TRADE & INDUSTRIAL POLICY STRATEGIES

INDUSTRIAL DEVELOPMENT PROJECTS

FURFURAL AND FURFURYL ALCOHOL PLANT (BIOCHEMICALS)

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A contribution to South Africa's Post COVID-19 Recovery Plan: Tapping into new and unmet sources of demand to support the establishment of new companies, factories, value chains and employment opportunities

Trade & Industrial Policy Strategies (TIPS) is a research organisation that facilitates policy development and dialogue across three focus areas: trade and industrial policy, inequality and economic inclusion, and sustainable growth

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INTRODUCTION

As South Africa responds to COVID-19 and aims to stimulate the economy and job creation post lockdown, an opportunity should not be missed to consider investing in new product markets which could increase the size and dynamism of the manufacturing sector. Such a package could contribute to arresting the current trend of deindustrialisation and shift the trajectory of the industrial base into new, sustainable growth areas and value chains. This would result in new factories, new downstream demand for primary and intermediate inputs, new export products, increased foreign exchange earnings, and importantly new direct and indirect long-term jobs.

Using the idea of "business *un*usual" TIPS economists have put together a Post COVID-19 recovery programme in South Africa that could provide the impetus to arrest the current trend of deindustrialisation and herald in the beginning of a new generation of industrial activity.

Seven initial projects have been identified. They represent a wide array of economic activity in the special purpose machinery, agro-industries, bioplastics, shipping, alternative fuel, biochemicals and automotive component manufacturing sectors.

This project looks at the commercial scale production of furfural and furfural alcohol from sugarcane bagasse for the local foundry industry and broader export market.

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FURFURAL AND FURFURYL ALCOHOL PLANT (BIOCHEMICALS)

PROJECT SUMMARY SHEET

TITLE	Commercial-scale production of furfural and furfural alcohol from sugarcane bagasse for the local foundry industry and broader export market
LEAD DEPARTMENT	Department of Trade, Industry and Competition.
PROJECT SUMMARY	The project is to construct a new 20 000 ton furfural and furfural alcohol plant which would be integrated into an existing sugar mill in the Nkomazi district in Mpumalanga. Raw materials and services would be transferred between the sugar mill and the furfural plant. A separate plant using utilities (steam and electricity) provided by the sugar mill will convert the furfural into furfuryl alcohol. Furfuryl alcohol is used in the production of resins mainly for large steel castings in the foundry industry. The location of the Mill on the Maputo corridor also provides a strategic export benefit along with being able to supply local South African foundries.
APPROXIMATE BUDGET	R675 million (initial estimate)
STAKEHOLDERS	• Private cane farmers that operate the farms and maintain steady cane supply who may participate through an investment offering. • Community members who participate in the industry through their shareholding in the agricultural joint ventures supplying sugar cane to the mill if their JV agrees to an equity share of the new business. • South African Sugar Research Institute, which assists and provides ongoing support in terms of appropriate seed cultivar, crop density and other agronomic and cultivation parameters for the region. • International firm (potentially identified) which will sign an offtake agreement; • Local and international engineering and construction companies to execute the building of the production plant. • Logistics company to facilitate export of the product via Maputo or alternatively a suitable harbour in KwaZulu-Natal. • Local agro-processing company (identified) with Good Manufacturing Practice accreditation to undertake the plant operation.
CAPITAL INVESTMENT	• Physical infrastructure of the complete production facility integrated with the sugar mill. This includes *inter alia* upgrades of the existing boilers to improve efficiency, hydrogen generation, upgraded effluent treatment and tank storage. • Capital equipment will be for the processing plant.
OUTCOMES	• Job creation: Main job creation is at the farm and this project will secure existing jobs in rural Mpumulanga. If additional cane is planted new jobs will be created. Mill and auxiliary services and the support service will also increase employment. • New export product and export revenue stream. Product to be sold locally but mainly to US and European market. • A strategic intervention to bolster the country's efforts to become a green economy and be the leader in Africa in green chemicals. • May assist in decreasing input costs to foundries of resins for sand moulds which currently decreases their competitiveness vis-a-vis BRICS (Brazil, Russian, India, China and south Africa) competitors and allows increased import penetration in castings.

Commercial scale production of furfural and furfural alcohol from sugarcane bagasse for the local Foundry Industry and broader export market

Introduction

The sugar industry plays an important role in South Africa due to its labour intensity and the rural location of the industry. The sugar growing and milling industry, which creates 92 000 jobs, supports nodes of rural economic development and opportunity mainly in Mpumalanga and KwaZulu-Natal. Industry experts suggest that these jobs and nodes of economic development are at risk due to the oversupply of sugar cane in the domestic market. Excess supply of domestic sugar is sold on the world market at prices which currently barely cover production costs. In response, the local sugar industry is investigating how to diversify its revenue streams to maintain profitability and current employment levels.

The new sugar industry business model is a triple stream model made up of: sales of sugar; co-generated electricity; and biofuel/biochemical production. The traditional sugar mill in these instances has evolved into a bio refinery, with revenue from the streams cushioning producers from the vagaries of the sugar market. A bio refinery is any facility that integrates biomass conversion processes and equipment to produce fuels, power and value added chemicals. Interest in bio refineries is growing as producers increasingly seek environmentally friendly chemicals manufactured from renewable resources as substitutes for fossil-based chemicals. This demand is driven by consumer demand, social expectation and more immediately increasing government regulation and intervention related to climate change and end-of-life product legislation. The biochemical industry is growing rapidly and such growth is expected to increase and accelerate.

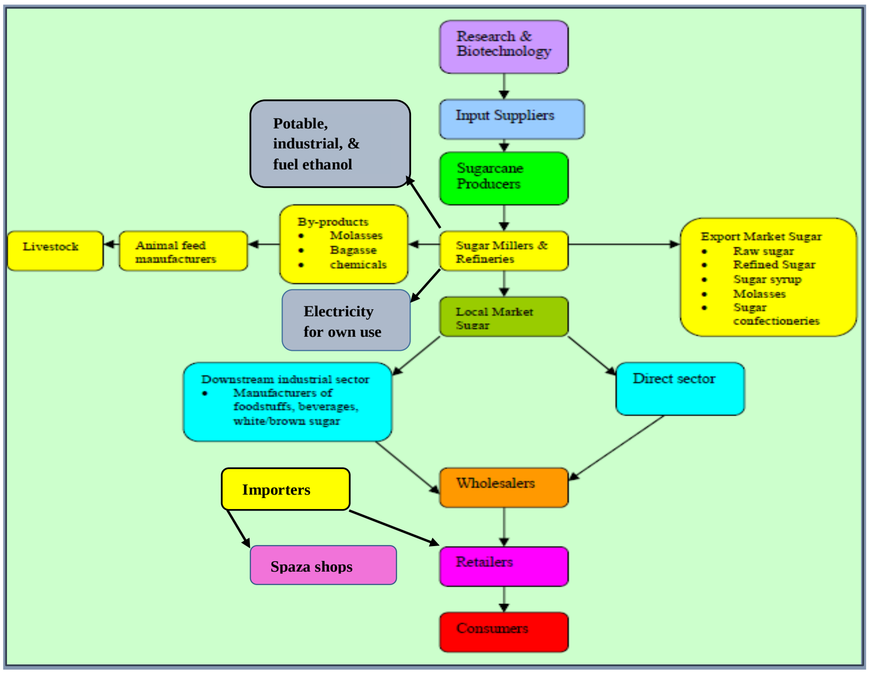
The waste product left over after sugar production is called bagasse. It is currently used to fire the boilers of sugar mills, making them energy self-sufficient. It is possible that this bagasse can be diverted on its way to the boilers and a chemical called furfural extracted from it before it is returned to the boilers for fuel (explained in more detail below). Furfural and furfuryl alcohol have multiple uses including providing an input substitute for high growth fabrics such as Spandex and as a basis for resins used in sand moulds in the foundry industry. This latter use is of particular interest as research in 2019 (Braude and Montmasson-Clair 2019) showed that high sand and resin input prices were a major explanatory variable in the lack of competitiveness of South African foundries in comparison to the BRIC's countries whose cheap imports are penetrating the domestic market and resulting in foundry closures and job losses.

This proposal, based on research conducted on behalf of the dti by TIPS on the sugar value chain, a report on the biomaterials sector for dti, DST and DEAT (Braude and Montmasson-Clair, 2019) and a report for the dti covering the international competitiveness of the South African Foundry Industry. As such the project potentially ticks three boxes: it aides the sustainability of the sugar sector; it potentially increases the competitiveness of the foundry industry and supports job retention in that sector; and it positions South Africa favourably in terms of moving into the biochemicals and green economy space and its potential high growth markets.

The sugar value chain

Figure 1 shows the multiple uses of sugar cane and its numerous by- products. Sugar cane is cut and harvested and transported to the mill. At the mill, cane juice is extracted, purified, filtered and then crystallised into raw sugar. Raw sugar is known to consumers as brown sugar. Raw sugar can be further refined and made into refined sugar known as white sugar or table sugar. White and brown sugars are then packaged either for direct consumption through the retail market or for indirect consumption through the industrial food and beverage market (jam, cool drinks, chocolates).

Figure 1: Sugar value chain



Source: Braude and Montmasson-Clair 2019

The three most important by products of sugar cane and sugar processing are: molasses, bagasse, and biochemicals. Molasses is the syrup from the final stage of crystallisation. It is mainly sold for animal feed and fertiliser. This use is well developed in South Africa. Bagasse is the dry pulp that remains after sugar cane is crushed and the juice extracted. It is a biowaste and can be used as a substitute for coal or oil in mill boilers. This opportunity is also well developed in South Africa and all mills are self-sufficient in terms of electricity. Finally sugar cane can be used as the basis for a range of biochemicals of which bioplastics is a particular example.

Furfural and furfuryl alcohol are particularly interesting biochemicals from an economic and commercial perspective as they are derived using bagasse (a waste product) as a feedstock. This means that production costs are extremely low within a sugar mill and allows the South African industry to potentially compete successfully again Chinese furfural and furfuryl alcohol which has a higher cost structure.

Furfural and furfuryl alcohol production

As part of the sugar production process the sugar mill generates a residual waste product from the sugar cane called bagasse. This is a fibrous material remaining after the sugar rich juice has been extracted. Some of this material is blended into animal feed, while the bulk of it is burned in the sugar mill boilers to produce energy for the mill. In the proposed project, the chemical constituents of the bagasse will be extracted and converted into furfural before returning a combustible residue to the sugar mill. As the furfural can be extracted and the bagasse returned for combustion with little energy depletion the marginal cost of producing the biochemical from the sugar mills perspective is virtually zero.

This understanding of the dynamics and economics of furfural production is important in determining the scale of the market opportunity. With the exception of one small plant in Austria, where furfural is produced in the process of cleaning up the effluent stream from a dissolving pulp mill, all other furfural is produced from agricultural residues, mainly corncobs. All Chinese furfural plants use corncobs as their raw material. There are currently two operating furfural plants, one in the Dominican Republic and one at Sezela in South Africa, which are attached to sugar mills and which use bagasse as their raw material. While agricultural residues are relatively inexpensive, the yield of furfural from these residues is very low. It takes 12 tonnes of corncobs to produce one tonne of furfural and about 34 tonnes of bagasse to produce one tonne of furfural. The critical issue is that furfural plants in China that use corncobs have to purchase them from local corn farmers. Market forces push corncob prices in China up to around US$120 per tonne in times of high demand, but because farmers have an alternative use for these corncobs as domestic heating during winter or as a natural mulch on their fields, corncob prices never fall below the effective coal equivalent price. When the cost of gathering these corncobs and transporting them to the nearest furfural plant are included, the raw material cost to these plants rarely falls below US$60 per tonne. Thus, the corncob cost alone contributes at least around a minimum of US$720 per tonne to the cost of the production of furfural.

In contrast, if bagasse that is en route to the sugar mill boilers to be burned as fuel to power the mill is diverted to a furfural plant for processing before being replaced by the residue from the same furfural plant at a very similar energy value, it can be said that the marginal furfural raw material cost to the sugar mill is very low or approaching zero. Then, although it takes 34 tonnes of this bagasse to produce 1 tonne of furfural, the raw material cost remains very low. It is important to note that once furfural is produced from bagasse, the residue from the furfural plant retains 95% of the energy value of the original bagasse. However, a furfural plant itself needs steam and the fuel cost to generate this additional steam needs to be factored into the cost of production. This gives furfural plants attached to a sugar mill, and operated as part of the overall sugar mill, an operating cost advantage with which Chinese furfural plants using corncobs cannot compete.

Uses of furfuryl in the foundry and textile industry

Although both furfural and furfuryl alcohol are flammable industrial chemicals, they are essentially environmentally friendly chemicals manufactured from renewable resources and leave no harmful residues when they decay. A wide range of chemicals are currently produced from oil that could equally well be produced using furfural as the raw material. As a chemical intermediate, at the current oil price, furfural is not competitive, but should the oil price rise again to around US$100 per tonne, or should consumer pressure for environmentally friendly solutions increase further, furfural could find a whole new range of uses and demand could expand significantly beyond its present level. Two key examples and markets for furfuryl and furfuryl alcohol are the textile industry (and particularly the green fashion industry); and the foundry industry (sand mould castings).

The South African foundry industry is characterised by two types of foundries: smaller, low volume, sand mould foundries which account for 80% of the sectors employment but only 20% of its output; and large, high-volume foundries which use permanent dies and produce 80% of the countries casting output. In a study to determine why small scale foundries were struggling to compete with cheaper imports from China and India, *one* of the explanatory variables related to the input prices faced by small foundries which utilise sand mould techniques.

Table 2 shows the key input costs facing foundries in BRICS nations. South African foundries enjoy the cheapest alloy input costs, and scrap metal costs in South Africa are roughly in line with BRICs competitors. Where South Africa is totally uncompetitive is in relation to plain sand and resin costs. Furfuryl alcohol is used in the production of resins for sand moulds and more importantly furfuryl alcohol based resins allow for sand to be reused after moulding. One of the key reasons why these input costs are so high in South Africa is because of the lack of competition on the supply side. As such increased furfuryl production could increase competition and decrease prices in the domestic resin market and could decrease the demand for plain sand forcing producers to offer more competitive prices.

Table 1: Input costs (US$ per ton)

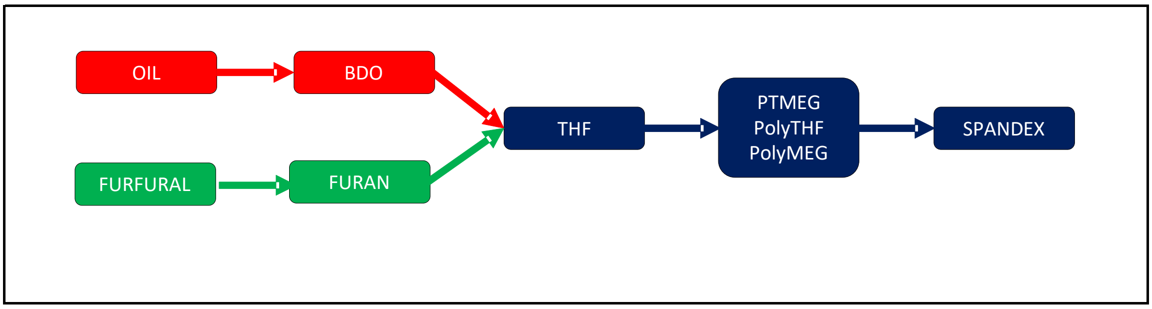
	ALLOYS	SCRAP METAL	PLAIN SAND	RESIN
Brazil	2025	380	20	3350
Russia	2600	370	50	2100
India	1213	462	793	1565
China	1588	543	481	1579
South Africa	1080	481	861	3633

Source: SAIF (2017)

Furfuryl alcohol is the chemical most used in the manufacture of resins, known as furan resins, which are used in foundries. Furan resin manufacturers use furfuryl alcohol to make a wide range of furan resins, all having somewhat different properties when used in foundries. The furfuryl alcohol content of a furan resin can vary from around 10% to as much as 90% but typically averages around 70%. In foundries, molten metal is poured into moulds where it solidifies in the shape required. Most steel castings are made by pouring molten steel into sand moulds. As the size of the casting increases, so does the stress on the mould and, in order to stabilise the sand, furan resins are used for all but very small castings. There are a wide range of resins available on the market, but furan resins have a niche in the market for the manufacture of moulds for larger castings weighing many tonnes. For these castings, the resin used needs to be able to withstand high temperatures and pressures, needs to set in a slow and controlled manner allowing for some manual shaping of moulds, and needs to be stable such that no gas bubbles damage the casting. From an economic point of view, the resin allows the casting to be stripped from the mould and the sand to be reused. This could increase the competitiveness of the domestic industry substantially. Furan resins thus have unique characteristics and are viewed as the superior option to meet the criteria required for the manufacture of moulds for large steel castings such as wind turbine components and ships engine blocks. They have practically no competition in this market.

A second use for plant-based furfuryl is in the textile and fashion industry. The most well-known example of the potential of green biochemicals in fashion is the product Spandex. Spandex is a very popular material which adds an element of stretch to most modern clothing and almost all sportswear. Spandex contains a thread which can be spun from PTMEG, PolyTHF or PolyMEG, depending on whether it is produced by DuPont, BASF or Lyondell, and which gives it its stretchy quality. All three are trade names for a polymer of tetrahydrofuran (THF). THF can in turn be manufactured from either butanediol (BDO) which is oil based or furfural which is plant based. Although almost all Spandex is currently produced using oil-based BDO, the increased momentum and activism in relation to green fashion in developed countries suggests that THF produced using plant-based furan is likely to be a future growth industry.

Figure 2: Plant based versus oil based production of Spandex



Source: Apparel Resources (2020)

As demand for green biochemicals increases so do the applications and opportunities related to products such as furfuryl. For example, in Europe soft woods which have for many years been treated with CCAs (Chrome/copper/arsenic) to prevent moisture and insect attack are now being treated with furfuryl alcohol. Although more expensive, furfuryl alcohol polymerises in the pores of the timber making it suitable for uses traditionally reserved for hard woods such as teak and mahogany. It also eliminates the danger that CCAs pose to people and the environment when timber treated in this way reaches the end of its life cycle.

Market

The total world market for furfural is around 400 000 tonnes per annum. The major use of furfural is for the manufacture of furfuryl alcohol and this consumes some 350 000 tonnes of furfural per annum. The largest direct consumption of furfural is for the refining of base oils. Some 50 000 tonnes per annum is used in this way. The proposed project would supply 20 000 tonnes into the global marketplace. Global reports suggest that the current furfuryl market was valued at US$551 million in 2019. It is expected to grow to US$700 million by 2024, a 4.9% CAGR.

Currently global leading players are: Transfuran Chemicals (Belgium), Central Romana Corporation (Dominican Republic), Pennakem (US), Silvateam (Italy), Illovo Sugar (South Africa), Hongye Holding Group Corporation (China), KRBL (India), Lenzing (Austria), Tanin (Slovenia), and Shandong Crownchem Industries (China). Only the plants in Dominican Republic and South Africa are sugar based and enjoy the cost advantaged explained above.

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