The wooden economy and the world's ultimate renewable

As a sustainably farmed resource that stores carbon, wood is increasingly being used not only in the built environment for houses and high-rises but also for its cellulose, lignin and sugars. These elements all have a role in helping the world find renewable and low-carbon alternatives to the likes of plastic, chemicals, steel and concrete.

Image Supplied: Renewability lies at the heart of the South African forestry sector, with trees planted, grown, harvested and replanted in sustainable rotations.

The Paper Manufacturers Association of South Africa (Pamsa), its members and its university partners are exploring the commercial potential of a range of products from the pulping and papermaking process, maximising product yield from each and every tree harvested.

"Two key advantages that commercially farmed trees bring are their renewability and their carbon storage," explains Jane Molony, Pamsa executive director.

Kings of carbon capture

Trees in plantations are essentially crops that are planted and replanted in rotations, with only about 9% of the total tree count being harvested in any given year. "This means that there are always trees growing, at different stages of maturity, and these trees are all absorbing carbon dioxide (CO_2) and storing the carbon," says Molony.

"The fact that trees are planted, harvested and replanted on the same land makes wood and paper a renewable and efficient resource," Molony asserts. "For a low carbon future, it's tremendously exciting."

With trees capturing more carbon from the atmosphere[i] than any other biome, they offer a means to mitigate the impact of climate change.

Paper itself is a biomaterial and one of the oldest technologies in the world. From chipping wood into small pieces to cooking them to produce a soup-like slurry and then drying the fibres into sheets, papermaking is a complex and fascinating process. Companies are continually looking at every aspect of their operations to reduce water use, energy consumption and air emissions.

Papermakers are no longer restricted to manufacturing paper and cardboard boxes. South African companies can use their raw material to make bio-based products, chemicals, plastics and fuels. Not only does this have an environmental and economic benefit, but it also opens up a whole new world for youngsters with an affinity for engineering, science and innovation.

Low-carbon careers in the bio-economy

"Careers in pulp and paper technology and process engineering have not traditionally been sexy, but as the sector finds ways to diversify in the face of reduced printing and writing paper demand, chemists and chemical engineers can help discover the wonder of wood, wood-derived chemicals and paper packaging," notes Molony.

This includes the potential of forest residues (bark and branches), wood pulp and paper mill waste to replace non-renewable materials such as plastics produced from oil or coal and other innovative products. Using their inherent biorefinery technologies, companies can extract a range of components such as cellulose, lignin and sugars from process streams that would otherwise become process waste. "This takes mills beyond paper, and into the realms of a biorefinery," adds Molony.

Natural polymers from planted trees

Cellulose – the most abundant organic compound and polymer on earth – is the major component of wood and the starting point for the various reactions.

Dissolving woodpulp, a purified form of cellulose, is suitable for subsequent chemical conversion into a range of products – it is spun into viscose and lyocell textile fibres for use in fashion and decorating textiles, cast into a film or regenerated into a sponge.

Wood also gives us products such as carboxymethyl cellulose or microcrystalline cellulose (MCC).

This fine powder is extremely versatile. It can bind active medicinal ingredients or vitamins into palatable tablets, stabilise emulsions or increase viscosity – which is why cellulose is added to low-fat yoghurt, and lipstick! It also acts as an abrasive or exfoliant in cosmetics, or an anti-caking agent in washing powders or foods.

"It is a misconception that 'sawdust' is added to food. MCC is an approved and safe food additive that passes through our bodies, unabsorbed," confirms Molony.

Tiny fibres with huge potential

Nanocellulose – tiny cellulose nanofibres (CNF) and nanocrystalline cellulose (NCC or CNC) – can be used in wound dressings and surgical gels, food supplements and edible packaging, or even as a composite for screens on electronic devices.

Tipped to be a rival to high-strength materials like Kevlar, nanocellulose composites have strength, barrier and performance attributes similar to, if not better than, carbon fibre. This makes them ideal for use in the automotive and aviation sectors.

Paper and paper packaging manufacturers are looking at ways to use nanocellulose to reduce the weight of paperboard without lowering strength and performance. The substance can also be applied as a recycling-friendly barrier coating instead of plastic.

Lighter footprints with lignin

Lignin is the glue that holds wood and plant fibres together. It is removed during the pulping process when manufacturing fine paper to prevent yellowing with age, with some 50 million tonnes being produced worldwide each year. Depending on the pulping process used, lignin can be recovered from the spent pulping liquors in different forms, i.e., lignin and lignosulphonates, or used as pellets for fuel.

The commercialisation of these lignin-based compounds creates opportunities in market segments outside of pulp and paper. Lignosulphonates are used in mining and road maintenance as a dust suppressant while their addition to ready-mix concrete improves the flow of concrete as well as reducing the water required, without compromising on strength. One of Pamsa's members is the world's largest producer of lignosulphonates from its South African and European operations.

Lignin also shows promise as a multifunctional and renewable alternative to petroleum-derived styrene plastics and foams.

Bio-chemicals from green gold

A substitute for diesel, bio-oils are one product obtained by heating wood in an oxygen-free environment, in a process known as pyrolysis. The solid product generated (bio-char) can be used as an enriched growing medium for seedlings or converted into high-grade activated carbon.

When wood waste is broken down by enzymes and fermentation, bio-ethanol is produced.

Furfural[ii], dubbed 'the sleeping beauty of bio-renewable chemicals', was one of the first bio-chemicals made from biomass. As a worthy competitor to oil-based chemicals, new interest has been sparked in furfural for the production of biofuels and bio-chemicals.

Furfural and its derivatives have been extensively used in the plastics, pharmaceutical and agrochemical industries. As a natural precursor to a range of chemicals and solvents, it is widely applied in fungicides and nematicides, transportation fuels, lubricants, resins, a rapid all-weather repair system for potholes and also for wood modification and book preservation. And that's just the shortlist.

Sweet sensations

Cellulose and hemicellulose are complex carbohydrates (polysaccharides) rich in various sugar monomers (building blocks of more complex molecules) which can be extracted during the pulping process.

Xylitol is a natural sugar substitute that can be made from xylose, the sugar molecule in hemicellulose. It also has oral health benefits due to its acid neutralising and antibacterial properties and is commonly used in chewing gum. Work to commercialise the manufacture of xylitol in South Africa is already being done by a Pamsa member, and as local demand picks up for these products, other South African mills will be poised to start production.

Sawdust and bark can yield high-value speciality chemicals and composites while paper sludge can potentially be converted into NCC, bio-polymers and bio-gas. "We know that these products can be made from wood pulp, but studies are showing that we can also push mill waste streams towards new production channels, instead of landfills," explains Molony.

Making the circular economy bigger

Work is being done by the South African pulp and paper industry through Pamsa's Process Research Unit and the master's student programme into biomass beneficiation such as the development of bio-based carbonate derivatives from lignin that can be used in the production of paper, glass and detergents, and exploring the commercial value of forest and mill residues.

By extracting more value from a tree, less goes to waste, Molony says. "This opens our sector up to make even more meaningful contributions to sustainable product development and sets up pulp and paper mills as biorefineries. This means we can improve our competitive advantage as a country, and offer innovative careers for young graduates."

"Along with the significant contributions by members' companies to research and development, Pamsa has partnerships with the universities of Pretoria, Witwatersrand, Stellenbosch, and the North West, as well as the support of the Department of Science and Innovation through the Sector Innovation Fund."

Not only do pulp and paper production add around R3.8bn annually to the South African economy, the growing and harvesting of trees and the making and recycling of paper products provide sustainable jobs for thousands of people.

And as a result, we keep removing carbon from the atmosphere by planting more trees.