November 2019

EXPORT GROWTH OPPORTUNITIES FOR NEW ZEALAND PROCESSED WOOD

Photos courtesy of Red Stag Timber, New Zealand; 1) aerial view of the company's mill in Waipa (background); 2) logs being harvested (inset top); and 3) boards being produced in mill (inset bottom)

A market review of selected products

Forest Economic Advisors

+64 27 430 2889 msmith@getfea.com getfea.com

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+64 27 430 2889 msmith@getfea.com getfea.com

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+64 27 430 2889 msmith@getfea.com getfea.com

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BACKGROUND AND SCOPE

The New Zealand wood processing sector presents significant opportunities for export-led expansion given the large volume of logs currently exported offshore (predominantly to China) that could otherwise be processed domestically.

The versatility of New Zealand radiata pine means that there are already a wide range of different wood products manufactured in the country using different processes and feedstocks, e.g., logs, sawn timber, veneers, EWPs, pellets, pulp and paper, etc., and the nature of the breakdown of the log means that these products are often interlinked from a manufacturing perspective.

Forest Economic Advisors (FEA) has been engaged by New Zealand Trade and Enterprise (NZTE) to provide a report that looks at these product opportunities, likely markets and indicative price levels. This report provides FEA's view on what products have the most export growth potential into what export markets, and therefore what wood processing expansion opportunities could be most attractive for investment. The analysis and opinions contained in this report are entirely those of FEA.

We note that this work could then lead to more detailed analysis if investors wish to investigate any of these product/market opportunities.

The scope of work includes the following:

1. Commentary on current and potential global wood processing factors affecting NZ, including opportunities and threats.
2. Target opportunities — a template by wood product type that includes the following:
   a. Description of Product
   b. Major Uses
   c. Currently Produced in NZ — Yes/No
   d. Major Importing Countries — Where are the Markets?
   e. Major Exporting Countries — Who is the Competition?
   f. Published Price Series (where available) or Suitable Proxy
   g. Key opportunities and constraints for a New Zealand manufacturer
3. Products to include in each template:
   a. Lumber — Structural/Appearance/Industrial
   b. MDF
   c. Particleboard
   d. OSB
   e. Plywood
   f. LVL
   g. LSL
   h. PSL
   i. CLT
   j. Wood Pellets
4. Commentary on export potential of new products or higher-value products

It is important to note that the scope of work excludes consideration of supply-side factors such as available wood supply, energy availability and other inputs that will be specific to each region of New Zealand, as well as likely global cost-competitiveness. The scope of work also excludes assessment of markets for pulp and paper.

msmith@getfea.com getfea.com

EXECUTIVE SUMMARY

This report provides FEA's view on which New Zealand processed wood products have the most export growth potential into what export markets, and therefore what wood processing expansion opportunities could be most attractive for investment. It is product/market focused and is not comprehensive, as the dynamic nature of the sector means things are constantly evolving. However, it does attempt to cover a number of key issues, in particular:

- Current and potential global market factors
- Key wood products
- New and evolving/expanding wood products

CURRENT & POTENTIAL GLOBAL MARKET FACTORS

Some key global market factors affecting international wood markets are elaborated upon in the section titled **Current & Potential Global Market Factors**:

- Beetle damage in central European forests have resulted in lower-quality logs and lumber flooding European and offshore markets. Even exports of salvaged logs to China have accelerated dramatically. For the foreseeable future, expect to see more low-priced logs and lumber entering export markets from Central Europe, negatively impacting log and lumber exporters elsewhere. This could be a short-term to medium-term negative factor for investors considering wood products from a New Zealand operation targeting the same markets but, in the longer term, could be positive given that the early removal of beetle-damaged timber will limit available harvest levels in those countries in the future.

- The ongoing US–China tariff could be a short-term to medium-term positive factor for investors considering wood products from a New Zealand operation as a permanent substitute for US imports, although the tariffs are reducing Chinese demand for logs and lumber, as the US is a huge export market for Chinese furniture and valued-added products. However, more importantly, the growth of SYP log exports from the US South to China has been curtailed right at a time when it could have been on a growth trajectory — similar to New Zealand radiata pine from 2008. Higher volumes of lower-delivered-cost SYP logs into China could have reduced export parity pricing of radiata pine logs to a domestic producer in New Zealand in the medium term. This now appears to be on hold.

- The availability of logs for processing is dropping in British Columbia as the Annual Allowable Cut (AAC) reduces. As BC's output reduces, it will likely continue to supply the neighbouring US and pull back on export markets, e.g., Asia. This vacuum will need to be filled by other producers, and these grades and price points could provide an opportunity for greater processed wood exports from New Zealand. Note that 2019 is proving an exception, with BC lumber exports through August up 27% to China due to weak US demand (although volumes to Japan have dropped due to reduced availability of high-quality lumber).

- Russia has emerged as a global wood processing power in recent years on the back of log export tariffs and quotas. It is the biggest lumber supplier to China and, as lumber exports continue to expand, other countries will lose market share there and be forced to look elsewhere. Any investor needs to be aware of these shifting Russian/Chinese market dynamics and the impact on their target products/markets.

- Chinese wooden furniture represents over 60% of all wooden product exports by value. Due to the tariff war, some Chinese firms are moving production to other "US tariff-free" countries. Chinese investors could look to build integrated supply chains in New Zealand that not only incorporate primary manufacturing (solid wood processing to lumber or veneers), but also offer remanufacturing of these products into valued-added products such as furniture and laminate flooring.

msmith@getfea.com getfea.com

- The growth of huge timber industrial parks in China will have major internal implications for both the supply chain/distribution of softwood logs and the local wood processing businesses using these logs. These timber industrial parks will create new saw lines, kilns, panel plants and remanufacturers that will change the cost-competitive landscape for equivalent imported products.
- Australia will continue to be (and increasingly so) a net importer of timber products — from the current 16% to an estimated 27% by 2030 (if per capita consumption can be maintained). Higher lumber prices, driven by increased log prices and stronger demand, will support both imports and substitution. Given the proximity of Australia to New Zealand, its similar culture and the Closer Economic Relations (CER) free trade agreement between the two governments, opportunities in Australia should be explored in terms of how New Zealand can adapt its timber products to meet Australia's grade/quality requirements, and supplant other importing countries over the long term.
- India is moving from a hardwood-dominated timber market to a softwood one as environmental concerns make hardwood logs and lumber more difficult to source. In this regard, New Zealand is well placed, as radiata pine logs are well-known to the Indian market. Unfortunately, lumber sawn from these logs in India is primarily used in low-value construction (formwork) and packaging applications, where it competes with lower-value softwood lumber imported from Europe. A higher-value opportunity would be to develop a market for traditional clearwood radiata pine grades that might find favour in the Indian furniture market. This is a medium-term opportunity, but any investor looking at valued-added remanufacturing in New Zealand should not discount the possibilities of the Indian market in the near future.

KEY WOOD PRODUCTS

A series of templates is presented in the section titled **Target Wood Products** for a selected range of processed wood products, excluding pulp and paper.

Table 1 below summarises these templates, including a snapshot of the top three global exporting and importing countries. The US (also being included in North America) is the top importing country for seven of these ten featured wood products. Interestingly, China features for imports of lumber only.

We note that most New Zealand exports of wood products (by volume) have historically gone to Australia and the Asia-Pacific region, as can be seen in Table 2. In general, we believe this region hosts the logical target markets for product output from newly installed New Zealand capacity. Existing supply chains and relationships in established markets such as the US and Europe

TABLE 1

Summary of Key Information from the Wood Product Templates

Product	Made in NZ	Published Prices	2018 Exports Top 10	Top 3 Exporting Countries			2018 Imports Top 10	Top 3 Importing Countries		
				#1	#2	#3		#1	#2	#3
Lumber	Yes	Yes	83%	Russia	Canada	Sweden	68%	USA	China	UK
CLT	Yes	No	Note 1	Austria	N/A	N/A	Note 1	Australia	N/A	N/A
MDF	Yes	Yes	63%	China	Thailand	Germany	47%	USA	Iran	Saudi
Particleboard	Yes	Yes	63%	Thailand	Austria	Germany	49%	Germany	Poland	USA
OSB	No	Yes	91%	Canada	Romania	Czech	79%	USA	Germany	Russia
Plywood	Yes	Yes	83%	China	Russia	Indonesia	60%	USA	Japan	S. Korea
LVL	Yes	Proxy	Note 2	NZ	N. America	Europe	Note 3	N. America	Europe	Australia
PSL	No	Proxy	Note 4	N. America	N/A	N/A	Note 4	N. America	N/A	N/A
LSL	No	Proxy	Note 4	N. America	N/A	N/A	Note 4	N. America	N/A	N/A
Wood Pellets	Yes	Yes	78%	USA	Canada	Vietnam	90%	UK	Denmark	S. Korea

Note 1: CLT exports are within region, e.g., Within Europe or North America; the exception is CLT exports from Austria to Australia
Note 2: LVL data not available. This shows major exporters to Australia which is seen as a major growth opportunity for high E-value LVL
Note 3: LVL data not available. This shows major regional importers
Note 4: PSL and LSL are only made and used in North America currently. PSL has been used in Europe and Japan in the past

Source: FEA; FAO

msmith@getfea.com getfea.com

TABLE 2

Summary of NZ Wood Product Exports Showing Percentage to Oceania/Asia by Volume

Product	Made in NZ	2018 Exports m^3	% Exports Oceania / Asia [1]	Top 3 Oceanian/Asian Countries		
				#1	#2	#3
Lumber	Yes	1,934,495	79%	China	Vietnam	Australia
MDF	Yes	600,222	88%	Japan	China	Vietnam
Particleboard[7]	Yes	72,031	99%	Japan	Australia	China
Plywood	Yes	30,307	95%	Australia	Japan	Cook Is.
OSB	No	Note 2	N/A	N/A	N/A	N/A
CLT	Yes	Note 3	N/A	N/A	N/A	N/A
LVL	Yes	Note 4	N/A	Australia	tbd	tbd
PSL	No	Note 5	N/A	N/A	N/A	N/A
LSL	No	Note 5	N/A	N/A	N/A	N/A
Wood Pellets	Yes	Note 6	N/A	S. Korea	Japan	tbd

Note 1: This is the % of all exports that went to Oceania (predominantly Australia) and Asia
Note 2: OSB is not made in New Zealand. The strandboard product make by Juken NZ is not true OSB
Note 3: No CLT exported from New Zealand
Note 4: LVL data not available. However significant exports are made to Australia
Note 5: PSL and LSL are only made and used in North America currently.
Note 6: No wood pellets exported from NZ. Indications that South Korea and Japan are future targets
Note 7: Juken NZ strandboard product captures in this HS Code and represents most of exports
tbd = to be determined. Unknown at the time of publication.

Source: FEA; FAO

are notoriously hard to penetrate, and ideally require establishment of distribution centres and on-the-ground sales staff to grow market share (e.g., some New Zealand companies' clearwood strategy into the US). Alternatively, the product needs to have a clear differentiated advantage against other wood species, like the permeability of radiata pine for evolving chemical modification technologies in Europe.

Table 3 summarises some of the key opportunities we believe are available to existing and new investors to expand processed wood exports. These are discussed in more detail in the individual templates for each wood product in the section titled **Target Wood Products**, including some of the likely constraints for each product.

TABLE 3

Potential Export Growth Opportunities

Product	Possible Export Growth Opportunities
Lumber - Structural	Upgrade structural properties to meet MGP10 requirement in Australia eg OEL™
Lumber - Appearance	Follow growth curve for European exterior products using green chemistry. Modify woods in New Zealand
Lumber - Industrial	Identify new industrial markets. Enhance with LFL® type technology
Panels *	Requires availability of residues/pulp logs. Highly fragmented markets. Investor must bring market channel
LVL	Upgrade structural properties to meet E13/E14 LVL market in Australia
PSL	Unproven in New Zealand and need technology agreements to access IP
LSL	Unproven in New Zealand and need technology agreements to access IP. Possibility to add value to corewood
CLT	Incorporate into an offsite manufacturing solution e.g. flat-packed housing for export. Mid-rise substitution
Wood Pellets	Brownfield expansion of existing players likely due to Asian growth

* MDF/Particleboard/OSB/Plywood

Source: FEA

It is important to recognise that any major wood processing investment in New Zealand is likely to benefit from exporting product; this is due to the small size of the domestic market and the need for large-scale manufacture to achieive the efficiencies necessary for cost-competitiveness. FEA recognises that there are also a range of regional and project-specific supply-side factors (wood supply, energy, labour, etc.) that investors will need to take into account and which fall outside the scope of this report.

msmith@getfea.com getfea.com

NEW AND EVOLVING/EXPANDING WOOD PRODUCTS

Differentiation into new or evolving/expanding wood products away from traditional commodity grades generally offers a higher-margin opportunity for investment. The section titled **Export Potential of New Products** discusses in more detail the technologies summarised in Table 4.

TABLE 4

Summary of New and Evolving/Expanding Wood Products

Product	Application	Comments
LFL® Advanced Framing Lumber	Structural	A possible opportunity for NZ sawmills to off-cuts and lower-strength boards by producing an engineered wood product
Zeno® Plus	Structural	CLT variation that has an LVL centre layer meaning no joints in the wall and better thermal performance
Panobloc®	Structural	A cross-fold panel filled with insulation material that can be engineered to give the required performance eg thermal, fire, acoustic
Mass Plywood Panels	Structural	A large-scale plywood panel where the use of veneers of different qualities allows more precise engineering of target specifications
OEL™	Structural	Pilot plant operational. Looking at expansion. Possible investment opportunity
Magnumboard®	Structural	Requires production of OSB in New Zealand. Could be imported initially to test market acceptance
Kerto Ripa box™	Structural	This technology has been developed by Metsä Wood and would require licensing to be used by an NZ company
Gutex / Steico / Pavatex / Heraklith	Insulation	Wood fibre, typically as chips, is used to make a natural, wood fibre insulation baord in Europe. Possible investment opportunity.
Accoya®	Durability	NZ Radiata pine used extensively for this European technology. Opportunity for technology to be deployed in New Zealand
Kebony Wood	Durability	NZ Radiata pine used for this European technology. Opportunity for technology to be deployed in New Zealand
ThermoWood®	Durability	Technology currently deployed in New Zealand. Possible investment opportunity to expand current capacity
Scion	Biobased	Largely pre-commercial opportunites that will require seed, early stage or start-up investment
Abodo — Vulcan	Other	Product commercialised and being used in construction. Looking at expansion. Possible investment opportunity
TTT Products - Multipole	Other	Business operating for many years. Looking to scale operations for global expansion. Possible investment opportunity

Source: FEA

The range of structural products look interesting, and the opportunity to develop these technologies in New Zealand will require more detailed investigation. For example, it would be valuable to understand if non-structural offcuts could successfully (and economically) be jointed together using the LFL® Advanced Framing Lumber technology to extract more value from the downfall generated in our structural sawmills.

The use of insulation board is not a well-known product application in New Zealand (where other types of insulation product are used), but the low carbon footprint benefits of a wood-fibre substitute may become more important in the near future for a construction sector that is seeing significant criticism for its carbon emissions.

For new durability products, New Zealand radiata pine is already being used as a feedstock for emerging wood-modification technologies out of Europe. There may be scope for those companies to look at New Zealand as a centre for international expansion and a beachhead to the Asian market in future.

Abodo and TTT Products are two New Zealand companies with a differentiated wood product offering.

msmith@getfea.com getfea.com

CURRENT & POTENTIAL GLOBAL MARKET FACTORS

The following are some of the factors and issues that need to be considered by investors when looking at wood processing in New Zealand. These are largely focused on timber and sawmilling (as the main primary manufacturing technology), but will flow through to secondary manufacturing that involves use of byproduct residues.

Although there is potential for domestic-driven growth, New Zealand's small domestic market (by international standards) means that exports are likely to offer the best pathway to major expansion of the New Zealand wood products sector. This will likely require either large-scale, low operating cost manufacturing plants capable of producing globally cost-competitive wood products of the right quality that can compete against similar grades from other countries and regions, or processing operations focused on innovative, higher-margin products that provide a point of difference in international markets.

Current global market factors impacting international log and wood product markets can be broken into three sub-sections:

1. Near-term to medium-term disruptors

- Bark beetles in Central Europe
- US–China tariffs

2. Developments in British Columbia, Russia and China

- Annual Allowable Cut (AAC) impacts in British Columbia, Canada
- Emergence of Russian wood processing
- Chinese wooden furniture exports
- Timber industrial parks in China

3. Markets to watch

- Australian market for softwood lumber
- Indian market for softwood lumber

BARK BEETLES IN CENTRAL EUROPE

The European spruce beetle and other insects are devastating the forests of Central Europe as they multiply out of control. Drought and high summer temperatures, in combination with winter windstorms — in short, optimum climate conditions for breeding — have allowed the beetle infestation to advance on an unprecedented scale.

This natural disaster has been in play for several years now, but it is only getting worse despite an ambitious salvage program in Germany, the Czech Republic, Austria, Switzerland, Poland and neighbouring countries. It is starting to look like a similar model to the devastation that began 25 years ago in the BC Interior due to the mountain pine beetle — also with climate change as a catalyst. Some recent statistics:

- In Germany, the timber harvest was 53.5 million m^3 in 2017 and grew to 64.4 million m^3 in 2018 as a result of the massive salvage effort. This 2018 level was above the 10-year average of 53.5 million m^3. The extra timber harvest volume and increased sawmill production have also resulted in surplus volumes of sawdust and wood chips, causing prices to plummet to levels last seen in 2009.

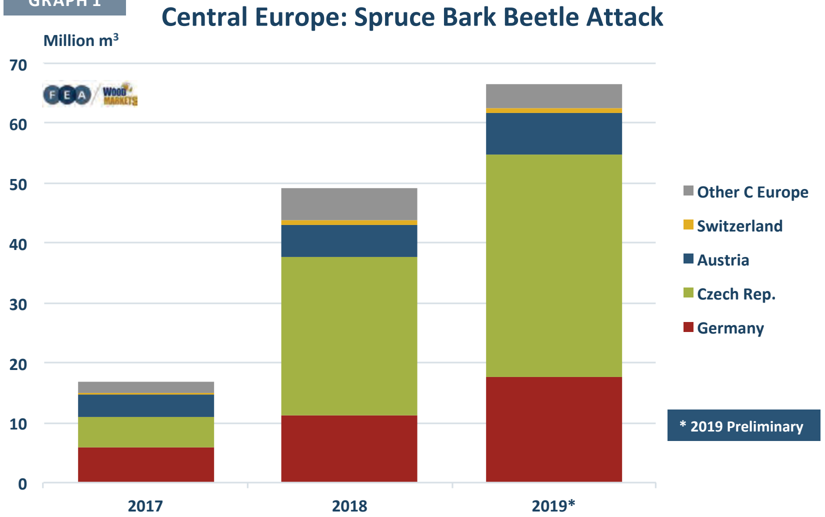
- In the Czech Republic, the Ministry of Agriculture expects about 37 million m^3 of beetle timber from an affected area of ~50,000 hectares. Relative to an annual harvest of about 17–20 million m^3, storm- and beetle-killed timber represents much more than the capacity of the industry in 2019.

msmith@getfea.com getfea.com

- In Austria, the 2018 volume of damaged timber caused by the bark beetle and storms together amounted to 9.5 million m^3 (bark beetles 5.2 million m^3; wind damage 4.2 million m^3); this is up from 2017's 7.2 million m^3. For bark beetle damage alone the infestations are as high as they have ever been in Austria.
- In Switzerland, beetle-killed timber reached 735,000 m^3 in 2018, a significant increase from 326,000 m^3 in 2017.

The total volume of timber damaged by bark beetles and windstorms in Central Europe since 2017 is clearly accelerating. In 2017, some 20% of the central European harvest comprised damaged timber, and in 2018 this increased to about 42%. The volumes of bark beetle-damaged timber are being led by the Czech Republic and Germany (Graph 1).

GRAPH 1



Source: EUWID; Holz Kurier; FEA

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Most initial reports suggest that the beetle harvest could last another two to three years, but new examinations indicate that the problem could get much worse over time. In further negative news, the drought conditions are impacting other species besides spruce in Europe's forests: fir, Scots and black pine, and hardwoods are all under stress, and the loss of mountain forests on steeper slopes (due to wind and beetles) intensifies the risk of floods and landslides.

Implications for Investment in New Zealand

Beetle-damaged and lower-quality logs and lumber have flooded European and offshore markets, and even exports of salvaged logs to China have accelerated dramatically. For the foreseeable future, expect to see more low-priced logs and lumber entering export markets from Central Europe, negatively impacting log and lumber exporters elsewhere. This could be a short-term to medium-term negative factor for investors considering wood products from a New Zealand operation targeting the same markets.

In the long term, this could be positive for New Zealand, as the early removal of beetle-damaged timber will limit available harvest levels in those countries in the future.

US–CHINA TARIFFS

The following extract from an FEA publication[1] gives an update on how the current US–China trade war is impacting lumber and other wood products exported from the US to China.

On August 23, the Customs Tariff Commission of the State Council in Beijing announced that China will impose additional levies on approximately $75 billion worth of US goods, including soybeans, oil and aircraft, in response to Washington's latest planned tariffs on Chinese imports. The Commission said that the country will add extra tariffs of 10% or 5%, depending on the product, on imports from the United States. Some of the levies were planned to be implemented starting on September 1, while the rest will take effect on December 15.

1 "Special Report: Tariffs update for US softwood lumber exports to China," *China Bulletin*, September 2019.

msmith@getfea.com getfea.com

From the HS Code listing released by the Commission, the tariffs on softwood lumber imported from the US will be increased as follows:

- Starting from September 1, an extra 10% tariff on:
  - o SYP (HS Code: 44071190) to 30% (from previously 20%); and
  - o Hemlock lumber (HS Code: 44071900), to 30% (from previously 20%).
- Starting from December 15, an extra 10% tariff on:
  - o Spruce and fir lumber (HS Code: 44071200) to 35% (previously 25%).

TABLE 5

China: Softwood Lumber Imports (m^3) from the U.S. by Species

HS Code	Product	2018 Jan–Jul	2019 Jan–Jul	1-year Change
44071130	Douglas-fir lumber	10,055	2,812	-72.0%
44071190	SYP lumber	230,862	156,999	-32.0%
44071200	Spruce/Fir lumber	2,460	1,381	-43.9%
44071900	Hemlock lumber	78,032	31,492	-59.6%
Total Softwood lumber imports		321,409	192,684	-40.1%

Source: FEA; China Bulletin, September 2019

According to statistics from China Customs, the softwood log and lumber supplied from the US to China dropped by 36% and 38% by volume, respectively, in the first seven months of 2019 compared with the same period last year. As shown in Table 5, SYP lumber volume supplied from the US to China was 230,862 m^3 in first seven months of this year, a decline of 32% from the same period last year, while Douglas-fir and hemlock lumber volumes dropped 72% and 60%, respectively, from the first seven months of last year.

By the end of 2019, China will have made five rounds of tariff adjustments on timber and wood products imported from the US since June 2018. The full listing of tariffs to be in place by December 15, 2019 are shown in Table 6.

TABLE 6

China: Tariffs Imposed on Softwood Logs and Lumber from the US — 2019

Products	Tariff before June 1st	Tariff after June 1st	New Tariff after Sep 1st	New Tariff after Dec 15
SYP log, 15cm+	25%	25%	25%	25%
SYP log, <15cm	10%	20%	20%	20%
Hemlock log, 15cm+	5%	5%	5%	5%
Hemlock log, <15cm	10%	20%	20%	20%
Douglas-fir log, 15cm+	5%	5%	5%	5%
Douglas-fir log, <15cm	10%	20%	20%	20%
Spruce log, 15cm+	10%	20%	20%	20%
Spruce log, <15%	10%	25%	25%	25%
Douglas-fir lumber	10%	20%	20%	20%
SYP/Hemlock lumber	10%	20%	30%	30%
Fir and spruce lumber	25%	25%	25%	35%

Source: FEA; China Bulletin, September 2019

China is also reported to be increasing its tariffs in December, as follows:

- US wood pulp imports to 10% (+5%).
- Recycled fibre (such as OCC and OPN) to 30% (+5%).
- Uncoated, unbleached liner paper, uncoated medium, kraft linerboard to 10% (+5%).
- Dissolving pulp (5%) and recycled pulp (20%) to remain flat.

Implications for Investment in New Zealand

In order to remain competitive in China, US suppliers are promising to drop their prices to their Chinese customers to cover all or part of the new (and additional/non-predictable) tariffs when they are first applied. This is an attempt to retain good sales relationships, but there is no doubt that supply from the US will continue to shrink. China softwood log and lumber imports are quickly shifting to new low-cost exporting countries as declining volumes from the US get replaced by myriad other sources.

This could be a short-term to medium-term positive factor for investors considering wood products from a New Zealand operation as a permanent substitute for US imports, although the tariffs are reducing Chinese demand for logs and lumber, as the US is a huge export market for Chinese furniture and value-added products. However, more importantly, the growth of SYP log exports from the US South to China has been curtailed right at a time when it could have been on a growth trajectory similar to New

Zealand radiata pine from 2008. Higher volumes of lower-delivered-cost SYP logs into China could have reduced export parity pricing of radiata pine logs to a domestic producer in New Zealand in the medium term. This now appears to be on hold.

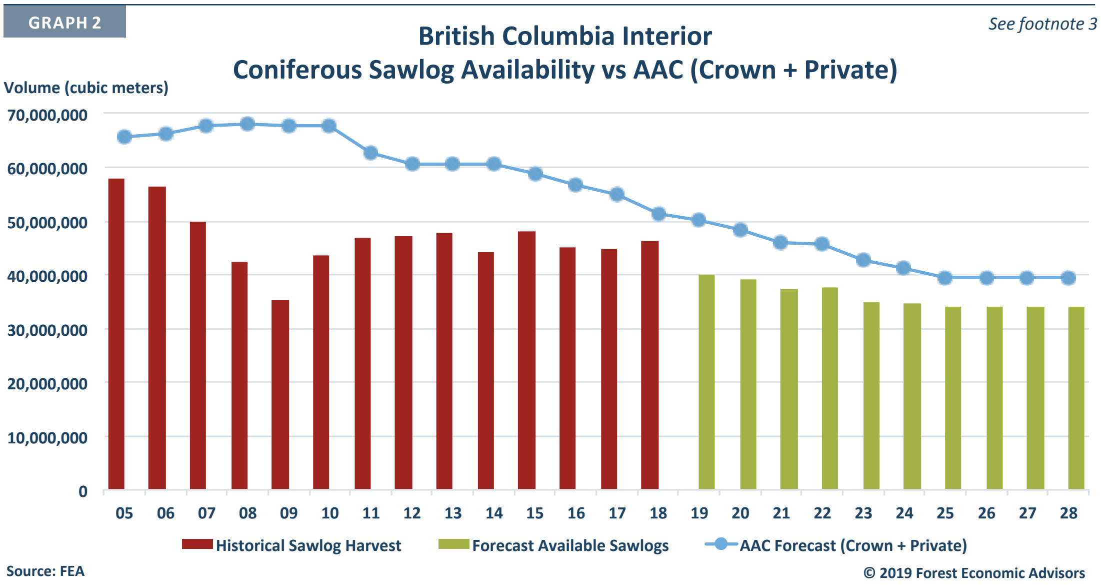
ANNUAL ALLOWABLE CUT (AAC) IMPACTS IN BRITISH COLUMBIA, CANADA

British Columbia (BC), the westernmost province in Canada bordering the Pacific Ocean, has a long and proud history in the forestry and forest products industry. BC harvests just over twice the volume of timber as New Zealand, but exports valued-added forest products (e.g., sawn timber, other wood products, pulp and paper) with more than 5.5 times the value. For example, BC exported about 25 million m^3 of softwood lumber in 2017 (mostly to the US) compared to New Zealand's total softwood lumber exports of about 1.8 million m^3 for the same year.

However, a new report[2] highlights that although the bulk of the mountain pine beetle (MPB) epidemic that has plagued the BC Interior for the past two decades is effectively over, new challenges are arising due to the allowable annual cut (AAC) rationalization process currently underway. Pressures from wildfire, spruce beetles, First Nations land reconciliation and caribou habitat protection are increasing the downward pressure on the official AAC forecasts.

The mid-term forecast (to 2028) shown in Graph 2 for the BC Interior region suggests an AAC of about 39.5 million m^3 in 2028 — 11.6 million m^3 below the estimated 2019 level.

GRAPH 2



As of early 2019, 57 sawmills and 9 veneer/plywood plants — a total of 66 sawlog-consuming mills — were operating in the region. In early May 2019 at an international wood products conference, the report authors projected that 13 more mills would close permanently — 4 have since announced their permanent or pending closure. The BC Interior's annual lumber production was about 26 million m^3 in 2018 and, given the projected ongoing curtailments, the forecast is for the sawmilling rationalization process to result in output of 20 million m^3 by 2028. The reduction in sawmill production will also impact downstream forest industry consumers of by-products. Pulp mills, pellet mills and bioenergy plants will feel a direct impact from a reduced supply of wood chips, sawdust, shavings and hog fuel.

2 *BC Interior Regional Fibre Supply Forecast — Life after the beetle: Analysis and forecast of BC timber availability and wood products production to 2028* ©2019 Forest Economic Advisors LLC and Industry Forestry Service Ltd. Available at www.getfea.com

Implications for Investment in New Zealand

BC is a major, wood products exporter. For example, it is the equal–largest softwood lumber exporter (along with Russia — see Lumber template in our **Target Wood Products** section), having about 23% of the global market share (admittedly, the majority goes to the US). As BC output reduces, it will likely continue to supply the neighbouring US and pull back on export markets, e.g., Asia. This vacuum will need to be filled by other producers, and these grades and price points could provide an opportunity for greater processed wood exports from New Zealand. Note that 2019 is proving an exception, with BC lumber exports through August up 27% to China due to weak US demand (although volumes to Japan have dropped due to reduced availability of high-quality lumber).

EMERGENCE OF RUSSIAN WOOD PROCESSING[3]

Russian softwood lumber output has risen steadily since the early 2000s, bolstered by increased log export taxes starting in 2006 that incentivized the processing of logs in Russia. A major driver of the higher output has been Russia's recent competitiveness in key markets, due in part to its devalued currency. With domestic apparent consumption remaining flat, lumber exports will continue to be the biggest catalyst for future increases in lumber production. Softwood lumber output for 2018 is estimated at 39 million m^3 (+55% from 2008). The outlook calls for a further expansion of Russian lumber output, but at a slowing rate given tight timber supplies and steadily rising hauling distances from forest to sawmill.

The most profitable Russian-owned sawmills in Russia typically have their own forest licences for the bulk of their sawlog requirements, and tend to operate larger-scale, more modern mills. Giving these top-quartile Russian mills a run for their money is a growing complement of Chinese mills now operating within Russia. Like the bulk of their China-based operations, they tend to be small in size, use older technology (e.g., simple band saws), be highly flexible, and enjoy some strong competitive advantages. Most notably, they can process any type of log, are able to achieve high lumber yields, and are skilled at producing the sizes, grades and lengths demanded by Chinese customers. Furthermore, these Russia-based Chinese mills enjoy low capital costs, and, by operating strategically, are able to achieve sawmilling margins that rival those of the larger-scale, modern Russian-owned mills.

As such, Russian lumber is highly competitive in China. In fact, it is the lowest-cost lumber supplier on a delivered basis to the Shanghai area against competing countries, and is even more competitive along China's northeastern coast (via ocean vessel or rail), and in central and western China (the latter due to rail cost advantages, including block trains introduced as part of China's One Belt/One Road initiative). With more kiln-dried/valued-added products and a range of improvements in rail logistics, Russian mills have been able to expand their economic reach to more regions and end users, becoming a formidable competitor in the all-important China market.

In terms of softwood lumber imports to China in 2018, Russia was again the largest supplier, with an increase of 1.36 million m^3 versus 2017. This jump was partially responsible for moderate declines in exports by several other countries, e.g.,

- Finland: down 32% (-550,000 m^3)
- Sweden: down 22% (-200,000 m^3)
- Canada: down 15% (-824,000 m^3)
- Total: down 22% (-1,574,000) m^3

Implications for Investment in New Zealand

Globally, China is the biggest importer of softwood logs (44% market share in 2018) and second-largest importer of softwood lumber (20% market share in 2018, just behind the US at 21%). By sheer size, any developments in China will affect markets

3 Commentary based on FEA report *Russia: Forest Industry Competitiveness & Export Outlook to 2025/2030 (With a Focus on China)*. See www.getfea.com

msmith@getfea.com getfea.com

elsewhere. As lumber imports from Russia continue to expand, other countries will lose market share in China and be forced to look elsewhere. Investors need to be aware of these shifting market dynamics and the impact on their proposed wood processing operation and target products/markets.

CHINESE WOODEN FURNITURE EXPORTS

According to information from the National Forestry & Grassland Administration, China's forest products trade value reached US$165.2 billion in 2018, an increase of 10.8% compared with 2017. Of the total trade value:

- Imports were US$83.7 billion, up 11.4%.
- Exports were US$81.6 billion, up 10.1%.

TABLE 7

China Exports: 2018 vs. 2017

Products	Volume 2018	Volume 2017	Volume % change	Value (USD millions) 2018	Value (USD millions) 2017	Value (USD millions) % change
Plywood (x000 m^3)	11,351	10,937	3.8%	5,549	5,108	8.6%
Fiberboard (x000 m^3)	2,503	2,987	-16.2%	1,119	1,147	-2.5%
Particleboard (x000 m^3)	356	313	13.7%	108	101	6.6%
Wood Door (x000 tonnes)	338	340	-0.6%	665	674	-1.3%
Wood Furniture (million pieces)	270	256	5.4%	13,488	13,729	-1.8%

Source: China Customs

Note: 1) Conversion from ton to cbm of Particleboard is 0.65;
2) Conversion from ton to cbm of MDF is 0.7;
3) MDF data is from HS Code 4411, includes laminated flooring;
4) Plywood data is from HS Code 4412, includes engineered flooring;

Source: FEA; China Bulletin, June 2019

The trade deficit grew to US$2.1 billion in 2018, compared with US$750 million in 2017 (which was when the first trade deficit occurred).

Of all wooden products exports, furniture was the largest category, representing 64% of total wooden products exports value in 2018. As seen in Table 7, this was followed by plywood, fibreboard, wood doors and particleboard.

China is the largest wooden furniture exporter in the world, with exports to more than 100 different countries and regions. The US was the largest export destination for China's wooden furniture, representing 41.2% by volume and 42.3% by value of total exports in 2018, as can be seen in Table 8. Of note, of all wooden furniture products categories — including office, bedroom, kitchen and "other" — the US market accounted for more than 73% of total Chinese kitchen wooden furniture export value in 2018.

TABLE 8

China: Wooden Furniture Export by Destination

Export Destination	Volume (million pieces) 2019 Jan–Apr	Volume (million pieces) 2018 Jan–Apr	Volume (million pieces) 1-year Change	Value (million USD) 2019 Jan–Apr	Value (million USD) 2018 Jan–Apr	Value (million USD) 1-year Change
U.S.	26	30	-13.3%	1,312	1,545	-15.1%
Hong Kong	1.4	1.8	-22.2%	202	247	-18.2%
Japan	6.5	6.9	-5.8%	242	254	-4.7%
UK	4.9	4.7	4.3%	204	205	-0.5%
Australia	3.6	3.9	-7.7%	167	187	-10.7%
Korea	2.3	2.3	0.0%	112	120	-6.7%
Canada	1.8	1.9	-5.3%	84	97	-13.4%
S.Africa	0.7	0.6	16.7%	98	69	42.0%
Germany	3.1	3.3	-6.1%	92	85	8.2%
France	2.6	3.1	-16.1%	78	82	-4.9%
Singpore	0.4	0.6	-33.3%	75	87	-13.8%
S.Arabia	1.2	1	20.0%	90	82	9.8%
U.A.E.	0.6	0.6	0.0%	51	54	-5.6%
Holland	2	2	0.0%	48	47	2.1%
Others	15.6	15.3	2.0%	725	759	-4.5%
Total	72.7	78	-6.8%	3,580	3,920	-8.7%

Source: FEA; China Bulletin, June 2019

The US also was the largest export destination for Chinese plywood products, at 11.2% by volume and 19.4% by value. In addition, the US was the largest export destination for China's wooden door and fibreboard products, taking more than 30% and 17%, respectively, of the total 2018 export volume.

Implications for Investment in New Zealand

The current trade friction between China and the US will further affect the ability of Chinese wood producers to ship to their largest market. However, it could also be seen as a positive opportunity for those domestic wood product and furniture industries that wish to upgrade their facilities and transform their business models. Due to the tariff war, some Chinese firms are moving production to other "US tariff-free" countries, while others are adjusting their export structure and/or looking to further develop domestic markets. Chinese investors could look to build integrated supply chains in New Zealand that not only incorporate primary manufacturing (solid wood processing to lumber or veneers), but also offer remanufacturing of these products into valued-added products such as furniture and laminate flooring.

TIMBER INDUSTRIAL PARKS IN CHINA

In recent years, several large and modern timber industrial parks with sophisticated market channels and supply chains have been built as new developments along the Yangtze River and many One Belt/One Road (BRI) cities, as shown in Figure 1. Some of those timber industrial parks include the following:

- Dafeng Timber Industrial Park (Dafeng Port)
- China National Forest Group (CNFG) — Zhenjiang Guolin Eco-Industrial City (Xinminzhou port)
- Rugao Port International Timber Industry Park (Rugao port)
- Tangshan Caofeidian Wood Industrial Park (Caofeidian port)
- CNFG — Huazhong International Timber Industrial Park (Jiujiang river port)
- CNFG — Chongqing Banan Timber Industrial Park (Chongqing river port)

The Chinese government released an environmental protection plan covering the Yangtze River Economic Belt in August 2017 — the latest move to protect the country's longest river from pollution. This will result in pushing significant industry upgrades further along the Yangtze River. Not only will the older, traditional timber distribution centres be affected, so will the newly built timber industrial parks (which will need to consider long-term and sustainable development as part of their business plans).

Based on strict government environmental protection policies, it is predicted that log imports at Taicang and Changshu

Timber Parks Built Along the Yangtze River

FIGURE 1

Source: FEA; China Bulletin, March 2019

ports will drop dramatically in the next three years. This is due to the closing of log fumigation facilities at Taicang port amid sawmill closures and relocations away from the area. Taicang will still be an important distribution centre for softwood lumber, and log volumes will still be imported to the Taicang area for further delivery to upper Yangtze River ports. Nonetheless, these developments are creating a huge development opportunity for the new timber industrial parks.

As an example, Xinminzhou port (230km away from Taicang) is one of the most important and successful ports to be developed in the last two years. Log imports to Xinminzhou port reached 2.8 million m^3 in 2018, an increase of 93% versus 2017. Log imports are expected to reach 3.5 million m^3 in 2019 and 5 million m^3 in 2020. It is predicted that around 3 million m^3 of log imports that were previously scheduled for Taicang will be transferred to Xinminzhou port in the next three years. Of all log imports into Xinminzhou in 2018, 600,000 m^3 were consumed within its own timber industrial park; the remaining volumes were transferred out to other regions by boat or truck.

The first stage of the timber industrial park has 60 sets of saw lines, with log-in production capacity of 700,000–800,000 m^3 annually. The main products are construction lumber and pallet/packaging lumber. The second stage will see the installation of 140 saw lines and 120 dry kilns, at which point log-in production capacity will reach 2 million m^3. Furthermore, a secondary processing zone features 73 hectares of available that will be used to attract manufacturers of furniture, wooden doors/ windows, fibreboard, particleboard, timber-frame house factories, etc., all using softwood timber species. The construction of this processing zone is expected to be completed by 2020.

Implications for Investment in New Zealand

The expectation is that the supply chain and distribution channels for softwood logs to China will see major changes in the next three years, impacting not only the traditional softwood log distribution centres but also their neighbouring sawmills that will no longer have feedstock. These impacts will need to be taken into account by any investor in a wood processing plant in New Zealand that is targeting the Chinese market: new saw lines, kilns, panel plants and remanufacturers at these emerging timber industrial parks will change the cost-competitive landscape for equivalent imported products.

AUSTRALIAN MARKET FOR SOFTWOOD LUMBER

Australia is a major importer of wood products including lumber, LVL and CLT (see relevant templates in **Target Wood Products**).

The installed capacity of Australia's softwood sawmilling sector is approximately 10 million m^3 of sawlogs, but it operates at about 80% of that capacity due to market and sawlog availability issues. The 10 largest sawmills in the country process some 75% of available supply. However, they also operate under a more complex operational structure than mills in North America (many with upward of 2,500 SKUs).

One of the contributing issues to the underutilization of sawmill assets has been a decline in average domestic real sawlog prices for growers. There has also been the attraction of rising real log prices when exporting to China. These trends have resulted in a 350% increase in the quantity of logs being exported from Australia over the past nine years. Of the total volume currently shipped, ~1.5 million m^3 is in the form of sawlogs, with the balance made up of sawable pulp logs and a small but growing proportion of plantation hardwood logs. Australia is now the world's fifth-largest log exporter (4.5 million m^3), behind New Zealand, Russia, the US and Canada.

Not surprisingly, recent structural changes have occurred in long-term saw log supply contracts in Australia that have led to a greater emphasis being placed on export parity pricing (as has been the case in recent years in New Zealand). The greatest risk in this shift is a possible faltering of the domestic sawmilling industry caused by reduced domestic capacity.

msmith@getfea.com getfea.com

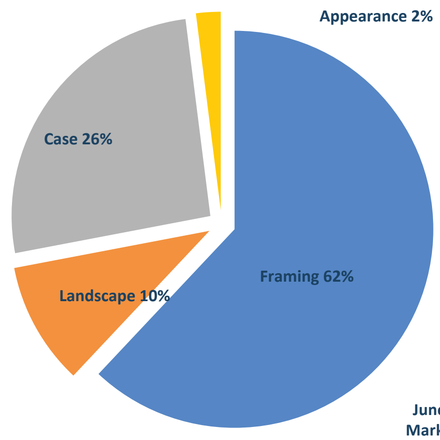
Domestic Timber Market

Total lumber consumption in Australia is currently estimated at 5.7 million m^3, of which softwood lumber makes up around 5.1 million m^3. Of this, some 4.3 million m^3 is domestically produced and 0.8 million m^3 is imported.

Australia's timber industry is strongly supported by housing demand. Softwood products currently account for about 88% of the country's lumber consumption, with about 5% of domestic output being exported. While the majority of the domestic sawmills are designed to focus on structural-grade products, there are also a number set up specifically to process industrial/case-grade (e.g., pallet boards) and treated landscape (e.g., sleepers, decking boards and fencing) products. The estimated net product mix from all Australian sawmills is shown in Graph 3.

GRAPH 3

Estimated Product Mix from Australian Sawmills



Source: FEA; June 2019 Wood Markets Monthly

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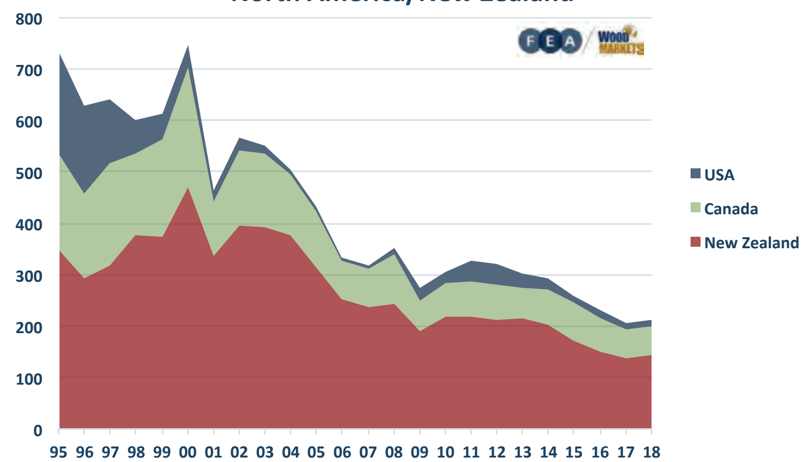
Australia's demand for timber products now exceeds current installed fibre conversion technologies. In order for the country to be self-sufficient in lumber products today, ~50,000 ha of additional softwood plantation would have already needed to be available for harvesting. Furthermore, meeting expected future demand based on prevailing population growth estimates would require an additional 350,000 ha of younger plantation fibre.

If the current 1.5 million m^3 of exported sawlogs were to be processed domestically, it would yield an estimated 0.8 million m^3 of lumber products — enough to cover the present volume of imported softwood. However, this does not address the projected increase in total consumption predicated on Australia's likely population growth.

GRAPH 4

Australia Softwood Lumber Imports: North America/New Zealand



Source: FEA; June 2019 Wood Markets Monthly

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Industry associations are now attempting to rectify the current and future supply shortfall by lobbying state and federal governments to support/incentivize a revised plantation development solution. Unfortunately, any impact is likely to take in excess of 25 years to be effective, placing Australia in the position of being a net importer of softwood lumber products for a long time to come.

msmith@getfea.com getfea.com

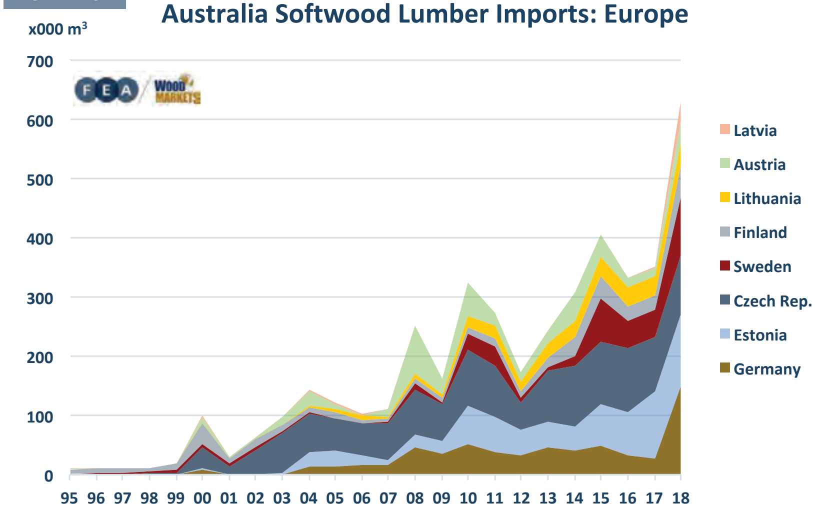
Lumber Imports

While net imports of softwood lumber products into Australia have ranged at 0.5–0.8 million m³ per year over the past 20 years, there has been a significant change in the source of those imports. For example, we have seen imports from New Zealand fall by 67% and imports from North America fall by 42% (Graph 4). Over the same period, European sawmills have moved from being a minor exporter to Australia to representing more than 75% of all imported softwood lumber products (Graph 5), due largely to the following factors:

- Expansions made to production facilities in Eastern and Northern Europe.
- Relatively low prices being achieved for the closer export option (the eastern coast of North America).
- Relatively stronger prices for structural products in the Australian market. (However, real prices for structural framing products in Australia have been steadily drifting lower over the past 15 years, and a continuation of this trend could have a significant impact on future imports.)

GRAPH 5

Australia Softwood Lumber Imports: Europe



Source: FEA; June 2019 Wood Markets Monthly © 2019 Forest Economic Advisors

Implications for Investment in New Zealand

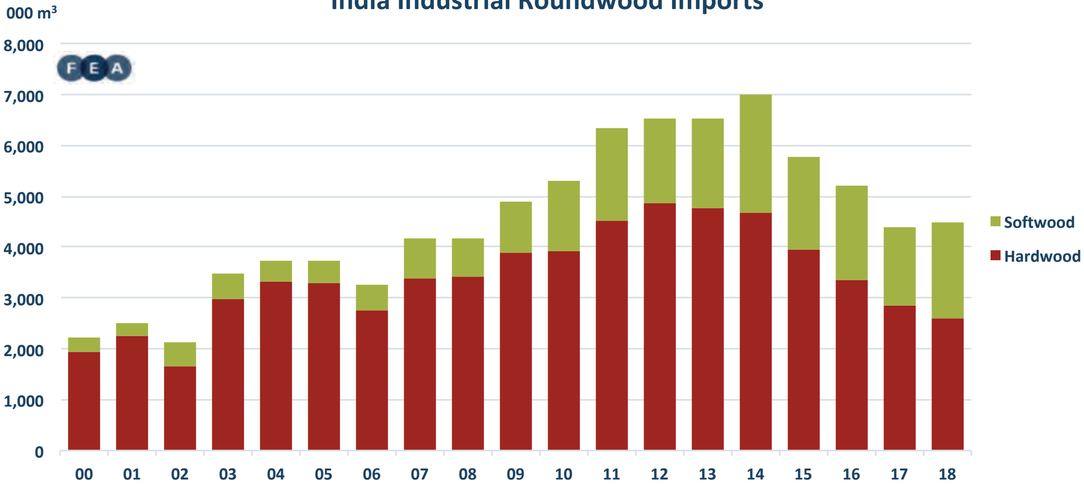
Australia will continue (and increasingly so) to be a net importer of timber products — from the current 16% to an estimated 27% by 2030 (if per capita consumption can be maintained). Higher lumber prices, driven by increased log prices and stronger demand, will support both imports and substitution. New Zealand has an ambition to be a greater net exporter of timber products. Given the proximity of Australia to New Zealand, its similar culture and the Closer Economic Relations (CER) free trade agreement between the two governments, opportunities in Australia should be explored in terms of how New Zealand can adapt its timber products to meet Australia's grade/quality requirements, and supplant other importing countries over the long term.

INDIAN MARKET FOR SOFTWOOD LUMBER

India's population is approaching 1.4 billion and is the world's largest democracy. Forests are 90% state-owned, and, since the mid-1980s, private-sector harvesting on public lands has been banned; government harvesting is restricted to specific

GRAPH 6

India Industrial Roundwood Imports



Source: FAO © 2019 Forest Economic Advisors

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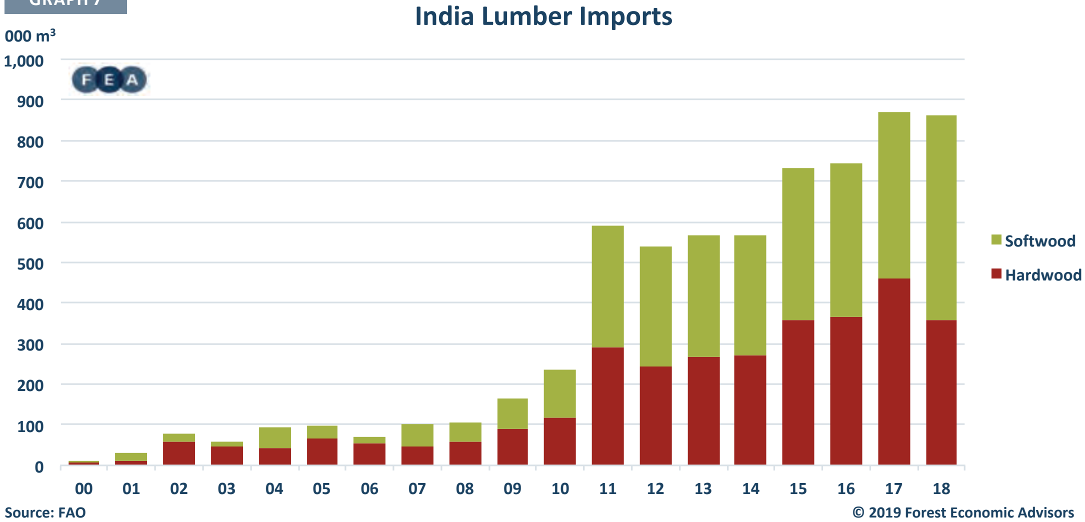
"plan areas". India's Supreme Court restricted all timber movement and harvesting activities from natural forests in December 1996.

GRAPH 7



Consequently, India has emerged to become one of the largest log importers in the world, traditionally with a hardwood focus. In terms of value, India was the second-largest importer of logs in 2018 (a distant second to China), with New Zealand the largest supplier of softwood logs (>90%) and Malaysia the largest supplier of hardwood logs.

At a value of US$240 million in 2018, India has significantly grown its lumber imports since 2010. Germany and the US are the largest suppliers, while Malaysia, Myanmar and Indonesia supply the most hardwood lumber. Wood tariffs apply to lumber imports, offering some protection to local sawmillers, but these have dropped from 30–50% (pre-2007) to 15–30%.

Historical imports of roundwood and lumber to India are shown in Graphs 6 and 7. Of note:

- Total log imports in 2018 are just under 4.5 million m^3, declining from a peak of about 7 million m^3 in 2014.
- Hardwood log imports are decreasing due to the Myanmar log export ban (teak) in 2014 and reduced imports of Malaysian hardwoods.
- Total lumber imports are just under 900,000 m^3, with significant growth in softwood lumber.

From a solely hardwood-log market, India's industry is becoming more diversified.

In terms of volume, logs will continue to dominate the market share in the near future, but lumber will continue to gain market share and will surpass logs in terms of value. India's softwood lumber demand will grow at a steady pace.

Graph 8 on the next page provides a forecast from Ganguly et al.[4] showing India's imported log and lumber demand out to 2035 with a demonstrable supply gap. The cumulative volume of the wood deficit between 2019 and 2035 is approximated at 36 million m^3 of wood. An opportunity clearly exists in India to promote high-quality softwoods for use in applications that have historically been the domain of tropical hardwood.

Ganguly et al. noted several implications of the supply gap:

- The shortage will be met by either the wood products industry or non-wood products. If non-wood products fill the void, it will be a failure for the wood products industry.
- There will be opportunities for species/grades not demanded currently.
- The market will become less price-sensitive, leading to opportunities for higher-value species.

4 *India: Wood fibre supply gap analysis.* A paper by Prof. Indroneil Ganguly, Prof. Chris Gaston and Dr. Wei-Yew Chang. Presented at FEA Global Softwood Log & Lumber Conference, May 8–9 2019, Vancouver, BC.

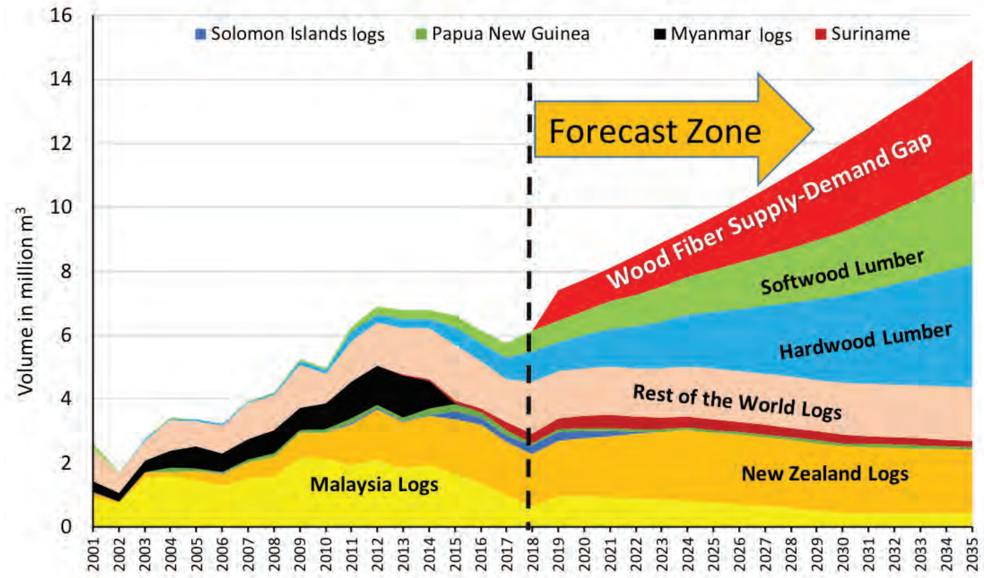
msmith@getfea.com getfea.com

Furthermore, the authors noted the following:

- There is a lack of awareness of softwood among wood manufacturers and little experience of familiarity with imported timber species. This is a definite requirement for education and extension programs.
- It is critically important to understand the nuances of the Indian market, and the differences in the demands associated with the bulk market versus the niche market.

GRAPH 8

Forecast of India's Imported Logs and Lumber Demand and Wood-Fibre Supply Gap



Source: ***India: wood fibre supply gap analysis*** (see footnote 4)

The demand for higher-quality lumber is increasing, and an opportunity clearly exists in India to promote high-quality softwoods for use in applications that have historically belonged to tropical hardwoods. Premium and higher-quality softwood species can have a huge market in India if the proper sizes and moisture content are offered. At this point, European species are favoured because they can provide stable prices and sell the required 25mm and 50mm sizes preferred by the Indian market.

Implications for Investment in New Zealand

India is moving from a hardwood-dominated timber market to a softwood one as environmental concerns make hardwood logs and lumber more difficult to source. In this regard, New Zealand is well placed, as radiata pine logs are well-known to the Indian market. Unfortunately, lumber sawn from these logs in India is primarily used in low-value construction (formwork) and packaging applications, where it competes with lower-value softwood lumber imported from Europe. A higher-value opportunity would be to develop a market for traditional clearwood radiata pine grades that might find favour in the Indian furniture market. This is a medium-term opportunity, but any investor looking at valued-added remanufacturing in New Zealand should not discount the possibilities of the Indian market in the near future.

TARGET WOOD PRODUCTS

New Zealand's dominant production wood species, radiata pine, is a medium-density, long-fibre wood species whose major attribute is its outstanding versatility to be used in a range of applications across the wood processing and pulp and paper segments.

In terms of solid wood applications, it has machining properties (e.g., turning, planing, moulding, sanding) that are equal to or better than most international softwoods. Although a medium-density species, the uniformity of this density and texture within boards gives excellent screw- and nail-holding performance. Relatively low extractive content (minimal heartwood) ensures good adhesive bonding and sound glued connections (e.g., dowels and finger-joints).

Radiata pine has an open cellular structure, such that, although it is non-durable in exterior usage, the wood can be easily treated with preservative chemicals. For exterior uses, New Zealand pine can be adequately treated by pressure impregnation, double vacuum and simple immersion methods. This characteristic means it can be used successfully in exterior applications such as decking and cladding.

The limited variation between spring and summer wood within a growth ring gives radiata pine excellent staining and painting properties. There is little colour variation between pieces — an advantage in the finishing of products. A large range of coating products — interior and exterior stains, oils, varnishes and paints — can be applied to the surface of radiata pine, giving a high degree of excellent finishing. Additionally, products can be stained to resemble many other traditional timber species.

The large and bulky fibres of radiata pine offer pulp properties that allow manufacture of unique construction products (e.g., fibre-cement board), as well as traditional pulp products (TMP and kraft), and paper products such as containerboard (for packaging solutions like cardboard boxes) tissue and newsprint.

Scion is a Crown Research Institute (CRI), which is a government-owned company that carries out scientific research for the benefit of New Zealand. Scion (previously Forest Research Institute) specialises in research, science and technology development for the forestry, wood and wood-derived materials and other biomaterial sectors. Scion has published a number of comprehensive technical bulletins over the years, including one on the use of radiata pine and Douglas-fir, that comprehensively covers these characteristics of both species in detail.[5]

This section provides a series of templates for ten different wood product opportunities in New Zealand as follows:

1. Lumber (Sawn Timber)
2. Medium Density Fibreboard (MDF)
3. Particleboard
4. Oriented Strand Board (OSB)
5. Plywood
6. Laminated Veneer Lumber (LVL)
7. Laminated Strand Lumber (LSL)
8. Parallel Strand Lumber (PSL)
9. Cross-Laminated Timber (CLT)
10. Wood Pellets

5 New Zealand Pine and Douglas-Fir. Suitability for Processing" Principal author/compiler – D, J Cown. Forest Research Bulletin 216. Rotorua, New Zealand. 1999

msmith@getfea.com getfea.com

For all ten different wood product opportunities, each template discusses the following

- Description of Product
- Major Uses
- Currently Produced in NZ — Yes/No
- Major Importing Countries — Where are the Markets?
- Major Exporting Countries — Who is the Competition?
- Published Price Series (where available) or Suitable Proxy
- Key Opportunities and Constraints for a New Zealand Manufacturer

1 LUMBER (SAWN TIMBER)

Description of Product

Lumber (or sawn timber) is the product of sawmilling, whereby wood fibre, in log form (or timber) is processed and converted into square-edged boards.

The sawmilling process also generates residues (bark, chips, sawdust and shavings). Additional processing of these boards, e.g., finger-jointing, machining to give specific moulding profiles, or lamination (gluing together and pressing) to give larger-dimension products, is called *remanufacturing*, and also generates shavings residues.

FIGURE 2

Schematic Flow Diagram of the Sawmilling Process

Source: https://www.mpac.ca/sites/default/files/imce/pdf/Sawmills.pdf

The following is a description of the sawmilling process shown in Figure 2:

- **Log receipt and debarking —** logs can be received at the sawmill with over half their weight as water. In this condition, timber is referred to as "green". Logs are sorted into piles in the log yard based on diameter and length and, where applicable, species, e.g., radiata pine and Douglas-fir in New Zealand. Logs are picked up and fed into the sawmill via a conveyor system with inline debarking.

- **Green mill (or primary breakdown) —** the initial production of square-edged boards that still have a high moisture content. Some lumber can be sold in this condition for low-value applications, with or without preservation treatment (see below), and is referred to as green, rough-sawn (g, r/s). The chips and sawdust residue produced are also green.

- **Kiln drying —** the process of taking green boards and heat-treating them in specially designed wood drying kilns down to moisture contents, typically, of 12–18%. Some lumber can be sold in this condition and is referred to as kiln-dried, rough-sawn (k/d, r/s). Note that the wood will shrink upon drying, and this needs to be accounted for when targeting specific final board dimensions.

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- **Machining —** the process of smoothing the surfaces of the rough-sawn board and obtaining a specific cross-section required by the market. In the planer mill, machining (also referred to as surfacing, planing, sanding or gauging) produces square-edged boards that are referred to as S2S (surfaced on two sides) or S4S (surfaced on four sides). Lumber that is sold in this condition is referred to as kiln-dried and machined (k/d, m/c). The shavings produced from kiln-dried boards are low in moisture content. Profiling to give specific moulded cross sections (e.g., architraves, skirting) is generally done in the remanufacturing plant.

- **Grading —** depending on whether the lumber is being used for structural or appearance purposes, different grading processes will be applied that may measure the board stiffness (bending strength), or the knot sizes and other defects that will be docked out if they exceed customer specifications for the product.

- **Preservation treatment —** wood is often used in outdoor applications and exposed to moisture that facilitates fungi growth, leading to decay (rot), or insects (e.g., borer, termites) eating the timber and creating damage. Some wood is naturally durable and can be used in outdoor applications in its natural form. However, many woods, including radiata pine, are not durable, and need to be chemically treated with a preservative to prevent decay and insect attack. There are different types of preservation chemical and processing plant depending on the level of treatment required (e.g., weatherboards on a house versus poles for piers used in the ocean) and the application (e.g., fence palings versus exterior architraves around windows and doors).

Major Uses

New Zealand radiata pine is suitable for a wide variety of product uses. It has machining properties (e.g., turning, planing, moulding, sanding) that are equal to or better than most international softwoods. Even though a medium-density species, the uniformity of this density and texture within boards gives excellent screw- and nail-holding performance. Relatively low extractive content (minimal heartwood) ensures good adhesive bonding and sound glued connections (e.g., dowels and finger-joints).

Radiata pine has an open cellular structure, such that, although it is non-durable in exterior usage, the wood can be easily treated with preservation chemicals. For exterior uses, New Zealand pine can be adequately treated by pressure impregnation, double vacuum and simple immersion methods. This characteristic makes it a preferred species for evolving wood modification technologies out of Europe.

The limited variation between spring and summer wood within a growth ring gives radiata pine excellent staining and painting properties. There is little colour variation between pieces — an advantage in the finishing of products. A large range of coating products — interior and exterior stains, oils, varnishes and paints — can be applied to the surface of radiata pine, giving a high degree of excellent finishing. Additionally, products can be stained to resemble many other traditional timber species.

The adaptability of radiata pine means it is suitable for a wide range of sawn timber uses, broadly classified as:

- **Structural —** used in the building and construction sector as a material with pre-determined strength properties for particular engineered applications, e.g., framing, beams, columns for the building substructure, decks, pergolas.

- **Appearance —** used also in the building and constructions sector, but in non-structural (visual or appearance) applications, e.g., interior fittings and fixtures (mouldings), windows and doors, weatherboards, barge boards. etc., as well as a range of other applications such as cabinetry, furniture, toys, etc.

- **Industrial —** used in a number of relatively short-lifecycle applications, e.g., wooden pallets, wooden crates and boxes, and cable drums. Relative to competitor materials such as steel and plastic alternatives, wood has the advantage of low cost, ease of repair, workability, and greater flexibility around sizes and dimensions.

The diversity of the applications means that radiata pine lumber comes in a wide variety of grades and dimensions depending upon the specific need (Figure 3).

FIGURE 3

Example of Radiata Pine Use in Structural, Appearance and Industrial Applications

Currently Produced in NZ — Yes/No

There are many sawmills in New Zealand, ranging in size from large mills like Reg Stag Timber (Rotorua) and Pan Pac Forest Products Ltd. (Whirinaki) that are processing close to 1 million m^3 of log-in per annum to smaller niche mills that can be processing less than 50,000 m^3 of log-in per annum.

The target products from these mills will depend largely on the logs they have been designed to process — mainly in line with the major uses discussed above.

Structural mills take higher stiffness structural-grade logs and look to maximise the higher-density (higher-stiffness) wood from the outer portions of the log to make higher-margin, structural-graded timber boards for the building and construction sector. Structural sawmills will produce non-structural grades (still used in construction) and industrial grades from the inner portion of the logs.

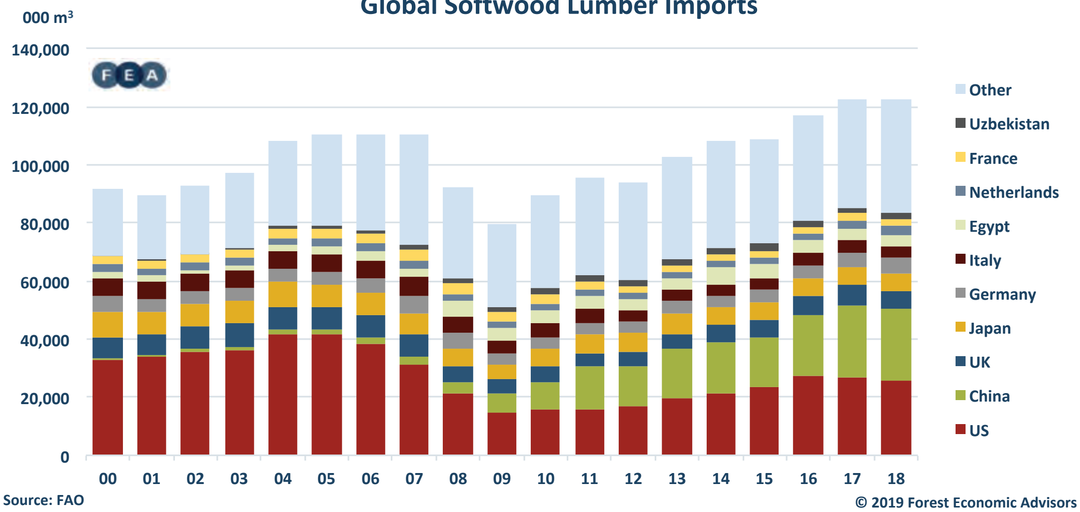
Appearance mills take pruned logs where the outer portion of the log contains large amounts of "clearwood" (free of knots and blemishes) that are used to make a range of appearance-grade products, referred to as clears, cuttings, dressing, pith-free cut of log. etc., which are further processed to make the variety of uses described above. Appearance mills will also generate very knotty, industrial grades from the unpruned centre of the log (known as the defect core).

Some sawmills are designed as "swing mills" and can process various mixes of the log grades above depending on current market conditions and where they can achieve the greatest return at the time.

Major Importing Countries — Where are the Markets?

GRAPH 9

Global Softwood Lumber Imports



Source: FAO

The total global volume of softwood (coniferous) sawn timber imports in 2018 was just under 123 million m^3. Of this volume, the US and China dominated at around 41% (50

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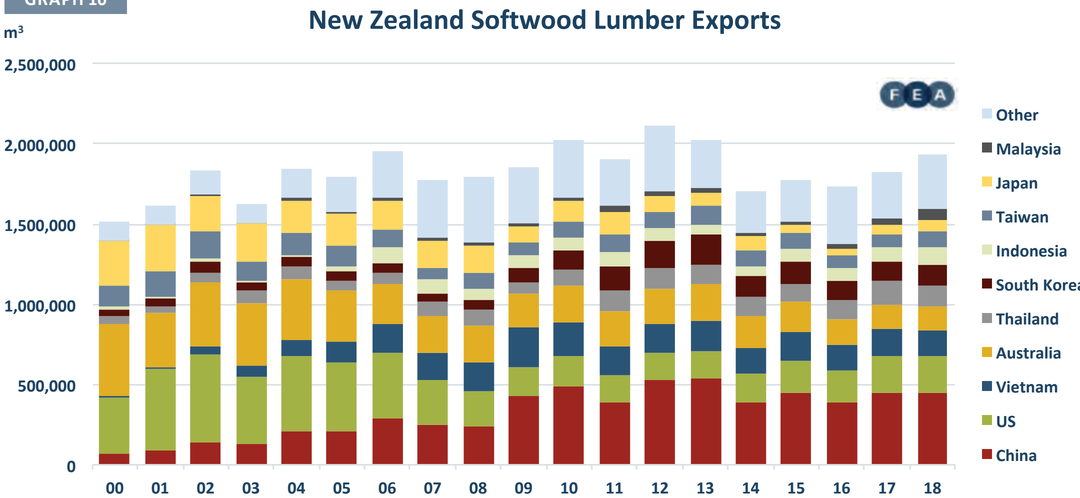
million m³). Graph 9 shows that total volumes have been increasing steadily, with the exception of 2009 and the immediate aftermath of the global financial crisis. Importing countries outside of the top ten still make up 32% of the worldwide market (almost 39,000 m³ in 2018).

GRAPH 10



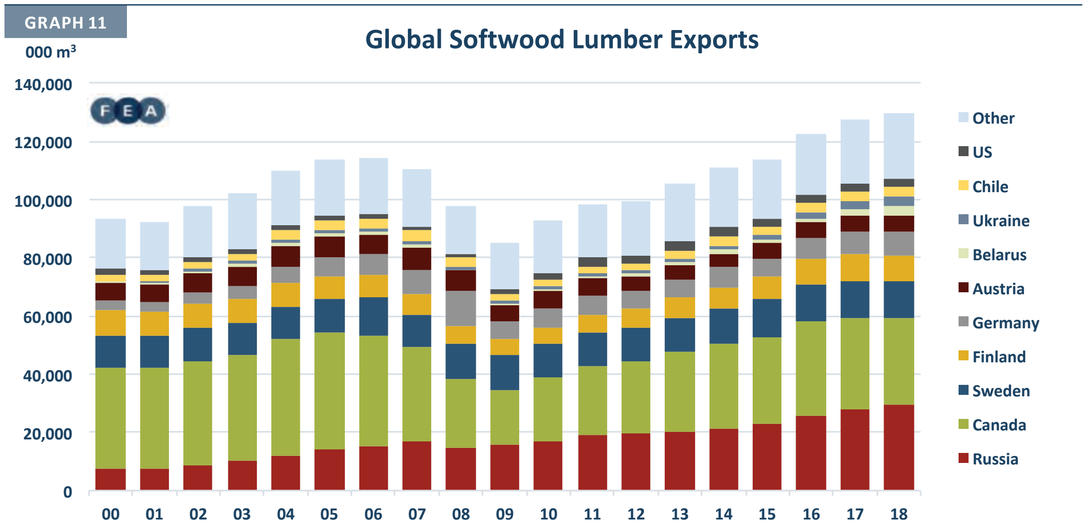
Source: Stats NZ © 2019 Forest Economic Advisors

New Zealand exports of softwood lumber are shown in Graph 10. In 2018, the volume was just over 1.9 million m³ — about 1.5% of total global imports. While significant volumes are exported to Australia and the US, Asian markets predominate — ~67% in 2018.

Major Exporting Countries — Who is the Competition?

Exports of softwood sawn timber by country are shown in Graph 11. Canada (exporting predominantly to the US) and Russia (exporting predominantly to China) are significantly larger exporters than the next three major exporting countries — Sweden, Finland and Germany. Canada and Russia together represent about 46% of the softwood lumber export trade; the next six biggest lumber exporters are all European countries.

GRAPH 11



Source: FAO © 2019 Forest Economic Advisors

A number of factors are impacting current lumber export dynamics. These are discussed in the section of this report titled **Current and Potential Global Market Factors**, with the most significant factors including the following:

- The bark beetle epidemic in Central Europe that is forcing countries such as Germany and the Czech Republic to send increasing volumes of damaged, low-cost timber into the Chinese lumber market at the expense of other countries exporting to China.
- The growth in Russian wood processing, underpinned by government log taxes and quotas initiated since 2006 and the coincidental emergence of new, efficient supply chains into inland China as a result of the Belt and Road Initiative (BRI).

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- The ongoing US–China trade war and the escalating tariffs that are causing significant reductions in US softwood log and lumber exports to China and equally, a slowdown in China given that the US is a major export market for Chinese furniture and value-added wood products.
- The forecast reduction in British Columbia sawlog availability due to reductions in the government-mandated AAC that will flow through to primary processing, resulting in less lumber production in the coming years.

Published Price Series (Where Available) or Suitable Proxy

Different price series are relevant for the three key product segments — structural, appearance and industrial-grade sawn timber.

Structural-Grade Prices

Structural grades are mainly utilised in New Zealand — see Table 9. The New Zealand Building Code allows use of SG8 (the most common strength grade produced from radiata pine structural logs) for a wide range of applications, including general framing and trusses.

Given that structural timber grades are used primarily in New Zealand, and that the market is dominated by two major players (Red Stag Timber and Carter Holt Harvey), there is no published price series for structural timber in New Zealand.

In Australia the grading rules are stricter, with a requirement for structural sawn timber equivalent to SG10 for general framing and trusses. This is the more dominant strength grade from their radiata pine structural logs, which are harvested at a later age (e.g., 35 years, versus 28 years in New Zealand). This requirement for a stiffer board has effectively acted as a non-tariff barrier for significant imports of framing timber from New Zealand to fibre-short Australia, with the gap being filled by European imports. New Zealand does export treated product to Australia for outdoor applications. FEA's *Wood Markets Monthly* publication gives prices for MGP10 grades in Australia, e.g.,

- Douglas-fir, Scantlings, 1-7/8x4", 8/24', green.
- Radiata Pine, MGP10, KD, treated (H2-F),100x38mm, 4.8m.
- Radiata Pine, MGP10, KD, 100x38mm, 4.8m.

TABLE 9

New Zealand Structural-Grade Use

Grade	Colour Marks (MSG)	Bending Strength (MPa)	Bending Stiffness (GPa)	Typical End Uses
SG10 (dry) (old VSG10)		20.0	10.0	Engineering grades where design requires higher strength and/or stiffness
SG8(dry) (old VSG8)		14.0	8.0	Lintels, floor joists, roof beams, general framing and trusses
SG8(wet) (old G8 grade)		11.7	6.5	Decking joists, Verandah posts, Pergola and other outdoor timbers
SG6(wet) (new grade)		7.5	4.8	Wet treated house framing equal to SG6(dry) when dry
SG12(dry) (old MSG12)	Purple	28.0	12.0	Engineering grades where design requires higher strength and/or stiffness
SG10(dry) (old MSG10)	Green	20.0	10.0	Engineering grades where design requires higher strength and/or stiffness
SG8(dry) (old MSG8)	Black	14.0	8.0	Lintels, floor joists, roof beams, general framing and trusses
SG6(dry) (old MSG6)	Blue	10.0	6.0	Lesser load bearing walls, truss webbing

Source: www.graderight.co.nz/downloads/Grade_Verified_Info_Sheet.pdf

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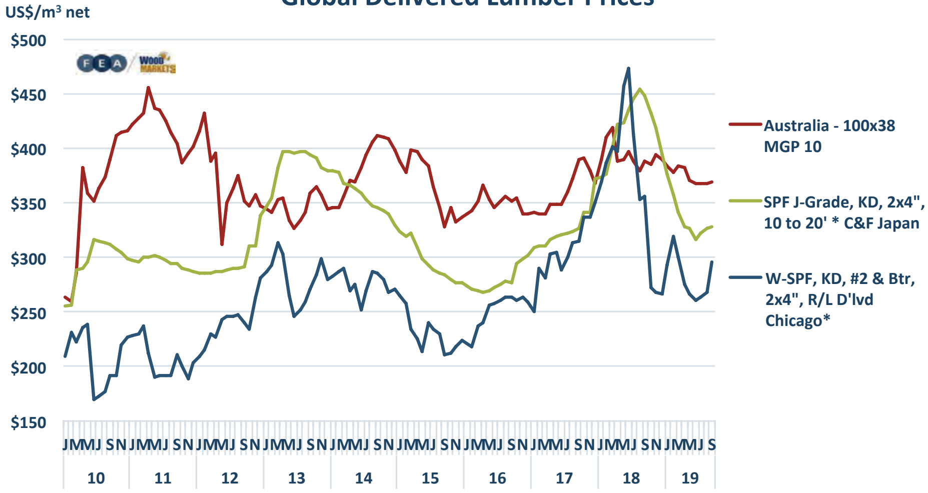
Graph 12 shows the consistently high delivered price of the 100x38mm, MGP10 grade in Australia versus other structural grades delivered to Japan and Chicago. This highlights the attractiveness of Australia's structural lumber market for European importers.

GRAPH 12

Global Delivered Lumber Prices



Source: FEA © 2019 Forest Economic Advisors

Appearance-Grade Prices

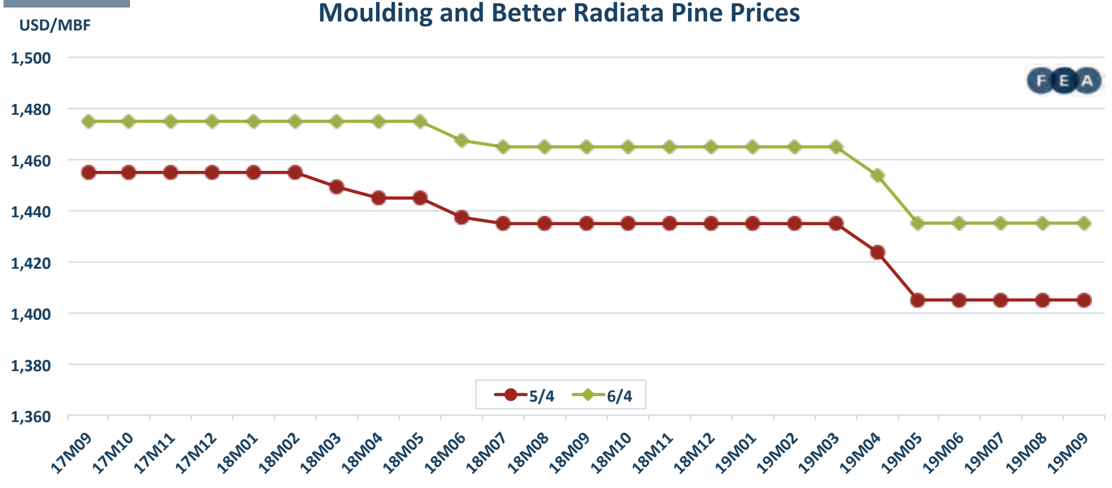
Appearance grades have been sold in significant volumes to the US market in two broad market segments, as follows:

- Selects (or Clears) to the big-box stores (Home Depot, Lowe's) for selling to their DIY customers. The larger widths and lengths from pruned New Zealand radiata pine logs made these boards particularly desirable for home projects such as shelving, tops for desks, etc. Grades include #1 Clears (no defects), #2 Clears (defects allowable on one face) and #3 Clears (defects allowable on one face and the edges).
- Random-width grades that are sold to remanufacturers who "defect out" knots and blemishes to give smaller clear pieces for specific applications, e.g., windows and doors or finger-joint stock. Grades include Moulding and Better (random-width lumber that allows 70% recovery of 1" and wider clear rips, with limited wane), #2 Shop (random-width lumber that can be defected into short length clears; each piece yields 70% recovery of 600mm or longer) and #3 Shop (random-width lumber that can be defected into short-length clears; each piece yields 60% recovery of 150mm or longer).

Selects pricing for radiata pine is not reported in any price series. Random-width grades are reported weekly in the Random Lengths publication (Graph 13) and pricing history can be easily tracked. Prices are net in US$ per thousand board feet, fob mill. To convert from US$ per thousand board feet to US$ per m^3, divide by 2.3585 on a full-sawn basis.

GRAPH 13

Moulding and Better Radiata Pine Prices



Source: Random Lengths © 2019 Forest Economic Advisors

In recent years, increasing volumes of radiata clearwood have been sold in rough-sawn, kiln-dried form to Europe as feedstock for the region's evolving wood modification technologies. However, there are no published prices for these grades, as they are being sold to specific end users (Graph 14).

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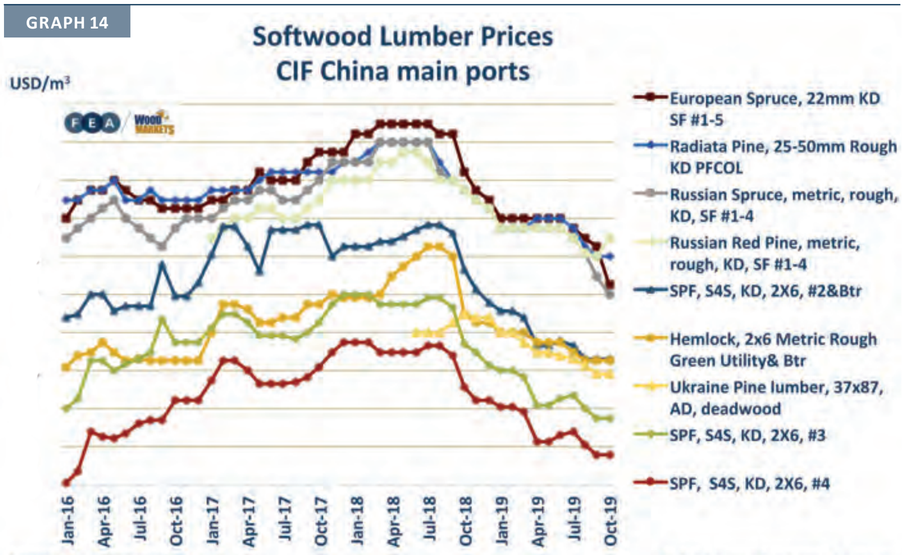
Industrial-Grade Prices

Significant volumes of low-value, industrial-grade lumber are sold into China for disposable structural applications, e.g., concrete formwork, packaging applications. A higher-value cuttings grade that can be defected (knots and blemishes docked out), finger-jointed and used for furniture and appearance applications is referred to as "pith-free cut-of-log" (PFCOL). FEA monitors pricing of these types of grades through its monthly *China Bulletin* and compares a radiata pine PFCOL grade with sawn timber species from other regions as shown in Graph 14.

GRAPH 14



Source: FEA; Importers in China

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Key Opportunities and Constraints for a New Zealand Manufacturer

Structural Grades

Structural grades are largely produced for domestic use in the New Zealand building and construction sector, with demand following housing starts and construction activity. There are limited exports of structural-grade logs to offshore markets, as the domestic markets are relatively well balanced in terms of supply and demand. Although structural grades are nominally 4x2", in actual fact the sawn dimensions are all slightly different in Europe, North America, Australia and NZ. One issue that hinders exports from one region to another is the downfall product. Even if New Zealand sawmills made the dimensions and grade properties for other markets such as the US and Europe — and were able to sell there cost-effectively — there will be boards that are sawn to these sizes in the New Zealand sawmills that do not meet grade.

The above means there is no structural radiata pine lumber exports to any market in the world (including from South America and South Africa) except Australia. Furthermore, the Australian market, despite being fibre-short, is not a major opportunity for New Zealand structural sawmills because their grading rules require a higher stiffness board (MGP10) for general framing and truss usage. Therefore, there is currently limited scope for New Zealand to expand domestic structural production to supply the Australian framing market.

The one exception is the OEL™ (Optimised Engineered Lumber) being produced by Wood Engineering Technologies Limited (WET) in its commercial-scale, pilot plant in Gisborne. This technology is now commercial and there are plans to scale up significantly in the future. SInce OEL™ can be engineered, it may be possible to make an MGP10 equivalent that could cost-effectively supply the Australian market and compete with current European imports.

Other technologies may also be adaptable to upgrade structural properties of New Zealand radiata pine to a level and at a cost that makes the Australian MGP10 market attractive. One example discussed below is LFL — laminated finger-jointed lumber — manufactured by Lamco Forest Products in Quebec (see **Export Potential of New Products** section).

Appearance Grades

The select and random-width markets in the US are relatively mature, and the ability for New Zealand to supply is going to be curtailed to some extent by the diminishing availability of pruned log supply. This is well detailed in the FEA Spotlight paper "The looming impact of diminishing pruned log supply on regional economic development in the Central North Island", from which Graph

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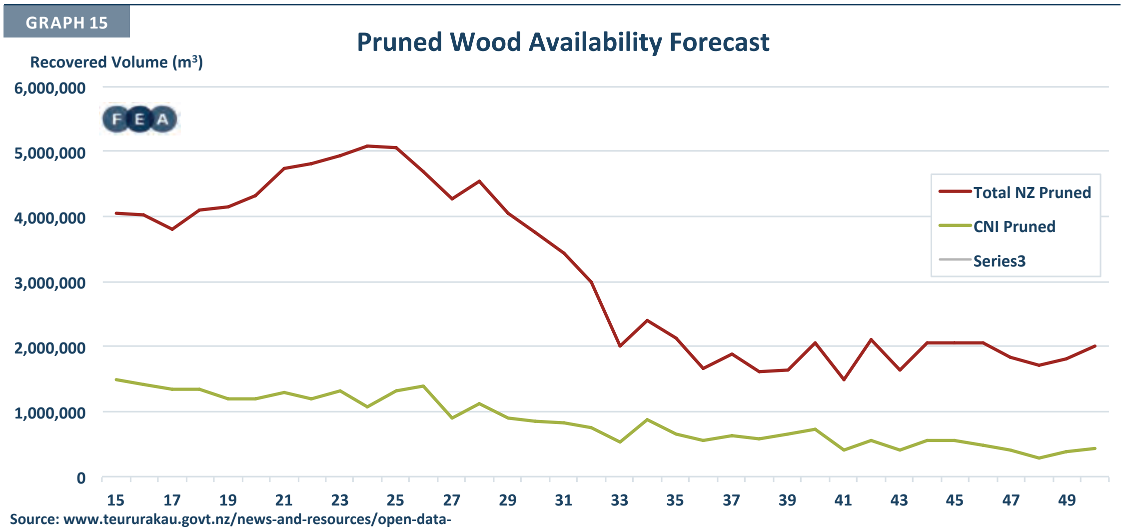
15 has been reproduced. This shows the forecast for pruned wood availability to 2050 from all of New Zealand, and just the Central North Island region.

GRAPH 15



Source: www.teururakau.govt.nz/news-and-resources/open-data-and-forecasting/forestry/new-zealands-forests/

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GRAPH 16

Source: NZ Stats

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Those mills that survive the loss of wood supply (typically the larger players that have reinvested in plant to improve quality and production efficiency) may still want to diversify their markets. The current growth of rough-sawn, kiln-dried clearwood exports to the European market (Graph 16), largely for production into outdoor products using green chemistry (e.g., Accoya® and Kebony wood), offers an opportunity to look at bringing these technologies to New Zealand. The valued-added, wood-modified product could be supplied from an adjacent sawmill or a cluster of nearby sawmills, and the wood modification plant in New Zealand used as a beachhead to supply Asia. This is already happening to some extent with the Thermowood technology being deployed at one sawmill in the Central North Island.

Industrial Grades

The major log grades currently being exported from New Zealand in large volumes (A-grade and K-grade) lend themselves more to industrial grades of sawn timber boards suitable for direct use as a limited life construction or packaging product. These boards can also be used for internal lamella in mass timber products such as CLT, with higher-stiffness boards used in the outer lamella to give the overall structural properties.

Slightly higher-value boards from industrial-grade logs can also be remanufactured for use in furniture manufacture and finger-jointing, after defecting out knots and blemishes.

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In general, these lumber grades are commodity products competing on price, where New Zealand sawmills have largely been price-takers. Although there are a number of mills manufacturing industrial grades, the industry still needs to significantly scale up production to utilise the increased A-grade and K-grade log supply. FEA is aware of one sawmill processing 100% of industrial-grade logs that has successfully established a niche business offering a differentiated product by dimension-cutting to their customer's preferred sizes (resulting in their customer having less wastage) rather than selling standard, nominal sizes. There are plenty of markets globally for industrial-grade lumber in lower-value packaging-type applications, but mills will need to compete on price with similar grades from other species in North America and Europe.

2 MEDIUM-DENSITY FIBREBOARD (MDF)

Description of Product

MDF uses chips as its primary feedstock. These can either be bought from nearby sawmills or made by debarking and chipping small-diameter/fast-growing trees, pulp logs or even forest thinnings.

MDF is an engineered wood product made by breaking down softwood or hardwood chips into wood fibres using a defibrator. These wood fibres are then combined with a binder mixture (waxes and resins) and formed into panels through application of temperature and pressure. MDF is generally denser than plywood, being made up of separated fibres (as opposed to solid wood veneers), but can be used in building applications suitable to plywood. MDF is stronger and much denser than particleboard. In New Zealand, MDF is typically sold in sheet sizes of 2440x1220 mm and in thicknesses of 9mm, 12mm, 15mm, 16mm, 18mm 25mm and 30mm. Other sheet sizes and thicknesses are generally available on request.

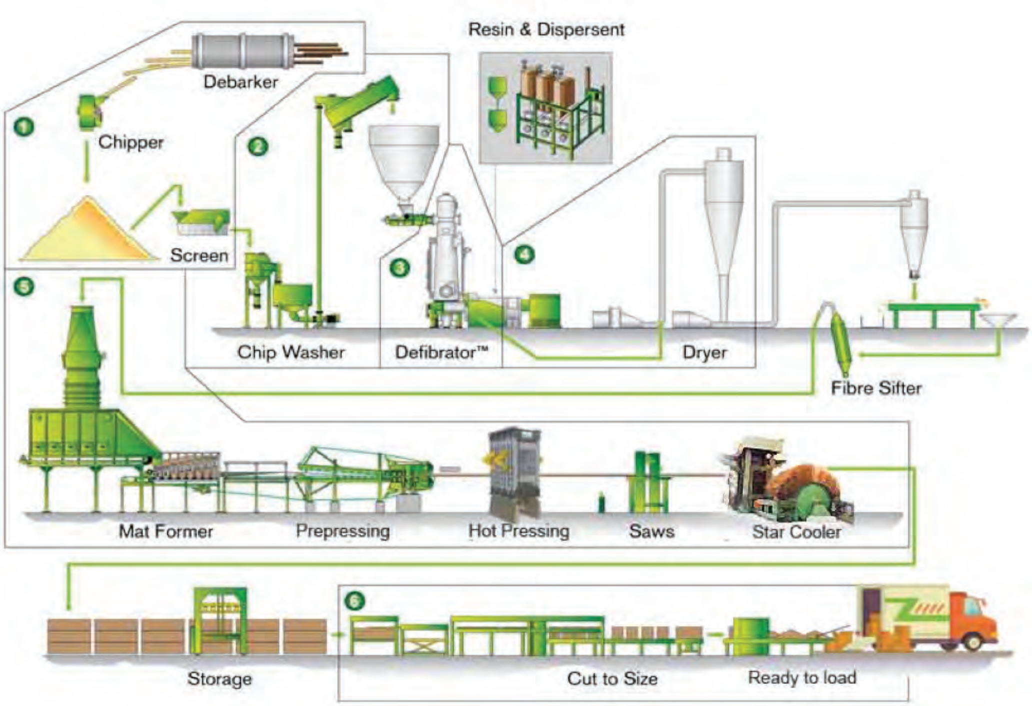
The process for making MDF broken in six broad processing steps is illustrated in Figure 4.

1. Debarking and chipping

The first step in the manufacturing of MDF board is debarking. The bark from the log is removed, decreasing grit and organic waste. Removal of the bark is needed to allow faster drainage of the water in downstream processing, and to give a finer surface finish. Once the bark is removed, the log is chipped. The chipper drum reduces the logs into evenly shaped chips that are screened. Oversized chips are rechipped, while undersized chips may be diverted for other uses.

FIGURE 4

Schematic Flow Diagram of the MDF Process



Source: https://pioneerpanelproducts.com/mdf-board-manufacturing-process

2. Chip washer

Producing quality MDF requires chips that are as free of impurities as

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possible. Debarking and screening are not enough; chip washing is essential for producing boards of low mineral content. This is particularly true if the MDF plant is purchasing chips, e.g., from sawmills. Existing impurities, in the form of metal, stones and sand, must be removed before the chips enter the process. Chip-washing also prevents refiner plate wear by removing undesirable contaminants.

3. Defibrator

The chips are preheated with steam and then fed into the defibrator for few minutes under high temperature, where they are ground to form a pulp. The process uses a disc refiner to separate the chips into individual cellulose fibres. A disk refiner consists of two vertical disks with serrated or otherwise contoured surfaces. One disk rotates clockwise, while the other either remains stationary or rotates counterclockwise. The chips are introduced between the disks through an inlet in the centre of one disk. As centrifugal force pushes the fibres out toward the perimeter of the disks, the abrasion experienced by the fibres cuts, softens, rubs and disperses them to the degree desired.

4. Drying

From the defibrator, the mechanically pulped material enters a blow line, where it is mixed with resin and wax. The wax improves moisture resistance and the resin initially helps reduce clumping, but ultimately is the primary binding agent. The fibres are then passed through a cyclone dryer, where they are quickly dried to the target moisture content.

5. Mat formation

The dried fibres are formed into mats and processed through presses.

Air conveys the resinated fibres from the dry storage bin to the mat-forming machine, where they are deposited on a continuously moving screen system. The continuously formed mat must be pre-pressed before being loaded into the hot press. After pre-pressing, some pretrimming is done. The trimmed material is collected and recycled to the forming machine. The pre-pressed/ trimmed mats are then transferred to the hot press. The press applies heat and pressure to activate the resin and bond the fibres into a solid panel. The mat may be pressed in a continuous hot press, or the precompressed mat may be cut by a flying cut-off saw into individual mats that are then loaded into a multi-opening, batch-type hot press. After pressing, the boards are cooled and stored prior to finishing.

6. Finishing Line

Once pressed, the boards are sanded, trimmed and sawed to final dimensions. They may also be painted or laminated. Finally, the finished product is packaged for shipment.

The surface finish is a key determinant of MDF quality, and sanders can have multiple heads for calibrating, finishing and super-finish brushes. Extra heads allow a gradual reduction in grit coarseness, giving a superior sanded finish. MDF has no visible wood grain, rings or knots.

Major Uses

MDF is used primarily for indoor applications due to its poor moisture-resistance. This includes furniture, cabinetry and flooring. It is available in raw form (Figure 5), with a finely sanded surface, or with a decorative overlay.

FIGURE 5

MDF Panels

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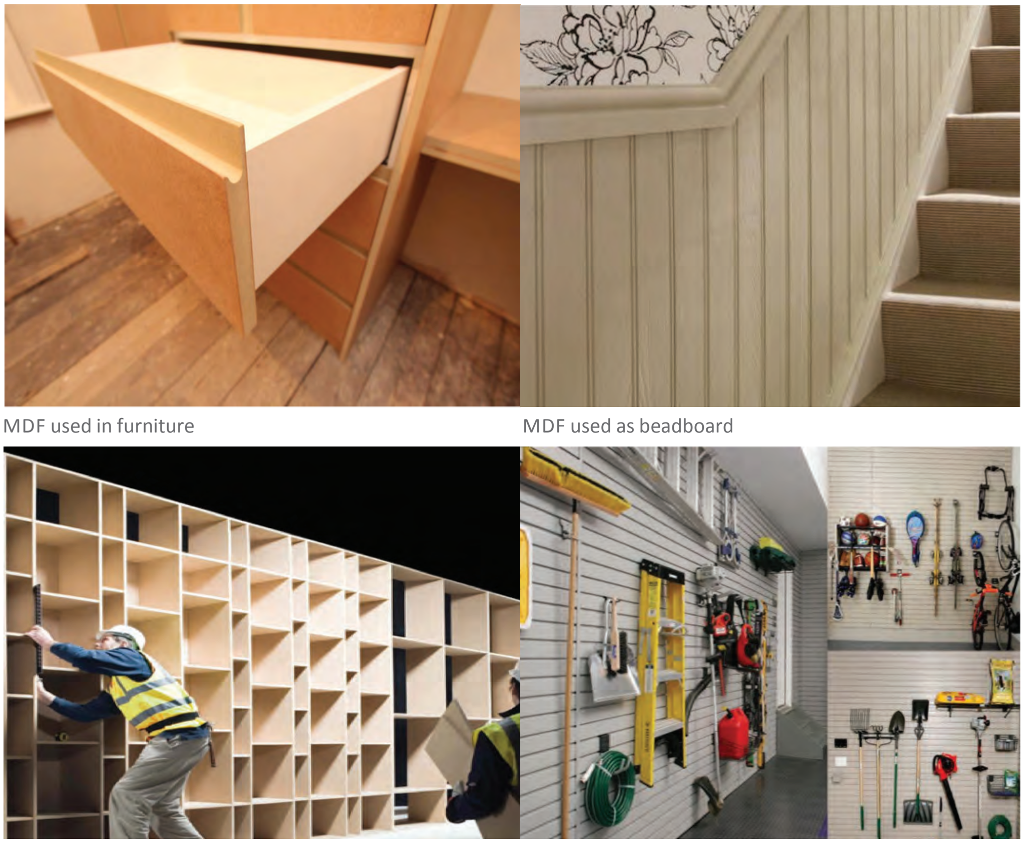
The finished quality of MDF depends on the quality of surface prior to applying the finishing materials. When the panels are used as substrate for thin overlays and liquid surface coatings, surface characteristics such as roughness and wettability play an important role in determining the quality of the final product. Most MDF panels are used as a substrate for thin overlays, such as melamine-impregnated papers in the furniture industry. In addition, various types of finishes, such as paint and lacquer, are directly applied to the sanded panel surface for use as furniture panels. In both applications, surface characteristics of the substrate panel, including absorption ability, wettability and roughness properties, are important factors determining optimum use of the panel products.

For example, surface roughness of MDF prior to finishing is highly important in determining the quality of the finished product. Any irregularity on the surface may show through the thin layer of the finishing materials.

As well as "regular" MDF, there are other types made for specific applications (Figure 6):

FIGURE 6

MDF Used in Different Applications



MDF used in furniture

MDF used as beadboard

MDF used as cupboard shelving

MDF used as slatwall

- **Bendy MDF —** also called flexible MDF, this product is processed to allow the panel to bend and curve to any desirable shape. Just like regular MDF, it can be painted, veneered or laminated to create one-of-a-kind pieces. It is most often used by architects and designers to create pieces with dramatic curves and slopes, requiring less time and cost than using other materials.

- **Ultralite MDF —** MDF's density and subsequent strength makes the composite fairly heavy. This type of lightweight MDF, however, weighs in at only two-thirds the weight of regular MDF. Its weight and durability make it ideal for projects that must be moved regularly, such as tradeshow booths, theatre set construction, mobile homes, event setups and "pop up" galleries or shops.

- **Fire-retardant MDF —** there are some places in which it is preferable (or even required) to use fire-retardant materials in construction. Fire-retardant MDF is often used in commercial buildings, including stores and offices, to adhere to building codes and requirements.

- **Moisture-resistant MDF —** standard MDF will swell both in length and thickness with even the slightest change in humidity, let alone direct contact with water. Moisture-resistant MDF (abbreviated to MR MDF) is manufactured using a special resin that imparts moisture-resistance. It is often used in places like bathrooms, kitchens and flooring, where humidity is a concern.

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- **Beadboard —** made using standard MDF, beadboard is manufactured with a faux tongue-and-groove pattern that is commonly found in wainscoting. Wainscoting and beadboard are often used interchangeably, although wainscoting typically refers to any sort of half-wall wood panelling; it can be constructed with traditional wood tongue-and-groove boards, but beadboard is a popular alternative due to its lower cost.
- **Slatwall —** a specifically designed MDF panel that features deep, lipped grooves used for display purposes. Its grooves perfectly secure many types of hanging hardware and shelving for the display of merchandise in retail shops and tools in home garages.

Table 10 shows the market mix for MDF in different applications in the US and Canada in 2018 compared to other panel products.

TABLE 10

Market Mix for MDF in the US and Canada

USA

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	56%	24%	11%	9%	100%
Softwood Ply	23%	30%	35%	13%	100%
Particleboard	14%	43%	31%	12%	100%
MDF	14%	55%	19%	12%	100%

Canada

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	66%	26%	2%	6%	100%
Softwood Ply	19%	44%	28%	9%	100%
Particleboard	14%	39%	33%	15%	100%
MDF	13%	55%	18%	13%	100%

Source: FEA estimates based on industry analysis for 2018

Currently Produced in NZ — Yes/No

There are three operating MDF plants in New Zealand — all in the South Island. Total annual production capacity is estimated at around 800,000 m^3. Daiken New Zealand owns two MDF plants — in Rangiora, Canterbury and Mataura, Southland. Nelson Pine Industries owns an MDF plant in Richmond as part of a wood processing complex that also includes an LVL mill.

1. Daiken New Zealand (Daiken)

Daiken New Zealand is a joint venture between two major Japanese companies — Daiken Corporation and Itochu Corporation. The joint venture was established in 2009 to purchase the original MDF plant at Rangiora, Christchurch from Carter Holt Harvey. In 2018, Daiken bought the Dongwha MDF plant in Mataura, Southland, giving it control of two of the three MDF plants in New Zealand.

The operation at Rangiora is known as Daiken New Zealand. This plant was originally built in 1975 by Canterbury Timber Products. The original line is a multiopening press with a current capacity of 105,000 m^3/year. A second continuous press line was installed in 1994 with capacity of 103,000 m^3/year. The plant is using around 350,000 m^3 of logs and wood chips, and 80%+ of the production is being exported. The MDF is branded Customwood® and is renowned for its superior colour consistency and quality. It is used in a variety of applications, including furniture construction, cabinetry and shelving, and design of children's toys.

The operation at Mataura is known as Daiken Southland. In April 2018, Daiken bought Dongwha Patinna, thereby acquiring the Dongwha MDF plant in Mataura, Southland and the adjacent Melamine Faceboard Plant (MFB). The plant was built in 1996 and has a single continuous press line with capacity of 203,000 m^3/year. In 2015, the product range was expanded via the addition of the melamine press, making it the only fully integrated MDF-to-melamine operation in New Zealand. Melamine board, a low-pressure laminate board, is widely used in a variety of industries, including cabinetmaking and kitchen manufacturing, and is noted for its high durability and scratch resistance. The plant is using around 350,000 m^3 of wood fibre, estimated to be about a 50/50 mix of logs and wood chips. Daiken Southland specialises in making niche MDF products such as Ultralite and thin MDF board, as well as the melamine-faced boards in white and a true-tones colour range.

2. Nelson Pine Industries (NPI)

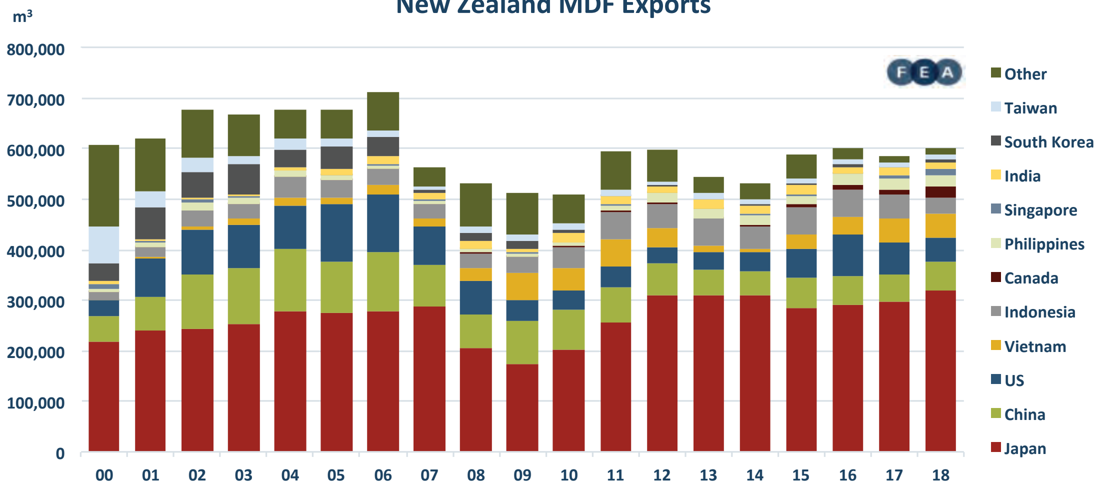
Nelson Pine Industries is a wholly owned subsidiary of the Sumitomo Forestry Company of Tokyo, Japan, which was formed in 1948 and is now one of Japan's largest forestry-based companies. NPI produces GoldenEdge® MDF as well as NelsonPine LVL. Production of MDF began in 1986, and the LVL plant was commissioned in 2002.

The original MDF plant, commissioned in 1986, produced 100,000 m^3, with board thicknesses ranging from 2.5–32 mm. An MDF mouldings plant was added in 1987, and a second MDF line added in 1991 increased capacity to 225,000 m^3/year. NPI commissioned a third line with annual capacity of 160,000 m^3/year in 1997. Total site capacity for MDF is now around 400,000 m^3/year. At capacity, the MDF would have a wood fibre requirement of around 700,000 m^3/year of pulp logs and wood chips. GoldenEdge® MDF is recognised as the leading brand in New Zealand and in worldwide export markets. It is sold into Japan, Asia, India, North America, the Middle East and South Africa. The product offerings include GoldenEdge® MDF Panelbrace™ Wall Bracing Systems and GoldenEdge® Thinline MDF Underlay.

New Zealand exports of MDF are shown in Graph 17. Clearly, the key market is Japan (53% of New Zealand exports in 2018) given the ownership structure of the New Zealand producers. The top five export destinations (Japan, China, the US, Vietnam and Indonesia) comprised 84% of

GRAPH 17

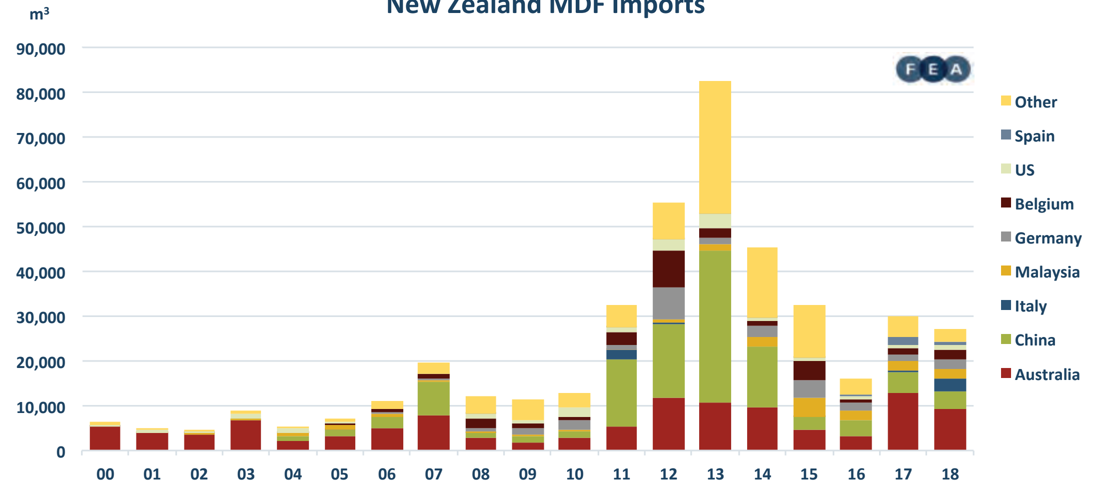
New Zealand MDF Exports



Source: Stats NZ © 2019 Forest Economic Advisors

GRAPH 18

New Zealand MDF Imports



Source: Stats NZ © 2019 Forest Economic Advisors

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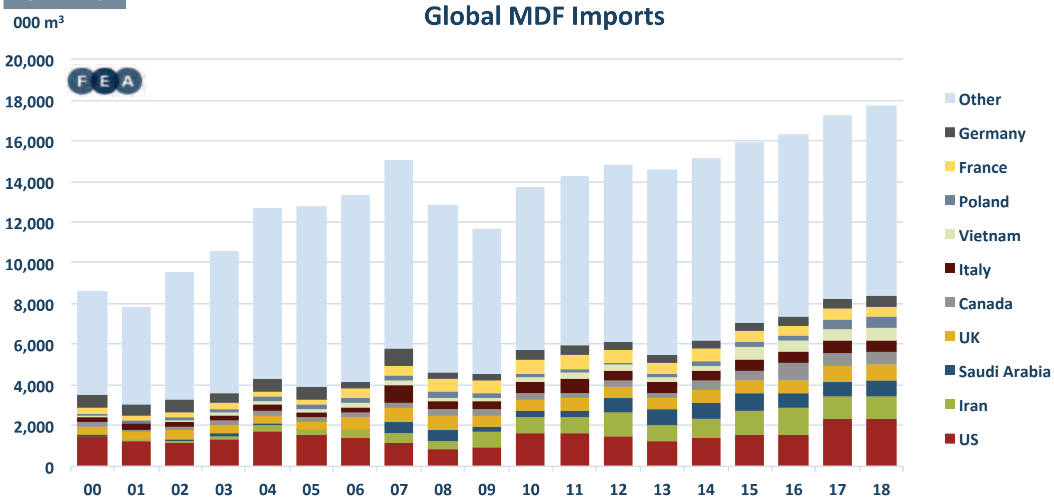
New Zealand exports in 2018.

New Zealand imports MDF (Graph 18) of less than 30,000 m³ per annum (about 5% of the export volume). These are generally brought in by distributors that supply direct. One example is Plyman (www.plyman.co.nz), which imports radiata-based MDF from China.

GRAPH 19



Source: FAO © 2019 Forest Economic Advisors

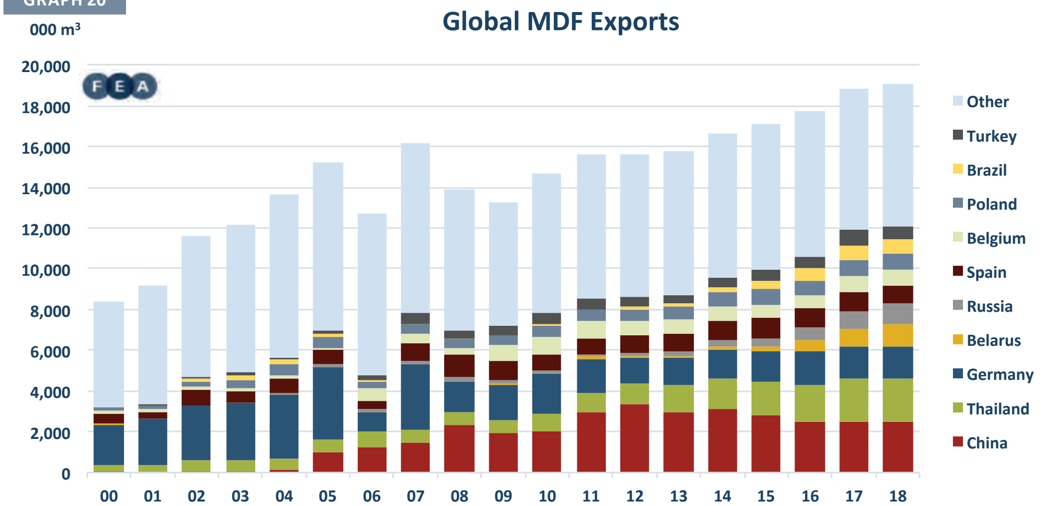
Major Importing Countries — Where are the Markets?

Graph 19 shows that global trade in MDF was just under 18 million m³ in 2018. The US and Iran are the two biggest importers, but together have only about 19% of the market for traded MDF. The top ten countries have only 47% the global market, making MDF an extremely fragmented commodity in terms of global market opportunities.

Major Exporting Countries — Who is the Competition?

Two Asian countries — China and Thailand — made up 24% of total MDF exports in 2018, with the top ten exporters contributing 63% of global trade (Graph 20). All of the other eight countries in the top ten (Turkey included) are based in Europe.

GRAPH 20



Source: FAO © 2019 Forest Economic Advisors

Published Price Series (where available) or Suitable Proxy

MDF prices are reported weekly in Random Lengths as Non-Structural Panels (Graph 21) and pricing history can be easily tracked. Data are shown for MDF plants both west and east of the Mississippi River for four different panel thicknesses. The data show prices for MDF on a net, fob mill basis per thousand square foot.

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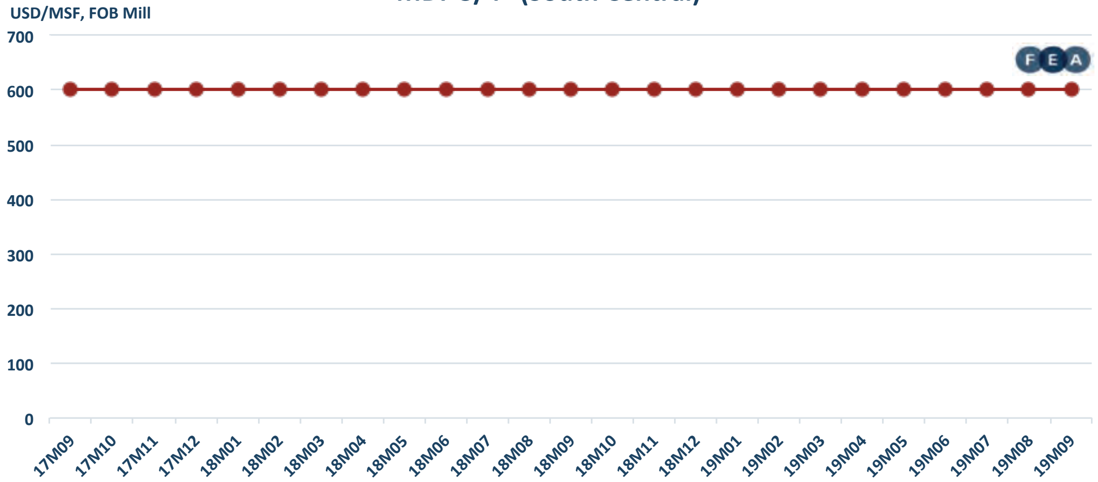
Conversion to US$ per m³

The prices in Graph 21 are on a per thousand square foot basis. Therefore, the thicker the material, the higher the price, as there is more volume. To convert to US$ per m³:

GRAPH 21

MDF 3/4" (South Central)



Source: Random Lengths © 2019 Forest Economic Advisors

- Convert the thousand square foot basis to m² (multiply by 92.903).
- Convert the thickness in inches to metres (multiply by 0.0254).
- Multiply the area in m² by the thickness in metres.

For MDF ¾" South Central, shown at US$600 per thousand square foot, the conversion is **US$600/thousand square foot/(92.903 x 0.75" x 0.0254) = US$339/m³.**

Key Opportunities and Constraints for a New Zealand Manufacturer

MDF is essentially a residues-based wood product that needs low-cost wood fibre such as pulp logs, plantation thinnings and wood chips from a sawmill. A modern greenfield site probably needs to be at a capacity of 700,000 m³/year of fibre in to produce about 400,000 m³/year of MDF. The capital costs for such a plant will be several hundred million dollars. This will require an investor to have certainty of supply regarding the wood fibre. Target regions in New Zealand will require availability of the right type of low-cost fibre in the volumes needed and controlled by some major players to look at a greenfield MDF plant.

An alternative option is expanding capacity at existing operations. The fibre and capital-cosyt requirements would not be so restrictive if adding a new line to a brownfield site.

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3 PARTICLEBOARD

Description of Product

Particleboard uses residual wood fibre, e.g., chips, sawmill shavings and sawdust.

It is an engineered wood product made by compressing mixtures of these residual wood fibres with a synthetic resin. In the flat-pressed particleboard, the chips are mainly parallel to the surface. The chips in the surface layer are thinner than those in the middle layer, so the surface of the particleboard is denser and more compact than the middle. Particleboard is cheaper, denser and more uniform than conventional wood, but is the lightest and weakest of the fibreboards. It is typically used where rigidity and appearance are less important than cost. The surface can be enhanced by painting or bonding thin veneers. It is highly susceptible to moisture uptake and swelling, and is not used outdoors or in areas with high levels of moisture. The exception is areas such as bathrooms, kitchens and laundries, but only as an underlayment that is shielded beneath an upper sheet of moisture-resistant material, e.g., vinyl flooring. In New Zealand, particleboard is typically sold in sheet sizes of 2440x1220 mm and in thicknesses from 9–30mm.

The process for making particleboard is illustrated in Figure 7.

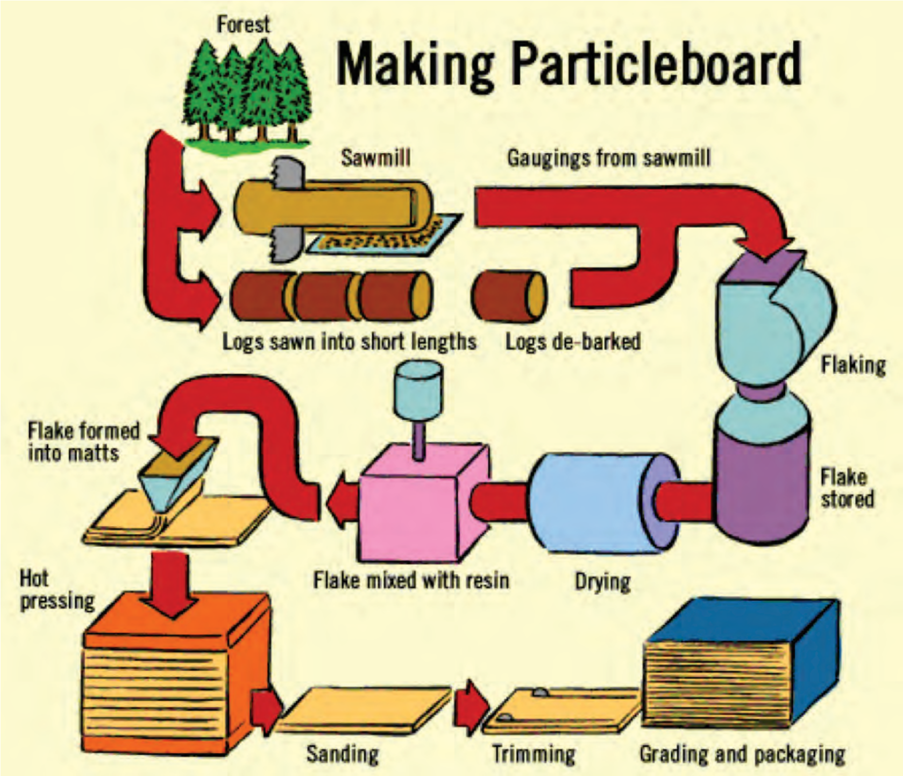
1. Debarking of logs

Where logs are to be chipped to provide some of the particleboard fibre mix, debarking is required. Bark can degrade particleboard properties if present in quantities of more than a few percent.

2. Chipping

Once the bark is removed, the log is chipped to produce a homogeneous product. Reduction may require a two-stage process that includes primary reduction of debarked logs to give large, coarse chips, followed by further milling to produce more "engineered" chips. Different equipment may be used to prepare chips of the required size and shape to form the fibre mix, depending on what other components, e.g., sawmill shavings, sawdust, are being incorporated. It is important to produce chip surfaces with as little damage as possible to improve particle–particle bonding, as a mechanically weak surface layer will lead to possible breakdown of the glue-line, resulting in degraded board properties.

FIGURE 7 **Schematic Flow Diagram of the Particleboard Process**



Source: http://louisestermandttimber.weebly.com/manufactured-boards.html

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3. Particle drying

The high moisture content of chips (and sawdust) from green wood (>100%) is too high for pressing and will create a high vapour pressure in the boards that can lead to delamination or "blows". Drying is necessary to ensure a much lower particle moisture content (around 2.5%, depending on resins and waxes) and give the fibre mix a more uniform moisture content. The process typically involves passing the particles through a stream of hot air.

4. Particle classification

It is critical to control the particle size distribution, i.e., optimise the position and size of the particles relative to their position in the board — small particles on the surface, bigger particles in the core, as shown in Figure 8. As well, the board is "balanced", i.e., the same amount of surface particles on both faces of the board in order to avoid distortion. Note that very small particles (fines) will consume more resin (high surface-area-to-weight ratio). Particles are classified by sieving or use of an air stream that carries away the smaller/lighter particles.

5. Furnish preparation

An adhesive or glue needs to be applied to the surface of the particles to bind them together. The resins are generally applied as liquids in the form of an atomised spray but can also be applied in solid (powder) form that forms a liquid on heating, before reverting to an insoluble, infusible solid form. Generally, the more resin, the better the particleboard properties — but more expensive! Thus, there is an optimum resin content that is around 8% for urea formaldehyde. Other additives (e.g., waxes, fungicides, flame retardants) may be blended in at the same time, with wax added typically at ~ 0.5–1.0%.

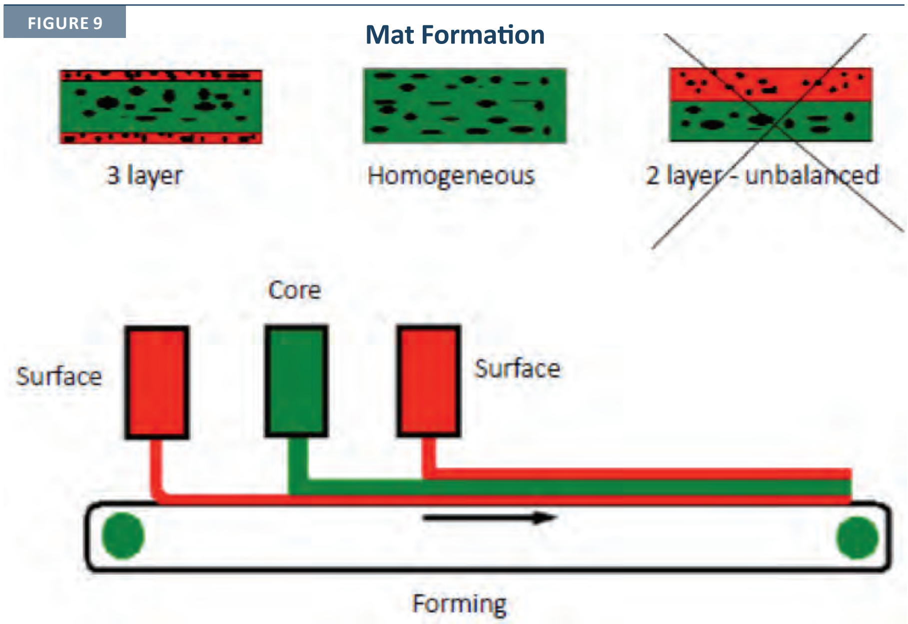
FIGURE 8

Particleboard Cross-section

Source: https://mycourses.aalto.fi/pluginfile.php/213918/mod_resource/content/1/2016_03_23_CHEM-E2105_Manufacture%20of%20wood-based%20panels.pdf

FIGURE 9

Mat Formation



Source: https://mycourses.aalto.fi/pluginfile.php/213918/mod_resource/content/1/2016_03_23_CHEM-E2105_Manufacture%20of%20wood-based%20panels.pdf

6. Mat formation

Forming is the process of laying up the "furnish" prior to pre-pressing and hot-pressing (consolidation). This is an important process in the formation of the board structure, strongly affecting properties such as bending strength, surface finish and optimised density. Boards may be "single layer", "multi-layer" (3,5) or "graduated" and must always be a "balanced" structure to prevent distortion or poor properties (i.e., neither two nor four layers is an option) as seen in Figure 9. Surface layers of "fine" particles (with a

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moisture content of 8–15% and a "core" of coarser particles (with a moisture content of 4–8%). The resin content of the surface layers may also be higher to give improved strength.

7. Pre-pressing and hot-pressing

Pre-pressing of the furnish is undertaken to reduce the bulk and give some mechanical strength to the mat for handling. It also speeds up the process of hot-pressing. Pre-pressing may be cold or hot, and it is critical not to pre-cure the adhesive.

Hot-pressing is the main mechanism for consolidation of the mat, the development of the board internal structure, and curing of the adhesive binding the particles together. The density profile of the particleboard is generated during hot-pressing. Pressing may be batch-wise in a single or multi-opening press, or in a continuous press.

8. Cooling and finishing

On exiting the hot press, the boards are trimmed before cooling. Panels need to be cooled before finishing (e.g., sanding) as, if done too soon, the board properties may be affected and tools will become clogged. After cooling, the boards are sanded to the final thickness and to give the desired surface finish. Frequently, the "raw boards" undergo further processing to add value, e.g., lamination or overlaying of a decorative finish.

FIGURE 10

Particleboard Panels

Raw panel

Laminated panel

Major Uses

Particleboard panels (Figure 10) are used in a variety of applications:

Construction industry

- Interior lining
- Floors
- Concrete moulds
- As web plates for beams
- Fixtures and fittings
- As a base material for parquet floors
- As a base material for covering strips

Furniture industry

- Furniture frames

Other applications

- Packaging
- Exhibition and fair structures
- Do-it-yourself

Particleboard is most commonly used in cabinetry and furniture that is not solid wood (Figure 11). It is easy to cover, making it ideal as a construction base that is going to be covered later with a higher-end material or finished product. Particleboard can be covered with many different surface materials, including veneer, melamine, laminate, plastic, paper, etc. The boards are usually coated on both sides in order to prevent warping. Boards are also made already primed for painting (treated with filler at the factory or coated with priming paper). The fire-resistance properties of particleboard can be improved with alkyd filler or melamine coating.

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Particleboard floors are tongue-and-grooved and can be either (1) a timber-framed particleboard floor fitted on top of the timber frame of the base or intermediate floor; or (2) a floating particleboard floor fitted on top of an isolating layer. The actual load-bearing structure of the floor may be, for example, wood or concrete.

Particleboard is also suitable for the interior lining of wall and ceiling surfaces that require painting.

Table 11 shows the market mix for particleboard in different applications in the US and Canada in 2018 compared to other panel products.

Currently Produced in NZ — Yes/No

New Zealand has two operating particleboard plants, both in the North Island and both small by international standards. Total annual production capacity of both plants is estimated to be around 70,000–80,000 m^3. New Zealand Panels Group owns the Kopine particleboard plant at Kopu and Laminex New Zealand has a plant in Taupo.

1. New Zealand Panels Group

The Kopine particleboard plant at Kopu, near Thames, has been owned by New Zealand Panels Group since 2015. It has a production capacity of around 30,000 m^3/year of particleboard. It produces two Codemark particleboard flooring systems (see next page).

- Kopine Ultralock™ is a unique particleboard flooring system that uses a patented glue system and grooved panel edges to provide a super-strong, moisture-resistant bond. It is also less prone to squeaking and peaking.

FIGURE 11

Particleboard Used in Different Applications

Particleboard used in cabinetry, before painting

Particleboard used as a floor

TABLE 11

Market Mix for Particleboard in the US and Canada

USA

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	56%	24%	11%	9%	100%
Softwood Ply	23%	30%	35%	13%	100%
Particleboard	14%	43%	31%	12%	100%
MDF	14%	55%	19%	12%	100%

Canada

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	66%	26%	2%	6%	100%
Softwood Ply	19%	44%	28%	9%	100%
Particleboard	14%	39%	33%	15%	100%
MDF	13%	55%	18%	13%	100%

Source: FEA estimates based on industry analysis for 2018

- Kopine Tongue & Groove is a particleboard flooring system that uses black plastic beaded tongues fitted into a grooved edge to bond the panels together (Figure 12).

As a business unit of NZ Panels Group, the bulk of the particleboard production goes to Prime Panels and Bestwood for use in the manufacture of pressed decorative panels for furniture and shelving, using melamine, high-pressure laminate and acrylic. These medium-density particleboard panels, available in a range of six thickness options from 9–30 mm, are branded as Kopine Fine and Fine MR. Fine MR has an added resin to provide water-resistance, allowing for occasional exposure to higher humidity or moisture.

FIGURE 12

Kopine Tongue & Groove

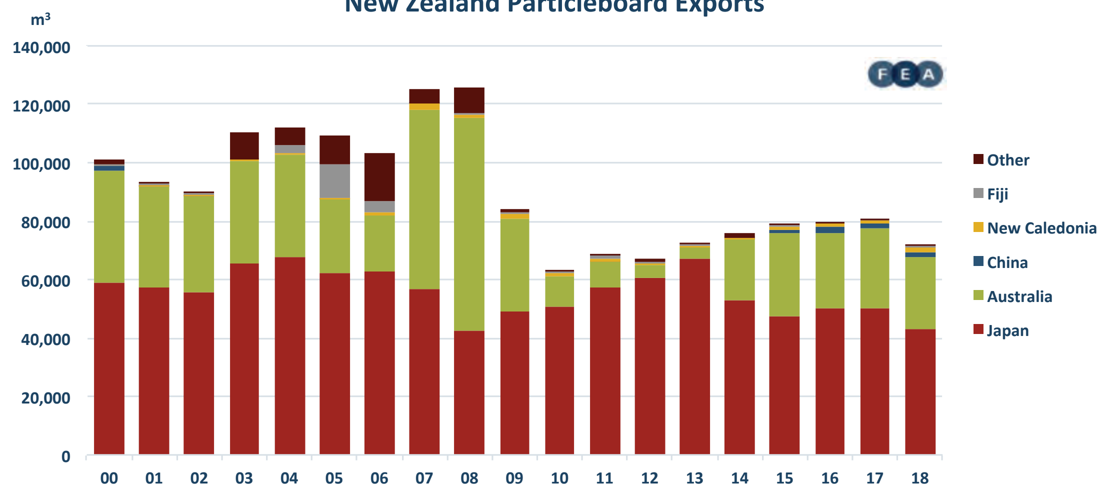
Source: www.kopine.co.nz/tongue-and-groove/

2. Laminex New Zealand

Laminex New Zealand forms part of the Laminates and Panels division of Fletcher Building Products Ltd, being a supplier to decorative surfaces and panel product manufacturers. It has a small particleboard plant in Taupo that is currently producing around 45,000 m^3/year using about 70,000 tonnes/year of sawdust and shavings. The product is branded Superfine® and is a medium-density, grainless, resin-bonded particleboard used as a substrate for high-pressure and low-pressure laminate, panel housing systems or joinery.

GRAPH 22

New Zealand Particleboard Exports



Source: Stats NZ

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New Zealand's exports of particleboard are shown in Graph 22. Total exports in 2018 were 72,000 m^3, dominated by two nations: Japan (60%) and Australia (34%). The data are confusing because they include products from Juken New Zealand's triboard plant in Kaitaia. In fact, most domestic particleboard is likely consumed in New Zealand, with very little exported.

New Zealand imports small amounts of particleboard (Graph 23) — about 2,400 m^3 per annum in 2018 (just over 3% of the reported export volume), with half of this coming from China.

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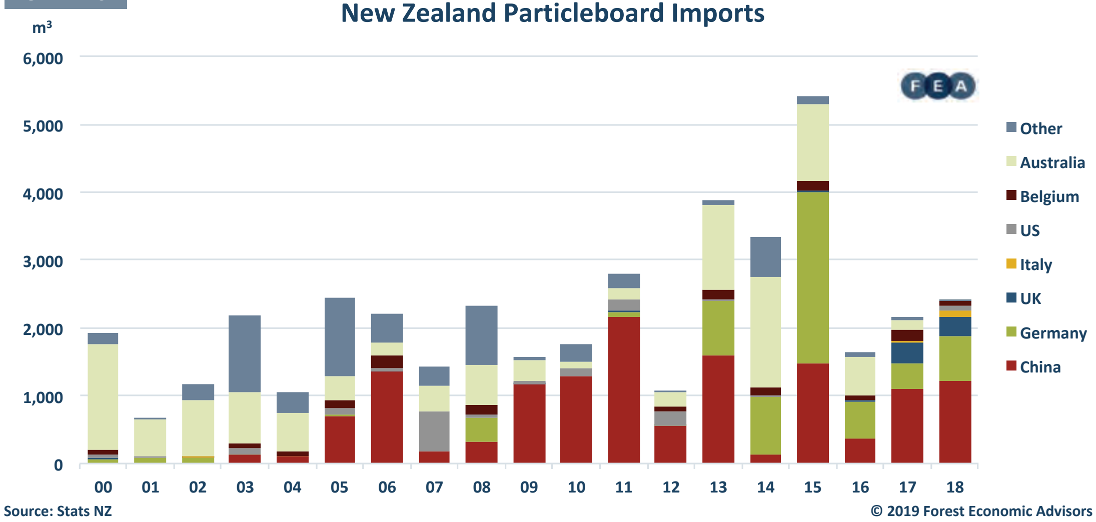
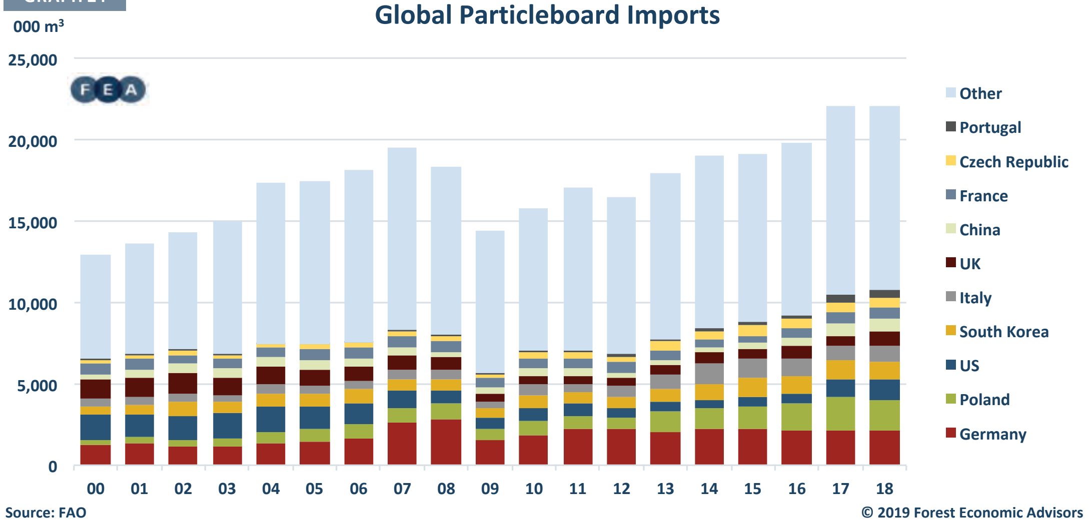
Major Importing Countries — Where are the Markets?

GRAPH 23

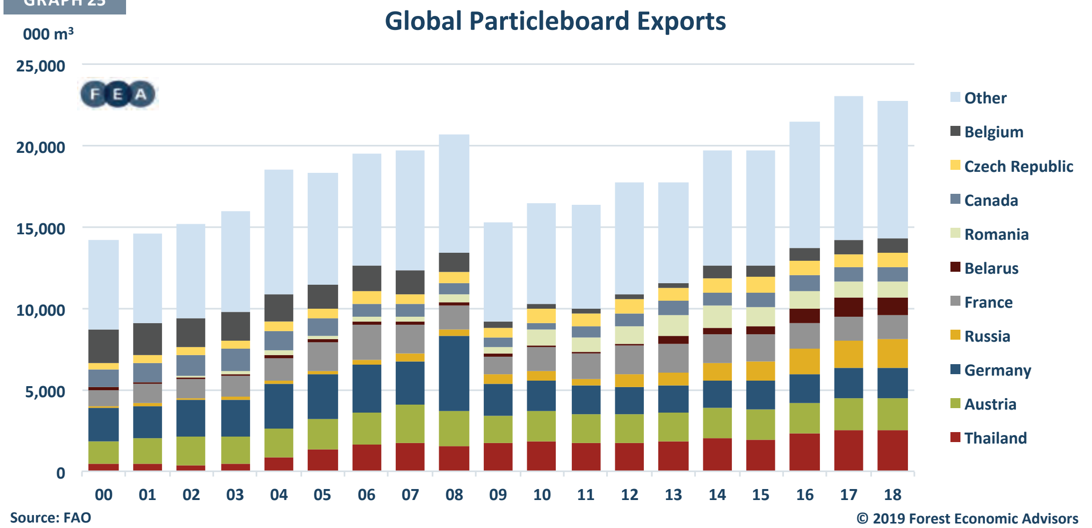


Graph 24 shows that global particleboard trade was ~22 million m³ in 2018. Germany and Poland are the two biggest importers, but combined have only about 18% of the market for traded particleboard. The top ten countries represent only 49% the global market, making particleboard a highly fragmented commodity in terms of worldwide market opportunities.

GRAPH 24



GRAPH 25



Major Exporting Countries — Who is the Competition?

Five countries — Thailand, Austria, Germany, Russia and France — comprise 42% of total particleboard exports, with the top ten exporters contributing 63% of global trade in 2018. Eight of these top ten are based in Europe. Thailand and Canada round out the top ten (Graph 25).

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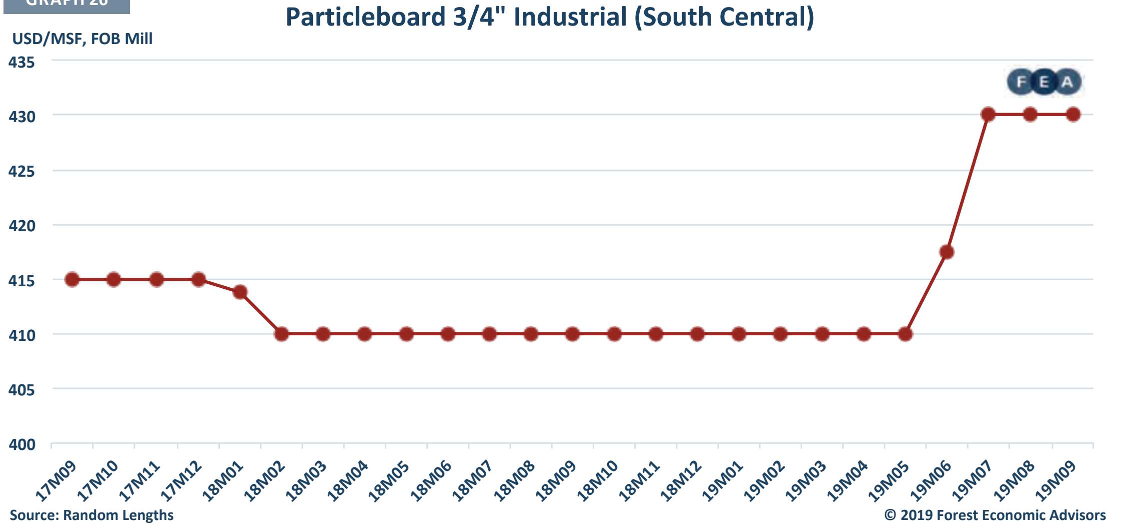
Published Price Series (where available) or Suitable Proxy

GRAPH 26



Particleboard prices are reported weekly in the Random Lengths publication as Non-Structural Panels (Graph 26) and pricing history can be easily tracked. Data are shown for industrial particleboard from plants in the western and southern US for six panel thicknesses. Interior particleboard as an underlayment is also shown for plants in the western US only. The data show prices for particleboard on a net, fob mill basis per thousand square foot.

Conversion to US$ per m³

The prices in Graph 26 are on a per thousand square foot basis. Therefore, the thicker the material, the higher the price, as there is more volume. To convert to US$ per m^3:

- Convert the thousand square foot basis to m^2 (multiply by 92.903).
- Convert the thickness in inches to metres (multiply by 0.0254).
- Multiply the area in m^2 by the thickness in metres.

For the South Central, ¾" industrial particleboard shown at US$430 per thousand square foot, the conversion is **US$430/thousand square foot/(92.903 x 0.75" x 0.0254) = US$243/m³**.

Key Opportunities and Constraints for a New Zealand Manufacturer

Like MDF, particleboard is a residues-based wood product that can utilise lower-cost materials, such as sawmill sawdust and shavings, that otherwise have energy value as a biomass fuel. The market in New Zealand is being met by the two current producers (recall that the export data are skewed by inclusion of triboard products), and particleboard imports are small. This means that any greenfield particleboard plant is going to have to export and, consequently, will need to be of significant scale to be cost-competitive against current international players.

We understand that a Chinese company has been looking recently to build a greenfield particleboard plant in New Zealand. Key statistics reported in media coverage were for a 600,000 m^3 particleboard-out plant using 700,000 m^3 of fibre input. The capital cost was reported to be an estimated $180 million on a 33-hectare site, with the operation creating about 110 full-time jobs. These are the sorts of dimensions any investor in a new particleboard plant is going to need to consider. As always, certainty of fibre supply will be critical, and the fibre mix will need to be low-cost (given that particleboard is the lowest-priced fibreboard product). This likely means co-locating either (1) near a major sawmill that can provide chips, sawdust and shavings without needing this fibre for its own biomass boiler; and/or (2) near forests with thinnings and other in-forest residues that could be economically recovered for a particleboard operation.

msmith@getfea.com getfea.com

4 ORIENTED STRAND BOARD (OSB)

Description of Product

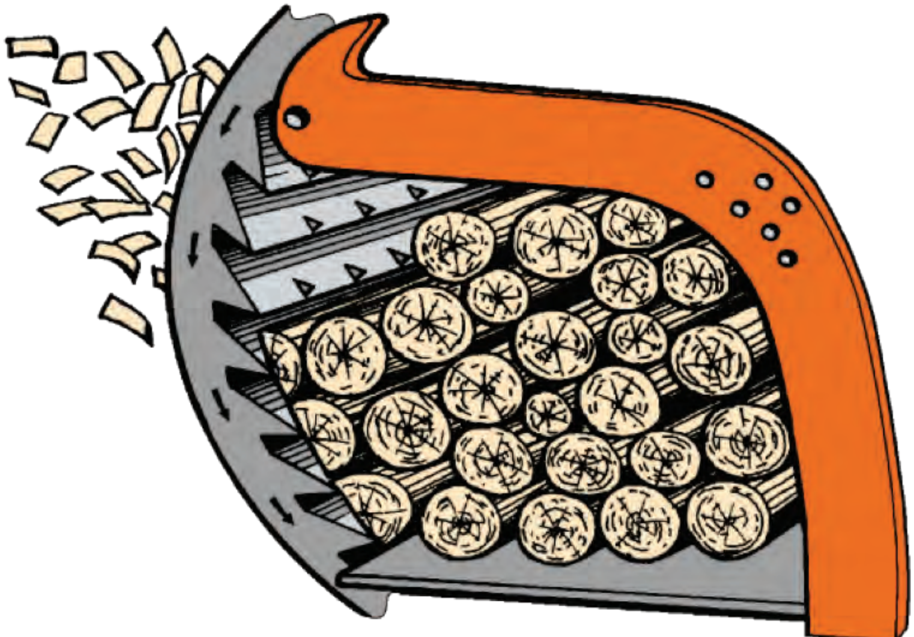
OSB can use small-diameter, fast-growing trees, pulp logs or even forest thinnings to generate strands.

Strands (or thin wooden strips) are used to produce wide mats that are then cross-layered, compressed and bonded together with waxes and resins (typically 95% wood fibre, 5% wax and resin) to make OSB. In North America, panel dimensions are typically 4x8', with thicknesses ranging anywhere from 5/16" to 1⅛" depending on application.

Logs are debarked and fed into “stranders” (Figure 13), where knives in either a ring or fan configuration (with perhaps 30–50 blades per strander) slice and dice the entire log into strands that are generally 3–6" long, 1" wide and 0.03" thick. Importantly, no wood is wasted in the process other than fibre that might be subsequently screened out due to undesirable features.

FIGURE 13

Schematic Diagram of a Strander



Source: www.arbec.ca/en/products/manufacturing-process

The strands are then passed through a rotary dryer to give a target moisture content (4–10%) before blending with a mixture of resins and waxes that vary by manufacturer, wood mix, time of year and other factors.

The mix of wood strand, resin and wax is then fed into an “orienter” (Figure 14) that forms a mat of individual layers superimposed perpendicularly to each other. The mats may be 3–8" deep on a continuous belt that is anywhere from 8–12' in width. This continuous mat is then cut to length to fit the particular press size (see below).

The mats are pressed at high pressure (depends on board thickness, but around 1,300 psi) and high temperature (above 200˚C), causing the heat-activated resins coated on the strands to cure and bond the strands, thereby forming a high-density structural panel. After exiting the press, the OSB boards are cut to size, trimmed, e.g., 4x8', and stamped according to grade. The boards may be further enhanced by adding a radiant barrier or tongue-and-groove edging before final quality control checking and bundling/packaging for delivery. When stacked, a sealant may be added to the sides to increase water-resistance.

Major Uses

OSB is a widely used, versatile structural wood panel (Figure 15) with favourable mechanical properties that make it particularly suitable for load-bearing applications in construction. As described above, OSB is manufactured from waterproof heat-cured adhesives and rectangularly shaped wood strands that are arranged in cross-oriented layers, giving an engineered wood panel that shares many of the strength and performance characteristics of plywood.

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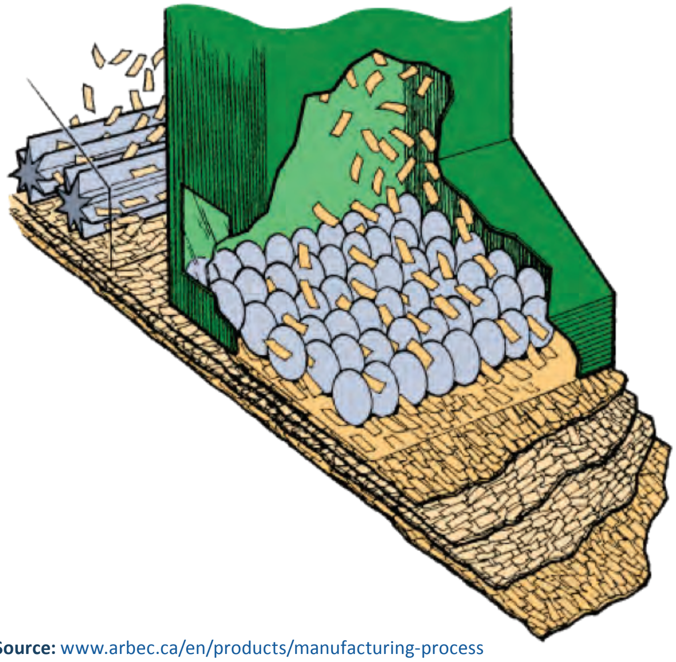
FIGURE 14 **Schematic Diagram of an Orienter**



Source: www.arbec.ca/en/products/manufacturing-process

OSB's combination of wood and adhesives creates a strong, dimensionally stable panel that resists deflection, delamination and warping; likewise, panels resist racking and shape distortion when subjected to demanding wind and seismic conditions. Relative to their strength, OSB panels are light in weight and easy to handle and install.

OSB is produced in huge, continuous mats to form a solid panel product of consistent quality with no laps, gaps or voids. Finished panels are available in large dimensions, minimizing the number of joints that can "leak" heat and admit airborne noise.

OSB is suitable for a variety of end uses (Figure 16), including structural applications, such as subflooring; single-layer flooring; wall and roof sheathing; sheathing ceiling/deck; structural insulated panels; webs for wood I-joists; and mezzanine decks. Non-structural applications include furniture frames, decorative wall panelling, shelving, packaging and crating, pallet manufacture, dry storage pallets and tops for industrial tables.

In North America, panel performance is determined by thicknesses; they typically include the following, in inches: 5/16, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4, 7/8, 1, 1⅛.

Panel sizes, in feet, include 4x8, 4x9 and 4x10, manufactured in 8x24' or larger panels that can be custom-cut by most manufacturers.

In Europe, four grades of OSB are defined in the relevant European Standard (EN 300: 2006 Oriented Strand Boards (OSB) — Definitions, classification and specifications) in terms of their mechanical performance and relative resistance to moisture:

- **OSB/1 —** General purpose boards and boards for interior fitments (including furniture) for use in dry conditions
- **OSB/2 —** Load-bearing boards for use in dry conditions
- **OSB/3 —** Load-bearing boards for use in humid conditions
- **OSB/4 —** Heavy-duty load-bearing boards for use in humid conditions

FIGURE 15 **Oriented Strand Board (OSB) Panel**

Table 12 shows the market mix for OSB in different applications in the US and Canada in 2018 compared to other panel products.

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TABLE 12

Market Mix for OSB in the US and Canada

USA

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	56%	24%	11%	9%	100%
Softwood Ply	23%	30%	35%	13%	100%
Particleboard	14%	43%	31%	12%	100%
MDF	14%	55%	19%	12%	100%

Canada

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	66%	26%	2%	6%	100%
Softwood Ply	19%	44%	28%	9%	100%
Particleboard	14%	39%	33%	15%	100%
MDF	13%	55%	18%	13%	100%

Source: FEA estimates based on industry analysis for 2018

FIGURE 16

OSB Used in Different Applications

OSB as a flooring material

OSB as a wall material

OSB as exterior wall sheathing

Currently Produced in NZ — Yes/No

There is no OSB made in New Zealand per the process described above. Juken New Zealand Ltd (Juken) make a strandboard product at its mill in Kaitaia as a single or double-sheet flooring material and for use as a ceiling panel, wall panel or decorative overlay. The process does use strands, but there is no orienter used so it is not technically OSB. This plant also makes the unique Triboard product, a three-layer panel with a strand core sandwiched between two MDF outer skins. Juken claims this results in a clean-lined panel that has high resilience and impact-resistance, as well as greater stiffness than similar products.

FEA research indicates that the Juken Triboard mill is processing up to a maximum of ~160,000 m^3 of pulp logs to produce around 75,000 m^3 of dense Triboard, and/or its components, strandboard and MDF. Around 10% of production was sold domestically, with 90% exported to Japan, Australia, India and other countries.

In September 2018, Juken announced a $30 million upgrade that will result in modernising the plant at the expense of some job losses. There has been no announcement on what impacts this modernisation will have on total capacity and product mix.

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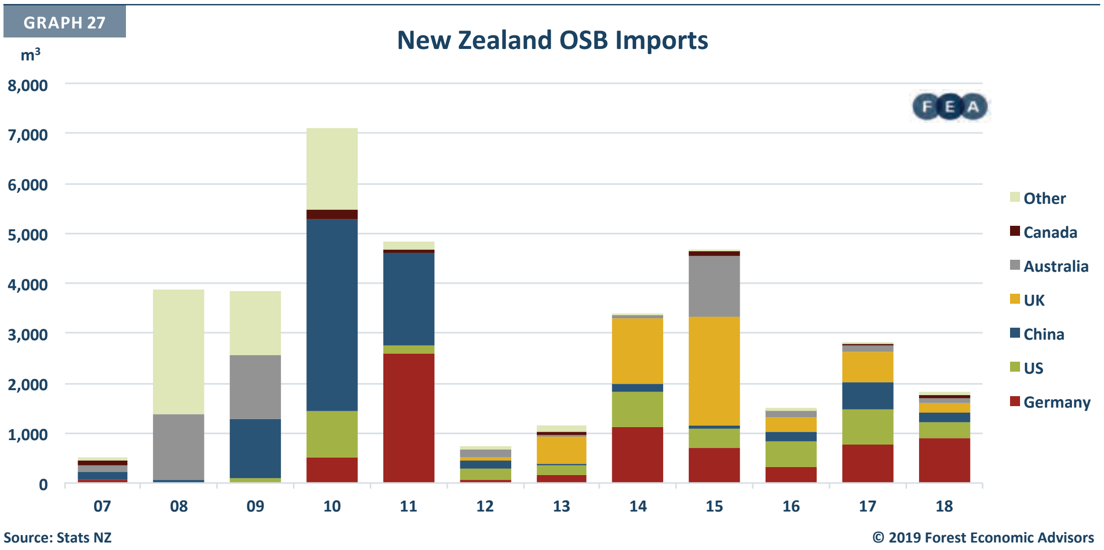
New Zealand imports small amounts of OSB per Graph 27. These are generally brought in by distributors who supply the major DIY stores with product for customers who have a specific need for OSB. One example is IBS Building Products (www.ibs.co.nz), which imports OSB from the Egger Group headquartered in Austria.

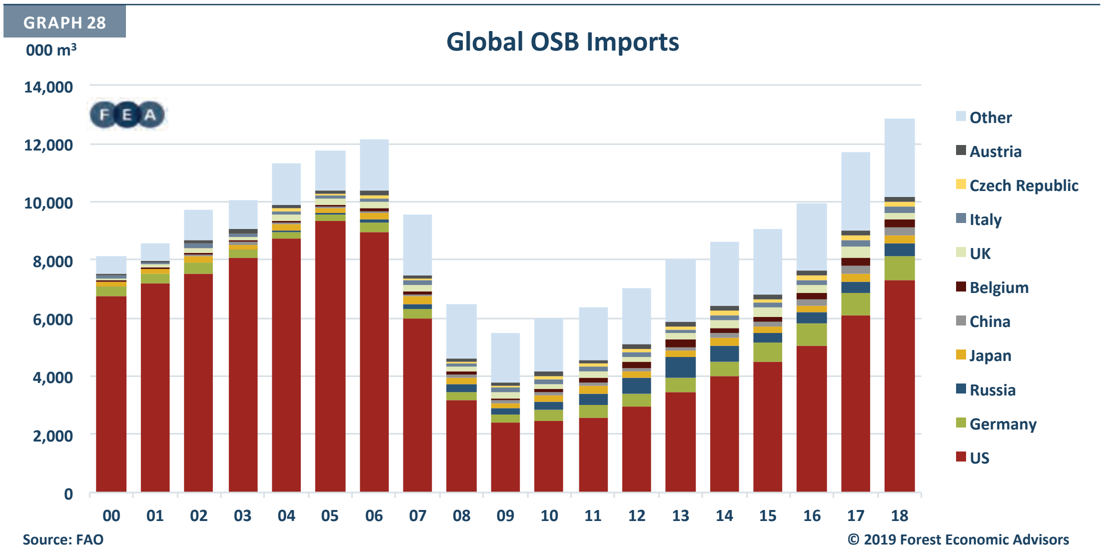
GRAPH 27



Major Importing Countries — Where are the Markets?

Graph 28 shows that global trade in OSB was just under 13 million m³ in 2018, and that the US is far and away the major importer (about 57% of the volume, at 7.3 million m³). Germany is the next-largest importer at 840,000 m³ in 2018, with all countries after that importing less than 400,000 m³ per annum. Seven of the top ten are European countries.

GRAPH 28



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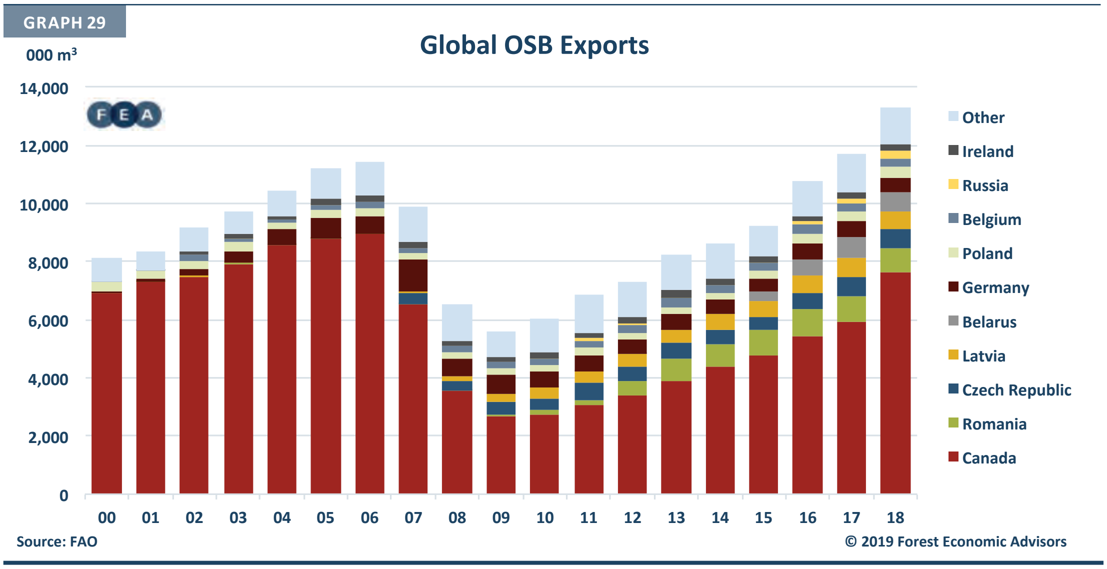
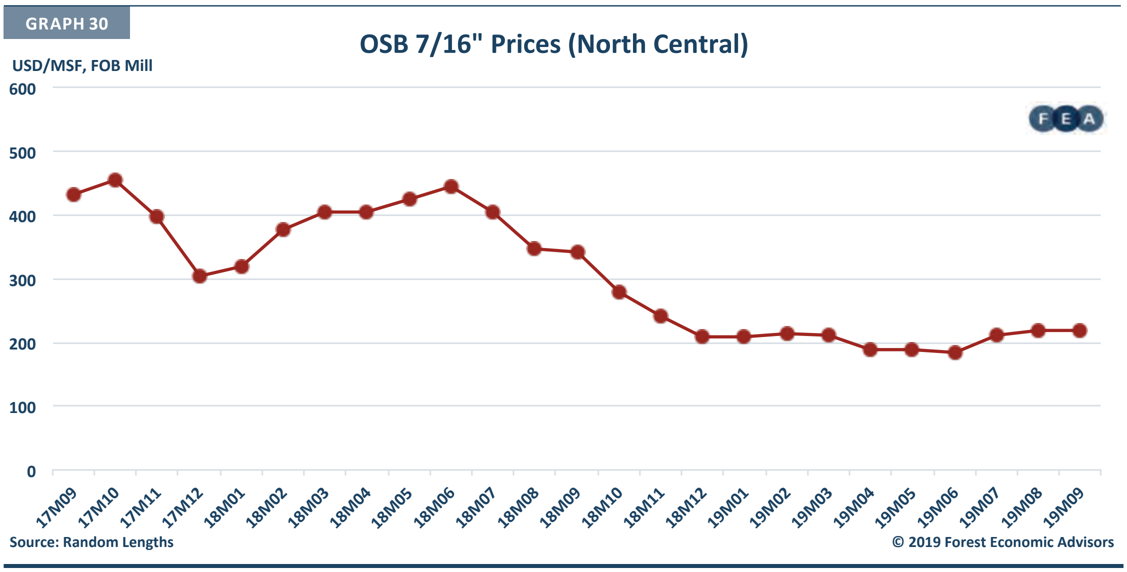
Major Exporting Countries — Who is the Competition?



In 2018, Canada (57%) was the major exporter of OSB — primarily meeting all US demand. The next nine biggest exporters are all based in Europe, effectively meeting the European demand (Graph 29).

Published Price Series (where available) or Suitable Proxy



OSB prices are reported weekly in the Random Lengths publication (Graph 30) and pricing history can be easily tracked. The data show OSB prices for (1) net, fob mill and (2) delivered to selected US locations for a variety of thicknesses on a per thousand square foot basis.

Conversion to US$ per m³

The prices in Graph 30 are on a per thousand square foot basis. Therefore, the thicker the material, the higher the price, as there is more volume. To convert to US$ per m³:

- Convert the thousand square foot basis to m² (multiply by 92.903).
- Convert the thickness in inches to metres (multiply by 0.0254).
- Multiply the area in m² by the thickness in metres.

For the North Central, 7/16" OSB shown at US$210 per thousand square foot, the conversion is **US$210/thousand square foot/(92.903 x 7/16" x 0.0254) = US$203/m³.**

Key Opportunities and Constraints for a New Zealand Manufacturer

OSB trade appears to be highly regionalised. In North America, Canada is supplying US demand, and in Europe, countries such as Romania, Belarus and Latvia are supplying demand for Germany, Russia, the UK and Belgium. China and Japan are the major Asian importers, with combined demand of around 500,000 m^3 per annum.

Despite this regionalisation, Canadian volumes to the US West Coast are likely to decrease as the AAC of forests in British Columbia continues to be reduced, meaning there may be scope for a New Zealand OSB operator to target Asia and the US West Coast. For example, two of the three BC OSB mills have shut down. The only mill that will be operating is LP Dawson Creek, which recently converted to OSB siding and is ramping up.

Countering this, capacity in Asia is increasing — with one OSB mill in Malaysia recently started up. We believe there are currently four OSB mills operating in China, with total capacity around 1 million m^3 per annum.

World-scale plants are typically processing up to 250,000–300,000 m^3 per line based on the press size. Any New Zealand operation would need to be at this scale to be cost-competitive with overseas producers to the Asian and US West Coast markets, and have ready access to pulp logs.

Given that New Zealand has no expertise in OSB manufacturing or marketing, there would appear to be two possible strategies worth investigating if the fibre supply and economics look attractive:

1. Examine whether a Canadian OSB manufacturer would consider investing in an operation in New Zealand to diversify its manufacturing base and supply the US West Coast as the AAC is reduced (with consequent loss of overall processing infrastructure).
2. Engage with Juken and understand what opportunities there might be to look at an OSB plant in New Zealand to complement the company's existing product ranges.

5 PLYWOOD

Description of Product

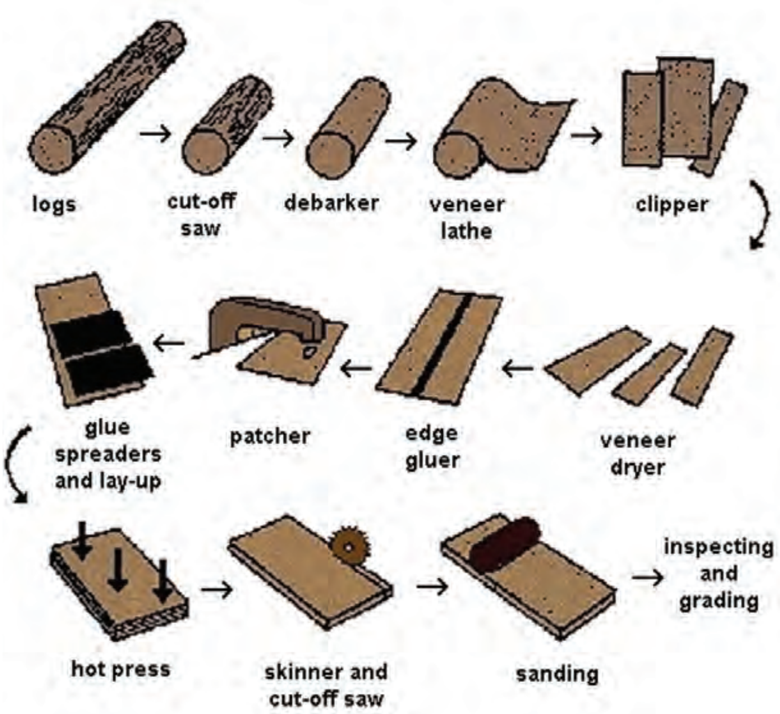
Plywood is made from sawlogs converted into veneers. These sawlogs are often known as "peelers" to reflect the veneer manufacturing process ("peeling"), and the fact that ideally they are straighter, more cylindrical and with less taper than the sawlogs used in a sawmill.

For plywood manufacture, these thin veneer sheets are cross-laminated and bonded under heat and pressure with strong adhesives. In North America, panel dimensions are typically 4x8', with thicknesses ranging anywhere from 5/16" to 1⅛" depending on application.

The process for making plywood is illustrated in Figure 17.

FIGURE 17

Schematic Flow Diagram of the Plywood Process



Source: https://timberatnbcs.files.wordpress.com/2012/06/plpic2-1.jpg

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In New Zealand, pruned peelers (from pruned forests) are of a high quality and yield a significant proportion of knot-free veneers for external faces, in cases where a clean, defect-free appearance is desired. Structural (or industrial) peelers are unpruned logs for all knotty grades of plywood.

Logs are delivered in specific lengths to the plywood mill and debarked. Before they are peeled into veneers, the logs must be softened or "conditioned". In New Zealand this is usually done by steaming (but could involve using soaking logs in heated ponds for several days overseas). The log (now called a bolt or block) is then peeled (turned against a sharp blade) in a rotary lathe to give continuous sheets of veneer. Full veneer mats or clipped sheets are dried to reduce the moisture content to the right level (generally less than 10%) for additional processing. As well, drying makes the veneer supple enough to avoid damage during subsequent handling. Veneers are visually inspected after drying and sorted into different grades prior to jointing (edge-gluing) for length/width and patching of defects on the surface.

The veneers are now ready for gluing and pressing. Plywood is constructed with an odd number of layers, with the wood grain of the adjacent layers perpendicular to each other. The veneers are coated with waterproof glue (either a roller or curtain coater) and laid up in sandwiches. Prior to hot-pressing, most mills cold pre-press the bundles when they are discharged from the gluing operation; the pre-press flattens the veneers and transfers the adhesive to the uncoated sheets. The load is held under pressure for several minutes to develop consolidation of the veneers. The primary purpose for the pre-press is to allow the wet adhesive to "tack" the veneer together to permit easier shifting of veneers when loading. Hot-pressing follows, whereby the veneer sandwiches are subjected to heat and pressure in a hot press until the glue is cured. Hot-pressing cures most synthetic resin adhesives. In hot-pressing, it is absolutely necessary to load, close the press and apply full pressure as quickly as possible. The goal of hot-pressing is for the centre glue line to reach the needed curing temperatures, and for it to remain at that temperature until the bond is strong enough to be handled.

FIGURE 18

Plywood Panel (7-ply)

After pressing, the plywood panels are trimmed, squared and selected for grades. Any further patchwork can be done before sanding (if required), inspecting and final grading. Once a panel has been graded, it should receive a grade stamp.

Major Uses

Plywood panels (Figure 18) have superior dimensional stability and an excellent strength-to-weight ratio, and are highly resistant to impacts, chemicals and changes in environmental temperature and humidity. Plywood is available in a wide variety of appearance grades, ranging from smooth, natural surfaces suitable for finishing work to more economical grades used for sheathing. In the US, there are more than a dozen common thicknesses and over 20 different grades, making plywood well-suited to many different applications.

Plywood is suitable for a variety of end uses, including subflooring, single-layer flooring, wall and roof sheathing, sheathing ceiling/deck, structural insulated panels, marine applications, exterior cladding, webs of wood I-joists, concrete forming, pallets, industrial containers, mezzanine decks and furniture (Figure 19).

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In North America, panel performance is determined by thicknesses, which typically include the following, in inches: 5/16, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4, 7/8, 1, 1⅛.

Panel sizes, in feet, include 4x8, 4x9 and 4x10.

Table 13 shows the market mix for plywood in different applications in the US and Canada in 2018 versus other panel products.

FIGURE 19

Plywood Used in Different Applications

Plywood as a flooring material

Plywood as a cladding material

Plywood being used as concrete formwork

Currently Produced in NZ — Yes/No

There are three operating plymills in New Zealand — all small by world standards — with a total annual production capacity estimated at around 180,000 m^3. They are Carter Holt Harvey Plywood Limited (Tokoroa), Juken New Zealand Ltd (Masterton) and International Panel and Lumber Ltd or IPL (West Coast).

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TABLE 13

Market Mix for Plywood in the US and Canada

USA

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	56%	24%	11%	9%	100%
Softwood Ply	23%	30%	35%	13%	100%
Particleboard	14%	43%	31%	12%	100%
MDF	14%	55%	19%	12%	100%

Canada

Product	New Res. Construction	Residential Improvements	Industrial	Commercial	Total
OSB	66%	26%	2%	6%	100%
Softwood Ply	19%	44%	28%	9%	100%
Particleboard	14%	39%	33%	15%	100%
MDF	13%	55%	18%	13%	100%

Source: FEA estimates based on industry analysis for 2018

1. Carter Holt Harvey (CHH)

Carter Holt Harvey Plywood Limited New Zealand (CHH Plywood) specialises in the manufacture and supply of both structural and non-structural plywood products, with familiar brands such as Ecoply®, Shadowclad®, Shadowply and Handiply®. These brands are suitable for a range of applications, including structural, exterior cladding, interior lining applications, DIY and packaging, among some of the many uses.

The plant is a dedicated plymill located on the Kinleith industrial complex just south of Tokoroa and was originally established by New Zealand Forest Products in the 1970s, with annual capacity of 40,000 m^3. It was expanded in 1994 to increase annual capacity to 100,000 m^3, using about 200,000 m^3 of logs.

2. Juken New Zealand Ltd (Juken)

Juken New Zealand (formerly Juken Nissho) is a Japanese joint venture between Juken Sangyo and Nissho Iwai. The company operated two veneer plants at wood processing complexes in Masterton and Gisborne that could produce both LVL and plywood. However, Juken has now closed the line in Gisborne following an announcement in January 2018.

The remaining Masterton plant was opened in 1992 and FEA understands that annual log input to the panel plant is around 130,000 m^3 of mostly unpruned logs. Of this, FEA believes that 80,000 m^3 is used to make around 40,000 m^3 of plywood. The balance of 50,000 m^3 of logs is used to make ~25,000 m^3 of LVL.

The product is branded J-PLY and is a general-purpose plywood panel used for a variety of ends, both structural and non-structural, internal and external, including construction panel, tongue-and-groove flooring, furniture, shelving, bracing and more.

J-PLY is also a versatile solution for design and feature purposes in which specified structural properties are required. As an independently certified engineered wood product, it is made in accordance with strict quality and environmental standards and is available in a wide range of sheet sizes and thicknesses.

3. International Panel and Lumber Ltd (IPL)

International Panel and Lumber (IPL) operate a plant on the West Coast of the South Island. Following ownership changes in its formative years, it became a 100% New Zealand-owned private company in 1991. The IPL plymill is situated in Gladstone, 10km south of Greymouth, and employs around 100 staff, making it one of the larger employers in the West Coast region.

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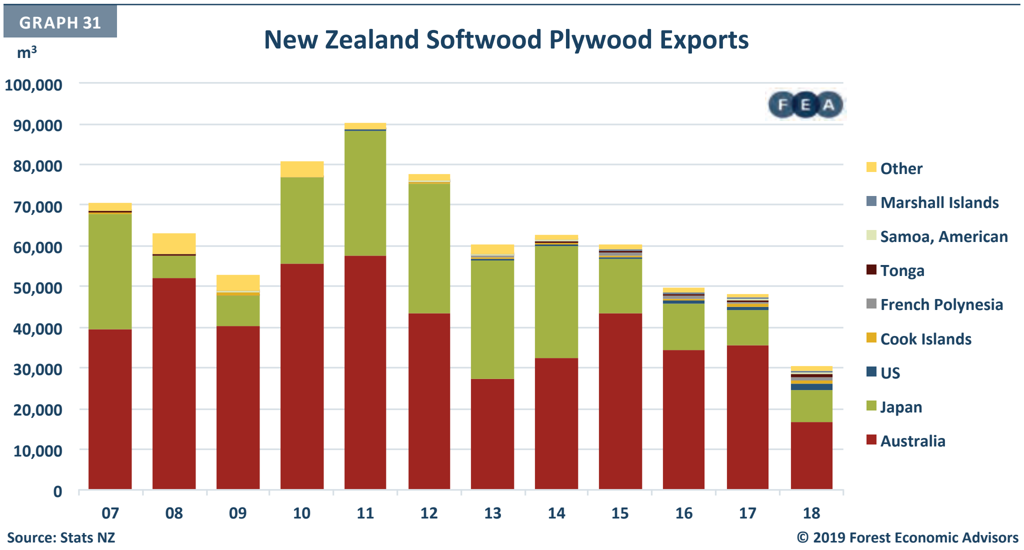
IPL originally produced plywood made from indigenous species sourced from the surrounding West Coast region, but since government restrictions on indigenous logging were implemented in the 1980s, plywood production is now based on radiata pine sourced from the upper South Island.

IPL is understood to have an annual log input of around 38,000 m^3, producing around 21,000 m^3 of plywood. Log input is 60% pruned peeler, targeting higher-grade products. Almost all of the production is sold on the domestic market, with smaller volumes exported to Australia and the Pacific Islands. IPL produces a range of plywood products, including exterior panelling (AlpineClad), interior linings (EliteLine), Bracing and Flooring (TuffPly), concrete formwork (FormPly) and a specialist product made for the sign industry (SignPly).

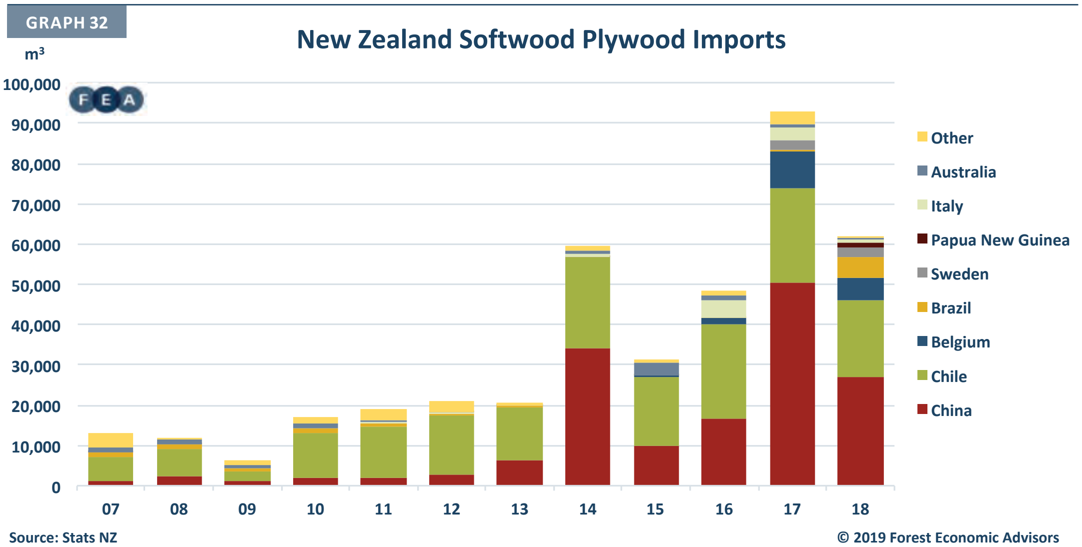
New Zealand exports of plywood are shown Graph 31, with the major markets being Australia and Japan. The drop-off in 2018 of about 20,000 m^3 likely reflects the closure of the Juken veneer line in Gisborne.

GRAPH 31



New Zealand plywood imports (Graph 32) are generally brought in by distributors that supply the major DIY stores with material that competes with NZ-made plywood. One example is IBS Building Products (www.ibs.co.nz), which imports radiata-based plywood from Arauco in Chile.

GRAPH 32



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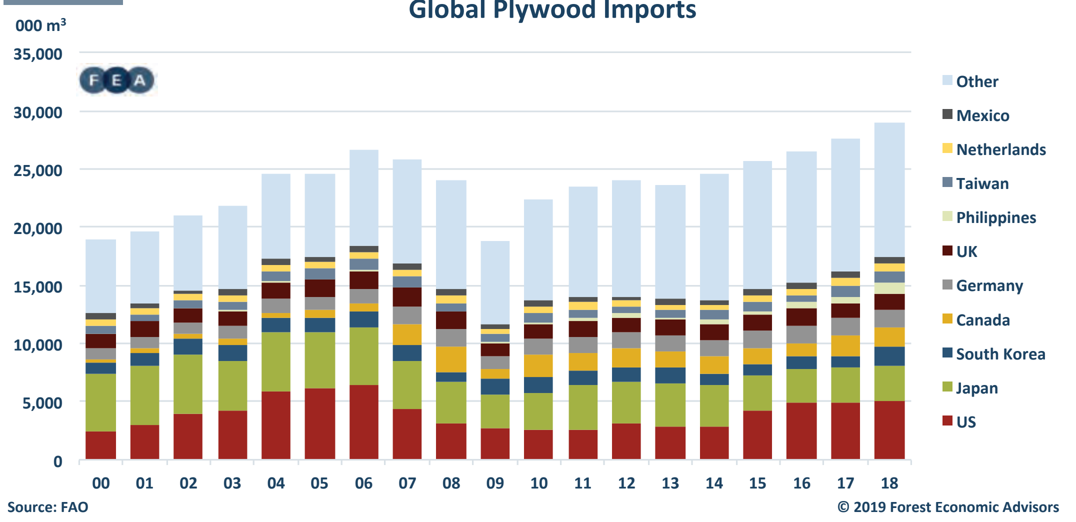
Major Importing Countries — Where are the Markets?

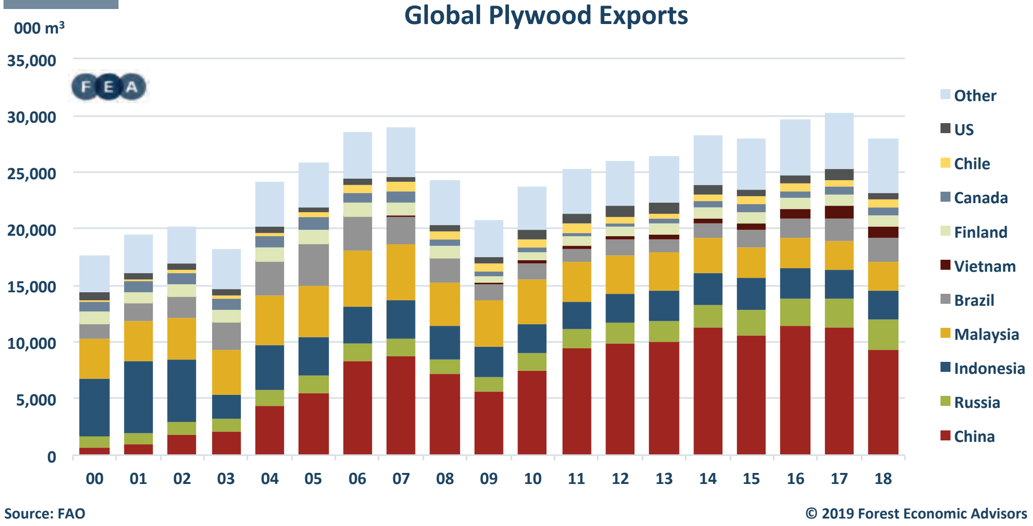
Graph 33 shows that global trade in plywood was almost 29 million m³ in 2018. These data are for softwood and hardwood plywood combined. The US and Japan are the major importers with about 27%. Nonetheless, the market is quite fragmented, with the countries outside the top ten importers making up just over 40% of the market in 2018.

GRAPH 33



Major Exporting Countries — Who is the Competition?

GRAPH 34



Three Asian countries — China, Indonesia and Malaysia — made up 51% of total plywood exports in 2018 (Graph 34). The data combine hardwood and softwood plywood, so does not give the clarity required when considering possible opportunities for radiata pine plywood.

Published Price Series (where available) or Suitable Proxy

Plywood prices are reported weekly in the Random Lengths publication (Graph 35) and pricing history can be easily tracked. Data are shown for both the US South and the US West across a range of plywood products (sheathing, sanded, underlayment, sidings and concrete formwork) at different thicknesses. The data show prices for plywood on a net, fob mill basis per thousand square foot.

Conversion to US$ per m³

The prices in Graph 35 are on a per thousand square foot basis. Therefore, the thicker the material, the higher the price, as there is more volume. To convert to US$ per m³:

- Convert the thousand square foot basis to m² (multiply by 92.903).
- Convert the thickness in inches to metres (multiply by 0.0254).

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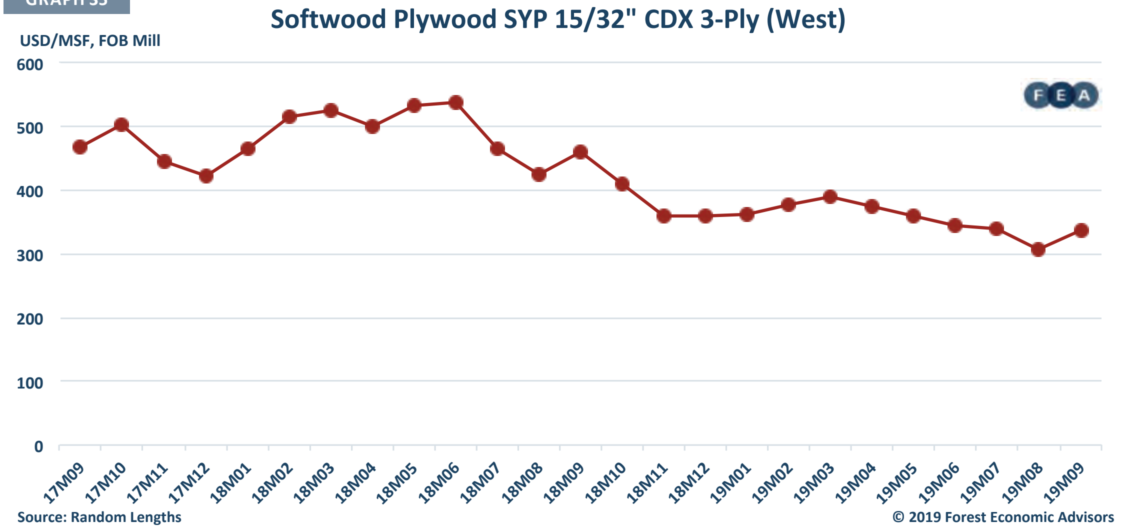
- Multiply the area in m² by the thickness in metres.

For the West Softwood Plywood, SYP, 15/32" CDX 3-ply shown at US$340 per thousand square foot, the conversion is **US$340/thousand square foot/(92.903 x 15/32" x 0.0254) = US$307/m³.**

GRAPH 35

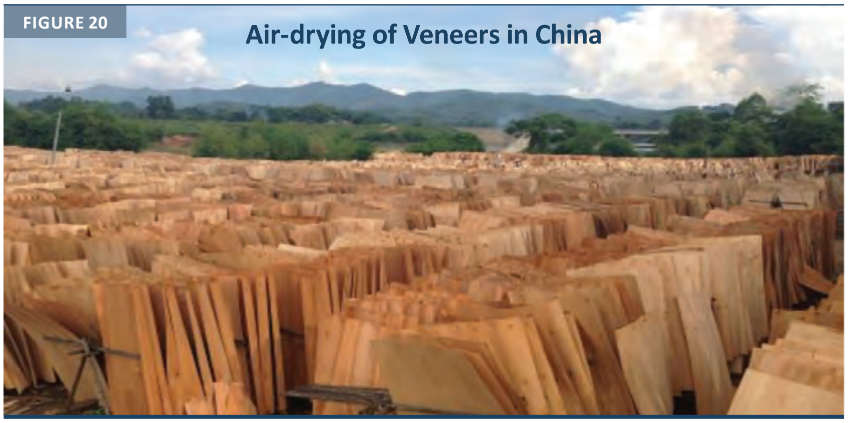


Key Opportunities and Constraints for a New Zealand Manufacturer

There is limited supply of high-quality "peeler" logs in the necessary concentrations throughout the various regions of New Zealand that could be used to feed a modern, greenfield plymill that would operate on a log-in basis of 500,000–600,000 m³ per annum for a modern-scale plant producing 250,000–300,000 m³ of plywood. This is especially so for a diminishing pruned log resource to make clear-face veneers for appearance-grade plywood.

FIGURE 20

Air-drying of Veneers in China



A reasonable volume of the A-grade and K-grade logs exported to China from New Zealand are converted to plywood. These Chinese factories are often small enterprises without modern, automated and continuous processing lines. However, the low cost of labour in China means these operations can get much higher recoveries at much lower costs. Veneers can even be dried by hanging outside in the sunlight (Figure 20)!

FEA is currently unclear whether A-grade and K-grade logs — much less straight and cylindrical than traditional peeler logs — could be economically converted to plywood in a modern plywood mill. The veneer recovery from the rotary peeling would be poor, which is why low labour costs in China make it viable to recover and stitch together a lot of these veneer fragments. Is the technology available to take into account the poor veneer-making characteristics of less straight, cylindrical logs and replicate, in an automated manner, what high-labour, small Chinese plywood mills can achieve?

If possible, this may offer an opportunity for a processing plant in New Zealand utilising more readily available A-grade and K-grade logs that would otherwise be exported. The economics of and rationale for such an investment would need further study.

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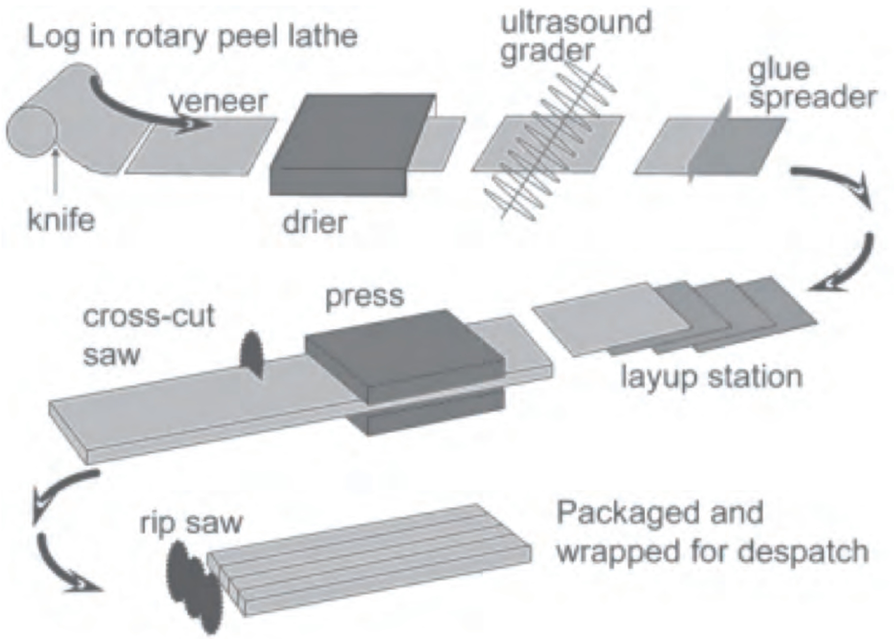
6 LAMINATED VENEER LUMBER (LVL)

Description of Product

LVL is made from sawlogs converted into veneers. These sawlogs are often known as “peelers” to reflect the veneer manufacturing process (“peeling”) and the fact that ideally they are straighter, more cylindrical and with less taper than the sawlogs used in a sawmill.

The wood veneers (typically 3mm thick), are laminated together using a phenolic adhesive in a continuous process, as shown in Figure 21.

FIGURE 21 **Schematic Flow Diagram of the LVL Manufacturing Process**



Source: http://www.nzwood.co.nz/wp-content/uploads/2013/06/NZW14085-SM-LVL-Manufacturing.pdf

Peeler logs are selected for their appropriate quality. They are debarked, cut to length and heated to condition the wood fibres, prior to peeling in a rotary lathe to produce a “ribbon” of veneer. The veneer is clipped to width and segregated into moisture classes for drying to a target moisture content of approximately 6%. Veneers are then sonically measured for stiffness and graded for width, moisture content and visual appearance. A combination of grades allows manufacturers to “lay up” different sequences of veneers to engineer LVL with specific properties for desired uses. The grain direction of all the veneers is similar and predominantly in the longitudinal direction. Veneers are delivered to the press in the predetermined lay-up sequence, passed through a glue applicator, and then positioned to form a continuous “slab” that is subjected to heat and pressure to cure the structural phenol formaldehyde resin. The cured “billets” of LVL, usually 1,200–1,250mm wide by 8–18m long, are then ripped and cross-cut for further processing or customer requirements. LVL leaves the factory with moisture content in the range of 8–15%.

Most of the LVL in Australia and New Zealand is manufactured in a standard range of sizes:

- Thicknesses usually vary from 35–75mm. The most common are 35mm, 45mm, 63mm and 75mm.
- Depths usually range from 90–600mm, with the most common depth production being in the 150–300mm range.
- LVL flange stock (for I-joists) is commonly 45mm or 63mm (1.77" or 2.48") thick.

Major Uses

LVL market segments and end uses in both Australia and New Zealand are very similar. LVL is used in a wide variety of applications:

- Structural applications include beams, headers, columns, formwork, truss chords, I-joist flanges, scaffold plank and structural decking, usually incorporating two or more cross-ply veneers for stability (Figure 22).
- Non-structural applications include joinery, furniture and fittings in which appearance and/or machining qualities are more important than structural reliability and bond durability. LVL for these applications is sometimes curved, covered with decorative overlays, or encased in other materials.

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FIGURE 22

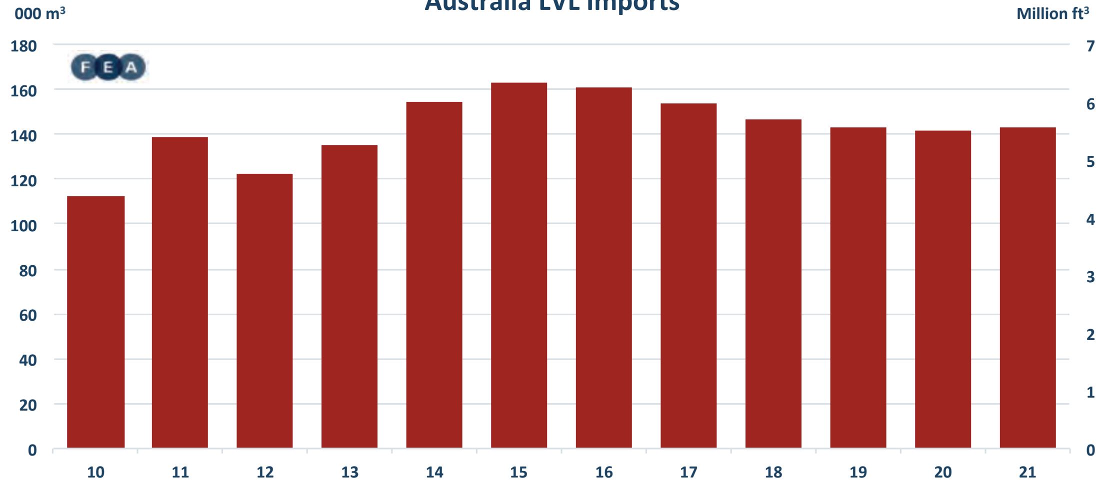
LVL and Use in Construction

In New Zealand, LVL is used primarily in non-residential construction and has not made significant inroads into the residential market. Consequently, consumption of LVL in New Zealand is much less than that seen in Australia on a per capita basis. One of the principal drivers behind this growth is the success of LVL as a substitute for steel. LVL is gaining market share against steel beams in non-residential construction because of its relatively light weight and competitive pricing. LVL has also taken share away from hardwood.

LVL has made significant inroads in the residential market in Australia as a substitute for hardwood sawn timber in applications such as beams, headers, truss cords and purlins. Restrictions on the availability of the hardwood resource have helped to spur gains in LVL market share in this segment. Radiata pine solid timber simply doesn't have the requisite strength properties to be a strong competitor. Furthermore, new houses are characterized by more open plan living, larger spaces and higher ceilings. Many of these features incorporate longer spans and the minimization of floor–ceiling separation — characteristics that in many cases are achievable only through the use of engineered I-joists and LVL beams/headers.

GRAPH 36

Australia LVL Imports



Source: FEA

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Australian LVL capacity cannot meet domestic demand. Recent and forecast imports of LVL into Australia are shown in Graph 36.

Currently Produced in NZ — Yes/No

The manufacture of LVL in New Zealand started in 1992, a few years later than in Australia, with the start-up of the Juken Nissho plant in Masterton. Currently, there are four LVL lines in New Zealand, operating with total annual production capacity of 316,000

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m³: Carter Holt Harvey (Marsden Point), Nelson Pine (Richmond) and Juken NZ. The latter has a line each at its Masterton and Gisborne facilities.

1. Juken New Zealand Ltd ("Juken")

Juken New Zealand (formerly Juken Nissho) is a Japanese joint venture between Juken Sangyo and Nissho Iwai. The company operates two LVL plants (located in Masterton and Gisborne). Both plants use plantation radiata pine. Juken produces 70–80% non-structural LVL for the housing market in Japan, and 20–30% structural LVL used for domestic consumption and exported to Japan.

Juken´s LVL pressing technology differs from conventional LVL lines in that it uses Japanese radio-frequency presses: 4x12' and 4x60' (1.22m x 3.66m and 1.2 m x 18.29m).

The combined annual capacity of the two LVL plants is 126,000 m³.

In January 2018, Juken announced the closure of its veneer line in Gisborne. However, it is still producing LVL using veneers sourced from its other mills in New Zealand.

2. Carter Holt Harvey Woodproducts™ NZ (CHH)

Located in Marsden Point, the Carter Holt Harvey LVL plant was founded in 2001 with annual production capacity of 80,000 m³. The plant is equipped with a 4x130' (1.22m x 39.62m) continuous Dieffenbacher press. In 2011 the facility was refurbished, adding an additional 20,000 m³ capacity.

CHH Woodproducts™ New Zealand is part of Carter Holt Harvey Building Supplies Group, owned by Rank Group, together with sister companies CHH Woodproducts Australia and Carters Building Supplies (a network of retail stores supplying a wide range of building materials to the trade and public throughout New Zealand). CHH Woodproducts™ NZ business group manufactures timber, plywood, and LVL.

3. Nelson Pine Industries

Nelson Pine Industries is a wholly owned subsidiary of the Sumitomo Forestry Co., Ltd. of Tokyo, Japan. The Sumitomo Group was established in Japan in 1691, in the field of mineral exploration. The Sumitomo Forestry Co., Ltd. was formed in 1948 and is now one of Japan's largest forestry-based companies.

Nelson Pine Industries was established in 1984 as an MDF manufacturing facility. Its first MDF line started production in 1986, followed by second and third lines commissioned in 1991 and 1997, respectively.

In May 2000, the company announced plans for a NZ$80 million LVL plant investment at its Richmond site. Veneer production began in 2001 and LVL production in 2002. Similar to CHH in Marsden Point, Nelson Pine's LVL plant is equipped with a 4x130' (1.22m x 39.62m) continuous Dieffenbacher press. The plant has an annual LVL production capacity of 90,000 m³ based on radiata pine.

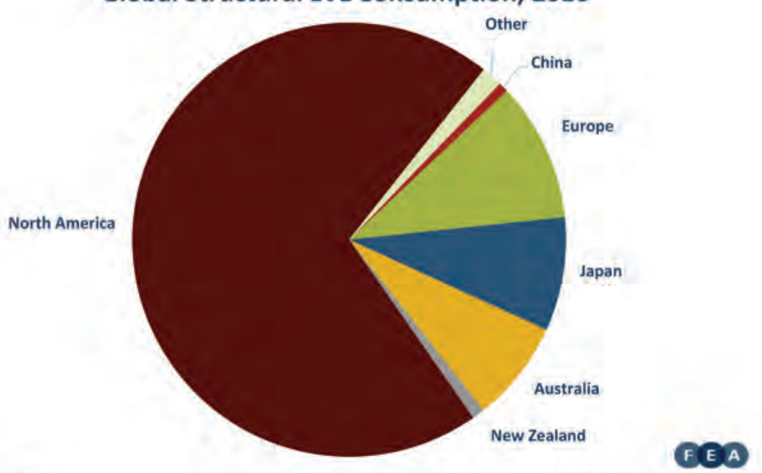
The company's full LVL portfolio includes structural beams and headers, concrete formwork and scaffold planks. Twenty percent of the plant's production goes to the domestic market, 40% is exported to Japan and sold through Sumitomo's distribution network, 30% is exported to Australia (full LVL product portfolio), and the rest goes to North America and the Middle East (LVL concrete form beams and scaffold planks).

Major Importing Countries — Where are the Markets?

Global consumption of LVL in 2016 was 2.89 million m³. North America is the leading consumer at over 70% of global LVL consumption, followed by Europe, Japan and Australia, each of which consume between 8% and 10% as shown in Graph 37.[6]

GRAPH 37

Global Structural LVL Consumption, 2016



Source: FEA

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In North America, the UK, Australia and Japan, the principal applications are beams and headers in residential and light commercial construction. This is because these countries all have 4x2' or "stick-built" construction cultures or, in the case of Japan, substantial use of 4x2' construction.

Most of New Zealand's LVL production is exported, with 87% exported in 2015. The three main destinations were Australia, Japan and the US.

Exports to Australia have been growing in recent years, driven largely by Australia's booming residential market. Exports have almost doubled, moving from 59,500 m³ in 2010 to 110,130 m³ in 2015.

The second-largest export destination for New Zealand LVL is Japan. However, export volumes have been declining in recent years, sinking to 70,000 m³ in 2015. In fact, exports to Japan have been falling by an average of just under 9%/year for the past five years as New Zealand LVL has lost share to Japan's domestic producers.

It is notable that two out of the three New Zealand LVL producers, Juken New Zealand and Nelson Pine Industries, are wholly owned Japanese subsidiaries, selling much of their production through their parent companies' distribution networks in Japan.

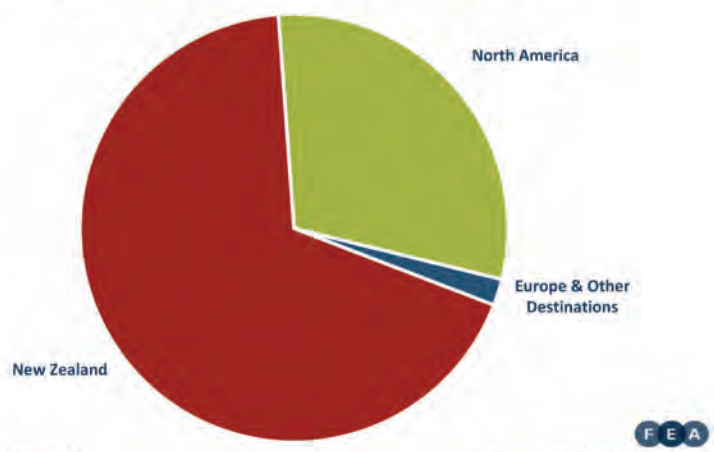
The United States is still a relatively small LVL export market for New Zealand, with export volumes typically not exceeding 3,000 m³ per year. Other, less significant, LVL export destinations for New Zealand include South Korea, China and the Middle East.

Major Exporting Countries — Who is the Competition?

The major market for New Zealand LVL producers is Australia, with imports of 161,000 m³ in 2016 that represent 73% of the country's total LVL consumption that year. The main exporters to Australia have been New Zealand, North America and Europe (Graph 38).

GRAPH 38

Sources of Australian LVL Imports, 2015



Source: FEA

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6 Please note that the data for LVL are not available at the same level of granularity as seen for other wood products.

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In terms of design properties, two types of structural LVL product can be considered:

- Low-grade, referred to as E11, typically has Modulus of Elasticity (MOE) values in the range of 10,000–12,000MPa and is used for light beams and headers and concrete formwork. This grade is produced using mainly radiata pine plantation logs.
- High-grade, referred to as E13 and E14, has MOE values in the range of 13,200–14,000MPa, and is used for higher loads and longer span beams and headers. Because of the relatively low specific gravity and density of radiata pine, this grade is more susceptible to imports from the US and (recently) Europe.

The LVL coming into Australia from North America is typically the higher E13 and E14 grades that New Zealand LVL manufacturers struggle to make with their low-density radiata pine resource. This represents an opportunity of around 50,000 m^3/year if New Zealand manufacturers can produce a higher-stiffness LVL product.

Published Price Series (where available) or Suitable Proxy

Four companies dominate the LVL space in North America: Weyerhaeuser, Boise Cascade, Roseburg and Louisiana-Pacific. They have different prices in different regions and keep this information confidential, so there is no published price series for LVL in North America as seen for other wood products.

In New Zealand, it is difficult to estimate and compare LVL prices given the relatively small volume of domestically produced LVL consumed in New Zealand (and the variety of grades). However, based on FEA analysis in 2016 of LVL average variable production costs in New Zealand of NZ$664/$m^3$, and assuming a gross margin of 25%, a selling price range of NZ$870–900/$m^3$ seems a reasonable estimate.

Key Opportunities and Constraints for a New Zealand Manufacturer

As discussed above, the big opportunity is to expand LVL exports is to target the higher-stiffness E13 and E14 LVL products into Australia (that are currently being supplied by North America and European LVL producers).

However, there are two issues that bear consideration:

1. Most high-stiffness logs are already committed to wood processors in New Zealand. LVL mills require both high stiffness and straight (minimal taper) "peeler" logs to maximise yield from the peeling process to produce veneer. Most logs exported out of New Zealand are industrial A-grade and K-grade logs.
2. Even if more high-stiffness peeler logs were available, the yields of high-strength veneers are low so that the manufacturer then has to find markets for the lower-strength LVL that gets produced from these veneers. The whole of the log output needs to be sold, not just the desirable E13 and E14 LVL products.

One way to overcome this is to look to strengthen the LVL through use of alternate higher-strength veneers, e.g., Douglas-fir or eucalyptus, or some form of fibre reinforcing such as fibreglass sheets. FEA is aware that some work along these lines has been carried out in the past, in one case looking at the shipping container floor market in which tropical hardwoods have historically been used.

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7 LAMINATED STRAND LUMBER (LSL)

Description of Product

LSL uses strands that are typically produced from small-diameter, fast-growing trees, pulp logs or even forest thinnings (Figure 23).

The oriented, flaked strands used to make LSL are bonded with isocyanate resin to form billets up to 3.5" (90mm) thick, 8' (2.44m) wide and 64' (19.5m) long. The characteristic that differentiates LSL from the related Oriented Strand Lumber (OSL) product is the ratio of strand thickness to strand length, known as the slenderness ratio. The slenderness ratio of LSL is >150. The slenderness ratio of OSL is 75–150.

Two types of LSL can be distinguished, either boards in which the strands are all aligned in the direction of the major axis of the product, or boards in which a portion of the strands are aligned in the direction of the minor axis of the product. The former is suitable for use as beams, rafters, sills and columns, and the latter for use as walls, floors and ceilings.

Laminated Strand Lumber was invented in the R&D labs of MacMillan Bloedel in the mid-1980s. Following the formation of Trus Joist MacMillan (TJM) in 1991, the first commercial LSL plant (in Deerwood, Minnesota) was started up in October 1991.

A second TJM LSL plant (in Hazard, Kentucky) started up in 1995. Following the acquisition of TJM by Weyerhaeuser, a third LSL plant was started up in 2002 (in Kenora, Ontario). A fourth LSL plant was started up by Louisiana-Pacific (in Houlton, Maine) in 2008.

FIGURE 23

LSL and Use in Construction

Major Uses

Unlike Parallam® PSL, TimberStrand® LSL was rushed into the market without sufficient market research and validation of its value proposition in key target markets. MacMillan Bloedel had originally intended LSL to be a structural substrate for doors and windows, with Anderson Windows the principal buyer. When the product didn't perform as promised, Anderson backed away and TJM was forced to shift gears and focus on structural framing applications in a plant that had been designed to supply industrial products.

TJM entered the structural framing market with three principal grades: 1.3E, 1.5E and 1.7E (the company also had ICC approval for grades up to 2.1E). From the beginning, the 1.7E LSL product had significant recurring field problems, including problems with weight (700kg/m^3), nailing and swelling. Moreover, the product wasn't profitable; as much as 80% densification was required to make a 1.7E product. This level of densification drove up wood costs and contributed to the field problems. Higher-than-expected volume of "shorts and fines", in addition to lower-than-expected net mill prices for residuals, also pushed up costs.

Despite millions of dollars of R&D, TJM — and subsequently Weyerhaeuser — was never able to profitably manufacture and market a 1.7E product. The grade was eventually dropped by Weyerhaeuser, although Louisiana-Pacific is still manufacturing high-grade (1.75E) LSL at its Houlton plant.

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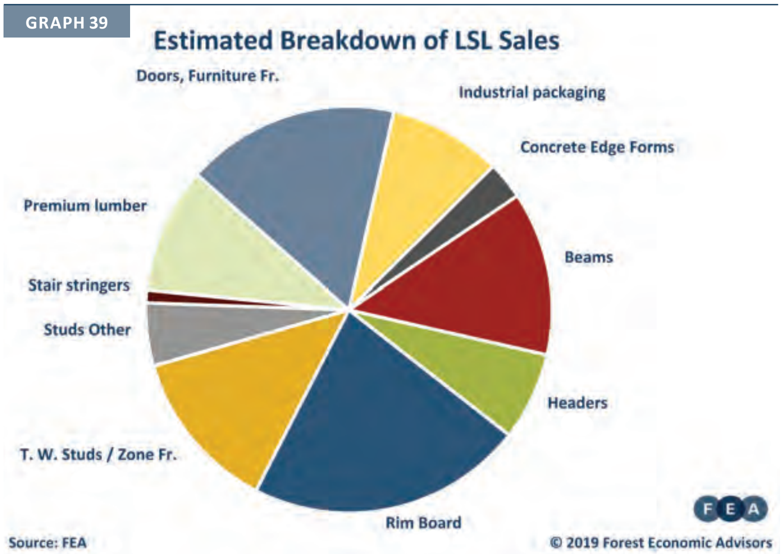
LSL is used in a wide variety of applications, both structural framing and industrial. In Graph 39, we estimate the breakdown by application in 2015.

GRAPH 39



Currently Produced in NZ — Yes/No

No — two companies are currently manufacturing LSL in North America from only two plants, with a total North American annual capacity of 524,000 m³:

1. Weyerhaeuser's LSL plant in Kenora, Ontario, Canada has annual manufacturing capacity of 312,000 m³. This is a dedicated LSL plant and does not produce OSB or OSL.
2. Louisiana-Pacific's Houlton, Maine plant has annual capacity of 212,000 m³. This is an OSB/LSL combination plant and is currently producing both OSB and LSL.

Two other companies have the ability to manufacture LSL and are currently evaluating whether they will enter this market:

- **Tolko:** Tolko built an OSB/LSL combination plant in Slave Lake, Alberta in 2008 that operated for a short while before curtailing operations because of poor market conditions. The "Athabasca" mill reopened in 2014 and is currently manufacturing OSB only. The plant is capable of manufacturing lengths of LSL up to 24' (7.32m). Additional capital investment in remanufacturing and handling equipment will be required for this plant to produce a full range of lengths to 60' (18.3m). If Tolko goes ahead with this investment, we estimate the Athabasca plant's LSL capacity at around 214,000 m³. Even without additional investment, Tolko can produce lengths up to 24' (7.3m), which would be adequate for most industrial applications.
- **Norbord:** Before it was acquired by Norbord, Ainsworth had planned to add a second line — capable of producing LSL — at its Grande Prairie, Alberta facility. In fact, the company had taken delivery of much of the machinery and equipment for the "GP2" line. Following the acquisition of Ainsworth, Norbord made a decision to send the GP2 equipment to Inverness, Scotland, where it will be used to expand OSB capacity at that plant. However, Norbord has not abandoned its interest in LSL and could conceivably manufacture and market LSL out of its Alberta OSB plant — although apparently there are no immediate plans to do so.

Major Importing Countries — Where are the Markets?
Major Exporting Countries — Who is the Competition?

PSL is manufactured and used only in North America.

Although FEA has not seen specific financial details, it appears that all LSL plants to date have struggled to achieve satisfactory returns on investment. Of the four LSL plants built, two are now permanently closed and dismantled (Hazard, Kentucky in 2009 and Deerwood, Minnesota in 2010).

Of the two remaining plants, Kenora is running close to capacity and appears to be performing well. Although the Houlton, Maine LSL plant seems to be making some headway, total LSL volume is still at only a small fraction of plant capacity.

With over 70% of LSL demand tied to new housing construction, FEA foresees LSL demand growing by an average of 6.3%/year from 2016–2021, and are projecting a small increase in capacity by 2019 (Graph 40).

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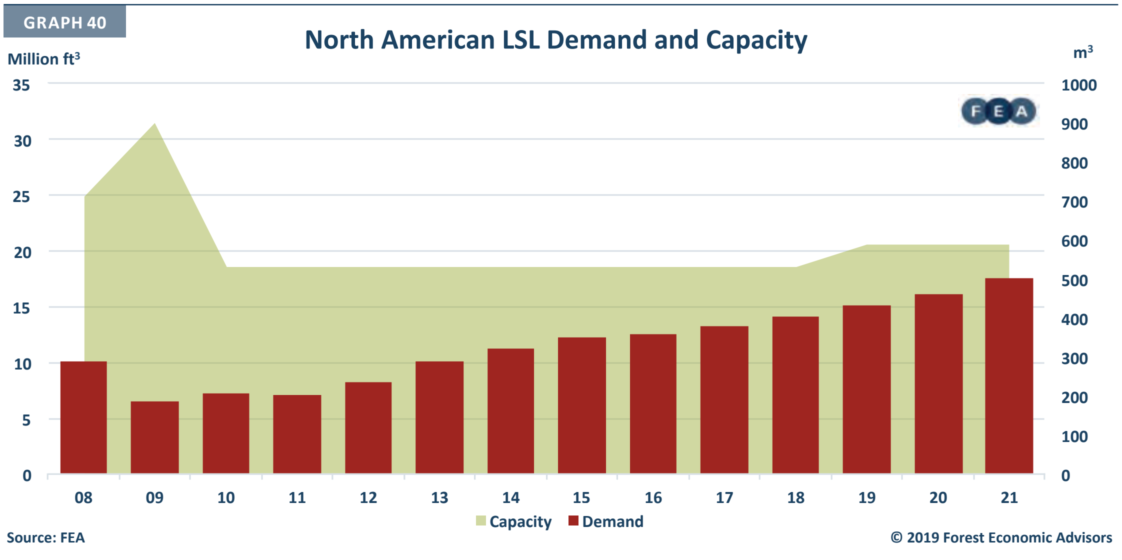
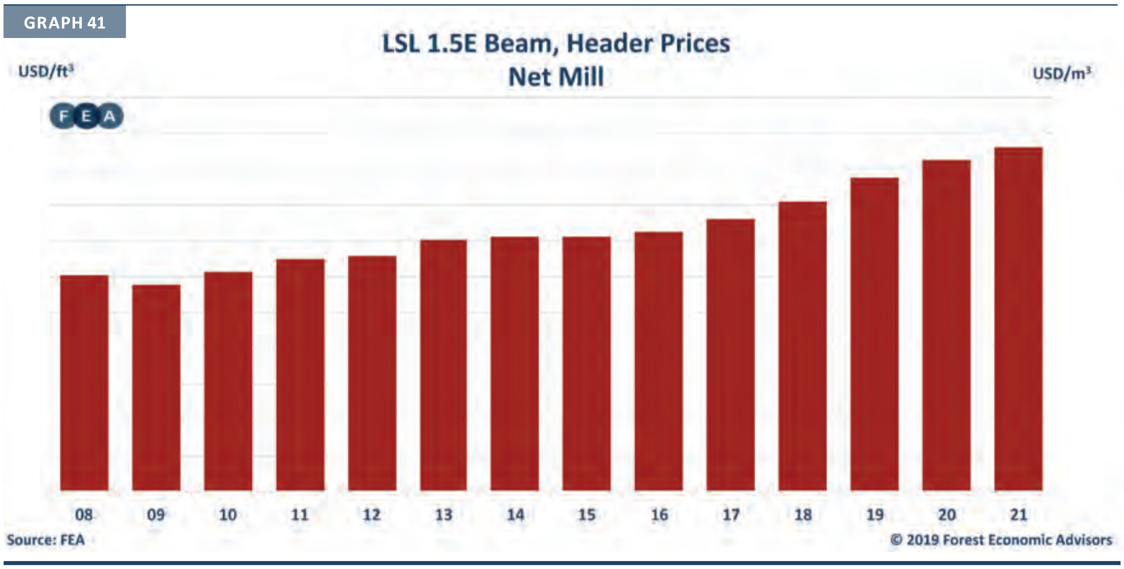
Published Price Series (where available) or Suitable Proxy



There are no published price series for LSL, as Weyerhauser and Louisiana-Pacific are the only two manufacturers operating today.



LSL is used in a large variety of applications and prices vary by application. For the purposes of this report, only beam and header prices are shown in Graph 41.

The main grades for LSL beams and headers are 1.3E and 1.5E. One LSL manufacturer makes 1.75E, but sales have so far been quite limited. Typically, the 1.5E grade sells at a discount to LVL 2.0E of 20%–25%.

Key Opportunities and Constraints for a New Zealand Manufacturer

Any investment in LSL production in New Zealand is going to require a business case and discussions with Weyerhauser, Louisiana-Pacific, Norbord or Tolko as the only parties with the requisite commercial manufacturing intellectual property and nuances around market opportunities.

The minimal optimum-scale plant would produce around 200,000 m³ per year of LSL product.

There is an opportunity for existing structural sawmills to use the lower-value corewood material from the centre of the log as a feedstock to an LSL plant, and produce additional structural grades to supplement the solid wood grades they manufacture from the stiffer outerwood of the log. This would require a significant investigation involving production of specimens that would need to be tested to ensure that necessary strength parameters are being met. The economics would then need to be investigated whereby this corewood would be “sold” into an LSL plant at better than the opportunity cost of exporting it as sawn timber for low-cost construction (concrete formwork) or packaging applications in Asia. An understanding of the capital cost of minimal optimum-scale LSL plant would be needed to calculate an appropriate return on investment measure.

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8 PARALLEL STRAND LUMBER (PSL)

Description of Product

Parallam® is a tradename for parallel strand lumber or PSL. The product is proprietary and the sole manufacturer of PSL world-wide is Weyerhaeuser.

PSL uses veneer as its primary feedstock. The veneers could be bought from a third party or a peeling line established in conjunction with the PSL line. Unlike other veneer-based products (plywood and LVL), sawlogs known as "peelers" are not necessarily the ideal feedstock. Although peelers are straighter, more cylindrical and with less taper than those used in a sawmill, the PSL technology is based on use of lower-value fibre from forest thinnings.

PSL is made from long (1–8', 0.3–2.44m) strands of clipped veneer, coated with phenolic resin and then pressed and cured with microwave energy to form continuous billets up to 30x40cm in cross-section and up to 20m in length.

Parallam® (originally called Dendrion) was invented in the R&D labs of MacMillan Bloedel (MB) in 1969. The original purpose of the technology was to convert forest thinnings into merchantable engineered lumber products. Early product was made with split strands; this method was later abandoned in favour of clipped veneer strands.

Both the product and manufacturing process were developed and refined between 1974 and the mid- '80s. The first commercial plant was a converted PSL prototype plant in Delta, BC that started up in 1990. A second plant was commissioned in Colbert, Georgia two years later. A third plant — a combination PSL/LVL plant — was built in Buckhannon, West Virginia in 1995. More recently, in 2008, Weyerhaeuser permanently closed the Colbert, Georgia plant, leaving two operating PSL plants with a total annual PSL manufacturing capacity of 170,000 m³.

Major Uses

FIGURE 24 **PSL Post-and-Beam Construction**

The product is primarily used as beams, headers, posts and columns in residential and light commercial structures (Figure 24). However, in larger cross-sections, PSL could be considered to be a heavy timber product, compatible with mass timber panel products.

Shortly after commercialisation of the product in 1991, industry leader TJ International and MacMillan Bloedel formed a joint venture limited partnership that combined the engineered lumber assets of both companies into one company called Trus Joist MacMillan (TJM). TJ International was the managing partner of the new company, with 51% of the equity. At the time of the formation of TJM, the combined engineered lumber operations of the two companies included five LVL plants, six I-joist plants, two PSL plants and one LSL Plant. The combined operations of TJM represented 66% of the entire industry capacity.

PSL and LVL were directly competitive products at the time the JV partnership was established. In order to minimize cannibalization, TJM rationalized the two product lines by restricting Parallam production to beams, headers, posts and columns of thicknesses of 3½" and thicker, and Microllam LVL production to beams and headers of 1¾" in thickness.

TJM prospered in the 1990s, growing sales by 170% —to $778 million — by 1998. In 1999, MacMillan Bloedel was acquired by Weyerhaeuser. In 2000, TJ international was also acquired by Weyerhaeuser. With these two transactions, Weyerhaeuser effectively acquired 100% of the assets of TJM, including Parallam® PSL.

Weyerhauser continues to sell PSL in thicknesses ≥ 3 ½" as beams, headers, posts and columns.

Currently Produced in NZ — Yes/No

No — only two Parallam® PSL plants are in operation today, one in the US (Buckhannon, West Virginia) and one in Canada (Delta, BC). The most recent PSL plant was constructed 21 years ago and, given that Weyerhaeuser permanently closed one PSL plant in 2014 and has substantially downsized much of its R&D support, it seems unlikely we will see additional PSL capacity in North America going forward.

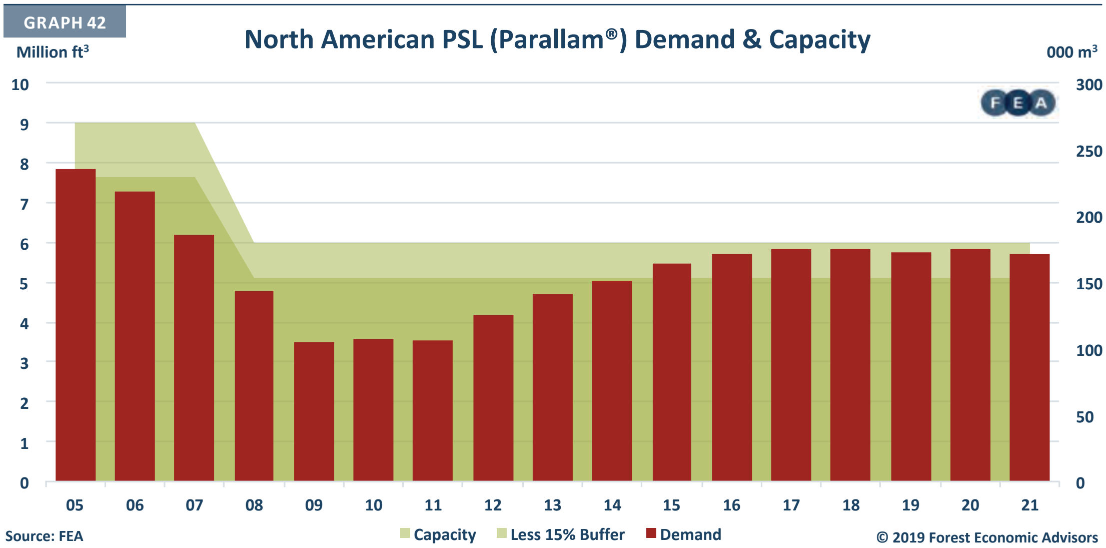
Major Importing Countries — Where are the Markets?
Major Exporting Countries — Who is the Competition?

PSL is today only manufactured and used in North America, although a great deal of PSL was used in non-residential applications in Europe, primarily Austria, during the early 1990s. PSL was also sold into Japan during the 90s.

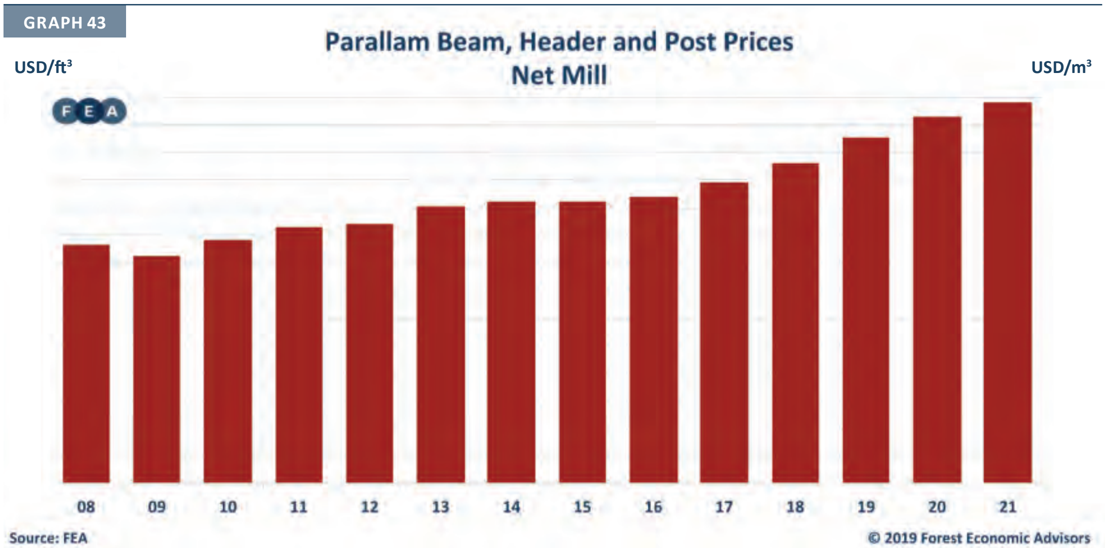
FEA believes that the existing PSL plants are currently operating at close to capacity. As the housing market recovers, demand in excess of current PSL capacity will have to be met by LVL and Glulam.

Weyerhaeuser does not publish operating results by product. FEA has estimated production in Graph 42. With a capacity ceiling of 170,000 m³/year (6 million ft³/year), demand has been capped at slightly below that level.

GRAPH 42



GRAPH 43



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Published Price Series (where available) or Suitable Proxy

There are no published price series for PSL due to the proprietary nature of the business (owned 100% by Weyerhauser).

Higher design values and thicker sections carry more value, and this is reflected in PSL prices that typically carry a 10–15% premium over LVL (Graph 43). For the purposes of FEA's price forecast, a premium of 12% has been assumed. For North America, it should also be noted that 100% of finished PSL goes into high-value, beam, header and post applications. By contrast, an average of 28% of the output of a typical LVL plant goes into relatively low-value flange stock for I-joist production.

Key Opportunities and Constraints for a New Zealand Manufacturer

The majority of the PSL patents have now expired and most of the individuals with product and process knowhow have either left or retired from Weyerhaeuser. Any investment in PSL production in New Zealand is going to require a business case and discussions with individuals known to us who are no longer working for Weyerhaeuser. FEA is aware of another contact with a potential interest in expanding an enhanced version of this technology, having been involved in its commercialisation.

The minimal optimum-scale plant would produce around 112,000 m^3 per year of PSL product.

The technology was premised on adding value to forestry thinnings and could be useful in areas where this wood fibre is available. The Central North Island would be excluded given that thinnings there are being consumed by the existing pulp and paper mills at Kawerau and Kinleith. However, a new veneer plant processing other available logs, or use of any surplus veneer capacity in the region, could provide an opportunity for fibre supply to a PSL plant anywhere in New Zealand.

PSL technology produces structural elements (beams, posts, headers, etc.) that have higher strength properties than we would normally attain from New Zealand-made LVL. This could open up an opportunity to substitute for higher-strength European and North American LVL products being imported in Australia (where New Zealand is currently not able to supply due to lack of high-stiffness veneer to make these higher-grade LVL products). Product testing would be required as a first step to determine what level of strength properties could be attained and how this might be enhanced by blending alternate species, e.g., Douglas-fir or eucalyptus.

9 CROSS-LAMINATED TIMBER (CLT)

Description of Product

FIGURE 25 CLT Panels (5-ply and 7-ply)

CLT is manufactured from kiln-dried, timber boards (lumber) produced by one or more local sawmills (Figure 25).

CLT is the dominant form of mass timber in the world today. CLT is a panel product formed by stacking and then gluing together successive orthogonal layers of sawn timber boards under pressure. The pressing is done typically in either vacuum or hydraulic presses and the panel is then prefabricated (sized and shaped) by computer numerical control (CNC) machines into a construction-ready building element that can be shipped to the job site for easy and quick assembly.

The number of layers in a panel can range from three to seven (and sometimes more), and panels can have door and window openings added, plus routings for electrical and mechanical systems, all before shipment to the building site.

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Typical panel dimensions* are:

- Thicknesses: 105mm (3-ply) to 314mm (9-ply)
- Widths: 2.4–3m
- Lengths: 9–18m
- Typical Spans: 3–11m

**Note that many other thicknesses/lay-ups, widths and lengths are available, depending on the supplier*

Major Uses

Mass timber is a category of framing styles typically categorised by the use of large solid wood panels for floor, roof and wall construction.

Mass timber systems are a complement to light wood-frame and post-and- beam construction (Figure 26).

FIGURE 26 **Mass Timber Systems Complement Light Wood-Frame and Post-And-Beam Construction**

Source: https://continuingeducation.bnpmedia.com/courses/think-wood/mass-timber-in-north-america/

Due to CLT's cross-laminations, the panels afford significant in-plane shear capacity. Since CLT panels resist high racking and compressive forces, they are particularly cost-effective in construction applications for multi-storey and long-span diaphragm applications, e.g., floors, roofs and walls. Furthermore, since CLT panels are typically formed offsite in a factory, this allows for a much shorter onsite construction time. This is a key differentiator for specifiers (architects and engineers) in selecting CLT as their preferred construction material for a project.

CLT is also used in North America as a ground production product, also known as crane mats, rig mats or access mats (Figure 27). The primary purpose of these mats is to provide access — and ground protection — for heavy vehicles and equipment in the building and updating of electrical transmission and distribution networks, gas and oil pipelines, wind plants, power plants and heavy-duty civil construction.

FIGURE 27 **Example of a CLT Access Mat**

This industrial use of CLT as a mat product has not gained acceptance in New Zealand. It is not clear if the key product differentiators, e.g., product cost,

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delivering product to site and lifecycle/reusability factors — the things that make CLT competitive against alternatives as a ground protection product in the US — are as relevant in the New Zealand market (where heavy-duty plastics are more prevalent).

Currently Produced in NZ — Yes/No

1. XLam, Nelson

New Zealand's only CLT plant, XLam in Nelson, has recently closed permanently. This plant was the first CLT plant to be built in the Southern Hemisphere. It had an estimated press capacity of 15,000 m^3/year is now owned by Mayflower Enterprise (also the owner of Hyne Timber).

The Nelson plant was originally built with one Fankhauser vacuum press, but a second, almost identical vacuum press has been added. Dimensions for both presses are similar at 16.3m x 3.4m. The greater amount of manual operation for vacuum presses (compared to mechanical presses) made them more amenable to producing visual-grade CLT with excellent surface finishes. With only one CNC machine, the plant's output capacity was limited to about 10,000 m^3/year.

In July 2017, XLam announced it had ordered a Hundegger PBA 3 CNC machine for the Nelson site as the first stage of a wider five-stage expansion plan. This machine was expected to increase operational capacity by 50% beyond the existing CNC, giving the plant a nominal capacity of around 15,000 m^3/year on a two-shift, five-day operation.

On May 1, 2019, it was announced that XLam would cease operations of its Nelson plant. In the words of XLam CEO, Shane Robertson, "…the existing highly manual, capacity-constrained operation in Nelson has been confirmed to be commercially unsustainable for future CLT manufacture."

2. Red Stag Timber

Red Stag Timber is an independent, privately owned timber company based in Rotorua. It was established in 2003 to operate the Waipa Mill that was originally founded by the New Zealand government in 1939 (and subsequently privatised in 1996). Red Stag Timber has made significant capital investment at the site, including a new USNR Tandem-Quadsaw sawmill line, and produces over 550,000 m^3 of lumber per year, with annual revenue of over $220 million.

Red Stag Timber have recently announced that it will look to invest in a 50,000 m^3 CLT plant at a cost of around NZ$20 million. It is still deciding on location (Rotorua or Auckland) and the feasibility around the steps to scale output. However, the company's expectation is that CLT usage could be underpinned to a large degree by KiwiBuild developments, discussed below. Currently, Red Stag has a vacuum press (16m x 4.5m) with a capacity of about 10,000 m^3/year that will be used to achieve product certification in 2019. Limited-length CLT should be available from early 2020, and full length from later in 2020.

Furthermore, Red Stag Timber is planning two reference projects to showcase the potential of timber as a construction material in large-scale building projects. The first project, in 2019/20, will be five-storey apartments at Clearwater Resort on the northern outskirts of Christchurch, using CLT and other panel products. The Ministry of Primary Industry, through its Primary Growth Partnership, is supporting about 8% of the NZ$20 million Clearwater project. Upon completion, there will be a second commercial/hotel project built in the North Island in 2020/21.

Major Importing Countries — Where are the Markets?
Major Exporting Countries — Who is the Competition?

FEA estimates global CLT capacity in 2018 (for use in construction only) at 1.84 million m^3, growing at 21%/year over the next five years, to reach 4.63 million m^3 in 2023.

Most of this capacity growth is occurring in Europe and North America. In Europe, there is continued growth in capacity investment in Austria and Germany, but the big capacity jump is occurring in the north — in Finland, Sweden and Latvia.

In North America, CLT capacity has been surging particularly in the US Northwest and BC.

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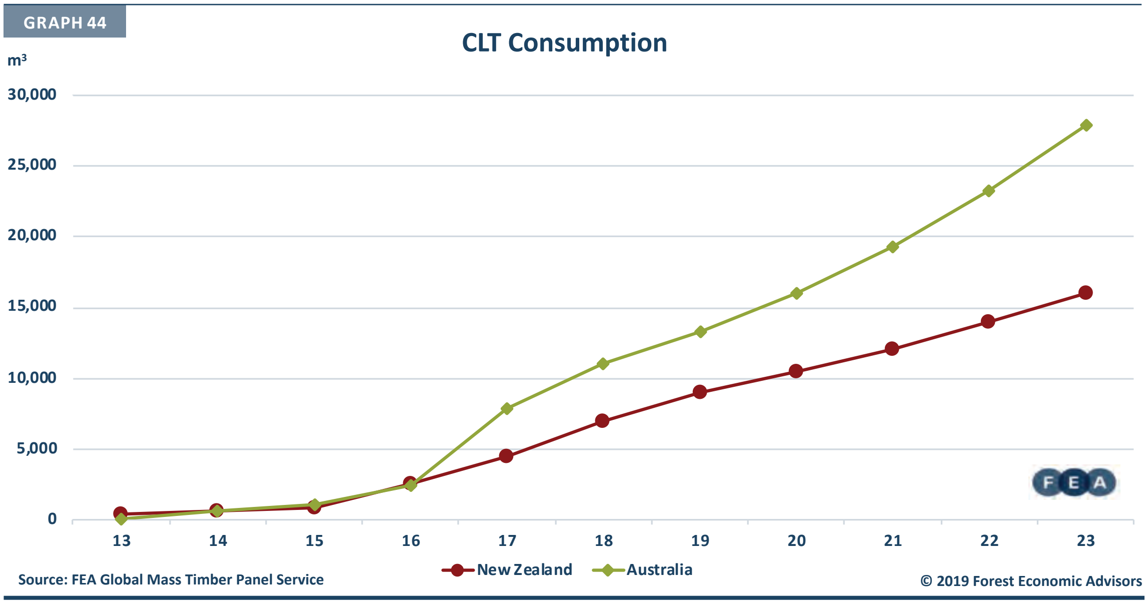
Most of this production is consumed within the wider geographic regions in which it is produced (e.g., in Europe, North America, Japan, Australia and New Zealand). As such, total global exports (between these regions) was only slightly over 20,000 m^3.

Three European companies — KLH, binderholz, Stora Enso — have for the past five years been the principal exporters in the world, with 95% of their exports in 2018 going to Australia and the US. All three of these European companies now have established sales offices in the US, and we expect their export volumes to grow.

None of the other regions have exported any significant volumes of CLT. However, going forward, XLam Australia (with the closure of its New Zealand plant) will become one of the world's largest exporters of the product (albeit due to the very small amount of global exports going outside production regions).



FEA has estimated CLT consumption in New Zealand and Australia, with a forecast to 2023 (Graph 44). Note that total consumption 2023 in both countries (estimated at ~44,000 m^3) could be met by the existing XLam Australia facility at Albury-Wodonga, without even considering competition from European imports.

Published Price Series (where available) or Suitable Proxy

There are no published price series for CLT due to the relatively small size and closed nature of the business. Exports outside major regions are only a small percentage of total capacity — about 1%.

Nonetheless, answering the question "What is the price of CLT?" would be like answering the question "What is the price of a building?"; the price of CLT is a one-off, just as each building that incorporates it is a one-off.

The price depends on a host of variables. Only in rare circumstances is CLT sold as "blanks". Rather, it is sold fully custom-fabricated for job site assembly into one-off structures in custom sizes that result in differing degrees of yield (and therefore cost). Prices must also incorporate the variable costs of design, engineering and modelling, as well as technical selling costs that typically vary across a wide spectrum for each project. Prices may or may not incorporate the costs of sequenced delivery and site assembly supervision. Therefore, there is no commonly applied price for CLT. The price will vary for each building; this further explains why there are no published price series for CLT.

The manufacturing cost of a CLT blank is very similar to the manufacturing cost of stock glulam. If CLT were sold as blanks (which is almost never the case), its price would be similar to that of stock glulam.

For CLT used domestically, it is important to note that New Zealand Standards for treatment of wood products, which are currently under review, will likely require all layers of the CLT panel to be treated as follows:

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- Structural applications to be treated with boron to give H1.2 Durability
- Indoor wet areas, e.g., bathrooms, may require more robust H3.2 Durability, with CCA or approved alternatives

This is significant because most European CLT (made from spruce) is not treated or has only an envelope treatment that would not be acceptable under these revised New Zealand standards. Moreover, the New Zealand market is currently not large enough to incentivise European CLT exporters to invest time, effort and money in developing a treatment technology to meet the New Zealand standards. The XLam Australia plant is be in a position to supply appropriately treated radiata pine CLT panels.

Key Opportunities and Constraints for a New Zealand Manufacturer

For the reasons discussed above, we believe any New Zealand manufacturer will need to establish a CLT factory as an enabler to manufacture value-added modular building components. A New Zealand manufacturer could incorporate CLT into a CNC-finished, flat-packed building solution that could be used in the domestic market as well as being exported. This adds significant value and intellectual property (in terms of building design) that make this approach very appealing. To be successful would require partnering with a distribution company in the target markets to overcome some of the barriers to entry discussed below (which would still be significant).

Another alternative is that New Zealand manufacturers could set up CLT production to supply primarily domestic building and construction projects. The volume requirements for a world-class CLT plant is >30,000 m^3 per annum. Ideally, a CLT plant could be built to supply a dedicated offsite manufacturing facility making CLT volumetric units.

New Zealand CLT manufacturers will need to be globally cost-competitive to underscore the export opportunity for value-added modular building components, and to compete in the domestic market against any imported CLT from Europe and Australia.

The barriers to entry around supplying a full-service offering to an offshore market include the following:

- Understanding local building codes and regulations
- Working with the local specifiers (architects and structural engineers)
- Specifying the CLT panels and producing in-house design drawings, typically using BIM (building information models), in conjunction with the local specifiers
- Managing a sequenced delivery of CLT panels to an overseas site to coincide with the construction program

The European producers have been doing this within Europe and, more recently, with significant projects in Australia and the US. They have significant brand and intellectual property advantages, offshore sales offices or distribution partners, as well as a seasonal need to export product in the northern winter so that their factories can operate year-round. As well, XLam Australia has a new state-of-the-art CLT plant in Albury-Wodonga that is not operating at capacity and will look to supply the New Zealand market after shutting the Nelson plant.

10 WOOD PELLETS

Description of Product[7]

Wood pellets are typically made from a mix of low-value wood residues (such as sawdust and shavings) that are generated in nearby sawmills. Wood chips can be used as well, but they are generally a more costly option.

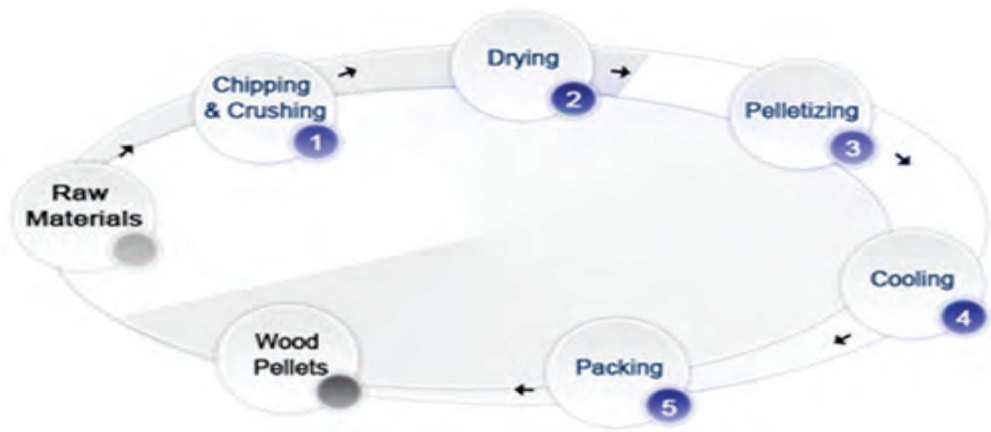
The residue mixture is shredded and compressed into small cylindrical pellets under high pressure when extruded through holes in a press. The natural lignin in wood is the binding agent that holds the pellets together. The pellets are denser than wood chips and have very good handling characteristics. They can be made from a wide range of sources of biomass, with the result that pellets made from different feedstocks will have different energy densities and other characteristics. Not all pellets are equal, and the specific characteristics of pellets must be specified to users in terms of the standards classification to which they have been produced. Wood pellets are a cleantech fuel.

Wood pellet fuel — with its minimal carbon footprint and extremely low ash and sulphur content — is experiencing increasing demand worldwide for residential use as a home-heating fuel, and for industrial use, to either fuel heat plants, e.g. boilers, or be used by electricity generators as a fuel to help reduce emissions from their thermal plants.

In residential applications, pellet-fuelled boilers produce hot water for central heating systems, and for domestic hot water. For commercial and institutional applications, existing coal-fuelled boilers can be converted to run on pellets, although higher performance is usually achieved through the installation of new, purpose-built and fuel-specific equipment. Pellets can be co-fired with coal in large heat plants, say for electricity generation, but will require specific fuel storage and handling facilities. Generally, pellet fuel can be incorporated into the existing coal-based power generation infrastructure. Pellets may be mixed with coal and burned with relatively minor modifications or capital outlay, or may need to be further pulverized according to the nature of the fuel supply equipment design for the heat plant.

FIGURE 28

Schematic Flow Diagram of the Wood Pellet Process



Source: http://www.pelletmill.net/Wood-Pellet-Plant.html

The process for producing wood pellets can be broken into five main processing steps, illustrated in Figure 28.

1. Chipping and crushing

Wood fibre for pellet manufacture is typically received as wood chips, sawdust and/or shavings (referred to as wood residues) from nearby sawmills. These wood residues are screened to remove any impurities (especially bits of metal or stones) and then reduced into much smaller, uniformly sized particles. When the thickness is larger than 10mm, or the size is greater than

7 The Description of Product has been largely extracted from a Bioenergy Association of New Zealand (BANZ) paper. It is referred to as BANZ Occasional Paper 18 *New Zealand Wood Pellets — Making the most of National and International Opportunities*. See https://www.bioenergy.org.nz/documents/resource/OP18-NZ-woodpellets-making-the-most-of-national-and-international-opportunities.pdf.

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50x50mm, a wood chipper is needed to chip the materials into smaller pieces. A hammermill is then used to further crush these small pieces into particles of less than 3mm in diameter.

2. Drying

After the wood fibre has been screened and crushed, drying is required since most raw wood materials (wood chips and sawdust) are "green" wood fibre with moisture contents of 50%+. The optimal moisture content for pelletising is 13–15%, so drying, e.g., using a rotary dryer, is required in the wood pellet plant to reduce the moisture content.

3. Pelletising

After crushing and drying the raw material, it is ready for the pellet mill. The pelletizing machine or press is the key piece of machinery in the plant. Typically, a ring die press is used that incorporates a ring-shaped die and set of rollers that reduce wear and tear between die and rollers (and require less energy use). The dried fibre is simply forced through the ring die press to form pellets of a uniform size and shape, optimal for combustion. Although starch can be added as a binder, chemicals are not necessary as the fibres stick together due to the naturally occurring lignin in the wood.

4. Cooling

After pelletizing, the temperature of wood pellets is 70–90°C and the moisture content is close to 17–18%. A cooler (using air moving in a counterflow direction to the pellets) is used to decrease the surface temperature of the pellets close to ambient air temperature and reduce the moisture content to 15% or slightly lower.

5. Packing

To protect the wood pellets from getting damp, and to improve storability, packaging is required. This can be in 15kg bags for residential sales via retailers, e.g., hardware stores, or sold in bulk bags for industrial use. Pellets can also be delivered by truckload to direct users or loaded into the holds of ships for export.

FIGURE 29

Radiata Pine Wood Pellets (diameter = 8mm; length = 40mm)

Major Uses

Wood pellets (Figure 29) are primarily used as a heating fuel, although they do have some niche applications — ranging from use as drilling additives to animal bedding. The two major markets for pellets are as fuel in the residential and industrial segments. Wood pellets can be made from hardwood or softwood fibre residues. Wood pellets have a few important advantages for use as fuel:

- Uniform characteristics
- High energy density
- Ease of handling
- Can be produced to specification
- Can be sold in bags suitable for residential use
- Low emissions and low waste ash production

Residential pellets (sometimes called premium heating) are used in pellet stoves and pellet-fuelled central heating systems. Consumers will typically buy 15 kg bags of pellets from a local retailer and store in the home. Industrial pellets are finding huge demand as a substitute for coal in large, utility power stations, largely motivated by government policies that promote renewable energy and the reduction of greenhouse gas emissions. This occurred initially in northwestern Europe (the Netherlands, Belgium,

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Denmark and Sweden) and the UK, but is now a growing opportunity in North Asia (Japan and South Korea).

There is a difference in wood pellet quality between residential (premium) grade and those used in industrial applications. All grades have the same required diameter (typically 6mm or 8mm) and length (less than 40mm) specifications, but premium pellets have the following four key characteristics (per the Pellet Fuels Institute in the US):

- Higher durability (>96.5), generally related to higher density giving less breakage and fines
- Lower fines (<0.5%, compared to <1% for industrial grades)
- Lower ash content (<1%, compared to up to <6% for industrial grades)
- Moisture content (<8%, compared to <10% for industrial grades)

ENPlus is a premium wood pellet standard agreed by the European Wood Pellet Council back in 2011. The objective was to create a quality standard to make the trade of wood pellets as a commodity simpler, with an understood price-to-quality relationship. This standard is used not only in Europe, but also by wood pellet manufacturers in North/South America and Asia (producers that are part of the ENPlus premium wood pellet certification scheme). The three grades, A1, A2 and B, are shown in Table 14.

TABLE 14 **ENplus Premium Wood Pellet Requirements**

Property	Unit	EN*plus* A1	EN*plus* A2	EN*plus* B	Testing standard [11]
Diameter	mm	6 ± 1 or 8 ± 1			ISO 17829
Length	mm	3,15 < L ≤ 40 [4]			ISO 17829
Moisture	w-% [2]	≤ 10			ISO 18134
Ash	w-% [3]	≤ 0,7	≤ 1,2	≤ 2,0	ISO 18122
Mechanical Durability	w-% [2]	≥ 98,0 [5]	≥ 97,5 [5]		ISO 17831-1

Source: https://www.pelheat.com/wood_pellets.html

Demand for wood pellets in New Zealand is relatively small and stagnant, with moderate growth in the residential market occurring in some regions to replace open fires with clean-technology low-emission heating, driven by changes to Regional Council policies around air quality.

Currently Produced in NZ — Yes/No

There are two major wood pellet producers in New Zealand — Nature's Flame and Azwood Energy — as well as other smaller manufacturers, e.g., Niagara, that are more niche/regional players.

1. Nature's Flame[8]

Nature's Flame was established by Solid Energy, and its single wood pellet plant operating today was built in 2009 in Taupo. Norske Skog Australasia bought the business in 2015 as part of a diversification strategy away from newsprint, but the European parent went into bankruptcy and was bought by Oceanwood Capital Management — the current owners. The Taupo plant has had a chequered history, caused largely by difficulties in getting sufficient heat onsite to dry the wood residue feedstock. The plant has a capacity of 85,000 tonnes/year of wood pellets based on a feed of 170,000 tonnes/year wood fibre. However, due to energy constraints, the plant has only ever run at about 30% of its capacity.

In June 2019, Nature's Flame reached agreement with Contact Energy for supply of 22MWt of geothermal energy. The energy supply system is expected to be fully operational by November 2019. This will allow the wood pellet plant to operate at capacity and will facilitate further expansion, allowing Nature's Flame to begin exporting wood pellets to renewable energy markets in Asia — particularly Japan and South Korea (see further commentary in section on FutureMetrics Reports below).

8 An excellent review of Nature's Flame's history and the geothermal energy expansion project can be found in the Proceedings 41st New Zealand Geothermal Workshop, November 25–27, 2019, Auckland, New Zealand. "Geothermal on a truck — the Nature's Flame geothermal direct use project" by Craig Stephenson and John Goodwin.

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2. Azwood Energy

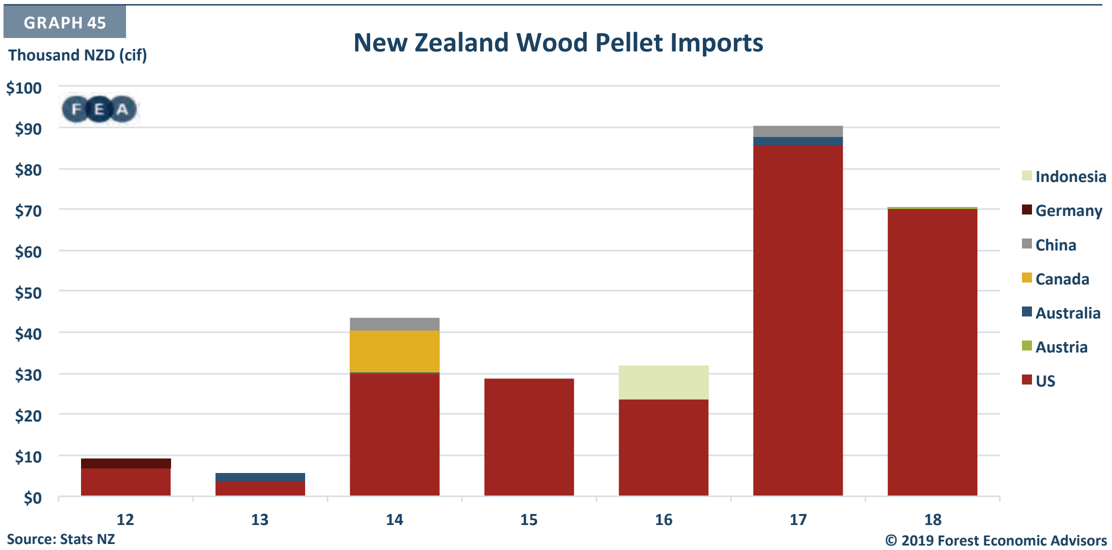
Azwood Energy is New Zealand-owned/-operated (for almost 40 years) and moves some 1,000,000 m^3 of raw and processed product each year across the entire range of wood fuels (hog fuel, chip, wood pellets). The company's products are fully accredited and endorsed by the Bioenergy Association of NZ (BANZ), and are shipped throughout New Zealand, Australia and Southeast Asia.

The company's wood pellet fuel brands, Firetime® and Onfire®, can be used for domestic and commercial use. There is an Onfire® Premium brand that is exceptionally low-ash. Wood pellets for residential use come in bag sizes of 10kg, 15kg and 20kg. The Firetime® product is also sold as a bulk wood pellet fuel for small to medium-sized heat demand users such as schools and office buildings.

Azwood Energy note that all of its fuels come from Nelson wood fibre grown in low-ash, low-silica soils.

New Zealand's imports of wood pellets are shown in Graph 45. Data from Statistics New Zealand show only the value of wood pellet imports, not the quantity. Clearly, the US has been the major importing country.

GRAPH 45



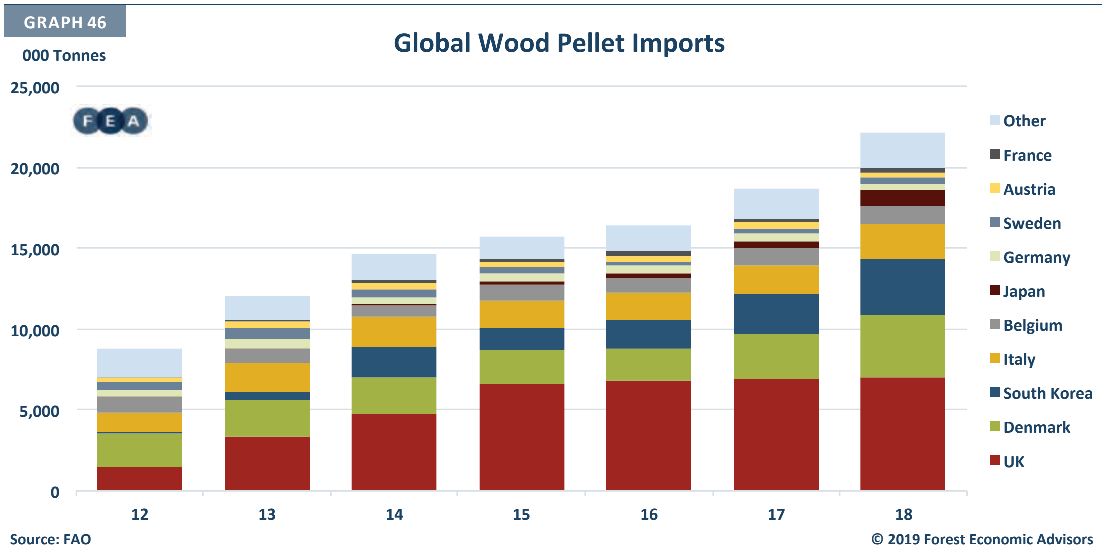
Source: Stats NZ © 2019 Forest Economic Advisors

New Zealand exported some wood pellets in 2012–2014 (ranging from $75k to $150k per year), but there have been no recorded exports since then.

Major Importing Countries — Where are the Markets?

Graph 46 shows that global trade in wood pellets was about 22 million tonnes in 2018. The UK, Denmark, South Korea, Italy and Belgium are the five largest importers, all taking over 1 million tonnes in 2018. These five

GRAPH 46



Source: FAO © 2019 Forest Economic Advisors

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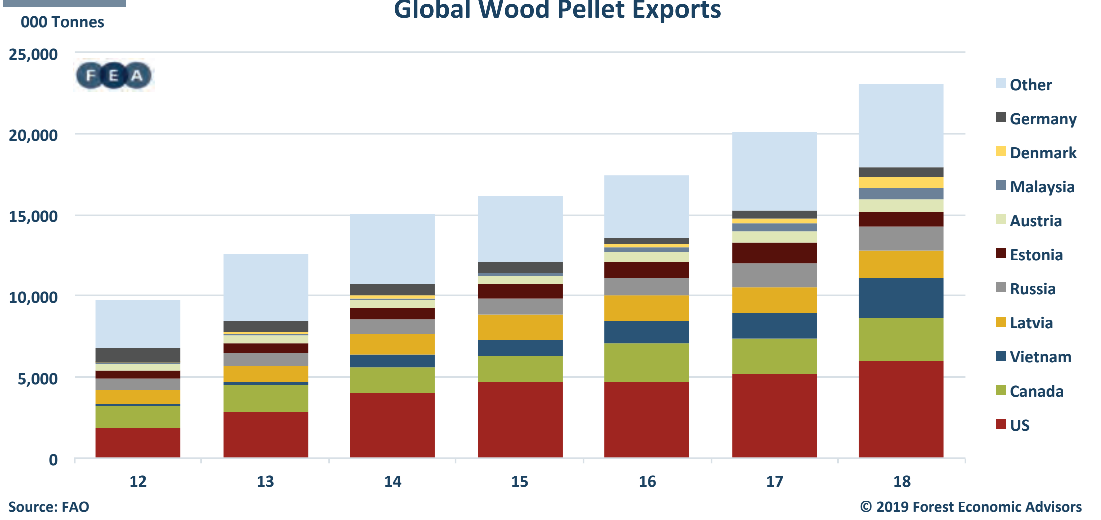
countries represent about 80% of the traded wood pellet market. The top ten countries imported just over 90% of the global market.

Major Exporting Countries — Who is the Competition?

GRAPH 47



Graph 47 shows that the top two exporters — the US and Canada — supply just over 37% of the market. The top ten exporters supply about 78% of total pellet exports.

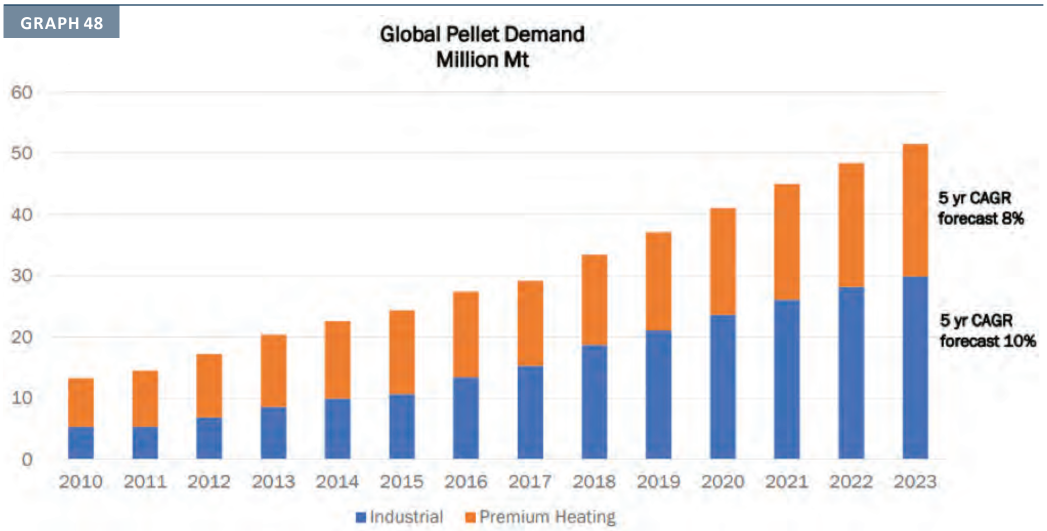
FutureMetrics Reports

FutureMetrics is a well-known and highly respected US consulting firm that provides information, operations analysis, market guidance and strategic advice to the wood pellet sector. It offers a number of free papers and presentations for download at www.futuremetrics.info. The information here is from their *North American Pellet Quarterly Report,* 2018Q4 issue (an example of one of the papers available for free download).

Graph 48 shows historical/forecast global wood pellet demand for the industrial and residential (premium heating) market segments. Five-year CAGR forecasts are 10% for the industrial wood pellet sector and 8% for the residential sector.

Historical and forecast industrial wood pellet demand by country can be seen in Graph 49. Projected growth in the Japanese and South Korean markets is significant.

GRAPH 48



Source: www.futuremetrics.info

Graph 50 shows supply countries into these two North Asian markets in 2018. Canada and Vietnam make up 94% of supply to Japan, whereas Vietnam, Malaysia and Thailand make up 91% of supply to South Korea.

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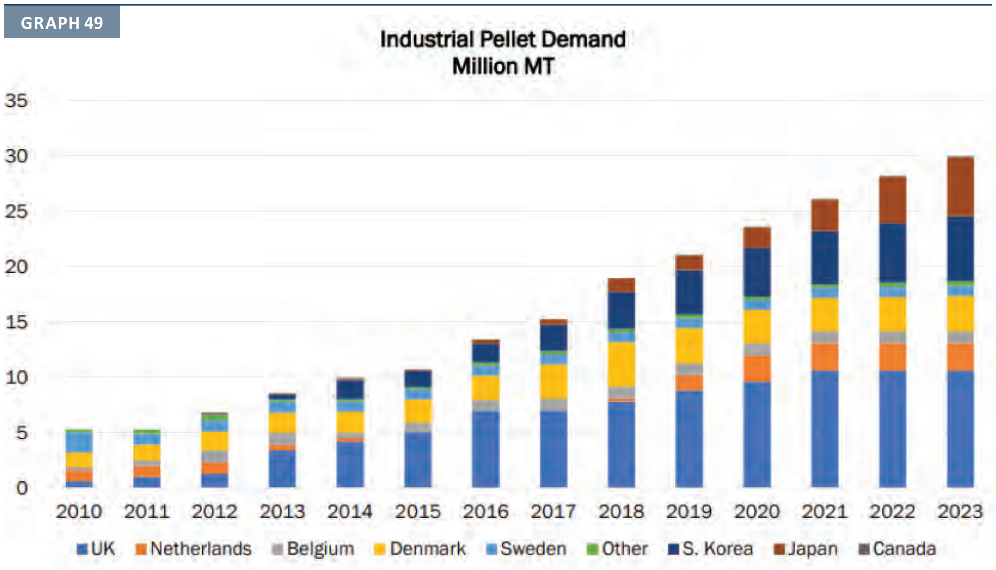
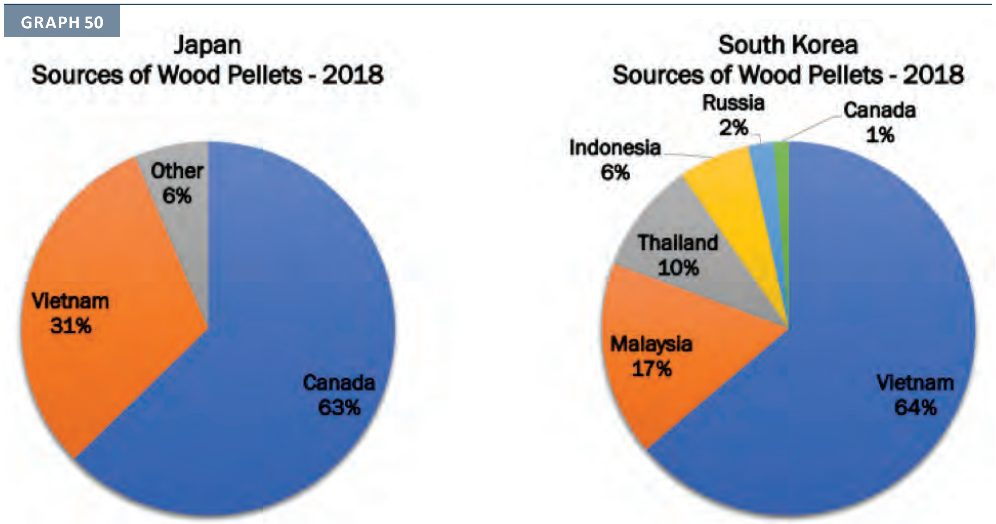
GRAPH 49



Source: www.futuremetrics.info

GRAPH 50



Source: www.futuremetrics.info

Published Price Series (where available) or Suitable Proxy

The most well-known and recognised source of pricing information on the wood pellets industry is Argus Media Group. Argus prices are used extensively by energy companies, governments, banks, regulators and other organisations as benchmarks for derivatives and as indexes in physical contracts. Argus prices cover crude, petroleum products, natural gas and LNG, petrochemicals, electricity, biomass, biofuels, fertilizers, metals and coal. They are accepted as accurate and reliable indicators of the real value of energy and related commodities.

See https://www.argusmedia.com/en/bioenergy/argus-biomass-markets.

Argus offers a Biomass Markets service for the international wood pellet, wood chip and palm kernel shell sectors. This is a convenient way to access prices, news and analysis for the global biomass industry. Several wood pellet markets are covered:

- Spot industrial wood pellet prices: cif northwest Europe, fob Portugal, the Baltics and Vietnam
- Spot premium wood pellet prices: delivered Northern Italy
- Spot wood chip prices: cif northwestern Europe
- Spot palm kernel shell prices: fob Indonesia
- Wood pellet and wood chip forward prices
- Wood pellet freight rates for key trading routes from North America, Portugal and the Baltics into northwestern Europe

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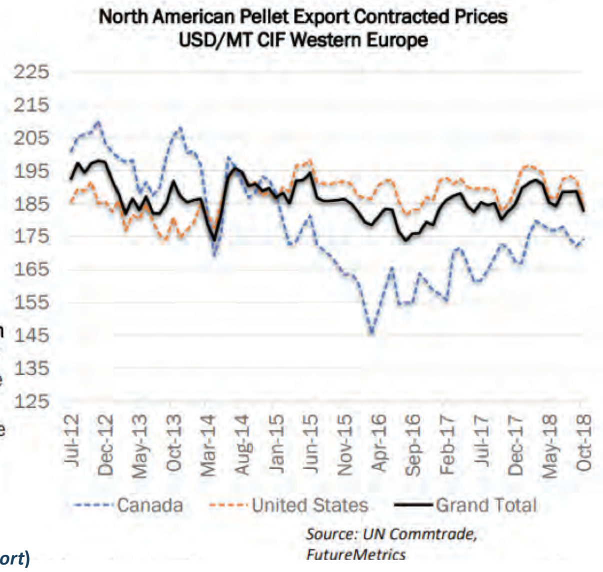
FutureMetrics, discussed above, reports a price series in their North American Pellet Quarterly Report. This is shown in Graph 51 (2018Q4 issue, available for free download from their website).

GRAPH 51

There are spot markets for wood pellets, however the vast majority of industrial wood pellets sold from North America are under long-term bilateral contracts. These contracts are typically, though not always, in local currency, which helps explain why the average contract price from Canada is now significantly lower than from the United States – since the Canadian dollar is comparatively weak (though it has recovered some recently).

In Q3 2018, FutureMetrics North American pellet export price index was $188.84/MT (CIF, Western Europe and UK). The average price of wood pellets from the United States was $192.28/MT, while the average price from Canada was $172.18/MT.



Source: www.futuremetrics.info
(2018Q4 *North American Pellet Quarterly Report*)

Key Opportunities and Constraints for a New Zealand Manufacturer

The growth of wood pellet demand globally, especially in Japan and South Korea, offers New Zealand manufacturers an opportunity to expand production (Nature's Flame has already indicated a desire to do so), as well as possibilities for new entrants to establish greenfield wood pellet plants at suitable sites in New Zealand.

The domestic market is well catered to by existing players that are established in the Central North Island and the South Island — where most residential pellet fires have been installed. There is expected to be some ongoing growth for biomass-based fuels, particularly in government facilities such as schools, hospitals. etc. As well, there may be unique situations that evolve due to the densification that comes about from pelletisation. For example, the Tairāwhiti region has a lot of slash left in the forests that could potentially be used to power a large co-gen plant. However, the cost to transport forest residues in this raw form may be prohibitive. An option, subject to an economic assessment, could be to install a wood pellet plant in the central East Cape region to improve logistics for getting a more dense and concentrated fuel source delivered to the co-gen plant. This has a further benefit of creating regional employment in a remote area that needs new industrial opportunities.

Despite the above, the major volume opportunity will be the export market. Given this export focus and the fact that energy demands are moderate for wood pellet production versus other wood processing alternatives, the key factors that will drive investment returns are low cost, suitable fibre delivered to the wood pellet gate, and proximity to a port for exporting to the target market. Availability of this fibre and its opportunity cost for other types of wood processing need to be carefully evaluated for each opportunity identified.

EXPORT POTENTIAL OF NEW PRODUCTS

New products being developed globally from a range of wood species may have potential to be manufactured in New Zealand for domestic use, and as a possible beachhead to the Australian and Asian markets. These wood products can generally be categorized into four main areas of focus:

- **Structural products —** new types of engineered wood products for construction, ideally suited for prefabrication use
- **Thermal insulation products —** wall and ceiling systems with enhanced thermal properties
- **Durability products —** exterior products based on green chemistry, avoiding traditional chemicals that are not perceived as environmentally friendly
- **Biobased fuel and chemical products —** extraction of valuable wood-based chemicals from residues, e.g., biofuels and bioplastics

STRUCTURAL PRODUCTS

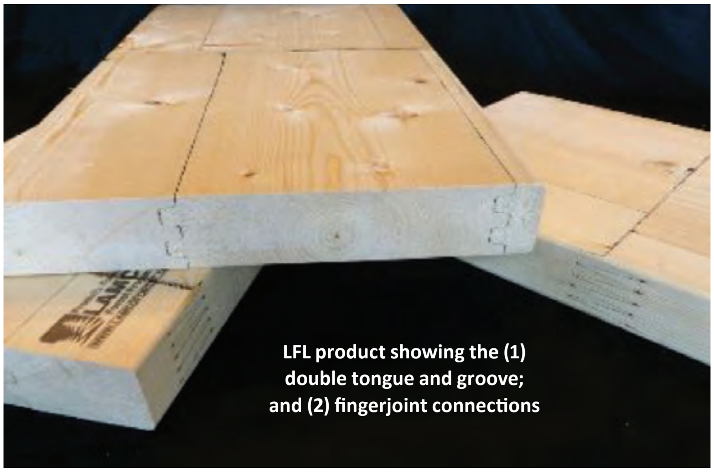
Mass timber products such as LVL, CLT and glulam require significant processing and are composed of solid wood (and adhesive) throughout their cross-section. This makes them a relatively expensive timber option in terms of producing the necessary structural properties for the spans and loads required in various building typologies. A number of alternative technologies have emerged into commercial use that may offer more cost-effective opportunities for radiata pine wood products.

LFL® Advanced Framing Lumber — www.lamcoewp.com

LFL, or laminated finger-jointed lumber, is manufactured by Lamco Forest Products in St. Félicien, Quebec (Figure 30). The company uses short lengths of timber of various cross-sections and manufactures them into larger cross-sections using patented tongue-and-groove edge and finger-joint technology.

FIGURE 30

LFL



Source: www.lamcoewp.com

The manufacturing process is described on the company's website as follows:

- **Raw materials:** 2x4 and 2x6 are cut into short lengths and tested for moisture, and pieces with major defects are removed to ensure consistency and stability.
- **Profiling:** The LAMCO Joint (double tongue-and-groove) is profiled, removing minor edge defects.
- **Panelising:** The small profiled boards are glued and assembled into panels.
- **Ripping:** Panels are ripped to the final desired depth or its multiple (up to 16").
- **Finger-jointing:** Short boards are finger-jointed into long boards of the desired length (up to 32'1").
- **In-line testing:** Each board is tension-tested to ensure structural integrity.
- **Planing and labelling:** The product is planed, stamped and labelled in accordance with third party inspection guidelines.
- **Final inspection and packaging:** Each piece in inspected again, then carefully packaged before shipping.

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LFL is available in a range of strength grades, including 1.6E, 1.7E, 1.9E and 2.1E. It is our understanding that the variable manufacturing costs for the lower-strength grades are approximately 20% below those of LVL.

This technology may offer an opportunity for New Zealand sawmills to add value to offcuts and lower-strength boards by incorporating them into an engineered product.

Leno® Plus — www.zueblin-timber.com

Zueblin Timber is a German company that has developed the Leno® Plus engineered wood product to complement more traditional timber building elements. Described as the "perfect building envelope", Leno® Plus was specifically developed for external wall construction to extend the Leno Building System. The only difference to traditional CLT is the internal layer — a stable and large format laminated veneer lumber (LVL) plate — that replaces the internal layers of the elements (Figure 31). Layers of softwood boards are glued onto the LVL from both sides. The room-side lamella layer can be delivered with pre-routed service channels that allow a simple and fast cable and/or pipe installation. Leno® Plus differs from other CLT due to its enhanced air tightness. Owing to the central layer of LVL, there are no joints in the external wall. Both a breathable and airtight envelope is created. Heat loss is thus reduced, and connection detailing and joining are significantly simplified.

FIGURE 31

Leno® Plus Timber Element

Leno® Plus timber element showing the LVL central lamella

Source: www.zueblin-timber.com

Panobloc® — www.techniwood.fr

Techniwood International Group is a French company with the aspiration to become the leader of industrial, sustainable, prefabricated building systems in France and abroad. The company has developed Panobloc®, a new generation of CLTi (cross-laminated timber with insulation) that encompasses the best features of existing wood panels (timber frame and CLT).

Panobloc® is a cross-fold panel composed of several layers of timber crossed at 90° and offset, then filled in with insulated materials (Figure 32) to give the required performance characteristics (thermal, fire- and structural-resistance, acoustics, etc.).

Panobloc® can incorporate a wide range of insulation materials (wood, glass or rock wool) within the same panel. Dimensions range from 6–60cm thick and up to 30 m² (8.5x3.5m in length and width). It is used in structural walls, curtain walls, floor–ceiling and roof panels, and can be used with all substructure types (concrete, metal or timber).

FIGURE 32

Panobloc® Panels

Panobloc® panel with insulation (left) and as structural elements in a building (right

Source: www.techniwood.fr

Mass Plywood Panels — www.frereslumber.com

Freres Lumber Company is a US-based company that produces both veneers and solid wood timber products. The company has two locations in Lyons, Oregon and Mill City, Oregon. Their manufacturing operations include small-diameter and large-diameter veneer plants, a veneer drying facility, a small stud mill, a plywood plant and a cogeneration facility.

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Freres has developed a new-to-market, veneer-based, engineered wood product: Mass Plywood Panel (MPP). MPP is a large-scale plywood panel with maximum finished panel dimensions up to 12' wide by 48' long and up to 24" thick. The panels may be customized to fit specific projects, constructed in 1"-thick increments that provide superior strength and performance (Figure 33).

FEA understands that the manufacturing process involves the following steps:

- Manufacture of "plywood panels" with varying percentages of veneer laid crosswise
- End finger-jointing of panels to make lengths up to 48'
- Some method of edge laminating to get to widths of up to 12'
- Laying up the panels and cold pressing to make the thicknesses up to 24"

FIGURE 33 **Mass Plywood Panel**

Source: www.frereslumber.com

The company claims that the use of veneer — and all the veneer grade and lay-up possibilities — will enable a more precise engineering of panels, which in turn will allow Freres to achieve the structural attributes of a CLT panel with 20–30% less wood.

One significant difference between CLT and MPP is its appearance. A plywood face with its wavy grain pattern, with plugged knots may not have as much appeal to architects as CLT.

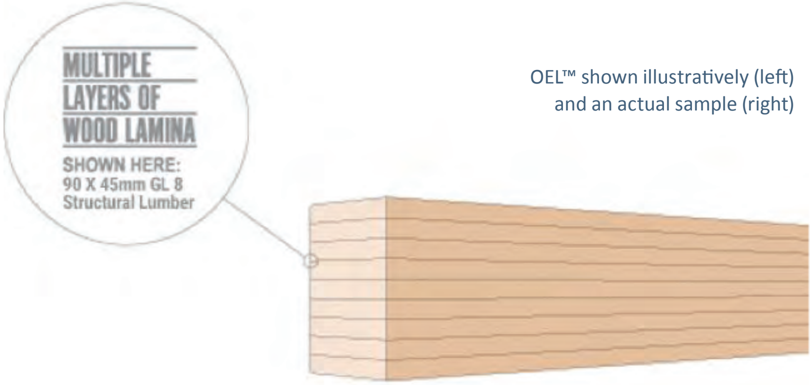
If MPP does gain traction, it could change the veneer market and be a potential boon to LVL manufacturers in that it would breathe new life into the "plywood" industry, and provide a relatively high-value home for residual veneer.

OEL™ — www.woodeng.co.nz

Wood Engineering Technology Ltd (WET) is a New Zealand-based company that has figured out a design and process for turning low-value weak wood into high-value structural-strength lumber. The company has called this new structural lumber "optimised engineered lumber" or OEL™ for short (Figure 34). Every piece of OEL™ is built like an I-beam — strong, straight and ideal for building houses.

OEL™ is a direct substitute for solid structural lumber produced in a traditional sawmill. However, OEL™ is a superior product with a higher performance rating than solid lumber and comparable to other high-performing engineered wood products — but at an attractive price point. OEL™ is able to be manufactured from lower-value New Zealand radiata pine K-grade or similar logs

FIGURE 34 **OEL™**



OEL™ shown illustratively (left) and an actual sample (right)

Source: www.woodeng.co.nz

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that are abundantly available and exported in large quantities.

A major advantage of OEL™ is that it grades as glulam, a form of laminated engineered wood product, and glulam out-performs the market specification in New Zealand and Australia for comparably graded structural lumber — for which OEL™ is a direct substitute. The product is also well suited to replace steel and concrete as wood increasingly becomes a sustainable and high-performing building material choice in medium-/high-density and commercial building applications.

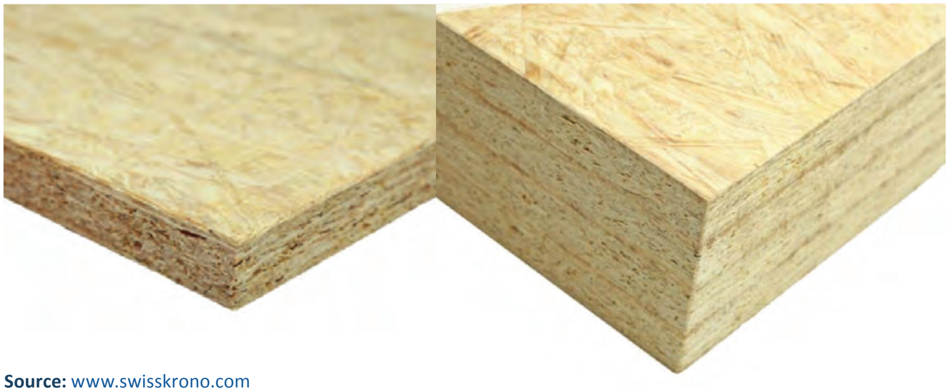
Magnumboard® — www.swisskrono.com

Headquartered in Switzerland, the SWISS KRONO Group is a world leading manufacturer of panel products, currently employing around 5,100 people globally. Construction products include raw chipboard subfloor boards, OSB, MDF and HDF. The company also has a range of interior products and laminate flooring.

SWISS KRONO has developed an OSB substitute for CLT. Called Swiss Krono Magnumboard®, the system is patented and can only be produced by authorized licensees (Figure 35). The business model operates as follows:

FIGURE 35

MagnumBoard®



Source: www.swisskrono.com

- SWISS KRONO first makes "OSB/4" panels that are 25 mm thick.
- The production plant is in Heiligengrabe, Germany.
- The product is produced from forest thinnings of spruce, also harvested in Germany.
- The panels, which can be made in lengths up to 18m, are shipped to authorized licensees who then secondary laminate the 25mm thicknesses into thicknesses up to 250mm.
- The licensees also machine the panels using CNC technology.
- The completed panels are either incorporated into prefabricated modules or made into panels that are shipped to the jobsite for assembly (Figure 36). In some cases, they are shipped to other builders.
- According to the manufacturer, OSB/4 is characterized by minimal swelling and shrinkage when exposed to moisture.
- OSB/4 is made with isocyanate resin, and so is 100% formaldehyde-free.

FIGURE 36

MagnumBoard® Used in Construction

Source: www.swisskrono.com

MagnumBoard® used as a structural wall panel

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We understand that the price point of MagnumBoard® is approximately 20% below that of CLT.

Kerto Ripa box™ — www.metsawood.com

Headquartered in Finland, Metsä Wood is part of the Metsä Group, which covers the whole wood value chain from sapling to product. Metsä Wood provides premium-quality wood products for construction, industrial and distribution customers. The company's primary products are Kerto® LVL (laminated veneer lumber), birch and spruce plywood, and Nordic premium timber. Sales were €0.4 billion in 2018, and Metsä Wood employs some 1,500 people.

Kerto-Ripa® box is a structural insulated panel (SIP) used as an enhanced design system for roof and floor elements (Figure 37). Based on Kerto® LVL load-bearing components and structural gluing, the box structure enables the elements to achieve very long spans of up to 20 metres. This makes it possible for structural designers to remove columns and increase design flexibility.

Kerto-Ripa® designed elements can be of both open and closed structure and are insulated to match the specific requirements of any building. Some key facts and advantages claimed by Kerto-Ripa® include the following:

FIGURE 37

Kerto Ripa Box™

Source: www.metsawood.com — Kerto-Ripa® box (or SIP) element being hoisted into place

- Used for roofs and intermediate floors
- Can span 9–20 metres (maximum length is 25m)
- Short assembly time — up to 1500 m^2 of weather protection in one day
- Kerto-Ripa® box slab is five times lighter in weight than equivalent concrete slab
- Kerto-Ripa® enables the main frames in smaller size and a lighter foundation
- The next phase of construction can continue immediately, in dry conditions
- Thermal and moisture behavior of the structures have been carefully tested by the Technical University of Tampere, Finland
- Kerto-Ripa® elements have European technical approval ETA-07/0029 and CE marking

The Kerto-Ripa® design system can be utilized by anybody who enters into a partnership agreement with Metsä Wood. This includes a license agreement to manufacture the elements as verified by the local authority according to local codes and regulations.

THERMAL INSULATION PRODUCTS

Thermal insulation of building systems is generally carried out using four categories of insulating material. as follows:

1. Glass wools (like the Pink Batts brand in New Zealand) are made from fibres of glass plus other ingredients (sand, soda, ash, borax and limestone) arranged using a binder into a texture similar to wool. The process traps many small pockets of air between the glass, and these small air pockets result in high thermal insulation properties.

2. Mineral wools are any fibrous material formed by spinning or drawing molten mineral or rock materials, such as slag and ceramics. The most well-known of these is ROCKWOOL insulation, a rock-based mineral fibre insulation comprised of basalt rock and recycled slag. Basalt is a volcanic rock (abundant in the earth), and slag is a by-product of the steel and copper industry. The minerals are melted and spun into fibres.

3. Rigid foam panels, of which there are really only three types: Polyisocyanurate known as Polyiso (PIR), Extruded Polystyrene (XPS, often called Styrofoam) and Expanded Polystyrene (EPS). Some precursors to form these products come from the petroleum industry, implying they are non-sustainable products with poor environmental credentials.

4. Wood fibre, typically as chips, can be used to make a natural, wood fibre insulation board (Figure 38). The product can be manufactured dry or wet and uses similar fibreboard production processes (in that an adhesive is added and pressing of a formed mat is required).

FIGURE 38 **Wood Fibre Insulation Board**

Source: www.greenspec.co.uk/building-design/woodfibre-insulation-intro/

Industrially produced wood fibre insulation board was introduced around 20 years ago after engineers in the timber-producing areas of Europe devised new ways of transforming timber waste from thinnings and sawmills into insulation boarding. Its uses include rigid insulation, sheathing and sarking for timber frames, roofs and flooring, as well as flexible insulation for studs and rafters.

Major companies in Europe involved in the manufacture of wood fibre insulation board include the following:

- Gutex — www.gutex.de
- Steico — www.steico.com
- Pavatex (now owned by Soprema) — www.pavatex.com
- Heraklith — www.heraklith.com produces a “wood wool” panel by compressing and binding extremely slim and slender shavings

Several companies are trying to establish wood fibre insulation board production in North America, but none have succeeded in any significant way thus far. The most recent major announcement was GO Lab Inc.’s purchase of the closed UPM paper mill in Madison, Wisconsin to produce three types of wood fibre insulation.[9] The production of these fibreboard-type products is not helped by the high capital costs for the processing plant. Furthermore, the market will have to be developed either through increased demand for green products or by adoption of greener codes and standards for building insulation products.

9 See https://www.centralmaine.com/2019/08/20/wood-fiber-insulation-company-closes-on-former-madison-paper-mill-for-1-9-million/

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DURABILITY PRODUCTS

In Europe, the restricted use of toxic preservatives to protect timber against rot and insects in outdoor uses (in-ground and above-ground) has resulted in the emergence of a number of “wood modification” technologies. These technologies can also result in a more stable wood product that requires less maintenance. Furthermore, as sustainability becomes a greater concern in the built environment, consideration of the entire lifecycle, and the embodied energy of construction and interior materials, will become increasingly important factors in the selection process.

Wood modification involves the action of a chemical, biological or physical agent upon the material, resulting in a desired property enhancement during the service life of the modified wood. The modified wood should itself be nontoxic under service conditions; furthermore, there should be no release of any toxic substances during service, or at end of life following disposal or recycling. The different wood modification processes are at various stages of development, and the challenges that must be overcome to expand to industrial applications differ among them.

It should be noted that the above does not necessarily exclude the use of a hazardous chemical in the preparation of modified wood, provided that no hazardous residues remain once the wood-modification process is complete. To modify wood, four main types of processes can be implemented: (1) chemical treatments; (2) thermo-hydro (TH) and thermo-hydro-mechanical (THM) treatments; (3) treatments based on biological processes; and (4) physical treatment with the use of electromagnetic irradiation or plasma. In this document, we will focus only on the three commercial technologies that fall within the first two processes, i.e.,

1. **Chemical modification by acetylation –** Accoya®
2. **Chemical modification by furfurylation –** Kebony Wood
3. **Thermo-hydro modification —** Thermowood

Accoya® — www.accoya.com

Accoya® is the brand name for an acetylated wood product produced by Accsys Technologies from its facility in Arnheim, Netherlands. The acetylation process involves reacting wood with acetyl anhydride to produce the modified wood plus acetic acid. Radiata pine from New Zealand is a key feedstock given that the sapwood is highly permeable — an important feature for penetration and reaction of the chemical.

The main uses of Accoya® wood include exterior windows and doors, decking, cladding and other civil construction applications. The acetylation process currently applied by Accsys Technologies yields chemically modified timber that offers highly improved physical, mechanical and biological material properties, e.g.,

- The biological durability of wood has been improved to the highest European durability class (Class 1), similar to the extremely durable tropical species teak (Tectona grandis) and ipé.
- A fibre saturation point below 15% results in swelling and shrinkage properties being reduced by 70–80% versus untreated wood.
- It has exceptional resistance to subterranean and Formosan termites.
- At treatment levels >20% (acetyl content), Accoya wood has been found to possess excellent resistance to marine borer attacks, even after 16 years of field exposure (of the same or better order than CCA-treated pine wood).
- There is an increase of 15–30% in hardness over untreated wood.
- Negligible impacts on the mechanical (strength) properties of the wood material are reported.

Accsys Technologies have announced that it expects to complete its third reactor and operate at full capacity from 2019Q4. This will give an annualised capacity increased by 50% to 60,000 m^3. Demand continues to exceed increased production, and plans

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are progressing to add a fourth Accoya® reactor in Arnhem to further increase capacity to 80,000 m^3. Furthermore, discussions are progressing with a potential partner concerning a possible Accoya® plant in the US in light of rising demand.

Given that radiata pine clear wood boards from pruned forests are a key feedstock in Accoya® production, and that the pruning regime is set to decrease further in New Zealand, Accsys Technologies may be interested in expanding production out of New Zealand to obtain better access to a diminishing raw material supply.

Kebony Wood — www.kebony.com

Kebony is a Norwegian company that has developed a patented, environmentally friendly processing technology whereby sustainably sourced wood species are impregnated with a liquid mixture based on furfuryl alcohol. With the addition of heat, the furfuryl polymer is grafted permanently into the wood cell wall, resulting in greatly improved durability and dimensional stability, and making the wood strong, as well as resistant to biological decay and harsh weather conditions.

Furfuryl alcohol is a liquid produced from agricultural wastes, e.g., sugar cane and corn cobs. Furfurylation is carried out by impregnating wood with a mixture of furfuryl alcohol and catalysts, and then heating it to cause polymerisation. The purpose of furfurylation is to improve resistance to biological degradation, and achieve dimensional stability by applying a non-toxic, proprietary, furfuryl alcohol polymer. Property enhancements are as follows:

- Biological durability of wood is upgraded to European Class 1.
- Mechanical properties of the wood, except for impact-resistance, are enhanced when wood is treated with a furfuryl-alcohol polymer. This includes greater hardness, elasticity and rupture moduli versus untreated wood; however, it is also more brittle.
- Depending upon the loading, Kebony wood exhibits strong dimensional stability and resistance to weathering.
- Furfurylated wood is a "green" wood product that holds an ecological label in the Scandinavian market (named "Swan").

The company Kebony AS has an annual production of approximately 22,000 m^3 (2016), and it is increasing its production capacity by building additional facilities in Belgium (Mantanis 2017). In addition, Kebony wood has been recently used in the production of exterior windows (like Accoya wood). Following a series of extensive quality tests in Germany, furfurylated wood is presently recommended by the German Association of Windows and Facades (VFF).

The company's production facility is in Skien, south of Oslo, and currently employs about 60 people with an annual output of 20,000 m^3/year. Due to continued annual growth, with international sales increasing by 30% year-on-year for the last seven years, a second factory was opened in Flanders, Belgium in late 2018. This will allow Kebony to double its annual capacity of Kebony Clear wood, while the Skien facility will focus on Kebony Character wood and continue as the research and technology hub.

With limited additional investment, the new facility in Flanders has the potential to quadruple its current annual production to 80,000 m^3 of Kebony wood. Radiata pine has been used to produce Kebony wood, and there may be options in the future to establish a processing plant in New Zealand to supply markets that develop in Asia.

ThermoWood® — www.thermowood.fi

Thermally modified timber is wood in which the composition of the cell wall material and its physical properties are modified by exposure to temperatures greater than 160°C, and conditions of decreased oxygen availability. There are various procedures to accomplish this, most of which differ according to the way they exclude air/oxygen from the system. For example, a steam or nitrogen atmosphere can be used in the kiln, or the wood can be immersed in hot oil. Thermal modification processes can be applied to a wide range of wood species, but they need to be optimised for each species. The property improvements gained are highly dependent on process conditions, treatment intensity (temperature, duration), wood species and the dimensions of the sawn timber.

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The most common commercial thermal modification process, named ThermoWood®, started in Finland in the early 1990s. It has been licensed via the International ThermoWood Association, with many operations throughout Europe and a growing number outside Europe. The International ThermoWood Association was founded in 2000. Today, there are 16 members from 8 countries. ThermoWood® is a registered trademark owned by International ThermoWood Association. The ThermoWood® trademark is a sign of wood products manufactured via a process developed in Finland. Only the members of the International ThermoWood Association have legal right to use the term "ThermoWood" with thermally modified timber. The utilization of ThermoWood is constantly increasing, and the aim of the association is to enhance ThermoWood® products. ThermoWood® production in 2018 was just under 210,000 m^3 across all licensees.

Thermally modified timber is suitable for use above ground, e.g., for outside use in cladding, terraces, decking, garden furniture, saunas and windows, but it is also suitable for interior as kitchen furniture, flooring, decorative panels and stairs. However, its properties and low strength do not allow it to be used in timber structures. Thermally modified timber was first developed to improve the performance and durability of softwoods, but it has more recently been extended to boost the performance of hardwoods, allowing certain low-durability hardwoods to be used outdoors with no additional protection.

Thermally modified timber is manufactured in New Zealand from radiata pine. Tunnicliffes in Edgecumbe has a small pilot kiln that is used to produce wood for beehives, among other uses. Donelley Sawmillers in Reporoa has had two full-scale commercial ThermoWood® kilns installed in the last five years. Thermally modified timber offers sawmills the chance to differentiate product mix in the future (as market acceptance of this material moves outside Northern Europe).

BIOBASED FUEL AND CHEMICAL PRODUCTS

In 2013, the Wood Council of New Zealand (WoodCo) commissioned what has come to be known as the WoodScape study.[10] This was a techno-economic analysis of wood processing options that used a financial modelling and market review approach to assess the potential of a range of traditional and emerging technologies. The primary metric used for assessing financial performance was Return on Capital Employed (ROCE). This metric reflects the attractiveness to investment of the technology. Other considerations were technical readiness of the process and the market opportunity for the product.

The study identified that a substantial section of the current wood processing industry is not adding much value to its inputs, with a valued-added ratio of less than 3. In contrast, for many of the emerging wood processing technologies, this ratio is ~4–6. WoodScape identified two promising areas showing solid returns (above 10%) and potential to add value. They included:

1. Engineered wood products (discussed earlier)
2. Fuels and chemicals

Fuel and chemical processing options rely on residues from primary processing. However, these technologies were in the early stages of development with significant technical risk, and not much has changed today. There are no significant commercialized technologies in New Zealand, where radiata pine is being used as a biomass feedstock for the primary purpose of producing high-value biobased fuels and chemicals. Scion, the New Zealand government-owned Crown Research Institute, is the lead agency for wood-related bioenergy, waste streams and other biomaterials. More information on Scion's work and possible technologies at the pre-commercial stage can be found on their website[11] in three sections:

- Biobased products and technologies
- Bioenergy
- Bioproducts for sustainable industries

10 See https://www.woodco.org.nz/index.php/strategic-plans/woodscape

11 See https://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/

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Some programs and technologies of interest are detailed below.

The Stump to Pump Programme 2013–2014

This programme, co-funded by MPI, Norske Skög and Z Energy, assessed the potential for creating biofuels from woody biomass. Scion was sub-contracted to provide research and technology expertise for the Stump to Pump feasibility assessment.

The study found that it was technically feasible to convert radiata pine residues to liquid biofuel feedstocks suitable for the New Zealand market. It also confirmed the availability and quality of woody biomass in New Zealand suitable for use in the production of biofuels. However, the global economic and energy outlook at the time made the commercial viability of Stump to Pump marginal and the risk too high.

Lignin

Lignin is a complex biopolymer with the potential to directly substitute for petrochemicals. Scion is developing technologies, such as biotransformation and hydrogenolysis, to isolate lignin and break it down. Lignin can then be used “as is”, or as the starting material for synthesising new polymers and material. Applications for lignin at Scion include the following:

- Carbon nanofibres
- Polymer blends
- Industrial resins such as coatings and bioadhesives

Woody biomass feedstocks

Woody biomass from plantation-grown trees is New Zealand’s most significant renewable energy resource. Increasing the area of planted forest by 1.8 million hectares could supply around 60% of the country’s transport fuels by 2040. Planted on low- to medium-quality land, energy forests would also provide ecosystem services such as erosion and flood prevention.

Ligate™ bioadhesives

Scion researchers have developed a truly sustainable adhesive technology for wood panels. Most wood panels in the world today depend on petrochemical, formaldehyde-based adhesives. Consumers and regulators are increasingly seeking more environmentally friendly options for a healthier home and work environment.

Ligate™ bioadhesives are based entirely on renewable ingredients, and are free of petrochemicals and formaldehyde. They are water-based, non-toxic and compatible with existing adhesive and wood panel manufacturing equipment.

Ligate™ is currently being evaluated through manufacturing trials with commercial partners.

Thermal processing

The energy in wood and other lignocellulosic biomass can be made more available by altering its chemical and physical properties using processes with varying temperatures and pressures, and with or without oxygen. Scion is developing thermochemical technologies to produce both liquid and solid biofuels from biomass.

Fast pyrolysis involves heating wood particles to around 500°C in the absence of oxygen, whereby they vapourise. When condensed, the vapours form a crude bio-oil. The remaining solids form char. The bio-oil can be upgraded and blended with fossil fuels and directly “dropped” into use.

Torrefaction also heats biomass in the absence of oxygen, but to lower temperatures than fast pyrolysis, thereby removing water and volatile components to give an energy-dense product. Forestry residues, bark, sawdust and other by-products of wood processing have the potential to replace coal, but “as is” they can be difficult to transport and use. Scion is working to improve the usability of woody residue as an energy source using torrefaction followed by compressing the torrefied wood into pellets, briquettes or logs.

OTHER TECHNOLOGIES

FEA, as part of a separate study for MBIE (Ministry of Business, Innovation and Employment), identified two emerging technologies that could be seeking investment in order to realise their global potential.

Abodo (www.abodo.co.nz) has developed an exterior timber product it has branded "Vulcan". It is based on thermally modifying radiata pine boards (so that no chemicals are needed for weatherboard applications) that are then laminated and cross-cut to give a face with a straight, parallel-grain appearance (Figure 39). Abodo believes that its Vulcan product offers a sustainable, lower-priced alternative to Canadian western red cedar ("WRC"). WRC has historically been logged from old-growth forests (more than 250 years old), but environmental pressure means this is becoming more problematic; younger, smaller-diameter, "second-growth" WRC forests are now being logged commercially, and this wood does not have the same high-quality wood characteristics as old-growth WRC (in terms of uniformity). This presents an opportunity for a sustainable alternative such as Abodo Vulcan. In the 2017 calendar year, British Columbia exported 1.59 million m^3 of WRC mainly to the US (87.1%) and also to China (3.3% and growing), the UK (2.0%), New Zealand (1.6%) and Australia (1.0%). Abodo's own enquiries indicate that WRC demand is greater than this current available supply, so the opportunity for its Vulcan product to offer a sustainable, high-performing alternative option looks compelling.

FIGURE 39 **Vulcan**

Western red cedar cladding (top) shown compared to Abodo Vulcan cladding (bottom)

Source: www.abodo.co.nz

TTT Products (www.unilog.co.nz) is a pole manufacturing company that has developed its Multilog pole (or "Multipole"). The Multipole (Figure 40) is produced by a hole-coring processing technology that took five years to perfect and can core a 10m log in less than a minute! The process has not been patented and remains a trade secret of TTT Products. The hole in the Multipole serves several purposes:

- Easier to treat with preservative chemicals as can penetrate from outside and from the core.
- Assists drying (much faster) and is subject to less checking/splitting.
- The pole is lighter, which has several benefits: easier to handle, lower transport costs (30% more volume on a truck), and lighter machines to install (important for sites with marginal ground conditions where heavier diggers could not operate).

FIGURE 40 **TTT Products Multipole**

Source: www.unilog.co.nz

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- Allows poles to be easily connected end-on-end, with special connectors for greater depth.
- The core allows hydrojetting to assist when craning poles into place.

Fundamentally, TTT Products' core offering is its ability to design a foundation solution for any ground condition anywhere in the world, i.e., ground improvement. The company has 35 years of experience in this market, including silty sites with high groundwater, in seismic zones, and working with Housing NZ (including the red zone in Christchurch). TTT's competition is fundamentally steel/concrete solutions used in similar applications, except marginal sites (e.g., silty) where they are unsuitable due to their weight. In these ground environments, TTT Multipole has a distinct competitive advantage in terms of both cost and installation time. The company has excellent case studies demonstrating this capability and, in particular, use of their raft system for a school development in Takanini, and ground-stability improvements for roading infrastructure along coastal areas of the Northwestern motorway in Auckland.

TTT Products estimates the size of the New Zealand market at around 100,000–200,000 tonnes/annum. Beyond that, ground condition-enhancing Multipoles for Asian markets, given soil and water table issues in their coastal cities (not to mention climate change impacts), mean that these markets could offer huge growth potential.

MARK SMITH

PARTNER

Mark Smith has worked for major corporations in New Zealand in the forest and forest product sectors (Fletcher Paper, Carter Holt Harvey) in strategic planning, operations management, R&D and new product development roles, as well as running start-up businesses looking to commercialize new product/process technologies in the timber industry. Recently, Mark has been involved in exploring how wood — especially mass timber — can be better utilized in New Zealand construction markets.

(604) 644-6874 msmith@getfea.com getfea.com