs and often set a floor on sales prices.

The conventional approach to economic modelling adopted by many corporates is based on discounted cash flow (DCF) analyses and calculating net present values (NPVs) and internal rates of return (IRRs). A typical period for a DCF analysis is 15 to 20 years. To perform a DCF and calculate NPVs and IRRs, forecasting key prices 15 to 20 years into the future is needed. A long-term oil price forecast to perform these calculations is needed.

Although there is a very extensive body of literature on oil price forecasting methodology, relatively little of this literature focusses on how accurate these models are. Some interesting research was done by the Deutsche Bundesbank (Reitz et al., 2009). Although this work was more focussed on shorter-term forecasting methodologies, they performed a statistical analysis on a number of what appear to be sophisticated methodologies compared with what they call a naïve random walk model. They conclude that the accuracy of all of the forecaster's methodologies is "negligible" and is not better than a no-change forecast. There is little reason to believe that longer-term forecasting methods should fare any better.

Long-term oil price forecasts are prepared by several reputable consultancies in the petrochemical arena but are generally proprietary and hidden behind a paywall. However, the annual World Energy Outlook prepared by the International Energy Agency (IEA) provides public domain forecasts. The accuracy of these forecasts has been evaluated (Wachtmeister, et al., 2018) and the results are plotted in Figure 26.

Figure 26: IEA long-term oil price forecast history

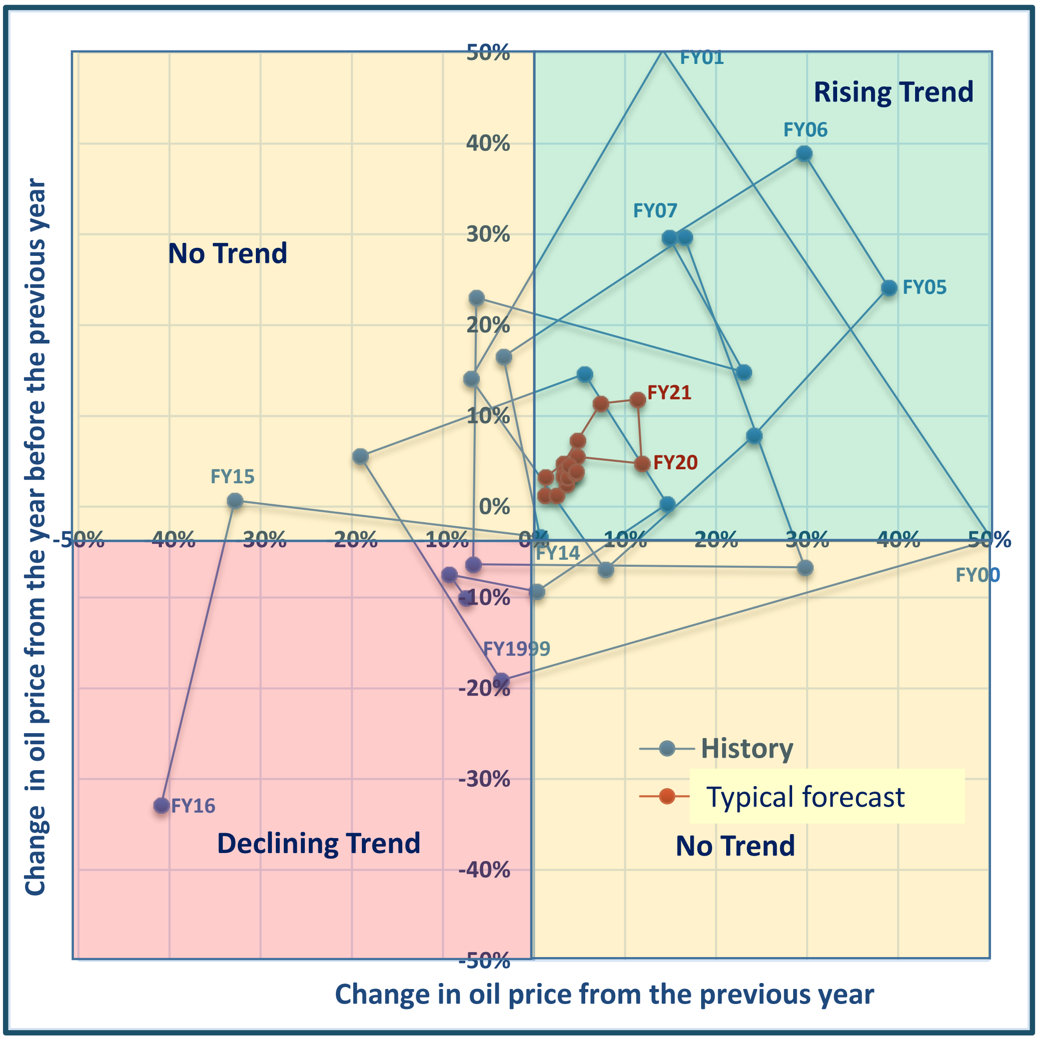


Source: IEA forecasts.

As can be seen from the figure, there is a large variation in the long-term forecasts, and they bear little relation to the observed reality. It is also worth noting that all the forecasts show smooth generally rising oil prices. Oil price volatility and variability is a very real phenomenon which has profound implications for petrochemical companies. Oil prices do not show the smooth behaviour found in forecasts.

It is worthwhile to also look at the forecasts in terms of price trends and volatility. An oil price volatility and trend plot is shown in Figure 27.

Figure 27: Oil price volatility and trend plot



Source: Authors' analysis from publicly available information.

Several observations can be made from Figure 27. First, for most of the historic period considered the oil price occupies the rising trend quadrant, followed by no trend and lastly a declining trend. Large declines can wipe out years of accumulated gains, as happened in 2015. The magnitude of the changes in history vastly exceeds typical forecast changes. Changes of more than 30% in a year, both positive and negative, are common. Typical forecasts suggest gently rising oil prices for the foreseeable future. The IEA forecasts generally see similar rising trends. The gently rising oil prices in the forecasts are not supported by history where there are much larger changes. The forecasts thus significantly underestimate risk and could even be construed as dangerously misleading. From a scientific perspective, the forecasts do not display behaviour consistent with the empirically measured reality. An appropriate analogy might be that the forecasts propose a gentle tailwind whereas the historical reality is that there are periods where there are hurricane force tailwinds and headwinds. There is no reason to believe that this will not happen in the future.

A better economic modelling approach is therefore to consider the whole range of plausible oil prices in combination with other key business drivers and not use deterministic DCFs based on an almost impossible-to-predict long-term oil price forecast.

Simple economic framework for Secunda

A model is created with as few input parameters as possible to create a meaningful model. The relevant input parameters are as follows:

Input variables

α:	Secunda fuel production fraction	(mass fraction)
F_C:	Fixed costs	(USS$bn/year)
V_C:	Variable costs	(US$/ton)
T:	Secunda total production	(mtpa)
O_p:	Brent Oil price	(US$/ton)
R:	Refining crack spread	(US$/ton)
Δ:	Chemical oil price adder over oil price	(US$/ton)
C:	CO_2 emission intensity	(mtpa CO_2/mtpa total Secunda production)
P_C:	Carbon price	US$/ton CO_2
M_{RG}	Methane rich gas sales revenue	US$/ton total Secunda production

A brief description of the 10 input variables is provided as well as why these are sufficient for a simple Secunda economic model:

Input variables

α, Secunda fuel production fraction

Secunda produces both fuels and chemicals. By mass, Secunda produces about 58% liquid fuels and 42% chemicals. It is important to differentiate these products because they are priced differently in the market. Fuels are priced based on the oil price plus a refining margin. Petrochemicals prices, such as polymers, also float on oil prices in the longer term. The chemical price adder is generally significantly larger than the refining margin reflecting the cost impacts of the additional processing required as well as the generally reduced economy of scale.

F_C, Fixed costs

The extended Secunda value chain (including derivative plants in Sasolburg) incurs fixed costs relating primarily to labour and facility maintenance costs. The definition of the fixed costs used in this report relates to the fixed costs as shown on the published Sasol income statements. They do not include additional costs such as capital expenditure and debt payments.

V_C, Variable costs

The variable costs are those costs which are proportional to the production rate and include feedstock and utility costs. These can be inferred from published financial statements.

T, Secunda total production

This is the Secunda total production of solid, liquid product and gaseous products from both Fisher Tropsch as well as gasification, as shown in Figure 11. This determines Secunda's revenues and this production is dominated by Fischer Tropsch originated liquid products.

O_p, Oil price

This is the Brent oil price, and this is correlated to the price of most of the fuels and chemicals Sasol sells.

R, Refining crack spread

The refining crack spread is the average price increment Secunda receives for its final product refined fuel prices above the oil prices. Refining adders are determined by the markets depending on global supply and demand for fuels and global refining capacity. Refining cracks can be volatile and are affected by geopolitical events and seasonality. The average refining crack spread for Secunda is determined by the basket of transportation fuels Secunda produces and can be estimated from the published financial statements. For modelling purposes, the inland location advantage of Secunda is included as part of the refining crack spread as this is the basis of Sasol financial statements.

Δ, Chemical oil price adder

The chemical price adder is the average price increment Secunda receives for its chemicals above the oil price. The chemical adders are determined by the markets depending on global supply and demand for chemicals and plant capacity. For global petrochemical commodities such as polymers a boom-and-bust cycle of oversupply and undersupply has been observed for decades (Chemical Market Analytics, 2021). A period of oversupply was observed after the financial crisis in 2008 followed by a boom period with significant additional capacity having recently been added causing a new bust period. This has depressed polymer adders' prices, which are forecast to continue for the next few years. Each petrochemical has its own set of market dynamics. The average chemical adder for Secunda is determined by the basket of petrochemicals Secunda produces and can be estimated from the published financial statements.

M_{RG}, Methane rich gas

Secunda exports a portion of its products as a natural gas substitute termed methane-rich gas. Around 23 PJ/yr is exported and is a valuable secondary source of income. MRG production is assumed to scale with total production and thus has units of US$/ton of total Secunda production.

C, CO_2 emission intensity

This is the amount of CO_2 emitted for each ton of production in the Secunda production chain. Because Secunda is mainly based on coal it has a relatively high CO_2 emissions intensity of about 7.9 CO_2/ton of total product, which is considerably higher than conventional refineries and chemical plants.

While carbon taxes are low or subject to exemptions this is not a crucial factor but, as carbon prices rise and carbon border taxes are applied in the future, carbon emissions intensity will start becoming a more important factor. Sasol's plan to reduce emissions by 30% by 2030 involves increasing efficiency and more use of renewable energy to assist in reducing the CO_2 emissions intensity, which is an important input variable for Secunda economic modelling.

P_C, Carbon price

This is the average price Sasol pays for each ton of CO_2 Secunda emits. It is currently about US$1.6/ton of CO_2 but is likely to increase significantly in the future. Carbon prices in Europe are volatile but are currently about €59/ton although they have been as high as €100/ton (Trading Economics, 2024). When exporting chemicals, the carbon intensity of the Secunda products will face increasing scrutiny and carbon prices are expected to increase significantly (Creamer, 2023b).

These 10 input parameters are sufficient to create a simple Secunda cash flow model. The following output variables are considered:

Output variables:

R:	Secunda revenue	(US$bn/yr)
E:	Secunda total costs (expenses)	(US$bn/yr)
G:	Secunda gross profit (R -E)	(US$bn/yr)

A brief description of these output variables is as follows:

R, Revenue

This is the total turnover for Secunda production sales measured in US$ billion per year.

E, Secunda total costs

This is calculated by adding the fixed and variable costs for Secunda. It is important to note it excludes capital costs and interest and debt repayment.

G, Secunda gross profit

This is calculated by subtracting costs from revenue.

The following three equations describe the output variables in terms of the input variables:

$R = \alpha T(O_P + R) + (1 - \alpha)T(O_P + \Delta) + TM_{RG}$

$E = F_C + TV_C + CTP_C$

$G = [\alpha T(O_P + R) + (1 - \alpha)T(O_P + \Delta) + TM_{RG}] - [F_C + TV_C + CTP_C]$

In considering the boundary where G=0, that is Secunda cash breakeven excluding (non-maintenance) capital expenditure and any debt costs, there are 10 independent input variables which create a 10-dimensional space. For simplification α is fixed at 0.58. To illustrate and plot sections of this space six of the remaining input variables can be fixed and the remaining three variables can be plotted. As an initial illustration, an attempt can be made to calculate F_C and V_C from existing financial information and to fix them for an initial analysis. The effect of changing them can of course be explored later. R, Δ and C can also be fixed to potentially be varied later. This leaves T, O_p, and P_C to be considered.

The equation for G with the 3 input variables remaining shown in green is:

$[\alpha T(O_P + R) + (1 - \alpha)T(O_P + \Delta) + TM_{RG}] - [F_C + TV_C + CTP_C] = 0$

If we fix $P_{C,}$ we then get a two-dimensional equation and can, for example, plot O_p on the y-axis and T on the x-axis and then also vary P_C by plotting multiple lines on this graph. This will then provide a complete picture of Secunda breakeven for all relevant oil prices, Secunda production volumes and carbon prices allowing a visualisation of Secunda cash breakeven for these input variables.

The preceding breakeven equation can then be rearranged as a two-dimensional equation to calculate the breakeven oil price with the variables shown in green as follows:

$O_P = F_C/T + (V_C + CP_C - \alpha R - (1 - \alpha)\ \Delta\text{-}TM_{RG})$

This is an equation of the form:

$O_P = F_C/T + D$
Where D is a constant.

Calculation of the input variables based on existing published information

The model input variables were calculated for the Sasol financial year ending 30 June 2023. The primary sources of information were:

- Sasol Limited's end-of-year results as of 30 June 2023 (Sasol, 2023d)
- Sasol South Africa's end-of-year results as of 30 June 2023 (Sasol, 2023d)
- Sasol Climate change report for the year ended 30 June 2023 (Sasol, 2023c)
- Sasol Business and Performance Metrics for the year ended 30 June 2023 (Sasol, 2023a)

The Sasol segmental and regional reporting methodology does not present Secunda only financial information. A Secunda standalone view was back-calculated/estimated by netting out such first-order factors as:

- Natref refinery impacts
- External coal purchases
- External white product purchase for resale
- Effects of inter-segment transfer pricing

Extracting Sasolburg specific operations data from these data sources (excluding Natref) was on occasion not possible using available data and a common average approach was assumed (particularly concerning fixed costs within chemicals South Africa).

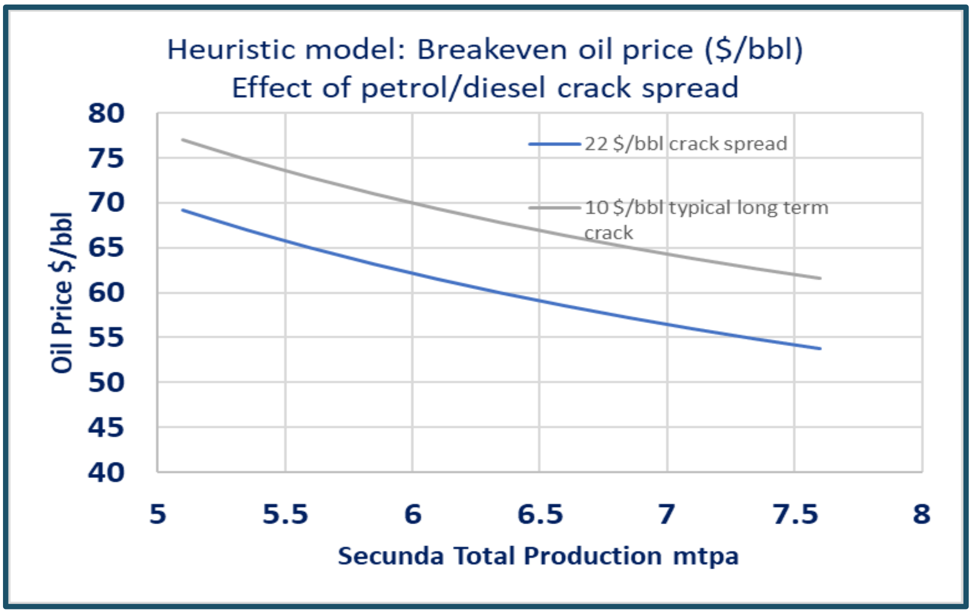
Model results and discussion.

Based on the analysis exercise the seven remaining input parameter values calculated for the base case are as follows:

α:	Secunda fuel production fraction	58%
FC:	Fixed costs	2.0 US$bn/yr
VC:	Variable costs	480 US$/ton
R:	Refining margin	194 US$/ton)
Δ:	Chemical oil price adder	404 US$/ton
C:	CO_2 emission intensity	7.89 (ton CO_2/ton total production)
P_C:	Carbon price	1.8 US$/ton
M_{RG}:	methane-rich gas	25.7 US$/ton of Secunda production

The base case oil price breakeven model output is shown in Figure 28.

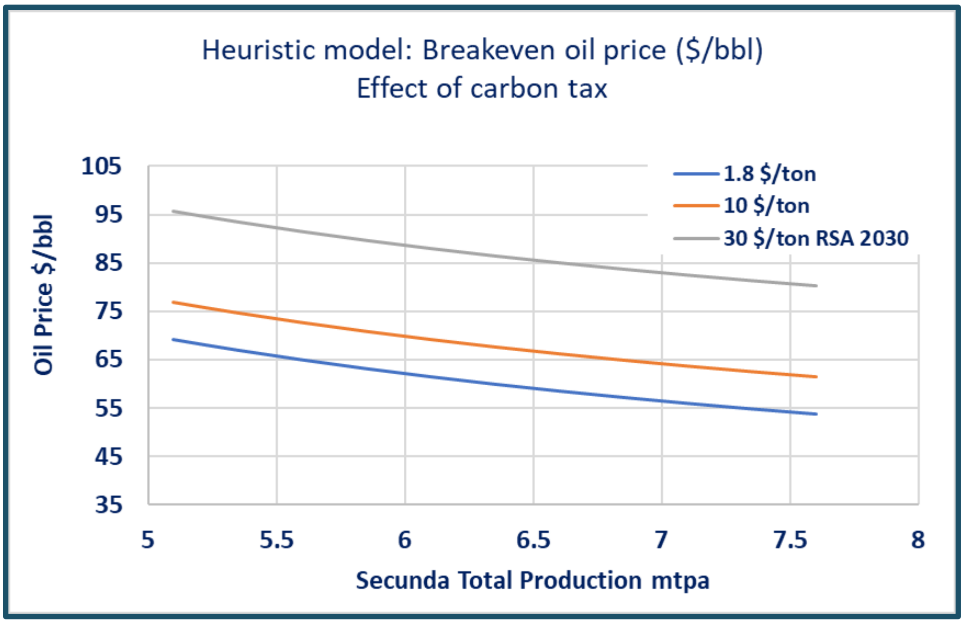
Figure 28: Base case oil price breakeven plot



The breakeven oil price is just below US$55/bbl for total production of 7.5 mtpa, decreasing to just below US$63/bbl for production of six mtpa. This provides a rough indication of what the implications of reducing production volumes are on the cash breakeven oil price.

It is now possible to perform sensitivities for some of the remaining input parameters. The effect of increasing carbon prices is shown in Figure 29.

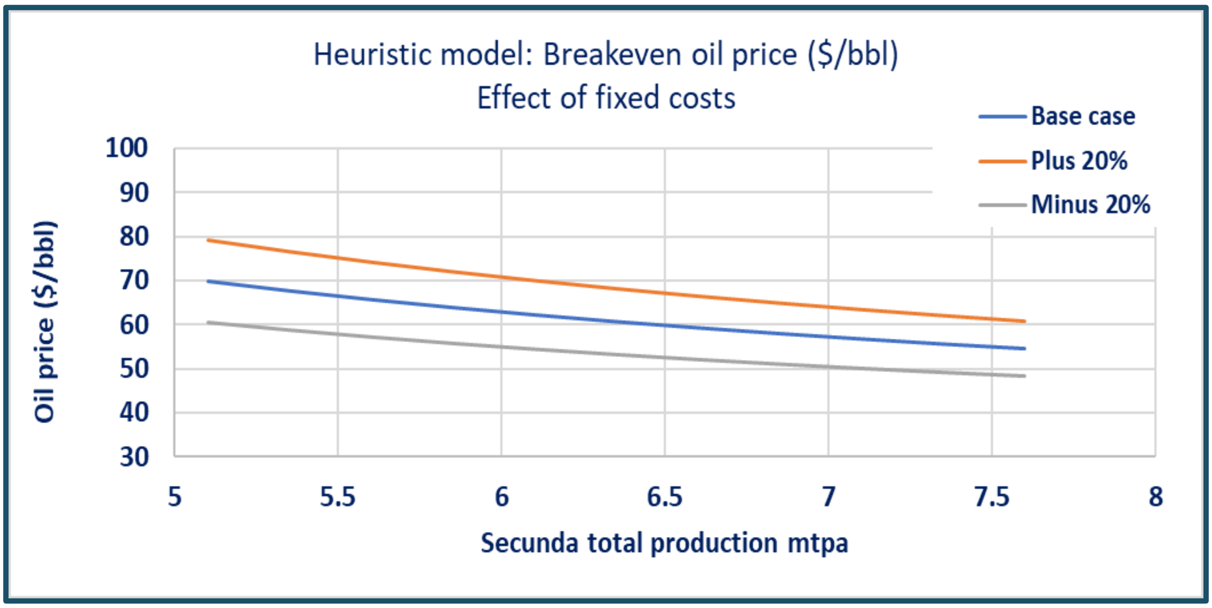
Figure 29: Effect of carbon price on breakeven oil price



The results show that a carbon price above US$30/ton and approaching European levels of US$50/ton is not reasonably affordable for Secunda and would render Sasol cash negative at current oil prices. Given Secunda's high carbon intensity this is not entirely unexpected. The present South African government target of US$30/ton CO_2 in 2030 is equally daunting.

The effect of increasing or decreasing fixed costs is shown in Figure 30.

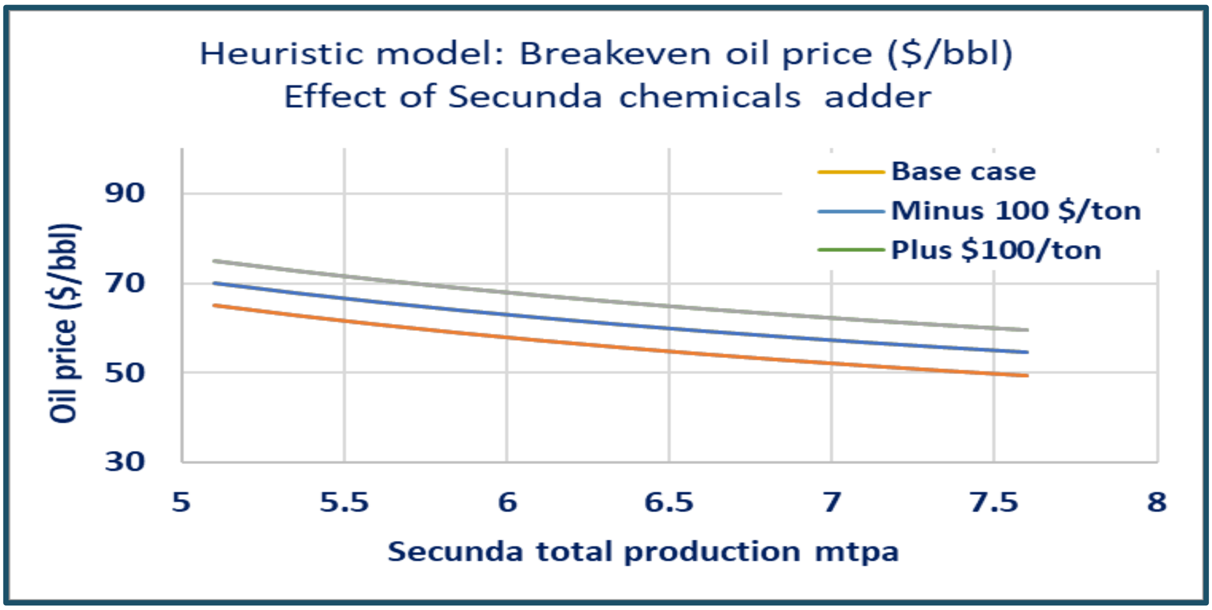
Figure 30: Effect of fixed costs on breakeven oil price



As production declines one of the options would be to reduce fixed costs employing a cost-cutting exercise. The effect of a 20% fixed cost reduction is shown. However, given the significant capital program to reduce Secunda emissions by 30% by 2030, one can question how feasible it will be to maintain fixed costs let alone decrease them. Projects such as the coal destoning and briquetting projects, among others, still need to be implemented and operated. The operational complexity of Secunda is increasing and the effect of a potential increase in Secunda fixed costs is also shown.

As discussed, the chemical price adder is subject to cyclical ups and downs. This is shown in Figure 31.

Figure 31: Effect of chemical price adder on oil price breakeven costs



The current breakeven analysis ignores two very real costs for Secunda. These are the capital costs required for Secunda to remain in operation and meet emission reduction targets as well as Secunda's contribution to interest payments and debt reduction. This data are not published but some rough estimates were made based on existing published information. These estimates are not intended to be accurate but rather to show the approximate effect of adding these additional costs.

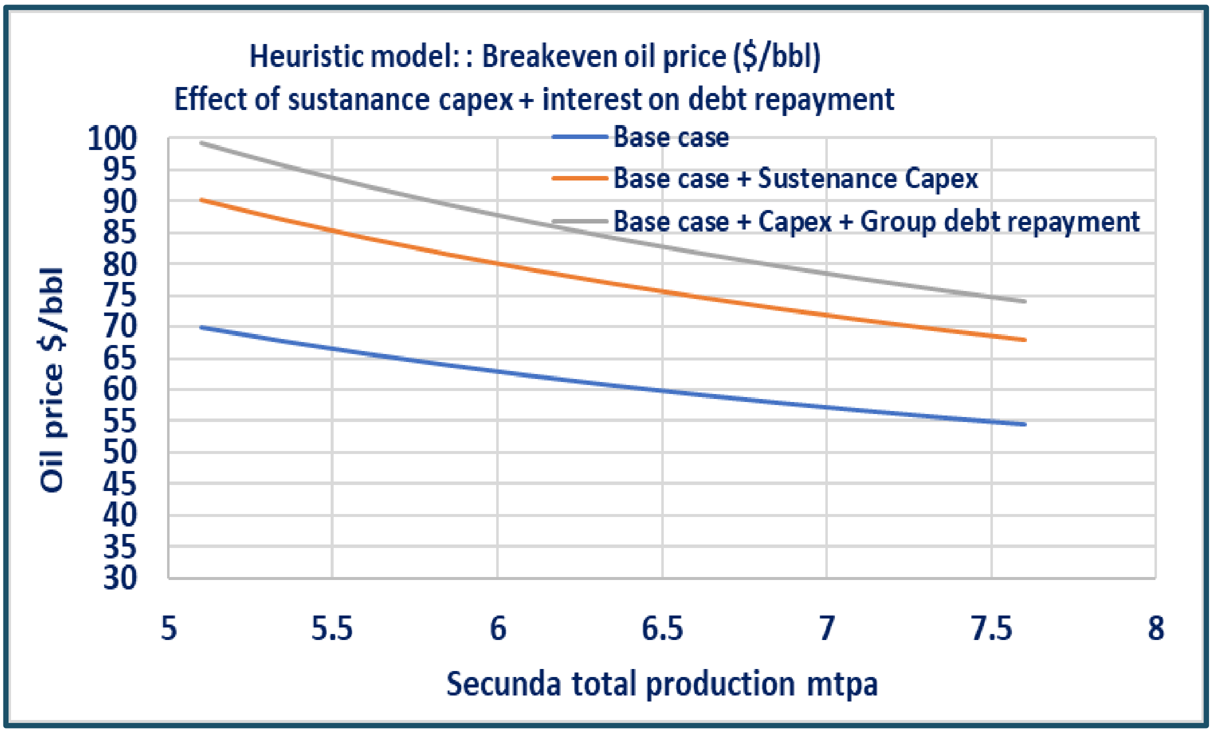
Sasol's total capital expenditure per year has been steadily increasing (Sasol, 2023e). In the 2023 financial year, Sasol's capital expenditure was R30.9 billion and is forecast to be R33-34 billion in 2024. Given the extensive capital programme for emissions reduction and major maintenance, it was conservatively assumed that the Secunda value chain would need to spend at least R15 billion of Capex pa in the years up to 2030. This equates to US$0.79 billion pa.

Sasol reported a gross US dollar-denominated debt of US$6.5 billion at the end of the 2023 financial year (Sasol, 2023e). Based on an assumption that Sasol's international business will not be able to afford this debt on its own it is assumed that it will be necessary for the Secunda value chain to assist with this debt burden. It was crudely assumed that Secunda would need to assist with at least USD2.5 billion of this debt. It was further assumed that at an interest rate of 5% and assuming the debt be repaid over 10 years an amount of US$0.32 bn pa would be required.

It is acknowledged that these assumed additional costs are somewhat arbitrary, but it is argued they are conservative, and they give an indication on what the imposition of these additional costs do to Secunda's cash breakeven costs.

The results including these additional costs are shown in Figure 32.

Figure 32: Effect of adding capital expenditure and debt repayment to Secunda breakeven oil price



It is important to note that the addition of these costs significantly increases the Secunda breakeven oil cost. It is also important to note that although significant capital will be spent to meet the 2030 targets production is set to decline which increases the breakeven cost.

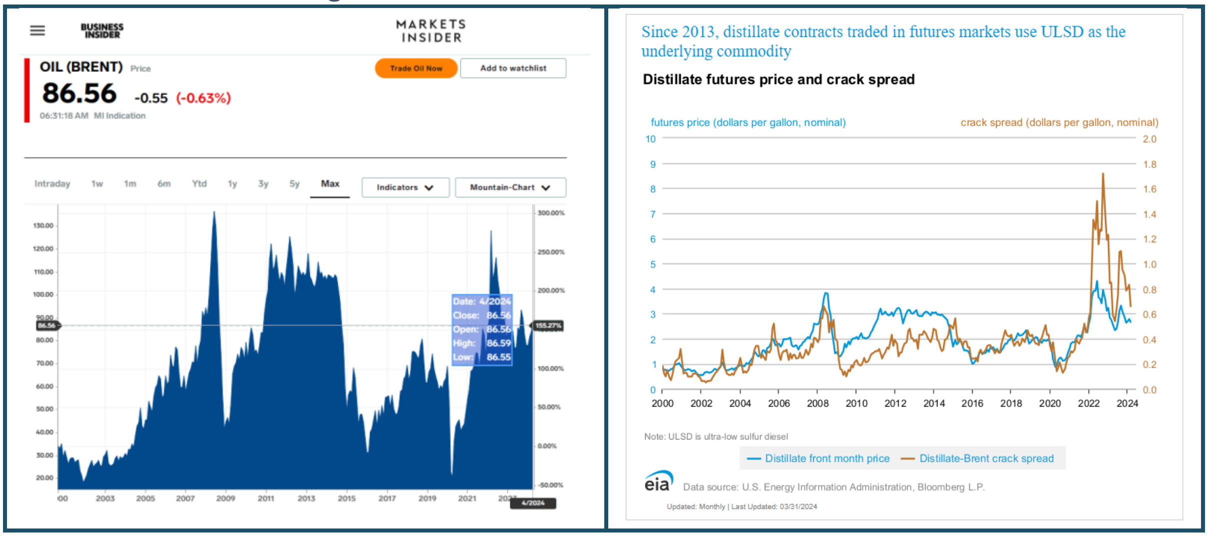
Should there be a period of sustained low oil prices (<70/bbl) for a period of six months or more in the coming years, the prospect of Secunda becoming cash negative (before hedging activities) is a distinct possibility. In principle, capital expenditure can be deferred in times of crisis but given the execution of large capital projects in the coming years, evaluating the feasibility of interrupting partially complete capital projects and what the consequences of that will be is needed.

Although this is a simplified model whose parameters have been calculated with incomplete information, it is argued that the model gives a useful indicative perspective of the economic challenges facing Secunda of a common base, particularly concerning the increase in carbon price closer to European type levels. Further updating and refining of the model with additional information and the addition of additional features is always possible should that be warranted.

APPENDIX C: Five-year share price history of reference petrochemical companies

Crude oil is trading in the upper end of its historical range in recent history. Furthermore, crack spreads (especially diesel), post COVID, have been at almost unprecedented levels. As such, post COVID has been an exceptionally beneficial time for oil companies as evident in the price history in Figure 33.

Figure 33: Price histories: crude oil and distillates

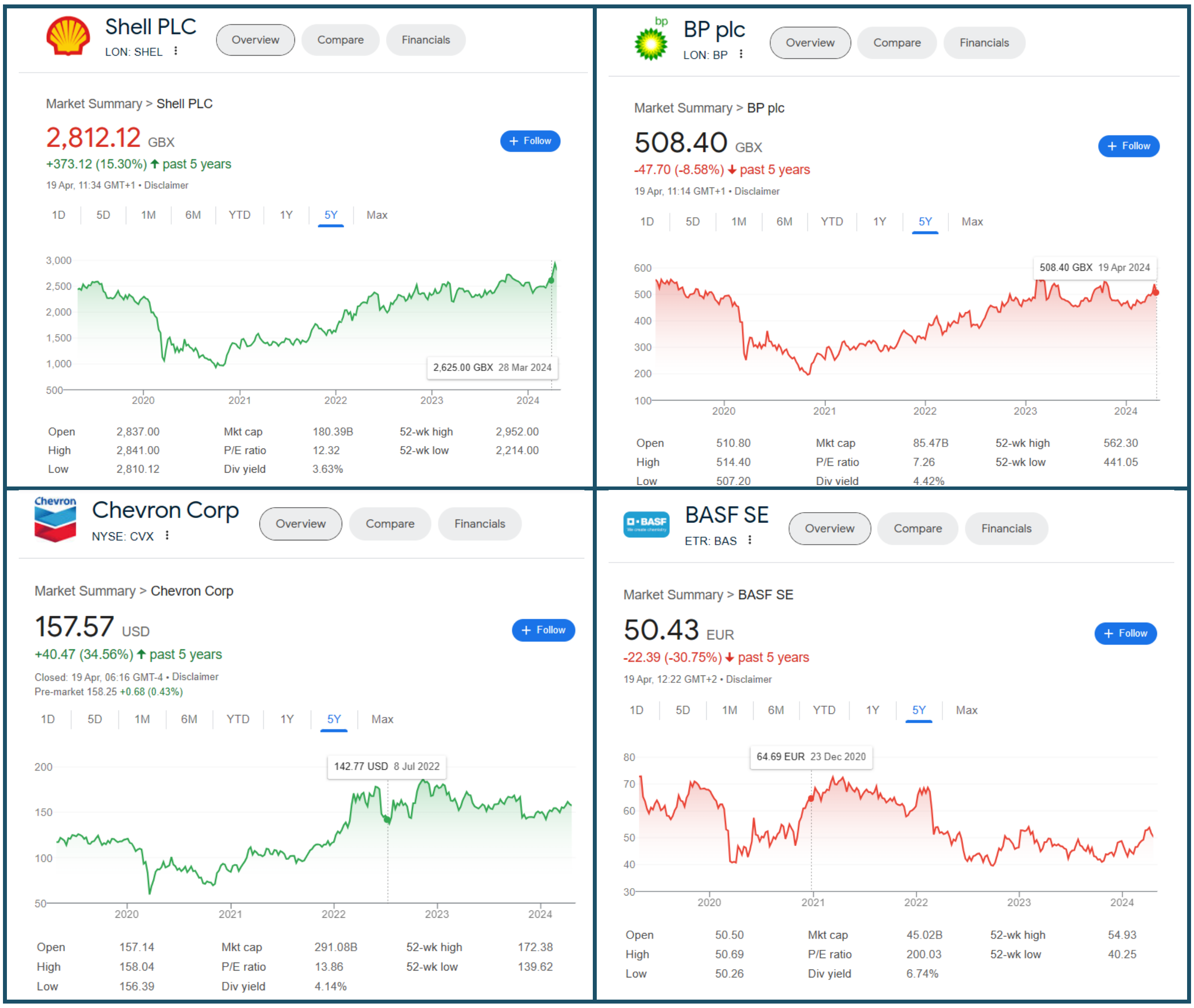


Source: Business Insider, 2024; EIA, 2024.

Many petrochemical and polymer prices are set at the margin by naphtha cracking, and thus barring any unusual supply/demand effects, integrated petrochemical companies would be expected to be strong. By way of example, the share prices of Shell, BP and Chevron have been on an upward trajectory in the post-Covid period – see Figure 34.

BASF represents an exception to this trend due to a combination of the impacts of the Russian invasion of the Ukraine (February, 2022) and the low level of the Rhine River hampering transport and operations in Ludwigshafen Germany (August 2023) and co-incidentally (in some reports) attributed to climate change (Clean Energy Wire, 2023). Nevertheless, over the same FY2023 period, BASF's share price was drifting upward despite these headwinds (based on data obtained via Google summary search results). (BASF SE, 2024)

Figure 34: Share price history of integrated fuel and chemical companies



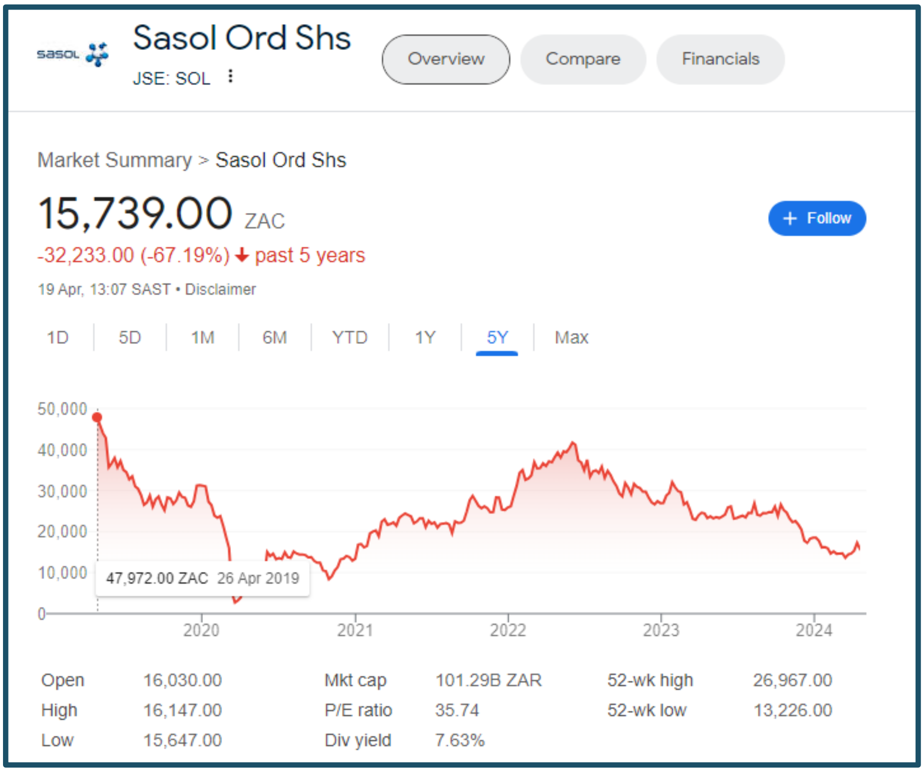
Source: Google search, Shell share price. BASF SE, 2024.

Sasol's integrated nature has changed materially since the start-up of the Lake Charles Chemical Complex given its size and earning potential. The share price of Sasol's JV partner LyondellBasell (LYB) is reported. LYB's share price drifted upwards over the FY2023 timeframe after being slightly stronger in the initial post COVID recovery period – see Figure 35.

Figure 35: LyondellBasell Industries NV share price

In contrast, Sasol's post COVID share price history reveals a very different trajectory – see Figure 36.

Figure 36: Sasol ordinary share price



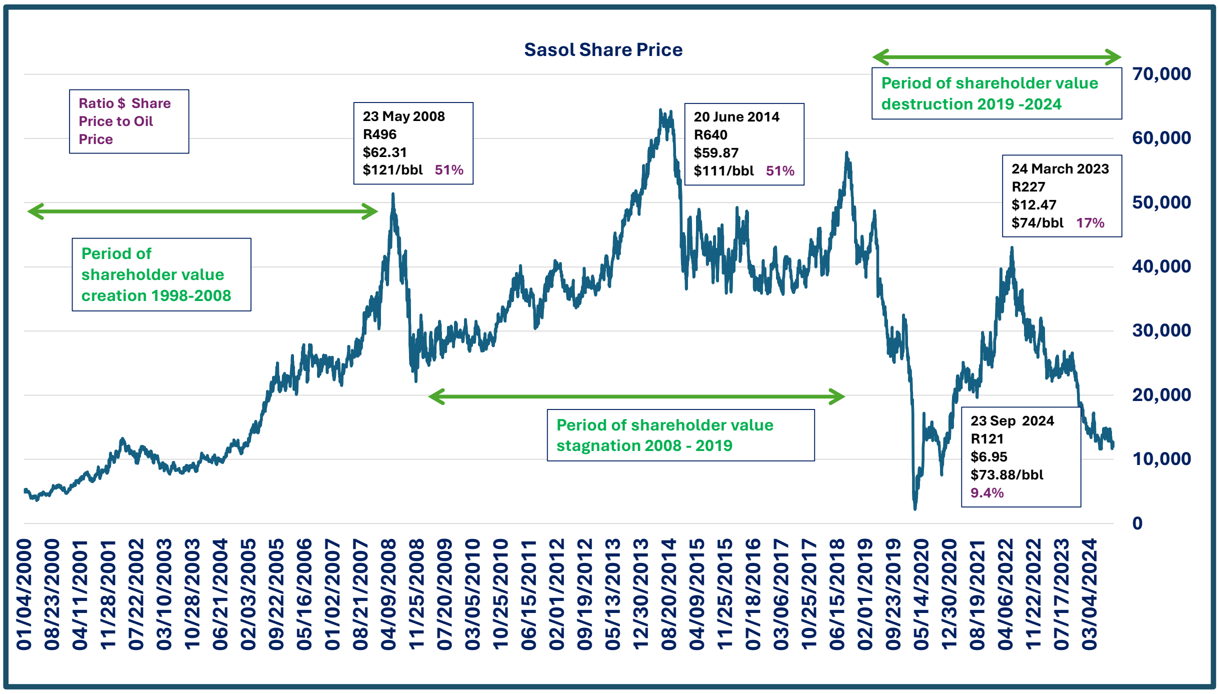
Based on this information, it was decided that there were no unreasonable external market pricing events that would warrant some form of pricing correction when calibrating the Sasol high level economic model to its reported FY2023 revenues.

APPENDIX D: Understanding Sasol's share price history

In reviewing and analysing Sasol and Secunda's future it is useful to understand Sasol's financial position and historical performance. Much useful information is captured in the share price history. Sasol's ability to maintain and potentially transform Secunda is tied up with its financial position and the appetite of shareholders and financial institutions to support and finance the transition of the company.

In a sense, the share price is a measure of the health and prospects of a company (Murphy, 2022). The Sasol share price history from 2000 is shown in Figure 37. The period since 2000 can broadly be divided into three eras. The first era was from 2000 until the financial crisis in 2008, the second era was from 2008 to about 2018, and the final era was from about 2019 to the present.

Figure 37: Sasol share price history, 2000 to 2024



Source: Google Finance, 2024.

Shareholder value creation 2000-2008

The first era saw the share price rising from below R30 to just below R500 a more than 16-fold increase. This was an era of unprecedented shareholder value creation. The oil price and the exchange rate were tailwinds during this period, but this is not a complete explanation. Good capital allocation, which generated returns above the weighted average cost of capital (WACC), growth of the business and international expansion were also important factors. Sasol became very well regarded by the market. Sasol's debt was also very low, and Sasol was even accused by some analysts of having a "lazy" (Laing, 2008) balance sheet. However, this "lazy" balance sheet with low levels of debt enabled Sasol to sail through the 2008 financial crisis relatively unscathed.

Shareholder value stagnation 2009-2018

The era from 2008 to about 2017 saw an initial crash associated with the financial crisis which affected companies across the board. A gradual recovery then followed and by mid-2014 the share price peaked at R640. Bearing in mind that the Rand is a volatile currency which has depreciated against the dollar. it is instructive to look at the US dollar share price rather than the Rand share price. In May 2008 the dollar share price was about US$62 and in June 2014 it was US$60.

The Sasol share price is unsurprisingly very sensitive to the oil price, which drives both revenue and profitability. During this era, there was an empirical heuristic proposed by analysts and other investors that the dollar share price of Sasol was about half of the Brent crude oil price. This ratio is reflected in light blue in Figure 37. This shows that this heuristic is approximately true in both 2008 and 2014.

There was no appreciable increase in the dollar share price in this era although regular dividends were paid. Overall, this was a period of shareholder value stagnation.

The culmination of shareholder value destruction 2019-2024

The LCCP and cost overruns

The financial investment decision for the LCCP was taken in October 2014 for an amount of US$8.1 billion (Sasol, 2024a) with an expected start-up date of 2018. The Sasol annual financial statements of June 2016 confirmed that after a detailed review of the LCCP the cost had escalated to US$11 billion (Sasol, 2016).

In early 2019 the true extent of the cost overruns and other problems at the LCCP became apparent with the costs escalating to US$12.9 billion compared to US$8.1 billion when the final investment decision was made in October 2014 (Sasol, 2024b). This was the culmination of several earlier announced cost increases.

The LCCP also faced several adverse events which were not planned for. There were two hurricanes, an arctic freeze, and the COVID-19 pandemic, which severely impacted the LCCP ramp-up plans and profitability. However statistical evidence (Flyvbjerg, 2014) shows that in the execution of mega projects, unplanned events are common and are often unaccounted for, leaving budget and time contingencies inadequate, and benefits receding into the future. It could perhaps be argued that the LCCP faced an unusually high number of adverse events.

In Sasol's trading statement, released by the Stock Exchange News Service on 8 February 2019, updated guidance was provided for LCCP's schedule and capital costs, which were estimated in the range of US$11.6-US$11.8 billion (Sasol, 2024c). In May 2019 a further cost escalation of about US$1 billion was announced (Heiberg and Rumney, 2019). In October 2019, joint CEOs, Bongani Nqwababa and Stephen Cornell, agreed to resign after an independent review of the LCCP project (News24, 2019).

These events precipitated a halving of the share price from August 2018 to November 2019. The reasons for the failed LCCP project were complex but the independent review flagged several factors (Sasol, 2020a) such as:

- The competence of the LCCP management team.
- A culture of excess deference to management such that the Steering Committee created to oversee the LCCP, did not exhibit sufficient scepticism toward reporting by the LCCP leadership team.
- Inadequate procedures to ensure that internal ethics complaints as to the LCCP were escalated appropriately.
- Inadequate control procedures within the LCCP control environment allowed erroneous and/or unsupported reporting by the LCCP leadership to go unchallenged without proper escalation of potential red flags.

Sasol gave assurances that all necessary remedial steps were being taken to resolve all the issues flagged, with Sasol indicating that these problems were ringfenced to the LCCP project and not indicative of a wider cultural problem within Sasol. However, the question of to what extent the LCCP management culture reflected the broader Sasol culture can perhaps not be so easily brushed aside.

Forced asset sales and shareholder value destruction

By the end of 2019, Sasol was in a vulnerable financial position and when the global COVID-19 pandemic surfaced in early 2020 the conditions were in place for a perfect storm and a full-blown crisis. The global COVID-19 lock downs in early 2020 caused the Brent crude oil price to drop below US$30/bbl causing Sasol an almost immediate cash flow crisis (Sasol, 2020b) given the apparent absence of any material oil price hedging program (Sasol, 2020c). This, taken together with high debt levels, meant Sasol potentially breached key debt covenants of net debt/EBITDA of three times with funding banks (Davie, 2020). The banks then required Sasol to embark on an urgent accelerated asset disposal programme with tight deadlines to reduce debt to more manageable levels by November 2020.

An additional option considered at the time was a US$2 billion rights issue (Heiberg, 2020) but with very low share prices prevailing this could have proved dilutive to existing shareholders and was not an attractive option for existing shareholders. In addition, the tight deadlines and regulatory compliance issues associated with a rights issue in both South Africa and the US rendered completion of a rights issue within the required timeframes problematic placing further pressure on forced asset sales.

This was a difficult time in the global economy and not ideal for forced asset sales. Several assets were sold with the most significant being a 50% share in the LCCP cracker and downstream polymer plants to LyondellBasell. Sasol retained ownership of the other LCCP derivative plants. Sasol ceded operational, business and marketing control of the LCCP polymer business to LyondellBasell.

Sasol classified the LCCP Base Chemicals business as disposal groups held for sale on 30 June 2020 and an impairment (Creamer, 2020) of R72.6 billion (US$4.2 billion) was recognised, reducing the carrying value of the disposable asset down to its fair value less the cost to sell the asset. The carrying value of the asset on 30 June 2020 was R71 billion (US$4.1 billion). By implication, the book value of the asset therefore amounted to US$8.3 billion. Sasol's 50% sale of the asset for US$2 billion placed a valuation of US$4 billion on the asset, which is at a 51% discount to the initial book value of the asset. The forced sale of the LCCP polymer business was value destructive for Sasol shareholders and correspondingly beneficial for LyondellBasell.

In February 2020, US investors filed a class action lawsuit against Sasol for misrepresentation and non-disclosure of material adverse facts related to the LCCP project (Hagens Berman, 2020). In September 2022, Sasol agreed to settle the lawsuit for US$22 million. (Reuters, 2022)

At the height of this crisis in March 2020, the Sasol share price went below R30 but with the successful implementation of the asset disposal programme and cost-cutting measures, the share price recovered to above R400 by May 2022. However, since that high point, the share price has been on a volatile yet downward trajectory.

The traditional Sasol share price heuristic of the dollar share price being half the Brent crude oil price broke down completely. In March 2023 the dollar share price was 17% of the Brent crude price and in August it was 16%. The Sasol share price history for the last six months is shown in Figure 38. At the time of writing (8 February 2024) the Sasol share price is US$8.07, and the Brent crude oil price is US$79.25. The dollar share price as a fraction of the Brent crude oil price has now declined to 10% from 16% in August last year. In the six months to February 2024, the Sasol share price has declined by 39% and is at the same level as it was in nominal Rands nearly two decades ago in 2005. At the time of writing (4 June 2024) the share price is trading in the range of R116 (US$6.20) with a Brent oil price of about US$77.bbl. The share price is thus only 8% of the Brent crude oil price compared to the 50% heuristic of the past.

Management turnover

The difficult times that Sasol has faced since 2019 have also taken its toll on staff and staff morale. There has been a spate of recent high-profile resignations at Sasol. Hanré Rossouw, Sasol's Chief Financial Officer, resigned and will leave at the end of October 2024 after only two years in the job (Moneyweb, 2023). Priscillah Mabelane, who was Executive Vice President: Energy Business at Sasol, resigned in March 2024 after less than four years in her job (Sasol, 2024d).

The Sasol CEO, Fleetwood Grobler, retired at the end of March 2024 and was replaced by a Sasol insider, Simon Baloyi. The chair of the board and non-executive director, Stephen Westwell, retired on 1 June 2024 (Green Building Africa, 2024). Prior to this the previous chair, Sipho Nkosi, resigned in November 2023 (Parker, 2023b).

In 2020 Sasol underwent a restructuring process and many experienced and senior staff left the organisation. Four years later, in 2024, another "streamlining" process appears to be underway and senior and experienced staff have taken early retirement or resigned.

Conclusion

The Sasol share price history for the six months preceding 4 June 2024 is shown in Figure 38.

Figure 38: Sasol share price history in the six months preceding 4 June 2024

It is thus fair to conclude that the Sasol market valuation is rolling off a cliff with an uncertain future. In the early 2000s, Sasol was very well regarded by the markets. After the financial crisis in 2008, shareholder value stagnated before a precipitous decline starting in 2019. It appears that the market has now lost faith in Sasol.