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HOW TO BUILD INDUSTRIALLY SCALABLE VALUE CREATION FROM TIMBER CONSTRUCTION BY-PRODUCTS IN NEW ZEALAND

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ABSTRACT: Global economies seek solutions for a circular economy and climate change mitigation. Forest biomass and sawn timber processing by-products offer several value-added components to replace unrenewable carbon-intensive materials. Generally, sawn goods utilize only approximately half of the harvested timber volume. When aiming for circular and zero waste construction, it is not enough to use local wood sources for timber construction unless all the wood streams- are fully utilized. Projects worldwide are developing biomass-based biorefineries, but the upscaling of these technologies require cross-sectoral and multidisciplinary partnerships. In this paper, we propose a plan for a holistic approach to analyse and visualise value-creation possibilities in the New Zealand (NZ) context, targeting locally sourced, underevaluated and undervalued wood species that can be used in construction and finishing. The focus is on finding solutions that are economically, socially, and ecologically sustainable. Additionally, with benchmarking to Finland, we present examples of industrial value-chains and by-products, to provide a baseline understanding on the scale-up potential with techno-economic feasibility.

KEYWORDS: added-value, by-products, circularity, timber construction, value-networks

1 – INTRODUCTION

Increasing the use of alternative, sustainably sourced biomasses, and side-streams to fulfill the basic need of shelter for the growing population is of utmost importance. For countries to be able to achieve their national and international climate goals, the construction sector must also reduce emissions and waste.

Globally, the construction and building sector accounts for 39% of CO_2 emissions and 40% of the waste [1, 2, 3]. Thus, sustainable production of construction materials that replace unrenewable carbon-intensive ones, is a global challenge and sustainable innovations have significant, international business potential.

Increasing resource-efficiency and cascading use of wood is of utmost importance when aiming for a circular built environment.

2 – BACKGROUND

2.1 ADDED VALUE FROM BY-PRODUCTS IS REQUIRED TO REACH SUSTAINABILITY

The share of the harvested wood products (HWP) used in timber construction typically utilizes less than half of the total harvested timber volume. The rest of the biomass is generally used as a source of energy and heat, or bulk products such as pulp and fiberboards.

Timber and its harvesting and processing residues (bark, saw dust, fine-dust, shives, needled/leaves) have additional, untapped valorization potential to meet the needs of the society and especially the construction sector, as wood can be used in, e.g., load-bearing structures, insulation, both interior and exterior surface materials, furniture and fittings.

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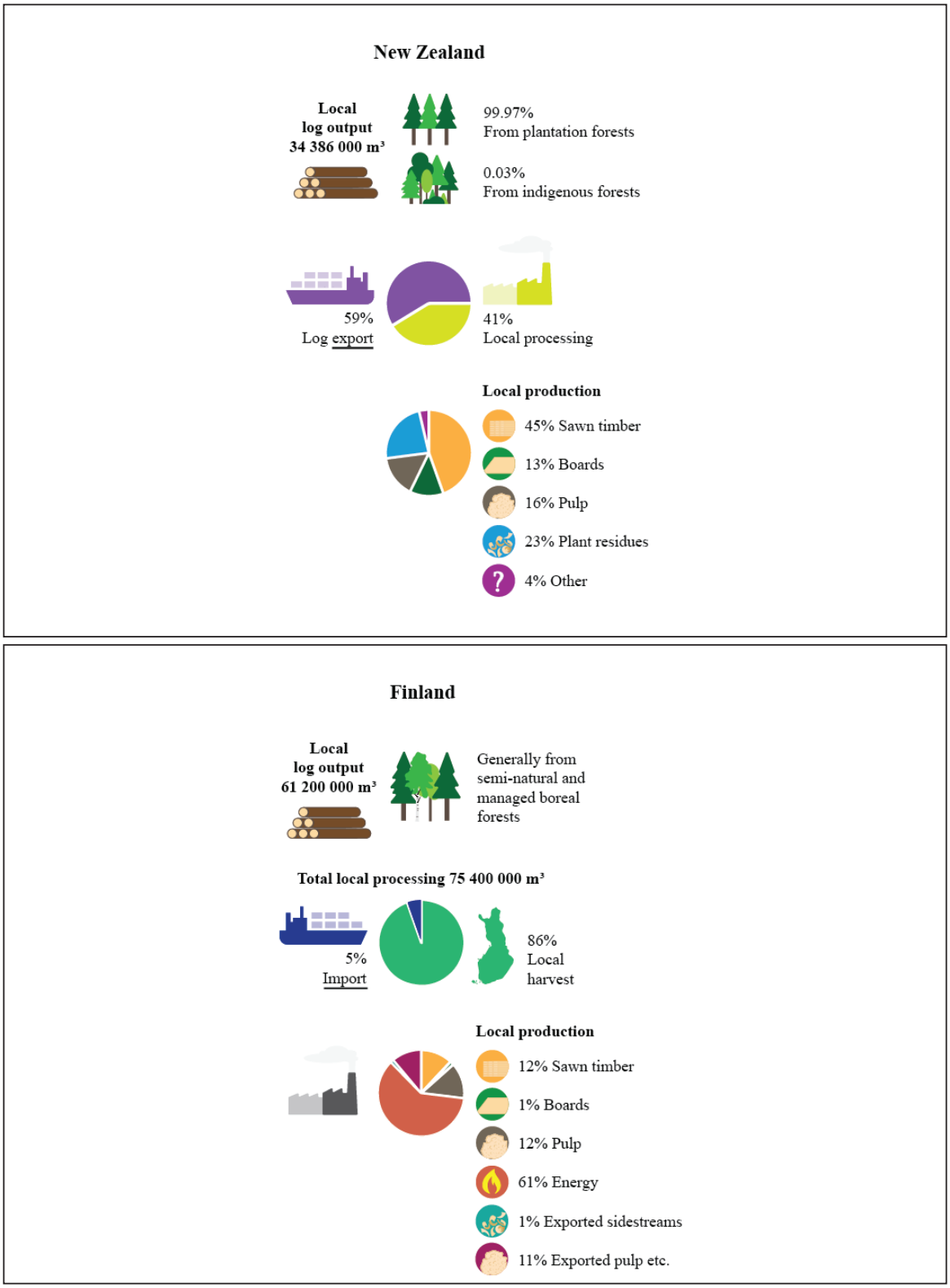

Figure 1. *Current situation of wood valorization in New Zealand (upper) and Finland (lower).*

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Additionally, the uses of wood-derived added-value components include but are not restricted to adhesive systems, preservatives, dispersants, coatings, and fire-retardants. Before comprehensive exploitation of wood raw materials for added-value, the timber sector does not become truly circular.

Biobased products utilising side- streams, by-products, and underutilized local wood sources store carbon and reduce the need for logging. For locally grown non-radiata timbers to be economically viable in construction projects at scale, multiple product pathways will be required from the whole felled tree biomass.

In New Zealand (NZ), only about 3% of domestic wood is used in construction [4, 5]. In addition, imported timbers for furniture and mouldings are valued at approximately $NZD395 million. There is also a large supply of imported outdoor timbers for decking and cladding. Increased substitution of imported for locally grown timbers is needed, but lacks value-chain analysis.

According to the NZ targets, growth in local wood sources is expected. Moreover, the national aim is to increase the wood use in the construction sector, including high-grade valorization potential from materials, and livelihoods especially for the indiginous communities.bioproducts and bioenergy [6]. Local, yet underutilized wood species have high potential as a source of raw materials.

2.2 WCTE – ABSTRACT FOCUS AND THEME

We propose a holistic plan to analyse and envision value-creation possibilities in the NZ context, targeting locally sourced, underevaluated and undervalued wood species that can be used in construction. This includes mapping of the opportunities to enhance the wood supply chain, and forecast added-value wood uses.

Our approch thus allows for strategic long-term planning of the wood value creation to achieve higher domestic uses of wood (**Figure 1**).

3 – PROJECT DESCRIPTION

We focus on economic, social, and ecological sustainability as corner stones in the analytical framework. We also include pre-selected example studies on existing industrial value-chains and by-products, to provide baseline understanding on the scale-up potential with techno-economic feasibility, benchmarked to Finland (**Figure 1**).

3.1 CURRENT SITUATION IN WOOD UTILIZATION IN NEW ZEALAND

Currently New Zealand's wood processing industry efficiently manages various types of residues generated at different stages of wood processing. Forest harvesting yields bark, broken stems, rootballs, and slash waste, which are predominantly utilized for landscaping and bioenergy.

Sawmill operations produce residues primarily converted into reconstituted panel products such as medium-density fiberboard (MDF) and particleboard. Pulpwood is processed into kraft pulp at facilities in Kawerau and Napier, whereas peeler logs are transformed into plywood and laminated veneer lumber (LVL), with resultant veneer waste directed towards onsite energy production.

Efforts to enhance the utilization of harvest residues and improve mill conversion rates are in progress, although New Zealand currently lacks a comprehensive bioeconomy strategy.

3.2 PLANNED DEVELOPMENT FOR WOOD UTILIZATION IN NEW ZEALAND

New Zealand intends to bolster circularity within its bioeconomy by optimizing the use of mill waste and expanding residue processing options. Any substantial increase in wood processing onshore will require additional efforts to process the waste residues from the increased log input.

Government regulations now mandate the removal of larger slash waste from erosion prone sites (logs more than two metres with large end diameters exceeding 10 cm) with a restriction to just 15 m^3 slash left on a cutover post-harvest [7], thereby enabling opportunities for higher-value production from these residues. The diversification of species beyond the predominant radiata pine is sought within plantation forestry [8], with the maturation of redwood and cypress plantations anticipated to become substantial sources of wood supply by 2040. Domestic markets for residues of radiata pine have proven essential to the establishment of a value chain pathway, in the form of panels, pulp and paper, and energy use.

Additionally, regenerating and planted native species are being considered for specialty products, [9] which could potentially replace current hardwood imports. Ongoing initiatives aim to improve market development for residues and byproducts to ensure economic viability.

3.3 FUTURE SCENARIOS OF HIGHER ADDED VALUE CREATION IN NEW ZEALAND MIRRORING FINLAND

By drawing upon Finland's model, New Zealand could advance high-value markets for wood processing residues (**Figure 2**). Potential examples include the conversion of slash into engineered wood products such as oriented engineered lumber (OEL), and the exploration of biotech extractives for applications in bioplastics, foams, and resins.

Developing alternative revenue streams from unique organic compounds found in hardwood and specialty timber sidestreams and processing residues may serve as replacements for petrochemical additives across various applications, thereby fostering greener building solutions.

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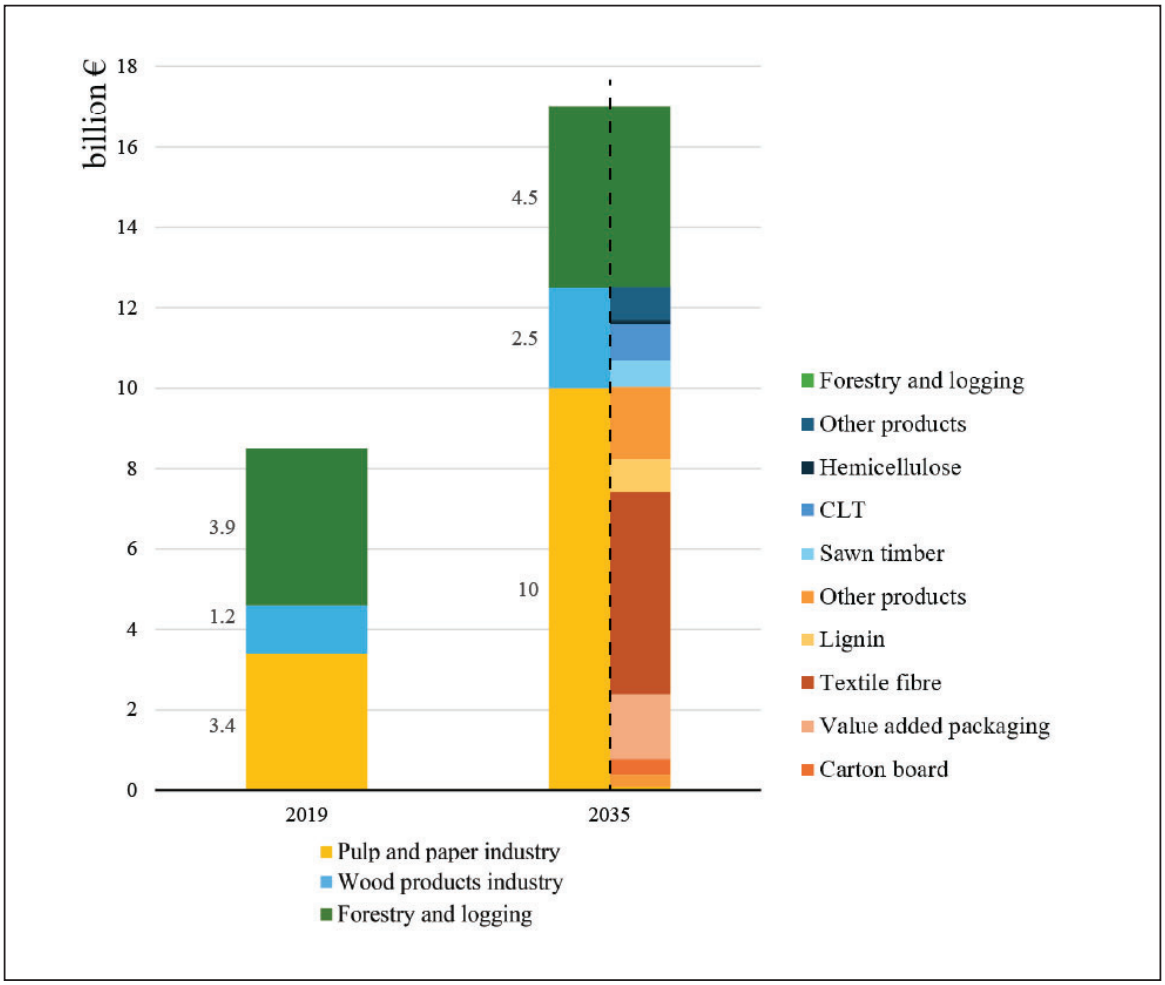

Figure 2. *Vision for doubling the value added from the forest sector in Finland by 2035 based on Lintunen et al. 2024 [11]. The product categories for calculations in the vision were selected due to the substantial innovations in the value chains in recent years, along with the availability of adequate information for value-added calculations.*

Moreover, the utilization of demolition timbers for circularity within the building sector could significantly enhance sustainable practices.

By focusing on these innovative applications, New Zealand has the potential to substantially elevate its wood utilization and bioeconomy, emulating Finland's exemplary approach.

4 – EXPERIMENTAL SETUP

The focus on framework and pre-feasibility analysis on yet overlooked New Zealand endemic wood species, namely hoheria sp., kowhai (*Sophara* spp.; [10]), and mangeao (*Litsea calicaris*), totara (*Podocarpus totara*), and beech species (e.g., *Fuscospora* sp); along with very promising locally grown exotic hardwoods such as Coastal redwood (*S. sempervirens*) for cladding and *E. saligna* for decking.

The study includes screening of other species, including those of the indigenous species programme, with the ability to grow specialty timber and by-products from the forests owned by Māori communities.

Example studies on, e.g., holistic impacts of the industrial-scale torrefied wood pellet plant, currently in planning phase, will be conducted.

In details, the tasks for research include the following:

(1) Indigenious species value-chain analysis with sustainably available harvesting volumes, wood supply-chains and the most potential high-added-value valorization routes with economic pre-feasibility analysis:

More in details, the calculations will be carried out based on the Finnish example of Lintunen et al. 2024 [11, 12]. The calculations will aim at evaluating the potential and impact of new forest-based bioproducts, looking into

(resource-based) production volumes, value added, and the necessary plant investments for increasing economic value.

A product portfolio will be selected to estimate future production volumes and value added using the available NZ data. This approach will involve strategic assessments and modeling to understand the investment requirements for production facilities.

We aim for preliminary, rough findings that are intended to indicate the future direction and magnitude of advancements in bioproduct development. Given that significant industrial production of the selected products may not yet exist, the produced estimates will serve as a foundational framework for continued exploration and discussion [11, 12].

Following its definition in the system of national accounts, we assess the value added of products and value chains by estimating the value of ouput and intermediate consumption (https://unstats.un.org/unsd/nationalaccount/glossresults.asp?gID=232). In addition, we estimate the factor income (i.e., capital and labor) of the value chains. Both approaches give an estimate of the value added. Capital income is directly linked to required investments, joining analysis of the two objectives.

The forest sector cannot rely solely on increased and/or diversified raw material use for growth in value added due to simultaneuos climate and biodiversity goals that are limiting wood use/harvests. Nationally both in Finland and New Zealand, as well as globally, the challenge lies in balancing these ambitions, considering responsibility and policy choices. Thus, the harvested volumes should be used as efficiently as possible, including the residues and by-products.

(2) Analysis of available wood processing residues for hydrothermal treatments and lignin extraction for higher-added value hemicellulose and lignin based products:

It is imperative to comprehensively analyze the quantities of residual materials in conjunction with detailed market segmentation. Furthermore, it is essential to incorporate active local engagement with various stakeholder groups, including indigenous communities, to determine their willingness to utilize underexploited species, should they be accessible, and to identify the intended applications of such species.

Additionally, there is a necessity to explore both advanced high-tech (low volume) and low-tech (high volume) utilisation options, as well as strategies to integrate local communities into broader economic development initiatives.

In this study, we focus on lignin valorisation as an example. The analysis will include testing different lignin isolation and analysis processes for biomass from various NZ wood species of interest. Convesion of lignin into value-added products for various applications will be envisioned [13].

The composition of obtained biomass will be subjected to detailed investigation in order to boost the valorization of lignin and/or other value-added chemicals from indigenous wood species. At first, the amount of lipophilic extractives will be analyzed [14]. Then, the extractive-free materials are used to determine the contents of cellulosic [15] and non-cellulosic carbohydrates [16], as well as acid-insoluble (AISL) and acid-soluble lignin (ASL) content will be evaluated [17]. Also, the amounts of inorganic materials in biomass will be appraised [18].

According to obtained data wood residues for the further hydrothermal treatment (HTT) will be selected. The HTT conditions, i.e., processing temperature, residence time and liquid to solid (L/S) ratio will be selected according to previous studies aiming to recover biopolymers with certain properties [19, 20, 21). Molar mass, purity, structure and functional groups of obtained biopolymers will be investigated in order to select further industrial applications [22, 23, 24].

(3) Holistic framework for local industrial ecosystems utilizing wood for timber construction and biobased chemicals needed in building-with-wood concepts, including the example.study of local indigenious raw materials and residues of wood processing:

This will include focus group interviews with local industrial stakeholders and land and forest owners, particularly representatives from Māori communities.

Additionally, a citizen science survey will be conducted to gather information on public perceptions of current wood and forest utilization, future expectations for forestry and wood use within a circular bioeconomy, identification of beneficiaries and those adversely affected by planned wood and forest exploitation and biomass valorization, and the values underpinning potentially divergent viewpoints.

5 – RESULTS

The study aims to evaluate the potential of new forest-based bioproducts in New Zealand by examining production volumes, value addition, and necessary investments, using strategic assessments and modeling to inform future directions for bioproduct development in light of simultaneous climate and biodiversity goals. The work will be based on the similar approach already carried out in Finland.

It will emphasize the analysis of wood processing residues for higher-added value products, engaging local communities to explore utilization options, and determining the willingness to use underexploited species for various applications while integrating economic development initiatives.

A holistic framework will be developed for local industrial ecosystems, involving focus group interviews

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and citizen science surveys to understand stakeholder perspectives on timber construction, biobased chemicals, and the utilization of indigenous resources within a circular bioeconomy.

As expected results, economic, social, and ecological sustainability of the timber use for pre-screened local wood species will be obtained. Also, examples on existing and planned industrial value-chains and their by-products will be analyzed.

6 – CONCLUSION

This study will provide a baseline understanding on the holistic usage and mainstreaming potential of underutilized local wood species within the buildings and construction sector in NZ, with techno-economic and social pre-feasibility analysis.

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