Forestry will drive New Zealand's circular bioeconomy – no twig or needle wasted

Elspeth MacRae and Michelle Harnett

Abstract

New Zealand's bioeconomy needs to expand and develop into one focused on sustainable design and renewable resources to meet the country's future financial, social and environmental needs. Products from biomass can replace petroleum products and more. New Zealand's largest source of biomass is planted forests. Trees have the potential to produce everything we need to transition to a circular bioeconomy. Aligning energy and raw material needs with resources and infrastructure would enable the production of high-value products, and utilisation of materials currently viewed as waste, thus creating prosperity in the regions and across the country. National, strategic and corporate leadership is needed now to build consensus and impetus to develop long-term planning and implementation.

Figure 1: The circular bioeconomy (based on Hetemäki, L., Hanewinkel, M., Muys, B., Ollikainen, M., Palahí, M., Trasobares, A., ... & Potoćnik, J. 2017. *Leading the Way to a European Circular Bioeconomy Strategy* (Vol. 5). European Forest Institute)

Forestry slash

Introduction

New Zealand is a bioeconomy. Pastoral, dairy and arable farming, horticulture and forestry have always been the backbone of the country's economy. Now challenges such as climate change, and the desire to protect our natural environment and ensure the wellbeing of the country's people, means our bioeconomy needs to expand and develop. We need to stop relying on the petroleum products and fossil fuels that have underpinned the nation's economy because they are finite, contribute to climate change, and pollute every corner of our world. We must transition to a new circular bioeconomy focused on sustainable design and renewable resources.

Circular bioeconomies are all about using biomass to produce the materials, chemicals, plastics and energy that have previously been made from fossil fuels. The resultant bioproducts can be reused, recycled, remanufactured or composted, starting the cycle again. This vision includes sustainable processes promoting societal wellbeing and prosperity, which in turn benefits the multiple ecosystems contributing to biomass production.

New Zealand's largest source of biomass is planted forests. Our developing (and future) circular bioeconomy will be enabled by trees. Trees, as living factories with the potential to produce everything we need, are key to us making the transition to a circular bioeconomy. Further, products from biomass are likely to be more than just replacement for petroleum products. New biobased products may have functionalities not provided by existing options, such as lower weight, heat and water resistance, durability, toughness and being flame retardant. Manufactured using 'green' processes, and able to be reused or recycled multiple times, at the end of their life bioproducts will decompose into carbon and water and contribute to creating new biomass.

A further important point for an economy based on exports and tourism is carbon neutral/low greenhouse gas (GHG) footprint products that will enable New Zealand to retain market access. This may be by meeting increasingly strict environmental import regulations or by reassuring consumers that our products can be used without damaging the Earth (guilt-free).

Some of forestry's least valued resources, like bark and forestry residues, have the potential to yield products that command thousands of dollars per tonne. As an industry, we need to use our leftovers better. We need to add value to slash left lying in the forest, piles of bark or lignin-rich black liquor from kraft paper-making through processing and new products to deliver employment, prosperity, sustainability and environmental benefits.

Biorefining and industry clustering

Using resources in new ways to make new products often requires new value chains and new ways of thinking and doing things. Circular bioeconomy manufacturing, for example, adapts and changes the oil industry concept of a refinery to that of 'biorefinery' processing biomass into a range of materials and products. Pulp plants can be thought of as nascent biorefineries – wood is processed into fibre, then paper, and the black liquor byproduct can be used in bioadhesive manufacture or burnt for energy. Timber processors (or clusters of processors) that produce high-value lumber then particle boards from the lumber residues are also 'biorefining'.

Ideally, waste from one process becomes the raw material for another, creating the right conditions for 'industrial symbiosis', defined as the association between two or more industrial facilities in which the wastes or byproducts of one become raw materials for another. Acting cooperatively, operating costs can be reduced and new business and job opportunities open up. The collective industries operating in the North Island town of Kawerau are a good example of industry symbiosis in practice.

Bark biorefining

The bark produced by the forestry industry will grow substantially from 2020 when the ban on methyl bromide use comes into effect and only de-barked logs will be able to be exported. Some bark is used for fuel and for landscaping, but much is simply burnt or left in the forest, ignoring its potential to yield a range of niche value-added products.

Bark is a tree's first line of physical and chemical defence against the environment, insects and disease. It is a rich source of antioxidants, antimicrobials, anti-corrosives, UV-absorbing, enzyme-inhibiting and water-proofing chemicals. Tannin is a well-known product extracted from some bark. It has been used in leather tanning for centuries and is widely available. However, such tannins are hydrolysable (they contain a sugar and can decompose in water). Tannins in pine bark are condensed (do not contain any sugar residues) and are more readily chemically modified, leading to a wide variety of products for a wide range of applications.

Scion has started a five-year research programme (2018–2023) to develop methods to extract and refine high-value chemicals and other products from bark using green chemistry and sustainable technology. The remaining solid waste, which has a high residual energy content, can be used as a renewable energy source. The research is supported by the Ministry for Business Innovation and Employment's Endeavour Fund.

One of the products the new bark biorefinery promises to deliver is significant quantities of water-repelling (hydrophobic) polymers, which are used in items ranging from paper coffee cups and rainwear to touch screen coating technology. The current market is dominated by petrochemical-based polymers, but biobased hydrophobic polymers are part of a rapidly growing market niche.

No bark biorefineries exist yet, although the research to extract valuable chemicals from forest waste streams has been going on for some time. We hope by 2023 to have made the first vital steps towards developing bark biorefining and be ready to develop a demonstration plant.

The range of high-value materials and products from a bark biorefinery could earn an estimated $400-600 million per annum and contribute $1.8 billion to New Zealand's GDP. With infrastructure in place, regional biorefineries have the potential to add several thousand new regional jobs by 2050.

Bioenergy

A circular bioeconomy also needs energy sources to replace coal, oil and gas. Wood is a traditional energy source, but can it be used more efficiently or effectively and to power everything from the family car to factories?

Solid energy – processing and forestry residues

The residues from processing timber, particle board products and paper are often used to supply energy to manufacturing plants. These residues, and especially the residues left after harvest, could be used more smartly, not only to supply power and heat to wood processors but also other nearby energy users, reducing both waste and GHG emissions.

Looking at demand for industrial heat, and gas, coal, geothermal and wood resources, Scion research has investigated how energy efficiency could be improved if wood processing industries were sited (clustered) together with the aim of identifying industrial symbiosis opportunities across New Zealand (Scion, 2019).

Case studies were carried out in four areas – Gisborne, Hawke's Bay, Southland and South Otago, and Ngāwha in Northland. For each region, their forest resources were used to estimate wood supply, harvest residue and heat demands. With an eye to processing onshore, the processing options that give the best returns on capital investment were modelled, as was the potential to supply energy to other nearby industries.

In the case of Gisborne, the theoretical best returns on capital investment would be from using currently exported raw logs to manufacture oriented engineered laminate (OEL™), industrial ply and oriented strand board (OSB). Residues from processing, plus biomass residues from the region, would be sufficient to supply heat and power to run the cluster. No opportunities to share energy with other large users were identified in Gisborne.

In the Hawke's Bay, a wood processing cluster near the Port of Napier could support square sawn log production, an OEL plant and provide lumber for cross-laminated timber (CLT) and possibly a small OSB mill. Residues from the processing would be sufficient to meet the heat and power demands of the new plants and replace coal heating at a nearby wool scouring plant, reducing GHGs by 15,000 tonnes/yr.

Similarly, opportunities existed in Wairoa and Balclutha to use energy from processing forest residues to replace the coal and gas used in meat processing and dairy plants.

Ngāwha, which has significant geothermal resources, could manufacture OEL, plywood and OSB, then, as geothermal energy is used, terpenes could be extracted from the residues. Finally the residues could, for example, be made into wood pellets for heating.

Capital investment for each cluster would be in the order of $200 million. Each cluster is expected to create 1,000 or more jobs and contribute $500 million to GDP.

Liquid biofuels

Forestry residues and low-value logs could also be processed into liquid transport fuels. A Biofuels Roadmap developed by Scion (2018) has identified a demand for marine, aviation and heavy transport biofuels – all modes of transport that are difficult to electrify using current technology. The roadmap focuses on drop-in fuels that can be used without modifying existing engines and can be distributed using existing supplier networks.

Different biofuel scenarios that consider the entire value chain have been modelled, from the land to grow biomass to the necessary technologies to process it, to calculate the lowest cost solutions.

One scenario assumes that 30% of the country's liquid fuel needs are met from radiata pine grown on non-arable land. Pyrolysis (heat in the absence of air) is used to break the biomass into bio-oil, which is then upgraded to give drop-in fuels. This scenario would decrease GHG emissions by five million tonnes a year (the equivalent of taking half the cars off the road), increase New Zealand's energy independence and boost regional economies.

The biomass would come from 250,000 ha of existing forest and 250,000 ha of new forest. These forests are likely to be in Northland, Bay of Plenty, the Central North Island, East Coast and the top of the South Island. Initial pyrolysis processing would be carried out close to the forests, eliminating the need to transport heavy wet wood. Bio-oil could then be trucked to upgrading plants close to centres of population and distribution hubs like ports.

Using the Gisborne/East Coast region as an example, this scenario would require 75,000 ha of new forest, along with four pyrolysis plants and four bio-oil upgrading plants. Capital expenditure would be of the order of $1 billion and over 1,000 new jobs would be created.

The Biofuels Roadmap identified that biofuel production and integration into the New Zealand economy was extremely unlikely to happen on its own. The necessary forward thinking, commitment and level of investment will need strong leadership at national, regional and corporate level to initiate and implement major components New Zealand-wide.

CO_2 in the circular bioeconomy

Carbon emitted when biomass is used for energy is part of a cycle driven by plants, known as the biogenic cycle. Emitted carbon is absorbed by growing plants to produce more biomass with no net increase in the amount of CO_2 in the atmosphere. This is fundamental to the circular bioeconomy. If trees, for example, were not harvested, they would eventually decay and release carbon anyway. In contrast, burning fossil fuels releases ancient carbon that has been stored for millions of years. This carbon is not part of the biogenic cycle and utilising it increases atmospheric levels of CO_2.

Some argue that wood is not a dense source of energy and producing and burning it results in higher CO_2 emissions than, for example, coal. However, comparing emissions only at the point of combustion ignores the emissions involved in production, processing, transport

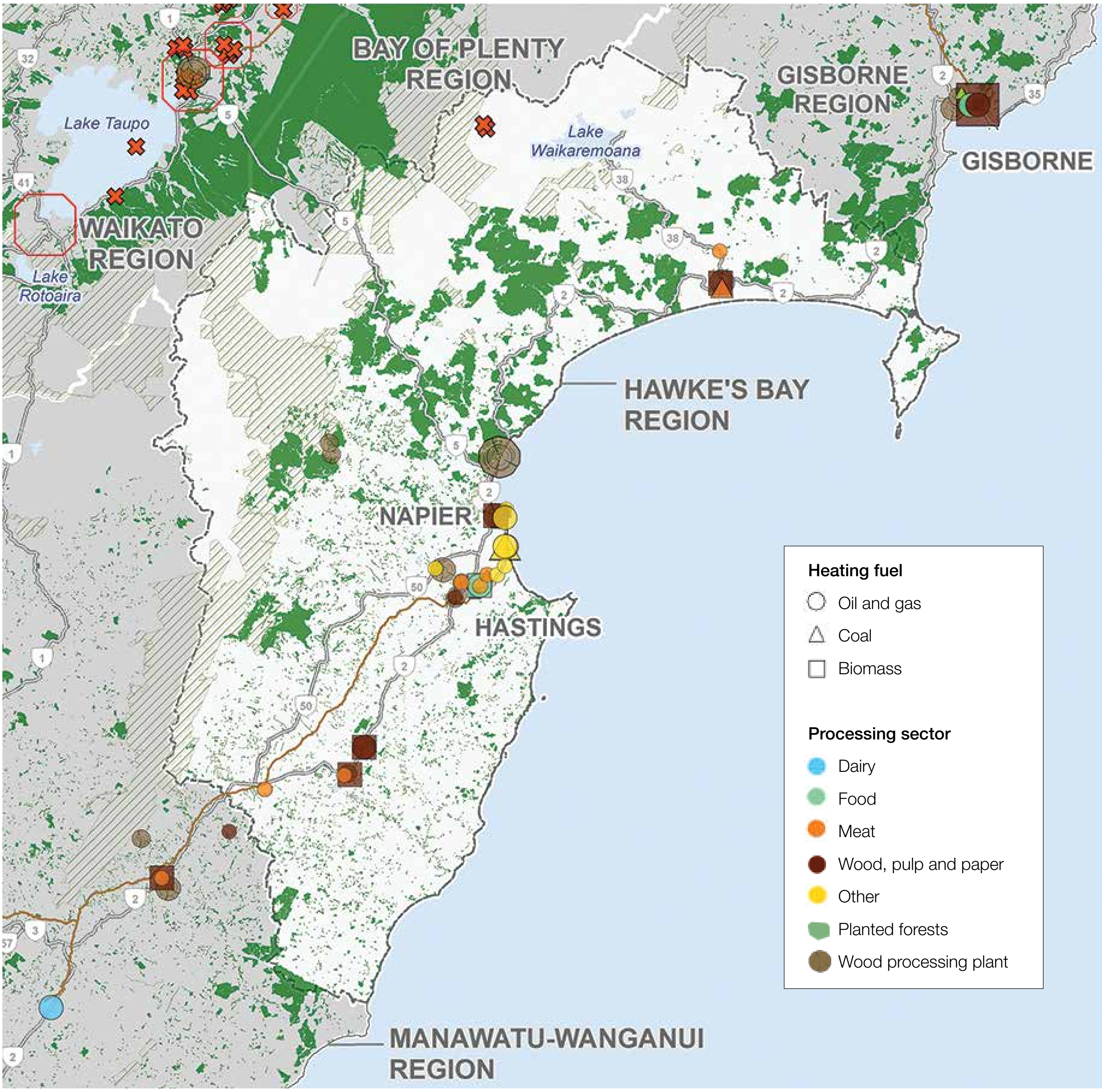

Figure 2: Forestry resources, primary processors and energy demands in the Hawke's Bay

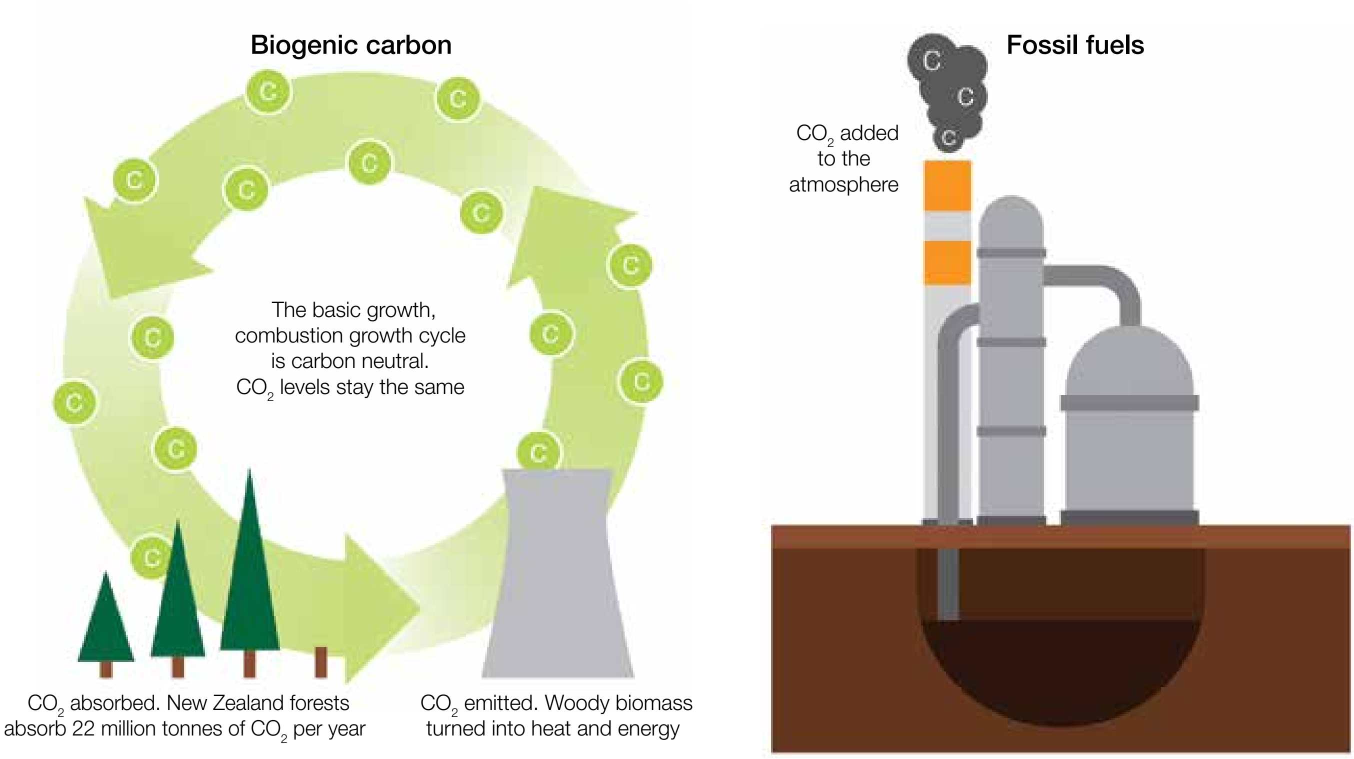

Figure 3: The biogenic carbon cycle vs fossil fuels

and biogenic carbon flows. Comparing GHG emissions per unit of energy, coal is responsible for emitting 50 times more CO_2 than sustainably grown New Zealand wood.

Conclusion

The bioeconomy in Europe is worth €2 trillion and provides over 22 million direct and indirect jobs. If New Zealand wants to be part of the bioeconomy boom, we need to take advantage of the opportunities that biorefining and industrial symbiosis create to add value to resources that have been treated as a waste disposal problem up until now. Bioproducts from bark, forest residues, other byproducts of wood and paper processing, and biomass from other primary industries have huge potential to replace petroleum products and be at the centre of our circular bioeconomy.

Moving forward there are challenges, including finding the money to invest in research and development, new manufacturing technologies and infrastructure. New technology can be very capital intensive, the investment cycle is long, and the emerging bioeconomy sector is unknown and thus risky territory for many investors.

There are also challenges around ensuring a sufficient and constant supply of biomass where it is needed. Growing biomass must be sustainable and socially acceptable. For example, using arable land for growing fuel crops such as canola or miscanthus is unlikely to be acceptable, in contrast to planting steeper, less productive land in forests. Coordinated planning and apportioning of resources is also essential. The above examples have focused on one 'industry' at a time, as shown by the two possible scenarios for using the wood supply around Gisborne. We need to think and plan more about how multiple industries could be supplied from one resource.

Coordinating resource supplies and producing new bioproducts will require new value chains. The interdisciplinary and cross-sectorial nature of the bioeconomy will need communication and cooperation between sectors that do not normally interact with each other.

The Biofuels Roadmap concluded that strong and astute national, strategic and corporate leadership would be needed to build the consensus and impetus to develop long-term planning and implementation to put all the components for production and distribution in place. A similar approach is likely to be necessary if New Zealand is serious about expanding, and circularising, the country's bioeconomy.

The prize is substantial. When the science and infrastructure is complete, regions around New Zealand could be running their own biorefineries as part of industrial clusters, employing people in highly skilled jobs and producing high-value environmentally-friendly products. If New Zealand can move quickly, we have the opportunity to be a global leader in circular bioeconomy markets and thinking. Are we up for it?

References

Scion. 2018. *New Zealand Biofuels Roadmap Summary Report: Growing a Biofueled New Zealand*. Rotorua, NZ: Scion. Available at: www.scionresearch.com./?a=63293

Scion. 2019. *Wood Energy Industrial Symbiosis*. Rotorua, NZ: Scion. Available at: www.scionresearch.com./?a=65430

Elspeth MacRae is Chief Innovation and Science Officer and Michelle Harnett focuses on communicating science at Scion based in Rotorua. Corresponding author: elspeth.macrae@scionresearch.com