BRIEFING NOTE

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# OPPORTUNITIES FOR NEW BIOREFINERY PRODUCTS FROM FORESTRY, TIMBER, PULP & PAPER WASTES

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## KEY FINDINGS

- Through a literature survey and in-house review, we identified 129 pathways involving chemical, thermochemical, biological and mechanical processing from seven types of waste and residues from the Forestry, Timber, Pulp & Paper (FTPP) industry (sawdust & offcuts, bark, leaves, sludge, black liquor, dregs and ash). The various processing pathways and associated technologies were assessed in terms of technology readiness level (TRL) and market potential.
- Established commercial technologies have guaranteed performance and could be implemented with little technology risk. They are hampered by not being cost-competitive with alternatives currently on the market or having low user/consumer preference. Several mature and established commercial technologies use the waste or residue directly or involve little processing - such as bioenergy (heat and power) and wood-based biofuels (i.e. firewood, wood-pellets, and charcoal). Several other established commercial technologies include the production of mulch, insulating material, filler and binder in cement and brick-making, and natural dyes. There are also established commercial technologies that can add value to black liquor; including for use as a dust dispersant and asphalt additive.
- Many other technologies that are still at the demonstration and early commercial stage and require additional R&D to guarantee performance, improve efficiency, reduce technology risks, and be cost-competitive in the market-place. For example, second generation ethanol, bio-oil, torrefied wood pellets, biochar, and carbon fibres. While pyrolysis for bio-oil and charcoal production is at the demonstration and early commercial stage, respectively; gasification is established commercially, and Sasol is currently producing one-fifth of South Africa's petrol and diesel from coal gasification. Aside from issues of biomass feedstock generally not being cost-competitive with coal, the optimal conversion of biomass to synfuels presents some technology barriers that will require additional R&D to reach commercialisation. R&D investment will also be required in order to improve the techno-economics of fractionating biomass to produce pure cellulose for numerous downstream products- such as nano-fibrils and nano-crystals, various C6 sugar products derived from cellulose, and other valuable co-products from lignin and the C5 sugars. This will require alternatives to the alkali Kraft process; such as dilute acid, steam explosion, hydrothermal liquefaction, organic solvents, ionic-liquids, sonication, ozonolysis, oxidation, microorganisms and enzymes.
- Innovation to lower production costs and establish markets, adjusting for the market distortions through fiscal mechanisms (incentives for using biomass and disincentives for fossil fuels), or accessing global markets that have more favourable prices through the inclusion of a green premium, may enable many of these technologies to reach commercialisation.

## INTRODUCTION

The Forestry, Timber, Pulp & Paper (FTPP) industry processing plants generate the majority of waste and residues – constituting 50% of the sawlogs received. Although many of these waste and residue resources are currently utilised for process heat, the FTPP industry does incur waste disposal costs, through on-site incineration, disposal to landfill and wastewater treatment. In addition, there are recognised opportunities to generate products with greater value-adding. This study aims to focus and prioritise R&D investment in the waste value adding in the FTPP sector; so that the most appropriate and viable technologies can be developed, thereby moving towards zero waste, and a green, circular economy.

## METHODOLOGY

There are a multitude of processing pathways to generate valuable products from forestry biomass; which can be defined by suitable technologies and technology combinations for a particular processing route. Through a literature survey and in-house review, we identified 129 pathways involving chemical, thermochemical, biological and mechanical processing from seven (7) types of waste and residues from the FTPP industry (sawdust & offcuts, bark, leaves, sludge, black liquor, dregs and ash).

## RESULTS AND RECOMMENDATIONS

The various processing pathways and associated technologies were assessed in terms of technology readiness level (TRL) and market potential; from which the following recommendations can be made:

Established commercial technologies have guaranteed performance and could be implemented with little technology risk. They are hampered by not being cost-competitive with alternatives currently on the market or having low user/consumer preference. Several technologies that are mature and established commercially use the waste or residue directly or involve little processing - such as bioenergy (heat and power) and wood-based biofuels (i.e. firewood, wood-pellets, and charcoal). Although the existing FTPP industry uses wood waste and residues for bioenergy, this typically involves generating internal process heat only, and at a low efficiency and there is the opportunity to generate additional value by means of combined heat and power as is currently being commissioned SAPPI in Ngodwana, Mpumulanga. In addition, there is a significant opportunity to generate additional value through wood-based biofuels - particularly wood-pellets and charcoal, for which the technology is at early commercial/commercial stage. These products have a large global market size and are pseudo-commodities, but more suitable for local use to provide secondary economic benefits. Examples include the provision of wood-pellets and charcoal for domestic and industrial heat and power, Rayon textiles and natural dyes. Many of these technologies are globally established and/or have a history of use, but are currently not cost competitive with the current petroleum-based products; such as coal, polyester and synthetic dyes.

There are several other established commercial technologies that can add value to wood wastes and residues - including the production of mulch, insulating material, filler and binder in cement and brick-making, and natural dyes. There are also established commercial technologies that can add value to black liquor; including for use as a dust dispersant and asphalt additive. However, these products are speciality chemicals with a relatively small global market size.

There are many other technologies that are still at the Demonstration and early commercial stage and require additional R&D to guarantee performance, improve efficiency, reduce technology risks, and be cost-competitive in the market-place. There are a number of demonstration and early commercial technologies for value adding to FTPP residues and wastes. For example, second generation ethanol, bio-oil, torrefied wood pellets, biochar, and carbon fibres. Most of these are pseudo-commodities, since they are bulk commodities with a large global market size, including petroleum oil replacements. Thermochemical processing occurs either through pyrolysis to produce bio-oil that can serve as a replacement for petroleum oil, or through gasification to generate syngas and synfuels as precursors for the synthesis of downstream products. While pyrolysis for bio-oil and charcoal production is at the demonstration and early commercial stage, respectively; gasification is established commercially, and Sasol is currently producing one-fifth of South Africa's petrol and diesel from coal gasification. Aside from issues of biomass feedstock generally not being cost-competitive with coal, the optimal conversion of biomass to synfuels presents some technology barriers that will require additional technology R&D to reach commercialisation.

An alternative processing pathway to thermochemical processing is the chemical fractionation of biomass to effectively separate the lignin and hemicellulose from the cellulose in the required yields and purity for numerous downstream products. To achieve this, alternatives to the alkali Kraft process - such as dilute acid, steam explosion, hydrothermal liquefaction, organic solvents, ionic-liquids, sonication, ozonolysis, oxidation, microorganisms and enzymes - will need R&D investment in order to improve the techno-economics of fractionating biomass to produce pure cellulose for products such as nano-fibrils and nano-crystals, various C6 sugar products derived from cellulose, and other valuable co-products from lignin and the C5 sugars; including furfural, levulinic acid, xylose, acetone, butanol, ethanol, sorbitol, lactic acid, and succininc acid. In addition, the production of many fine chemicals from biomass through fractionation - such as essential oils, proanthocyanin, vanillin, B-sitosterol - is limited by the fact that these chemicals are present in very small quantities within wood residues; that limits this opportunity unless combined with another product processing streams.

The wastes from the timber industry are more widely distributed compared to that from the pulp & paper industry, which is more consolidated due to the presence of only a few mills. Since the scale of production and the transport costs will have a strong influence on the levellised cost of production. Techno-economic studies will need to be carried out for each FTPP mill (or cluster of mills) in order to assess the optimal location and size of the proposed value adding industry relative to the available biomass and associated transport costs. In addition, existing FTPP operations have limited amounts of waste available, such that many of these opportunities may be limited by available biomass and the lack of economies of scale. As such, an alternative to simply using waste streams as a feedstock could be to consider the full diversification of FTPP operations to new product streams. For example, switching from producing pulp & paper only to producing a range of products; including textiles such as Rayon, fibre bio-composites, lignin- based binders and fillers, nano-crystalline cellulose, cellulose nano-fibrils, and the C5 and C6 sugar platform fine chemicals).

Current market prices do not reflect the environmental externalities associated with using petroleum-based products, nor the potential benefits associated with the development of a bio-economy, involving a switch to renewable bio-based products for future human material and energy needs. Although assessing the economic feasibility of these technologies was beyond the scope of this study, several technologies are known to be limited by the cost of production, rather than by not technology readiness. Innovation to lower production costs, adjusting for the market distortions through fiscal mechanisms (incentives for using biomass and disincentives for fossil fuels), or accessing global markets that have more favourable prices through the inclusion of a green premium, may enable many of these technologies to reach commercialisation.

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