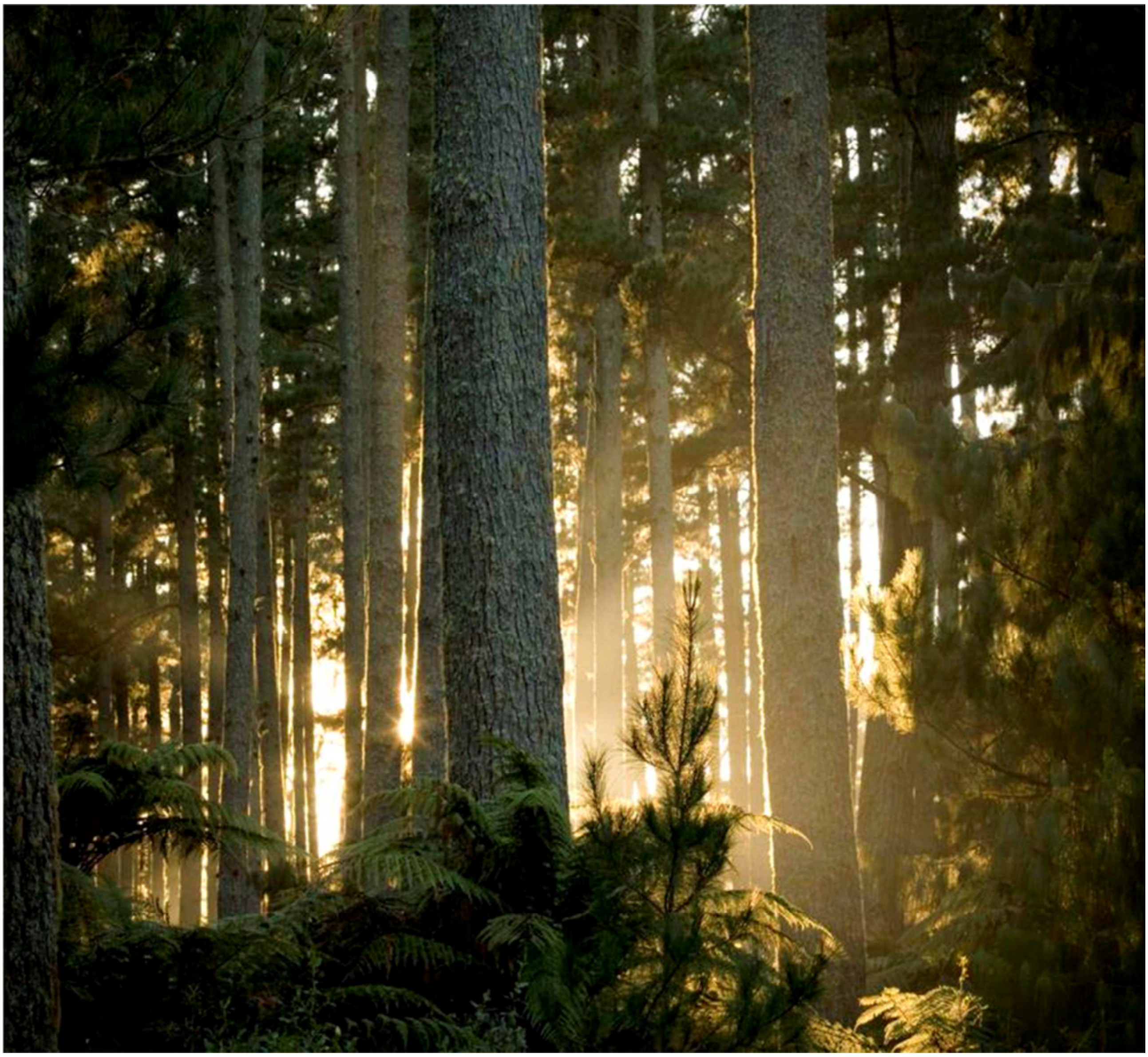
WoodScape Study – Technologies and Markets

February, 2013



www.scionresearch.com

SCION

forests · products · innovation

REPORT INFORMATION SHEET

Report Title WoodScape Study – Technologies and Markets

Authors Andrew Goodison (FPInnovations),Peter Hall (scion), Michael Jack (scion), Luke Barry (Scion),

Client Wood Council Of New Zealand Inc (Woodco)

Client Contract No: QT2625 and 77113

Sidney Output Number 50739

Signed off by Trevor Stuthridge

Date February 2013

Confidentiality Requirement Confidential (for client use only - Woodco, Ministry of Primary Industries & New Zealand Trade & Enterprise; until released by Woodco)

Disclaimer

The information and opinions provided in the Report have been prepared using the WoodScape model, available industry data and exchange rates set at the date of production of the report. Accuracy of the outputs are subject to the accuracy of the data available and used, exchange rate fluctuations and the limitations of the model. They are also specific to specified circumstances and scenarios and are not necessarily transferable to different circumstances. Users of this report use the report entirely at their own risk. The Report has been provided in good faith and on the basis that reasonable endeavours have been made to be accurate (as of the date of production of the report) and not misleading and to exercise reasonable care, skill and judgment in providing such information and opinions. The report is not a substitute for proper due diligence of business opportunities or the exercise of sound business decision making processes.

Neither Scion, nor any of its employees, officers, contractors, agents or other persons acting on its behalf or under its control accepts any responsibility or liability in respect of any information or opinions provided in this Report.

WoodScape — Mapping the future for New Zealand's forest products

woodco — WOOD COUNCIL OF NZ INC

www.scionresearch.com

WoodScape Study – Technologies and Markets

Andrew Goodison[1], Peter Hall[2], Michael Jack[2] & Luke Barry
1. FP Innovations, Vancouver, Canada 2. Scion Rotorua, New Zealand
February 2013

Table of Contents

INTRODUCTION

The WoodScape study was commissioned by Woodco to identify technology options for the New Zealand wood processing and forestry sector to realise the Woodco strategy of doubling exports to NZ$ 12 billion by 2020.

This report provides a description of the wood processing technologies considered in the study and an overview of the markets for the products from these technologies. Other reports from the WoodScape study include:

- a summary report that presents the key findings of the study for Woodco's strategy,
- a regional opportunities report that explores some of the regional differences in more detail,
- a summary presentation of the WoodScape Study (Powerpoint).

The main component of the WoodScape study was a techno-economic assessment of a range of wood processing technology options that could be implemented in New Zealand. The selected technologies ranged from traditional technologies like sawmilling and pulp and paper, to emerging technologies like bio-ethanol. The selected technologies represent a comprehensive, but not exhaustive, list of wood processing technologies. The technologies included in the study were limited the lack of reliable data on some technologies of interest. A financial analysis of the included technologies was used to develop an understanding of what is possible in New Zealand and became the foundation for the key recommendations presented in the summary report.

The goal of this assessment was to understand the full range of options for the New Zealand wood processing industries and to provide insight into those available for realising the Woodco strategy. The results therefore serve as a high-level assessment of the technologies from a broad New Zealand-wide perspective and provide a starting point for more detailed site-specific assessments. This process was assisted by the WoodScape technical working group.

In assessing the technologies an investment perspective was taken and three critical questions were asked;

- What is the development stage of the technology? Is it a mature technology with small technical risk, or is it still under development?
- What is the technology's potential economic return? The main metrics considered were: return on capital, specifically Return on Capital Employed (ROCE); and cash flow, specifically Earnings Before Interest Tax, Depreciation and Amortisation (EBITDA per 100k odt of infeed)?
- What is the potential market for the products of the technology?

This report provides a commentary on each of the technologies considered in the project. The document is structured as individual technology sheets that provide:

- a summary of the results of its financial performance
- a brief introduction to the technology and its stage of development
- commentary on international and domestic markets for the products of the technology, and
- a sensitivity analysis of the results.

Technologies

The study team assessed 39 separate technologies of which 18 were classified as traditional and 21 as emerging technologies. In the study, technologies that could be bought from existing manufacturers who had built similar plants before were labelled "traditional", and technologies that were likely to be a first of kind facility were labelled "emerging." When size variations were included this amounted to 63 technology variations that were modelled for this study. Only technologies that had reached at least pilot plant stage were included in the study to ensure the reliability of capital and operational costs.

For the purpose of the study, the technologies were grouped into six different subsets:

1) Sawmilling: technologies were traditional. A total of eight variants were considered based on scale of production, and the end market targeted by the sawmill (Structural, Appearance and Industrial).
2) Engineered Wood Products and Panels: technologies included anything that involved reconstituted products like laminated veneer lumber, oriented strand board and other panel products like MDF or particle board. Ten technologies were looked in this category.
3) Secondary Wood Products: this was the smallest category and held some of the newest technologies. Three technologies were examined in this area, of which two were emerging.
4) Pulp and Paper: five traditional technologies were examined. Technologies that could repurpose a pulp mill were categorised under the product they produced and therefore would show up in Fuels & Chemicals.
5) Power and Heat: eight technologies were considered ranging from gasification (emerging) to combustion (traditional). Five of the eight technologies were emerging.
6) Fuels and Chemicals: included ten emerging technologies covering biocrude, drop in fuels, tannin production and lignin extraction.

Technologies in WoodScape Study

Technology Group	**Traditional**	**Emerging**
Sawmilling	Structural (4), Appearance (3) and Industrial (1)	
Engineered Wood Products	LVL (2), OSB (3), Plywood (2), Particle Board (2), MDF (2), CLT & Glulam	OEL, OSL & WFP composites
Secondary Wood Products	Remanufacturing untreated & appearance	CO2 modified wood, Thermally modified wood
Pulp and Paper	Kraft (3), Liner Board, BCTMP, Newsprint	
Power and Heat	Power, Combined heat and power (2), wood pellets (3).	Gasification to power and heat and power, Pyrolysis to heat and power Torrefied wood pellets
Fuel and Chemicals		Catalytic pyrolysis (2) Lignin polymers / Super critical water (2) Gasification - Ethanol - Lumber or lime kiln - Methanol - Acetate - FT diesel (3) Tannin extraction (2) Pyrolysis biocrude Dissolving pulp Lignol Ethanol fermentation

*Number in brackets indicates number of scale variations

The other variable considered was scale of production. In most cases, the sizes chosen were based on what would be considered world scale. Some technologies were downsized for the purpose of this study in order to better fit with the New Zealand regional wood resources.

The technical readiness of each of the technologies was assessed as part of the study. Technical readiness was considered an important measure as it reflects a degree of risk to an investment. Higher technical risk often means that a significantly higher financial return is required to attract capital investment versus a lower technical risk project.

Financial analysis
The financial assessment of the technologies was based on a financial model developed as part of the study. The process used to develop the financial model (hereafter referred to as the WoodScape model) is summarised in Figure 1. With assistance from the technical working group (TWG), the team developed a short-list of wood processing technologies relevant to New Zealand. Financial models of these technologies were then created based on a wide range of data sources. Data for the technologies, such as capital and operating costs, came from a variety of sources including contributions from approximately 20 industry participants and technology suppliers.

Product prices were taken from a variety of public and private sources, including a commissioned report on markets by Indufor. The technology data sheets and results were put through a rigorous review process by the team, the TWG, technology suppliers and industry participants. They were also presented at five regional workshops, in; Rotorua, Whangarei, Gisborne, Nelson and Dunedin.

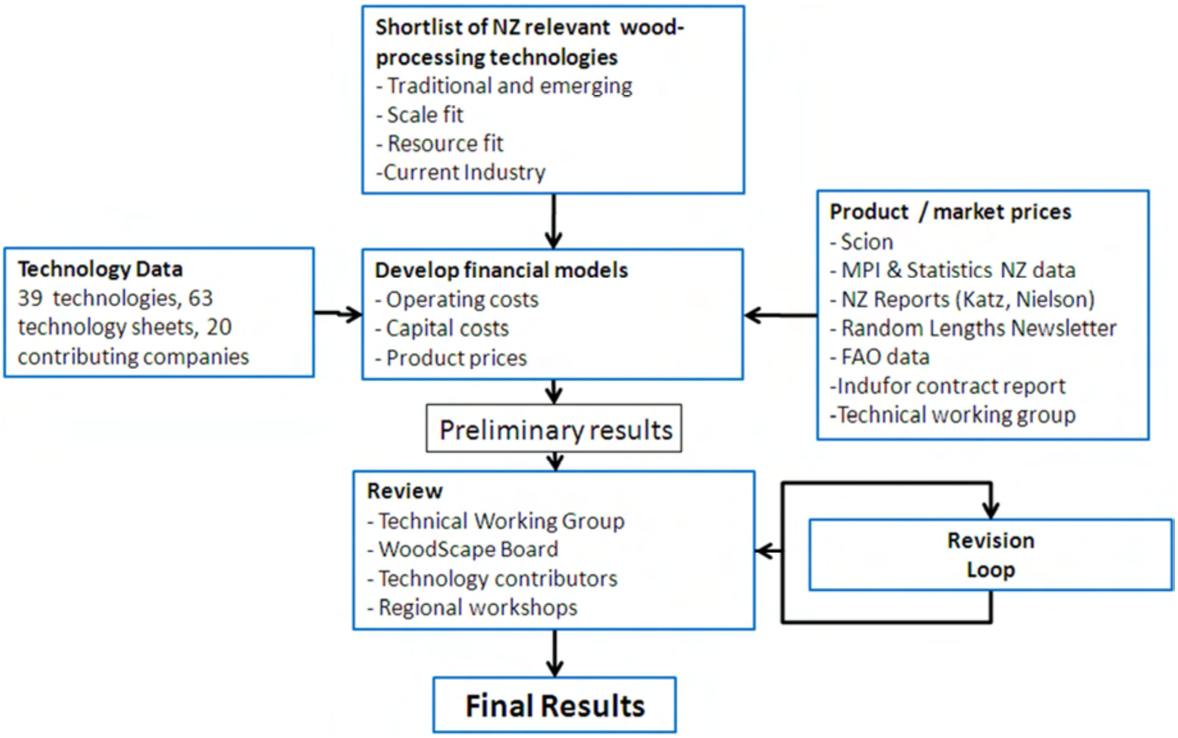


Figure 1: WoodScape model development process

The fundamental assumptions underlying the WoodScape modelling approach are:
- markets are available for total production
- feedstock to the technology is appropriate to the process (7 different categories of feedstock were considered including log grades, residues and lumber for secondary processes)

- capital costs assumed new plant built in New Zealand (there were also two retrofit options – new plant added to an existing facility)
- plant utilisation was at global best practice, and
- product prices and imported consumables were linked to the USD.

The key assumptions behind the base case are:

- product prices were based on 2012 figures (Indufor report, Random Lengths Newsletter, http://www.fao.org/corp/statistics/en/, WoodScape Technical Working Group, Ministry of Primary Industries, Statistics New Zealand)
- the exchange rate was set at 1NZD =0.82 USD
- log prices were based on Agrifax 2012 average, and
- energy prices - MED Energy Data File 2011.

Wood processing technologies have been modelled on the assumption that the feedstock to the technology will be appropriate to their process. Seven categories of feedstock were considered with different costs. Most technologies are sensitive to feedstock costs, and supply of the appropriate log grade or residue feedstock at an average 2012 price is assumed in the base case analysis. The log and residue prices assumed in the WoodScape base case are given in Appendix A.

The primary metric used for assessing financial performance was ROCE since the technologies were mainly being looked at from an investment perspective. This metric reflects how attractive to capital the technology is. In addition to ROCE, another important financial metric was EBITDA per oven dry tonne (ODT) of input feedstock (a measure of cash flow).

Markets

The market opportunity for the products from the technologies is also crucial. The available market reflects whether or not the investment can be successful in the long term, and therefore its potential to contribute to the Woodco strategy. The team adopted a broad market perspective for each technology. The model baseline was set at current prices, but when considering the market outlook a five year perspective was adopted. Market and product price information was gathered from a range of sources including a report by Indufor[1] that was commissioned specifically for this study.

The general market perspective adopted was that:

- the global economy returns to growth over time, led by Asian economies; and that most products produced by the WoodScape technologies would be targeted at an Asian market rather than North America
- in the case of building materials, it was assumed that residential markets in the US would continue to recover and, combined with Asian growth, would lead to healthy demand for wood products
- in the case of Pulp and Paper, the long term outlook was for continuing weakening of paper grades with regular demand for packaging grades, and
- Biofuels and Chemicals were treated as a limitless market, as was energy and electricity, due to the relatively small scale of wood based technologies with respect to existing refineries or energy assets.

Multi-criteria assessment: financial return; technology readiness; market opportunity

Each technology was assessed against multiple criteria including: potential financial return to an investor; technology readiness; and market opportunity for its products. In this

[1] http://www.indufor.fi/

process each of the technologies was assigned a score from 1(low), to 5 (high) for each of the metrics of:

- ROCE
- technology readiness
- market (size, growth potential and maturity), and
- EBITDA.

The basis for the scoring is outlined in the following table:

Score	ROCE	Technology*	Market*	EBITDA / odt
1	<0%	Emerging – high technology risk	Small / Undeveloped	<$0
2	0 to 5%		Large / Undeveloped	$0 to $50
3	5 to 10%	Emerging - Low technology risk	Medium size / Developing	$50 to $100
4	10 to 15%		Mature and small	$100 to $150
5	>15%	Traditional – very little technology risk	Mature and large	>$150

*Subjective assessment of technology & market status

Primary analysis of ROCE was carried out for a base case of log prices, product prices, energy costs and foreign exchange rates as of 2012, as described above. The sensitivity of each technology to key drivers was assessed by examining changes to the ROCE due to changes in feedstock price, labour, product prices, energy prices and capital by +/- 5%.

Overall Findings

The ROCE results ranged from a high of about 20% to negative values. Very few of the technologies considered met the current bar for high risk venture financing (25% and above). A handful of technologies met the ROCE target for a going concern (10-12%). The ROCE and EBITDA for each technology under base case assumptions are presented in Appendix B.

The technologies that performed the best and worst against each criterion are presented in the following table:

Top and Bottom Technologies Ranked by Metric

ROCE	Markets	Technology	EBITDA
Top 10			
Dissolving Pulp (170k / 1.0M)	Plywood (120k m3 / 200k)	Glulam (9k m3/ 9k)	Glulam (9k m3/ 9k)
Lignin Polymers (1.25M)	OSB (750k m3 / 1.25M)	Dissolving Pulp (170k / 1.0M)	Cross laminated Timber (30k m3 / 35k)
WFP Composites (125k / 300k)	Liner Board (300k / 0.75M)	Plywood (120k m3 / 200k)	Catalytic pyrolysis - Aquaflow (700k)
Kraft (1.0M / 4.54M)	OSB (450k m3 / 765k)	OSB (750k m3 / 1.25M)	Catalytic pyrolysis - Aquaflow (350k)
Plywood (350k m3 / 640k)	Structural sawmill (700k m3 / 1,200k)	Liner Board (300k / 0.75M)	Dissolving Pulp (170k / 1.0M)
Catalytic pyrolysis - Aquaflow (700k)	Structural Sawmill (425k m3 / 750k)	OSB (450k m3 / 765k)	CO2 Modified wood (9.6 k m3 / 9.5k)
OSB (750k m3 / 1.25M)	Wood Pellets (70k)	Structural sawmill (700k m3 / 1,200k m3)	Fischer-Tropsch Diesel NZ (1.0M)
Lignin Polymers M (0.62M)	OSB (200k m3 / 344k)	Structural Sawmill (425k m3 / 750k)	Kraft (1.0M / 4.54M)
Plywood (120k m3 / 200k)	Thin Board MDF 1.0M	Remanufactured Appearance (23k m3 / 31k)	Lignin Polymers (1.25M)
OSB (450k m3 / 765k)	Value Added Particle Board 200k	Wood Pellets (70k t / 170k)	Kraft Pulp (300k / 1.6M)
Bottom 10			
Gasification CHP (8 MW / 112k)	Lignin Polymers M / 0.62M	Fischer-Tropsch Diesel NZ (5.0M)	Gasification CHP (8 MW / 112k)
Gasification to Power (17MW / 300k)	BioCarbon / 260k	OEL (50k m3 / 100k)	Remanufactured Untreated (32k m3/ 37k)
Remanufactured Untreated (32k / 37k)	Pyrolysis plant - Boiler Fuel / 230k	Fischer-Tropsch Diesel NZ (1.0M)	Gasification to Power (17MW / 300k)
Tannin Hot water (1.3k /28k)	Tannin Sulphate / 28K	Fischer-Tropsch Diesel DOE (160M / 1.6M)	Tannin Hot water (1.3k t / 28k)
Structural sawmill (25k m3 / 45k)	Pyrolysis plant + Power / 320k	Methanol via syn-gas (270k)	MDF Mill (400k m3 / 1.0M)
Appearance sawmill (50k m3 / 90k)	Lignol Commercial / 0.8M	Tannin Sulphate (1.3 k t / 28K)	Structural sawmill (25k m3 / 45k)
Power (60 Mwe / 638k)	Torrefied Wood Pellets 71k	Lignol Commercial (0.83M)	Ethanol via Fermentation (1.6M)
Wood syn-gas to Lumber kiln (230k)	Wood syn-gas to Lumber kiln / 230k	Syn-gas to lime kiln (170k)	Appearance sawmill (50k m3 / 90k)
Appearance sawmill (100k m3 / 180k)	Tannin Hot water / 28k	Ethanol via Fermentation (1.6M)	Wood syn-gas to Lumber kiln (230k)
Oriented Strand Lumber (71k m3 /132k)	Catalytic pyrolysis - Aquaflow / 350k	Tannin Hot water (1.3k t / 28k)	Power (60 Mwe / 638k)

Based on these results, several key messages can be derived:

1. Cash versus capital: several of the biofuels and chemicals options rank very high in EBITDA/ODT of input wood; however they do not maintain their rankings when it comes to ROCE. This is a direct reflection of the amount of capital that must be put in to establish these types of facilities. Capital efficiency is critical in these areas.

2. ROCE versus market: the ROCE were all calculated on the basis that the market would consume everything the facility produced, essentially a 100% operating rate. When markets are taken into consideration the results can change dramatically, for example, Glulam does very well in both EBITDA and ROCE; however it does face a limited market, reducing its overall rankings.

3. Global commodities: the market ranking is very sensitive to size of the market and as a result, highlights several commodity options. To be successful in these markets, it is important to be globally competitive. This does not just mean large scale, as in the case of Oriented Strand Board and Structural Sawmills, the scale also needs to be appropriate to the available wood supply and market. Cheap fibre and/or labour can be offset by cost effective shipping rates.

4. The wood processing industry is heavily interdependent (See Appendix C) and this interdependency between primary Solid Wood Processing (SWP) and manufacturers of reconstituted wood products (RWP) is fundamental. The modelling has shown the returns to all industries are highly sensitive to feedstock costs and product prices. The SWP industry is reliant on its sales of residues to remain profitable and the RWP industry is equally dependant on this low cost source of fibre. Development of additional processing in either solid wood processing or reconstituted wood processing will need to recognise the interdependence between SWP residues and RWP inputs.

Sawmilling – Appearance & Industrial Sawmilling

	Appearance Sawmilling (90,000* m^3)	Appearance Sawmilling (180,000* m^3)	Appearance Sawmilling (360,000* m^3)	Industrial Sawmilling (727,000* m^3)
ROCE	1	1	1	1
Market	5	5	5	5
Technology	5	5	5	5
EBITDA	1	1	2	1

*Log input volume

Technology Overview

The WoodScape model looked at three types of sawmills; appearance, industrial, and structural facilities. The primary differences between the facilities is scale, log type consumed, yields and final product mix or mill net revenue per cubic metre. In all cases, a greenfield mill was considered and in the larger facilities they were based on a state-of-the-art mill. The one caution with this approach is the considerable variability in how a sawmill can be set up. Many different components could be added, such as anti-sap stain, different kiln configurations, and as such, the capital numbers could swing significantly.

Market Overview

Total global softwood trade is ~100 million m^3 pa, of which, less than 15% is used in typical appearance end uses (FaoStat website). Industrial estimates of total volume are hard to predict as wood destined for this market may be classified as virgin wood, or may be reclaimed wood (wood re-sawn at a later date for industrial uses.)

Appearance grade softwood supply is tight, as traditional sources of long length clear pine, such as old growth Ponderosa, Scots and Korea pine is declining. The availability of clear grade pine from plantations is mainly found in New Zealand, and overall supply is limited to the availability of pruned logs. New Zealand has an estimated pruned log supply of some 3 million m^3 pa currently. Over the coming decade, this is expected to expand by a further 1 million m^3 pa. Total potential “clear” lumber supply from this resource is estimated at 1 million m^3 by 2020. Of this, it can be estimated that half will be used for a range of non-appearance grade end uses such as cladding, decking and primed joinery products. This would leave some 0.5 million m^3 for supply into the global softwood appearance grade market.

Demand for appearance grade softwood lumber is expected to be strong. However, supply is becoming tighter, limiting consumption growth. New Zealand is well positioned to continue to supply global markets with appearance grade softwood lumber. To successfully compete in these demanding markets, New Zealand will have to be price competitive, and supply a superior product and service.

Significant options exist in many of the emerging Asian markets presently supplied by logs. China has already seen a strong growth in its lumber imports from New Zealand. The outlook for lumber sales to China is good. It will however, require effort to improve the position of Radiata pine lumber in this market. In markets such as India, import duties still present a major barrier to lumber imports but over time, these are expected to reduce.

In many of the smaller Asian markets, Radiata pine is increasingly accepted for a range of end uses from low value packaging lumber to high-end clear lumber for furniture. The potential demand is large, but New Zealand’s success will depend on its ability to supply and market Radiata pine lumber effectively into those markets.

WoodScape Model Performance

In the WoodScape model, appearance and industrial sawmills did not perform well unless at scale. The ROCE ranged from -2 to 0% in the two smaller appearance options, while the bigger appearance mill had a ROCE in the 5 - 6% range. The Industrial facility had a ROCE around -3%.

Key to understanding sawmilling is to consider the sensitivities. Sawmilling, in particular, is sensitive to pricing and log costs. This means swings in global prices or foreign exchange will particularly impact the industry. In addition, sawmilling is one of the technologies that is most sensitive to labour. As a result, it is one of the few technologies where increasing labour productivity will have a material impact on the overall financial results.

ROCE Sensitivity (+/- 5% change)

	Appearance Sawmilling (90,000* m^3)	**Appearance Sawmilling (180,000* m^3)**	**Appearance Sawmilling (360,000* m^3)**	**Industrial Sawmilling (727,000* m^3)**
Feedstock	3.4%	3.4%	3.4%	2.7%
Labour	1.1%	1.0%	0.8%	0.5%
Pricing	5.0%	5.0%	5.1%	4.2%
Energy	0.3%	0.3%	0.3%	0.3%
Capital	0.2%	0.1%	0.1%	0.2%

*Log input volume

Sawmilling – Structural Sawmilling

	Structural Sawmilling (45,000* m^3)	Structural Sawmilling (360,000* m^3)	Structural Sawmilling (750,000* m^3)	Structural Sawmilling (1,200,000* m^3)
ROCE	1	1	2	3
Market	5	5	5	5
Technology	5	5	5	5
EBITDA	1	1	2	2

*Log input volume

Technology Overview
The WoodScape model looked at three types of sawmills; appearance, industrial, and structural facilities. The primary differences between the facilities is scale, log type consumed, yields and final product mix or mill net revenue per cubic metre. In all cases, a greenfield mill was considered and in the larger facilities they were based on a state-of-the-art mill. The one caution with this approach is the considerable variability in how a sawmill can be set up. Many different components could be added, such as anti-sap stain, different kiln configurations, and as such, the capital numbers could swing significantly.

Market Overview
Globally, structural lumber is predominantly used in regions where wood frame housing is an acceptable building method. Most of the wood used is typically softwood. Key areas where wood frame houses are constructed include North America, Western Europe and Oceania. In most other countries, use of structural lumber is mostly limited to roof construction (Biopathways, 2010).

Of the total global softwood demand of some 290 million m^3 pa it is estimated that approximately 50% is used in some form of structural application. This would indicate a total global demand for structural lumber of about 145 million m^3pa. Current global demand is suppressed due to low construction activity in all of the key structural wood using regions. As the economic situation improves, demand for structural lumber is expected to follow strongly.

New Zealand's market for structural lumber is relatively small and the total current domestic structural lumber market has been estimated at some 400,000 to 500,000 m^3 pa and construction activity is currently at low levels (approx. 15,000 units per annum). The expectation is for a considerable lift in construction activity driven by the Christchurch rebuild and housing shortage in Auckland.

One of the key limitations for New Zealand growing its share of the global structural lumber market is the inability of a large percentage of the harvest to produce high strength lumber. New Zealand's Radiata pine resource does not have global acceptance for the production of structural lumber, and as such, the key markets for this product will remain the domestic and Australian markets.

WoodScape Model Performance
Structural sawmills, in general perform better than appearance or industrial facilities in the WoodScape model. ROCEs range from -2% to - 3% for smaller scale facilities, while for the larger options it is the 10% to 14% range. Similar to Appearance and Industrial sawmills, the sensitivity to pricing and feedstock is driving the model, as is the scale of facility in terms of labour sensitivity.

As feedstock cost and lumber pricing is largely beyond the direct control of any wood processing company, especially in a global export market, the key to the future of sawmilling will mean managing the labour productivity on site. This does not just mean pursuing scale or size, it means that where ever possible, automation is necessary for long term globalisation.

ROCE Sensitivity (+/- 5% change)

	Structural Sawmilling (45,000* m3)	Structural Sawmilling (360,000* m3)	Structural Sawmilling (750,000* m3)	Structural Sawmilling (1,200,000* m3)
Feedstock	3.0%	3.0%	3.1%	3.7%
Labour	1.7%	1.1%	0.7%	0.4%
Pricing	4.9%	5.0%	5.0%	5.5%
Energy	0.3%	0.3%	0.3%	0.3%
Capital	0.1%	0.1%	0.3%	0.4%

*Log input volume

A key finding in the regional workshops was that most regions, except the East Coast, have significant latent capacity in their sawmilling infrastructure. If demand increases, then these mills can increase their utilisation and throughput. This latent capacity may limit options for new plants.

Engineered Wood Products & Panels – Cross Laminated Timber

	Cross Laminated Timber 35,000 m^3 lumber in
ROCE	4
Market	3
Technology	4
EBITDA	5

Technology Overview

Cross laminated timber (CLT) is a system whereby massive solid timber panels are fabricated by bonding together sawn wood with structural adhesives. Each layer of the panel alternates between longitudinal and transverse lamellae. Alternating the grain directions of each layer reduces many of the weaknesses that previous timber products display. CLT is considered a complete building system allowing a company to build a multi-story building. It is in commercial use in several European countries, including Austria, Germany and the UK, and is beginning to be produced in North America. Two plants are operating in Canada and three under construction in the United States (Biopathways, 2010).

Market Overview

Total global demand is currently 700,000 m^3 pa. The majority of this is within Europe, but the US is also expanding. Total usage is expected to reach 1 million m^3 pa over the next two years. Significant further growth is expected with several major wood promoting agencies working hard to increase market penetration into the non-residential sector. The majority of this work is being done in major wood consuming regions; however marketing is not focused on Asia at this stage.

New Zealand supply is still very small, but expected to ramp up over the coming year. CLT presents a strong growth opportunity in New Zealand, however exports will still be key to longer success, as will developing the acceptance of CLT within the national and Australian building codes. European and North American suppliers have significant scale, and New Zealand will have to ensure it is competitive against those suppliers, especially if the business case calls for export of the product.

WoodScape Model Performance

CLT performed well in relative terms for New Zealand. Its ROCE was in the 12% range which put it in the upper quartile of performance. The technology was very sensitive to pricing, which as a developing market, is a significant risk. Pricing will have to be competitive against concrete and steel construction techniques.

ROCE Sensitivity (+/- 5% change)

	Cross Laminated Timber 35,000 m^3 lumber in
Feedstock	0.8%
Labour	0.3%
Pricing	2.4%
Energy	0.0%
Capital	0.7%

Engineered Wood Products & Panels – Laminated Veneer Lumber

	Laminated Veneer Lumber (50,000* m^3)	Laminated Veneer Lumber (200,000* m^3)
ROCE	3	3
Market	4	4
Technology	5	5
EBITDA	3	3

*Log input volume

Technology Overview
Laminated veneer lumber (LVL) is produced from veneers aligned in parallel to maximise strength in a particular direction. The product has a high strength to weight ratio and is typically used as a beam. Some architects are currently using LVL as massive timber panels for specific visual applications.

Market Overview
The global market for LVL is estimated at some 1.8 million m^3 pa. Key production areas are North America (0.8 million m^3), Europe (0.5 million m^3) and New Zealand (0.3 million m^3). Most LVL is consumed locally, with the exception of Japan and Australia, who are major importers.

Global demand is expected to grow strongly. LVL is increasingly accepted as a high quality structural beam product, and growth is expected in all markets globally. LVL demand in New Zealand is closely linked to construction activity, and expected expansion in this area is likely to see strong demand growth.

Further potential for expansion of LVL production in New Zealand exists. However, for structural LVL, the potential locations are limited as manufacture requires high density (high strength) veneers, and much of the New Zealand Radiata pine resource does not meet the required properties. LVL plants are not considered viable in Otago and Southland and the resource of suitable structural grade logs is constrained at present in other regions.

WoodScape Model Performance
LVL performance was approximately 5 - 6%, a relatively strong performance when considering other technology options. It is quite sensitive to pricing which will be dictated by its performance against concrete and steel.

ROCE Sensitivity (+/- 5% change)

	LVL Small	LVL Large
Feedstock	0.6%	0.9%
Labour	0.8%	0.8%
Pricing	2.5%	3.2%
Energy	0.2%	0.3%
Capital	0.5%	0.5%

Engineered Wood Products & Panels – Medium Density Fibreboard

	MDF (1,000,000*)	Thin Board MDF (1,000,000*)
ROCE	1	2
Market	4	4
Technology	5	5
EBITDA	1	2

*Log input volume

Technology Overview
Medium density fibreboard (MDF) is produced by mechanically refining wood chips down to fibres and then pressing the resultant fibre mix together in the form of a board or moulding. The process is a well established technology with turnkey solutions available from key manufacturers around the world. The process can produce commodity types of boards or it can be used to produce higher value components like thin panels (for laminate flooring applications) or shaped mouldings.

Market Overview
The MDF market initially developed in Europe and North America and penetrated the cabinet and furniture markets as the substrate of choice, competing against particleboard. MDF's superior finishing capability allowed it to move into higher value applications that particleboard could not provide. Recently, Asian demand has grown very strongly driven by demand for domestic and export furniture manufacture and for laminate flooring. Although some inter-regional trade occurs, the majority of MDF consumed is manufactured within the regions. Until recently, MDF usage was limited to interior use, but recent developments now allow for the manufacture of exterior grade MDF.

One important factor in the market is the recent growth of mouldings. Mouldings have been used globally for hundreds of years, made mainly from solid wood and then from finger-jointed material. Now however, alternative mouldings materials such as MDF and plastic are expanding their market share. The ability of MDF to produce a completely straight, consistent product is making it the material of choice. Traditionally, mouldings have been produced close to the end use; this has changed in the last 30 years with a global trade in mouldings developing.

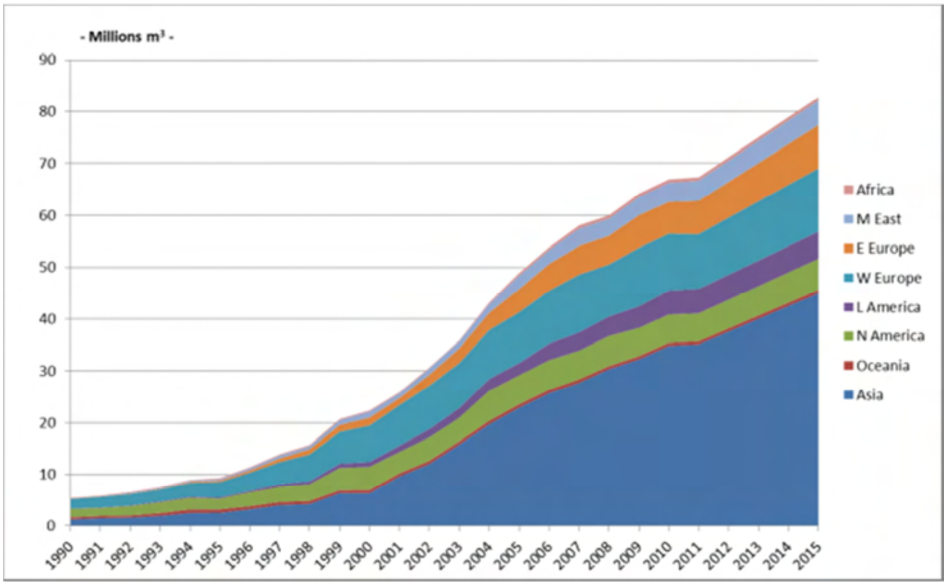
The major global import market has been the US, with supplies mainly coming from South America and New Zealand. At the height of the US building activity in 2007, total imports of softwood mouldings reached some 1.3 billion linear metres. Current levels have declined to 700 million linear metres. Some 80% of this is supplied by Chile and Brazil, with New Zealand having a small but sustained share.

Demand for solid wood mouldings is expected to recover substantially over the coming years. The mouldings sector is expected to remain competitive, as alternative products will continue to target this segment.

New Zealand's exports of mouldings are expected to grow as global markets recover. However, the market is likely to remain competitive due to competing countries' supply capability and product substitution. New Zealand has potential opportunities for developing its MDF industry in the future, and the consistent and high quality of the fibre used lends itself to the development of modified and specialised MDF products.

New Zealand has a relatively high per capita consumption of MDF (50 m^3/1000 pa) and the total market has been relatively stable in the 175-200 000 m^3 pa range over the past decades. Demand outlook for MDF in New Zealand is static.

Over recent years, the Asian MDF market has been very competitive, but due to rising fibre costs in Asian markets, opportunities for New Zealand MDF are opening up. Future success will very much depend on New Zealand being able to supply competitively high quality and speciality grades of MDF products into this expanding market.



Source: Indufor

WoodScape Model Performance
The results of the MDF model indicate that a basic MDF facility designed to produce raw board would end up with a ROCE in the -4% range. The speciality plant producing a thin board product performs better in the 2% range.

Key to success in lifting ROCEs will be managing pricing (ensuring high value products) and managing feedstock prices. The WoodScape model is based on pulpwood prices so other sources of clean fibre that can reduce that cost, will improve performance.

ROCE Sensitivity (+/- 5% change)

	MDF	**MDF Thin Board**
Feedstock	0.5%	0.5%
Labour	0.2%	0.2%
Pricing	1.6%	1.4%
Energy	0.2%	0.3%
Capital	0.2%	0.2%

Engineered Wood Products & Panels – Particleboard

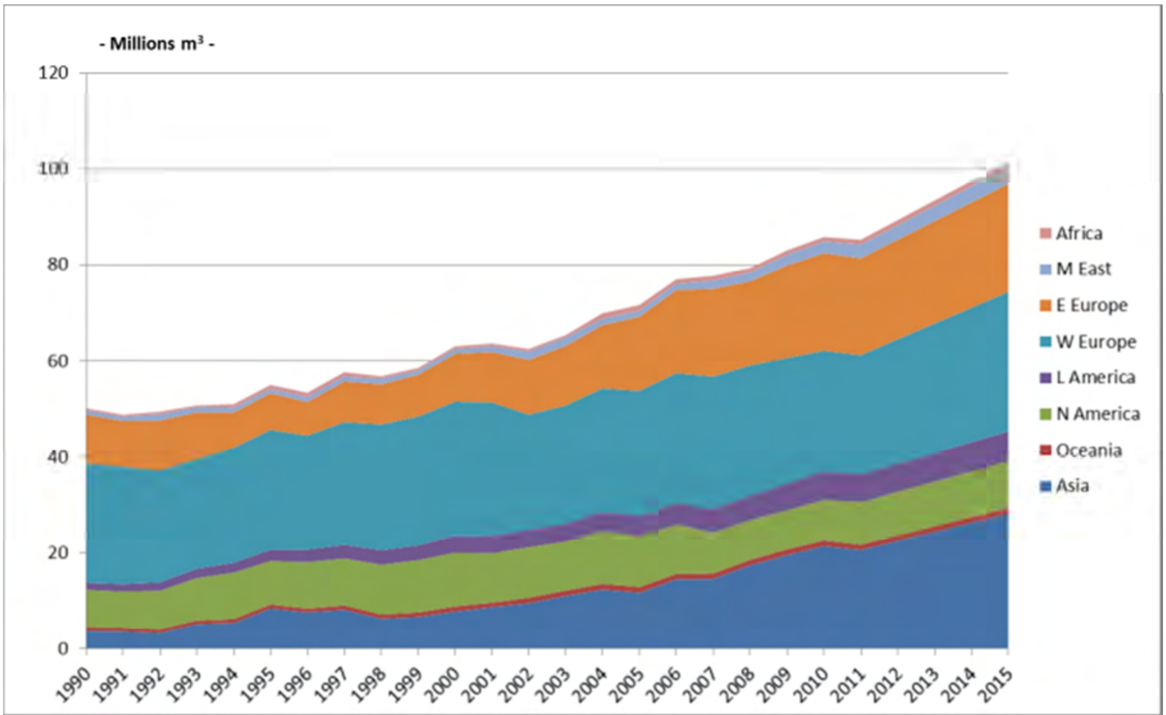
	Particleboard 200,000* m^3	Particleboard 400,000* m^3	Laminated Particleboard 200,000* m^3
ROCE	1	3	2
Market	4	4	4
Technology	5	5	5
EBITDA	2	2	2

***Log input volume**

Technology Overview
Particleboard (PB) is similar to MDF except instead of refining the fibres, particles are hammer milled and then pressed into boards. Particleboard cannot be produced as thinly as MDF as it does not have the internal bonding strength, however particleboard is often laminated and then used in cabinetry. The global market for PB has expanded strongly over recent years. The key success factor for PB is the ability to utilise a low quality and therefore low cost raw material to produce a widely used board material.

Market Overview
PB is a predominantly locally consumed product, and inter-regional trade is small. Total demand for PB has continued in the past two decades, and the outlook is positive. Europe, both Western and Eastern, is the largest market for PB, and demand in Asia is expanding rapidly. Demand outlook for PB in New Zealand, however, is relatively static, with growth opportunities limited due to a decline in furniture production and cyclical construction activity.

PB is a relatively low cost/price product, resulting in freight being a major component of the final product cost. This hinders New Zealand's ability to produce PB competitively for export. Asia and Eastern Europe are expected to see the strongest future growth in PB demand, which will be mainly supplied domestically.



Source: Indufor

Standard or commodity grades of PB present limited opportunities for production in New Zealand. Only if more specialised, or niche PB products could be developed, is New Zealand likely to be able to competitively supply into the growing Asian markets. Niche products would likely focus on PB with specific or unique properties such as water resistance.

WoodScape Model Performance

The WoodScape model contains three versions of PB. The first two are raw board plants producing a commodity grade, and are at two different scales. These plants have ROCE's of -3% to 1%. The third, value-added PB facility performs slightly better with a ROCE in the 3 to 4% range. Key to success is identifying the value-added market and pricing that will improve the results.

ROCE Sensitivity (+/- 5% change)

	Particleboard 200,000 m^3	Particleboard 400,000 m^3	Laminated Particleboard 200,000 m^3
Feedstock	0.2%	0.4%	0.2%
Labour	0.3%	0.4%	0.4%
Pricing	0.9%	1.4%	0.9%
Energy	0.0%	0.0%	0.0%
Capital	0.1%	0.0%	0.2%

Engineered Wood Products & Panels – Optimised Engineered Lumber

	Optimised Engineered Lumber 100,000* m^3
ROCE	4
Market	3
Technology	3
EBITDA	3

***Log input volume**

Technology Overview
Optimised Engineered Lumber (OEL) is a developing technology for processing K or L grade logs into a structural wood product. This falls into the ‘engineered wood products’ category. The process first saws the logs (targeted at K or L grade logs) into 10 mm thick planks, which are then dried, finger jointed, rearranged and glued into a structural lumber substitute. The goal is to take a lower value, non-structural log and create a higher value structural product. The technology is still at demonstration scale and has not reached full commercialisation.

http://www.oel.co.nz/
(Venture statement describes the process in more detail)

Market Overview
The market for this product is expected to be substantial and to expand nationally and globally, as it is for a number of related products (LVL, CLT, Glulam beams). The OEL product will also be competing against structural sawn lumber, the price for which meeting MSG8 and MSG10 will, to a large extent, dictate the market price. However, the OEL product should have some market advantage as it will have a known and consistent performance and quality.

WoodScape Model Performance
The OEL technology in the WoodScape model ranks mid-range (11.9%) in the ROCE results. This ROCE is better than for an industrial sawmill which would be taking much the same log grades as its in-feed. OEL is very sensitive to the market price of the product, and feedstock cost is also important.

ROCE Sensitivity (+/- 5% change)

	OEL 100,000Y* m^3
Feedstock	1.6%
Labour	0.8%
Pricing	4.6%
Energy	0.0%
Capital	0.4%

***Log input volume**

Engineered Wood Products & Panels – Oriented Strand Board

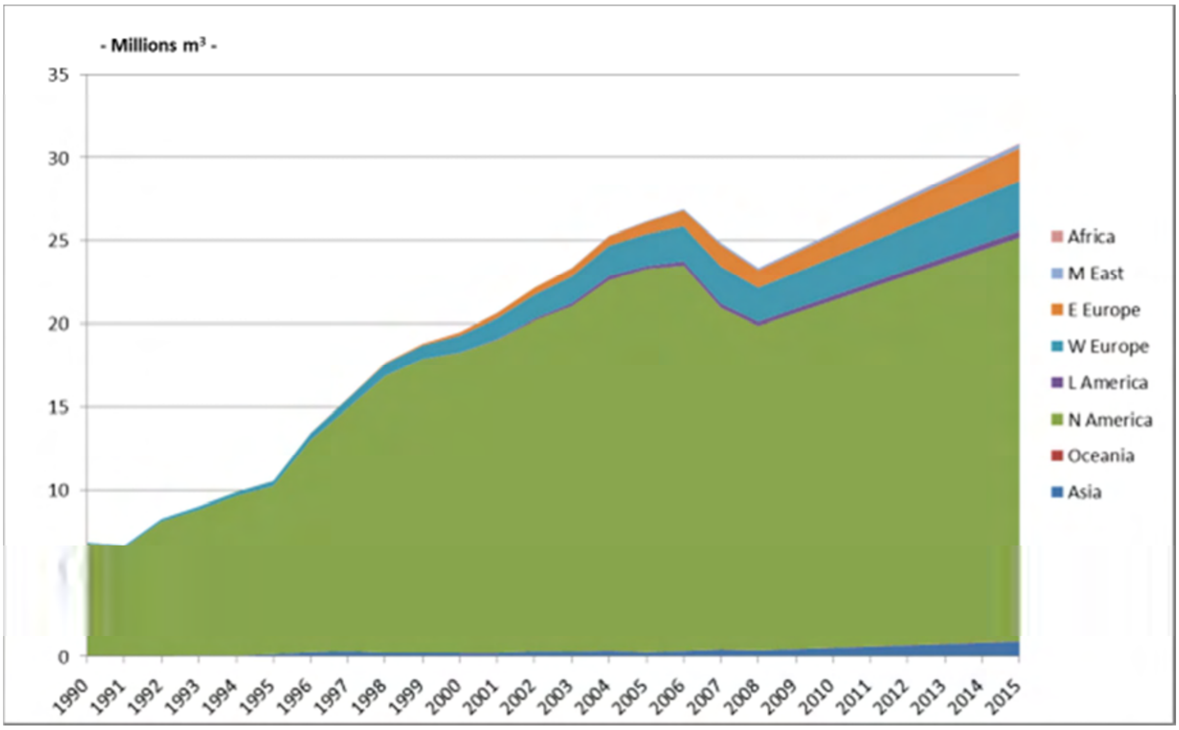
	OSB (344,000* m^3)	OSB (765,000* m^3)	OSB (1,250,000* m^3)
ROCE	4	5	5
Market	5	5	5
Technology	5	5	5
EBITDA	2	2	2

***Log input volume**

Technology Overview
Oriented Strand Board (OSB) is a technology developed in the 1970s to produce a structural panel from low value, or wastes species, of wood. It saw rapid growth through the 1980s and '90s and today has replaced most of the plywood usage in North America.

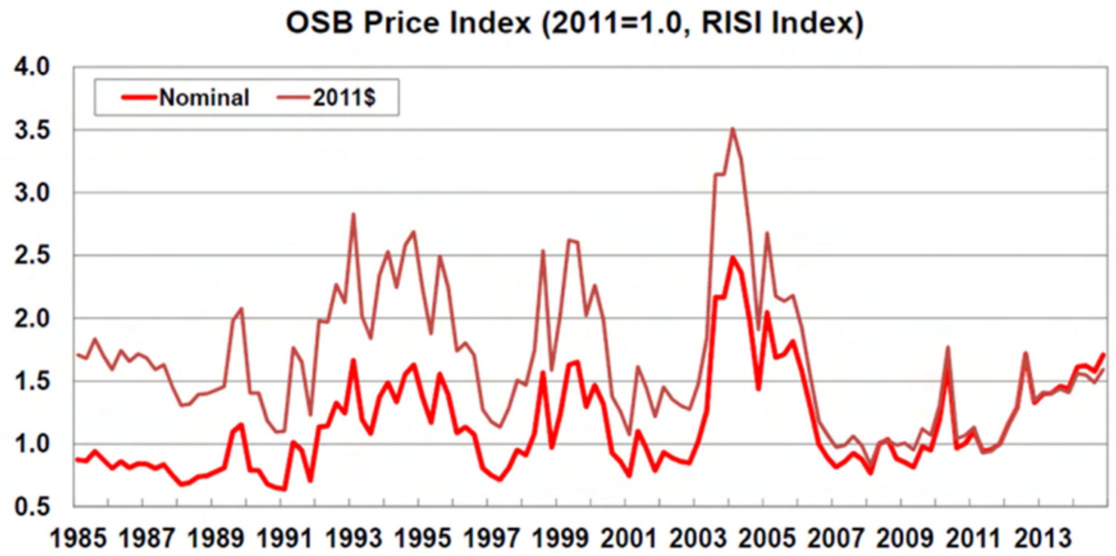
The process is quite simple: logs are flaked into strands; the strands are dried and oriented in a mat, which is then pressed to various sizes and thicknesses. The panels can be created in a batch press or in a continuous press. The process has gone through several generations of production facilities, with the scale of the facilities increasing dramatically.

Market Overview
OSB is primarily a product for the North American market with it almost completely replacing plywood in the residential markets. As a result, the performance of OSB producers is tied tightly to the US housing market and, to a lesser degree, the European construction market. Recent forecasts are projecting a gradual recovery in these markets so the outlook is good for OSB producers in North America and Europe.



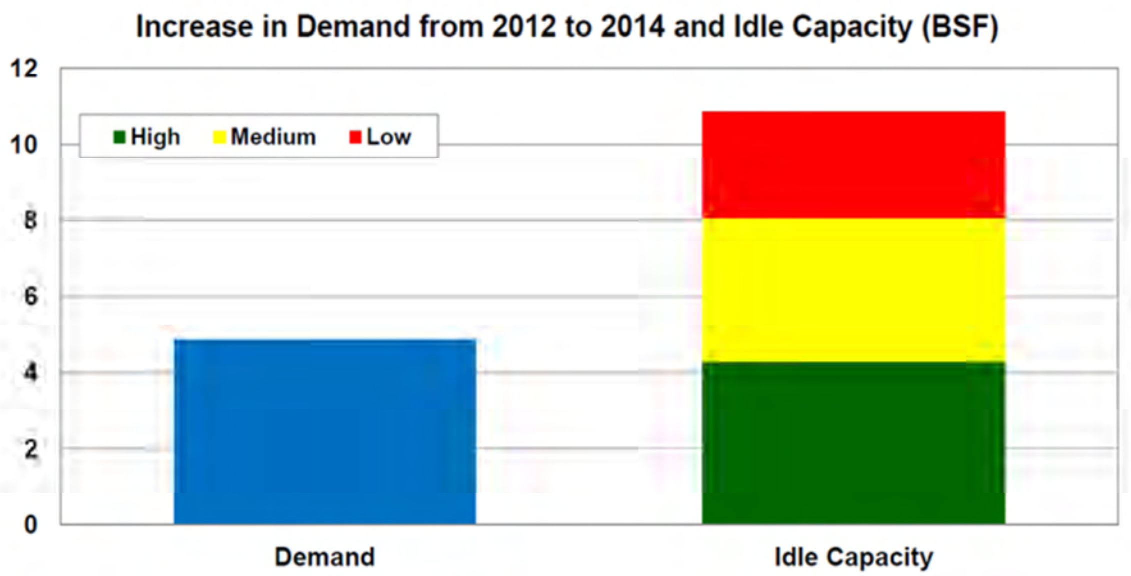
Source: Indufor

The primary challenge, however, is with supply. The OSB industry has been exposed to significant swings in supply, with oversupply being a problem in many years. As a result, the pricing volatility in the OSB market is extreme and many producers have succeeded or failed dramatically depending on their ability to time the market in terms of starting up new capacity or restarting idled capacity. The chart below demonstrates the impact on pricing that supply has driven.



Source: RISI - North America Structural Panel Market: A tale of Two Markets October 2012

Looking to the future, the same concerns of oversupply exist. Although the US housing market is set to come back, there is sufficient idle capacity to supply this demand in the immediate future. Some of the small capacity plants will be permanently shut, but housing need to rise significantly to absorb the high and medium idled capacities.



Source: RISI - North America Structural Panel Market: A tale of Two Markets October 2012

With no OSB demand in New Zealand or Australia, the options for an OSB mill here are limited. Any investor in this technology would need to spend as much time on market development as on the implementation of the technology. In addition, it would be critical for the market development to be focused on Asia with penetration against existing supply in North America challenging. Key to this strategy is the location of OSB mills that are currently idled.

As seen in the map below, most of the shut or idled capacity is in eastern North America and it is unlikely they could compete in an Asian based strategy. The real threat would be the idled western Canadian mills. US based idled mills would be focused on the domestic housing market recovery although there are good container rates shipping from the east coast to China.

Source: FPInnovations – Business Analysis Group

WoodScape Model Performance

OSB performs surprising well in the WoodScape model, with ROCE's ranging from 6%-16% depending on scale of the plant, and based on the feedstock being pulpwood. If the feedstock is changed to a K or A grade log, the ROCEs drop significantly. In this model, the target market is Japan, and the pricing and freight costs reflect this. This is generally a high value market targeted by western Canadian mills, so competition would be strong.

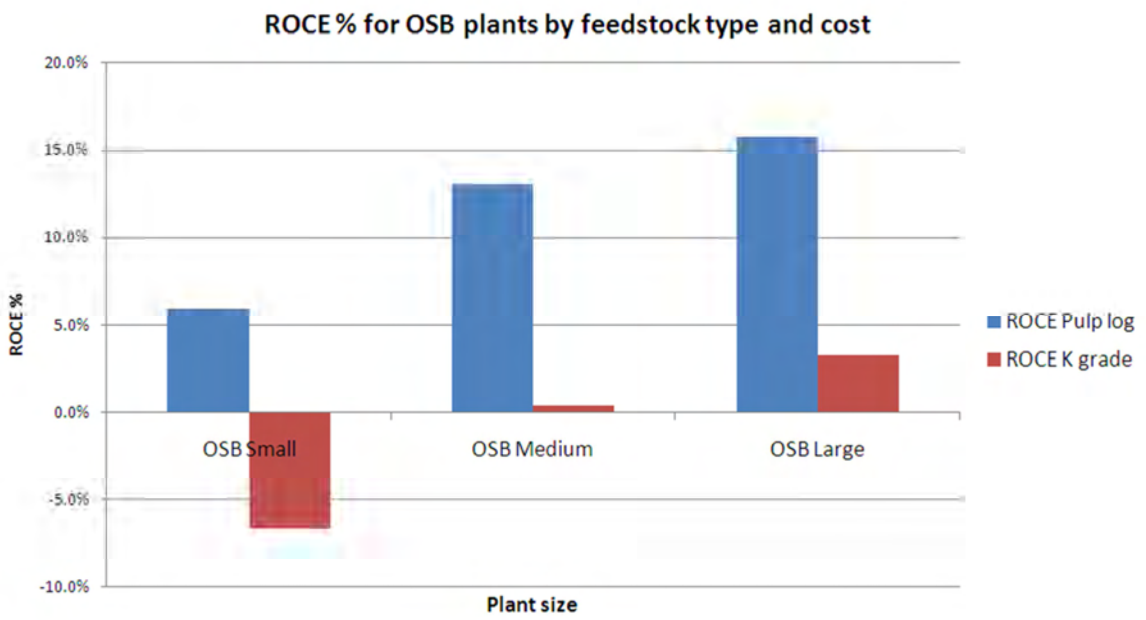
The graph below shows the impact of log price on the ROCE of OSB. The rationale behind using a K grade log price as well as a pulp log price was the significant volume of K grade being exported from some regions (Central North Island, Northland and Nelson) where the pulp log supply is constrained in the short term.

It is important to note that although OSB is one of the higher ranking technologies, the only viable strategy is to develop a new market for the product in Asia, preferably in a region where New Zealand has a significant shipping advantage. It is likely that this market would not be based on wood residential buildings and sheathing, but more on the concrete form market to replace industrial plywood. If this type of strategy was not employed, North American mills with idle capacity will operate to generate cash and limit New Zealand's potential.

ROCE Sensitivity (+/- 5% change)

	OSB (344,000* m³)	OSB (765,000* m³)	OSB (1,250,000* m³)
Feedstock	0.9%	1.0%	0.9%
Labour	0.7%	0.4%	0.3%
Pricing	3.3%	3.3%	3.3%
Energy	0.1%	0.2%	0.2%
Capital	0.3%	0.6%	0.7%

*Log input volume



Source: WoodScape

Engineered Wood Products & Panels – Oriented Strand Lumber

	Oriented Strand Lumber 132,000* m^3
ROCE	1
Market	3
Technology	3
EBITDA	1

***Log input volume**

Technology Overview
Oriented Strand Lumber (OSL) is a relatively new development based upon basic OSB technology. The process is essentially the same, except the goal is to produce a dimensionally thick product that can replace framing lumber, as opposed to the OSB panel. The argument for the technology is that a completely straight stud is produced every time, and that has value in the market. This is a similar market approach to when MDF started to replace pine lumber based mouldings.

Market Overview
The opportunity for OSL is essentially the same as that for structural lumber. It can be considered a growing market; however the key to this will be product acceptance and pricing development sufficient to support the plant.

WoodScape Model Performance
The ROCE for OSL in New Zealand is approximately -5%.

ROCE Sensitivity (+/- 5% change)

	Oriented Strand Lumber 132,000* m^3
Feedstock	0.1%
Labour	0.1%
Pricing	0.4%
Energy	0.1%
Capital	0.0%

***Log input volume**

Engineered Wood Products & Panels – Plywood

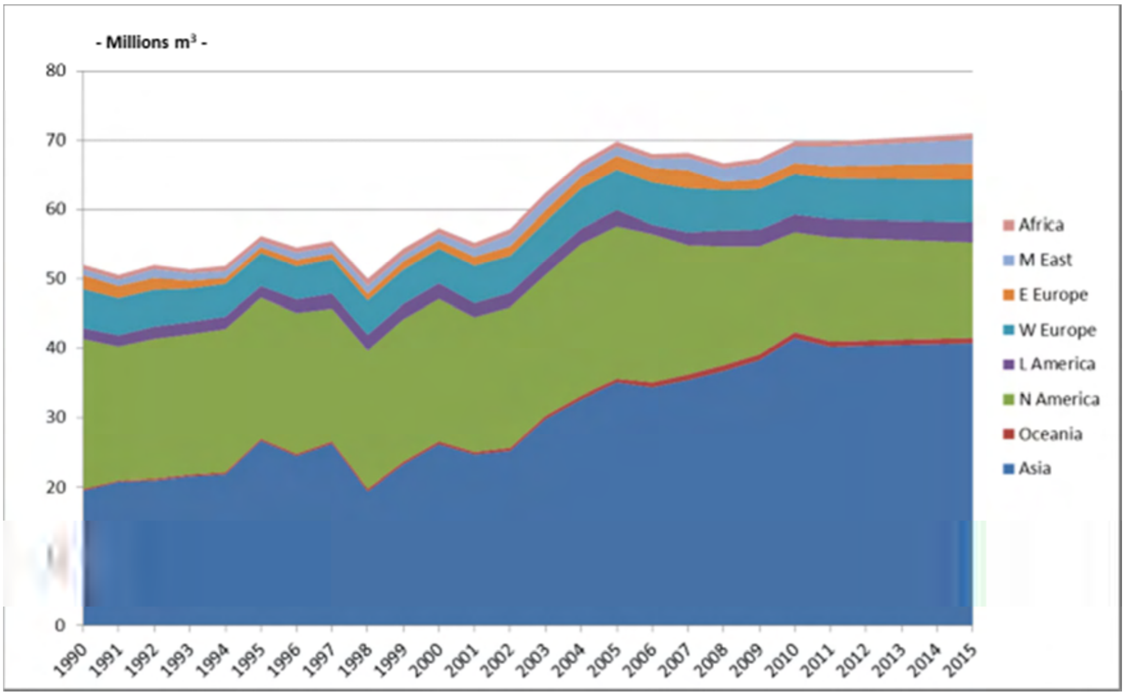
	Plywood (200,000* m^3) Appearance	Plywood (640,000* m^3) Industrial
ROCE	4	5
Market	5	5
Technology	5	5
EBITDA	4	3

***Log input volume**

Technology Overview
Plywood is made up of a number of veneers and cross-angles to produce a stiff and stable wood panel. It has been manufactured globally for well over 100 years. Plywood goes into in a wide variety of end uses from packaging to construction and high end furniture. Plywood is manufactured from both softwood and hardwood or a combination of both.

In North America, the plywood market for softwood production has shifted to niche applications while hardwood plywood is more targeted for appearance applications.

Market Overview
Total global supply and demand has been relatively stable; however there have been developments within different regions. Asia, although traditionally a large producer, has become the largest consumer of plywood while North American usage is declining as plywood is gradually being substituted by Oriented Strand Board. Total plywood demand within New Zealand is expected to remain stable, with small fluctuations driven by changes in construction activity.



Source: Indufor

Plywood could potentially present an opportunity to New Zealand. To compete effectively, production costs would need to be world leading, requiring state of the art, large scale production.

WoodScape Model Performance
The industrial plywood mill in the WoodScape model gives a ROCE of approximately 17%, high in comparison to other technologies. This ROCE is for a highly automated plywood facility, producing a high volume of product. The facility is sensitive to pricing, foreign exchange and capital. It also has a high component of labour costs. At this point in the study, options of further reducing labour with more capital for automation were not examined.

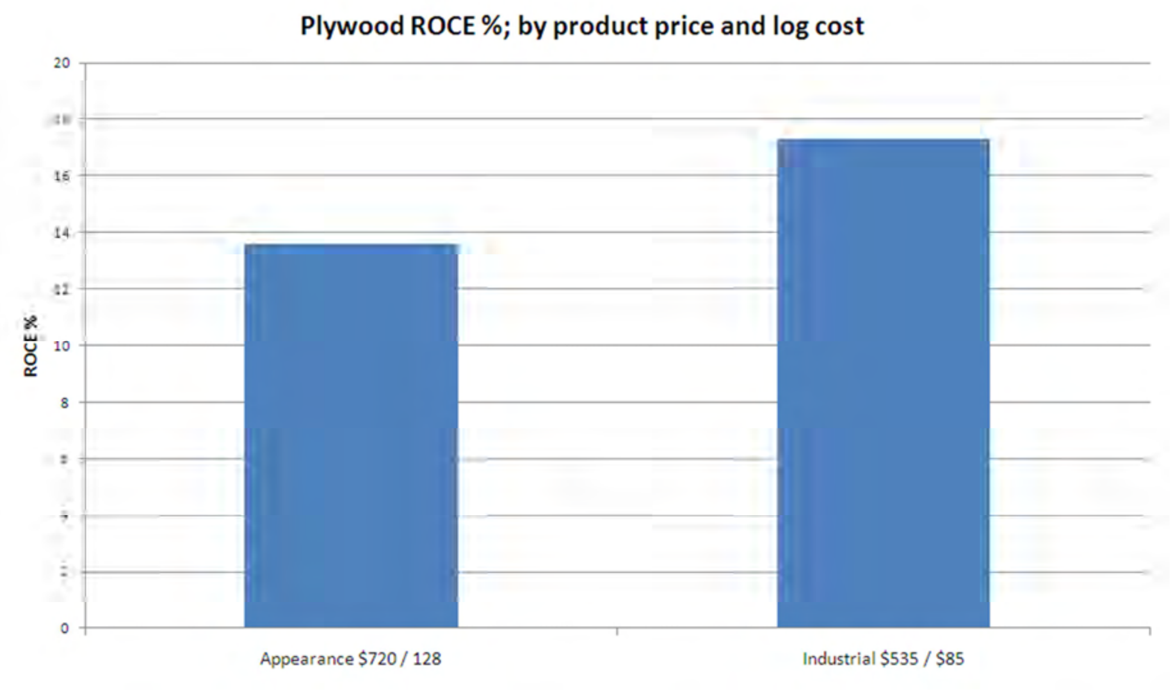
ROCE Sensitivity (+/- 5% change)

	Plywood (200,000* m^3) Appearance	**Plywood (350,000* m^3) Industrial**
Feedstock	1.4%	1.4
Labour	0.9%	0.5
Pricing	4.1%	4.4
Energy	0.5%	0.7
Capital	0.7%	0.8

***Log input volume**

Plywood Production – Appearance grade versus Industrial grade
One of the key themes in WoodScape is moving manufacturing back to New Zealand. Indufor expects that the bulk of the log exports to China have an end destination in plywood. As a result, one of the scenarios considered in the WoodScape model was the trade-off between producing appearance plywood and a much cheaper industrial grade.

To model this, it was assumed that the more valuable appearance plywood would produce a 100% appearance product from a more expensive peeler log, while the cheaper industrial plywood could be made from less expensive K & A grade export logs.



The graph clearly shows that the differential between infeed log prices is sufficient to offset the reduction in revenue achieved by producing an industrial product, given the lower capital cost and higher throughput of the industrial plant. It is important to note, however, that a different approach to the final product may be required when producing commodity industrial plywood.

The industrial mill inputs were based on information from a South American plant, which has significantly higher output for slightly increased capital costs when compared to the appearance plywood mill.

Engineered Wood Products & Panels- Wood Fibre Plastic Composites (WFP Composites); Retrofit to MDF Plant

	Wood fibre plastic composites (300,000* m^3)
ROCE	5
Market	3
Technology	2
EBITDA	4

*Log input volume

Technology Overview
Wood fibre plastic composite is a wood fibre pellet (WFP) which is used as a feedstock in the plastics industry. The initial processing is similar to making the fibre that goes into MDF. The fibre has chemicals added, is formed into a low density mat and then diced into pellets. The pellets are used to provide polymer reinforcement to polyolefin compounds as moulded resin plastics. The technology is new but is now licensed and developed for commercial use. The process would be retro-fitted to an existing MDF mill using the same front end and providing an alternative product and market stream.

Market Overview
The market for wood plastic composites, and therefore WFP, is expected to grow globally. Use of this material is predicted to expand rapidly over the next five years in North America, Europe and Asia with some development in New Zealand. The WFP is added to moulded resin plastics to add strength and is a substitute for short fibre glass re-enforcing. Product pricing is yet to be fully established due to the newness of the product, but as it is substitute for another existing material, it will be largely driven the price of the established competitor product (glass fibre).

WoodScape Model Performance
The WFP composite gave a ROCE of 19.3%, at the upper end of the rankings. The process for making the product is new, but similar to that for MDF. The greater risks are associated with market volume and price, and the process is highly sensitive to the product price.

ROCE Sensitivity (+/- 5% change)

	WFP Composite (300,000* m^3)
Feedstock	0.4%
Labour	0.3%
Pricing	2.5%
Energy	0.1%
Capital	0.8%

***Log input volume**

Secondary Wood Products – CO^2 Modified Wood

	CO2 Modified Wood 9,500 m^3 Lumber in
ROCE	4
Market	3
Technology	3
EBITDA	5

Technology Overview
CO^2 modified wood is appearance grade lumber that has been treated with supercritical (high pressure) CO^2. This treatment makes the wood more stable and durable. Chemicals can be added to the process to give a range of colouring options. The colour is diffused deep into the solid wood allowing the material to be cut, moulded and shaped and retain a uniform colour. Some hardening also occurs, as the process rapidly removes water from the wood.

Market Overview
The market for durable non-chemically treated woods is growing both nationally and internationally. The current market for modified wood is in excess of 10 million m^3 pa. Prices vary with the degree of treatment and colouring but there is potential for a high value added product. Principal markets are furniture, and exposed interior wood panels and fittings. The product is a substitute for high-end hardwoods.

WoodScape Model Performance
The ROCE of the CO^2 modified wood process was 11 - 12 %, reasonable in comparison to many other technologies and placing it in the upper third of the rankings. The process has relatively high capital costs for a relatively small volume of output and is highly sensitive to product price. There is a well established market based on the uses of tropical hardwoods and these will largely set the price for the product.

ROCE Sensitivity (+/- 5% change)

	CO^2 Modified Wood
Feedstock	1.2%
Labour	0.2%
Pricing	8.2%
Energy	0.0%
Capital	0.5%

The CO^2 modified wood technology is modelled as an addition to an existing appearance mill. The results show that it would add value to a proportion of the mill's output and improve ROCE and EBITDA results for the sawmill.

Secondary Wood Products – Glulam

	Glulam 9,000 m^3 lumber in
ROCE	4
Market	3
Technology	5
EBITDA	5

Technology Overview

Glulam, or laminated timber (LT), allowed for the development of long span timber beams which are known for performance and greater stability. These beams are often used in larger scale commercial construction where a wide span needs to be bridged. The process is simple and well known. Lam stock (wood sized and dried appropriately) is face laminated together in different combinations depending on the final strength characteristics needed. The final product may be planed and coated depending on customer specifications.

Market Overview

It is estimated that the total global market for LT exceeds 5 million m^3 pa. The market for standard grades of LT continues to expand, as end users demand known performance and quality. This market is expected to continue to expand.

Custom made large scale LT timber and beams are used in structures where they generally form part of the architectural appearance. One of the largest users traditionally is the Japanese building trade, using large volumes of laminated posts.

LT presents a growth opportunity in New Zealand, key to this being the continued development of products within this category whereby the properties of Radiata pine are fully utilised.

WoodScape Model Performance

The Glulam technology performs well in the WoodScape model. It has a ROCE in the 13% range and as a result is in the first quartile of results.

ROCE Sensitivity (+/- 5% change)

	Glulam
Feedstock	0.7%
Labour	0.2%
Pricing	2.2%
Energy	0.0%
Capital	0.9%

Whilst this technology rates well, the market for Glulam is small in comparison to other markets (e.g. Sawn Lumber) and the process demands structural lumber as feedstock. Overall, Glulam has strong potential but at relatively small scale.

Secondary Wood Products – Re-manufacturing

	Appearance 31,000* m^3	Untreated 37,000* m^3
ROCE	3	1
Market	5	5
Technology	5	5
EBITDA	3	1

*Lumber in

Technology Overview
Re-manufacturing is the secondary processing of sawn lumber created during the primary breakdown of the logs. Re-manufacturing can create a range of products. The modelling here covers two options: a simple level where the untreated product is dressed blanks and raw finger jointed material; and a more intensive level where the material is also moulded or dressed, treated and possibly painted. The products are used as scotias, skirtings, window and door frames, wooden doors etc.

Market Overview
Current markets are weak and competition is coming from South America. Market volumes are expected to rise as housing markets recover, but competition is likely to remain. The major market has been the US, and key competitors in this market are Chile and Brazil. Australia has also been a market, with domestic competition likely in that market. Availability of pruned logs is a key for New Zealand mills.

WoodScape Model Performance
The ROCEs for the two different levels of re-manufacturing are quite different. The untreated, or lower level manufacturing option, has a ROCE of -8.8% which is at the lower end of the results. The appearance level re-manufacturing has a ROCE of 9.0%, giving a spread of nearly 18% between the two. A key to this is the product price available. The higher level (appearance) re-manufacture has a much higher product price and a much greater value add, and ranks highly in the GDP per odt results. Both are highly sensitive to product price and lumber prices, and have greater sensitivity to labour costs than most other technologies.

ROCE Sensitivity (+/- 5% change)

	Reman. - Appearance	Reman. - Untreated
Feedstock	2.9%	2.8%
Labour	1.8%	1.1%
Pricing	5.6%	3.7%
Energy	0.2%	0.3%
Capital	0.3%	0.2%

Secondary Wood Products – Thermally Modified Wood

	Thermally Modified Wood 9,200 m^3 lumber in
ROCE	4
Market	4
Technology	4
EBITDA	3

Technology Overview
Thermal modification of sawn lumber is a process designed to add durability to the wood without the addition of chemicals. The process is done at temperatures above those used during drying, but in a controlled atmosphere to eliminate the risk of combustion and reduce the production of pyrolysis products. The product is more decay resistant, less likely to absorb water and may have some colour change (darkening). The process is seen as being more environmentally friendly as it does not use chemicals and the wood is easier to dispose of at the end of its life.

Market Overview
The market for non-chemical, un-treated but durable wood is already large and seen as having green credentials, encouraging expansion. This treatment will expand market options for Radiata pine lumber and re-manufactured products, as untreated radiata has low durability, especially where it is exposed to moisture. The development of the thermal modification process is ongoing and the products will require testing before full market acceptance. The current targeted end-uses include decking, garden applications, joinery and flooring but also different infrastructure applications.

Current supply is in the range of 100 – 200,000 m^3 pa and increasing as various leading global lumber companies are investing in this technology. This supply picture is contrasted against the total potential market for modified wood, being estimated at over 10 million m^3 pa globally (Indufor). Once available, demand in New Zealand is expected to expand and could reach some 100 000 m^3 pa.

WoodScape Model Performance
The ROCE of the thermal modification process is 11.5 %, and similar to that for the CO^2 modified wood process. This puts it in the upper third of the rankings. It is highly sensitive to feedstock and product price, and in fact this option has some of the highest sensitivity to price of all the technologies. Detailed market studies, including pricing strategies, should be considered as part of the due diligence on this technology. There is still some risk attached to the technology based on proving the product. Employment levels are low in this technology so employment and GDP impacts are low.

ROCE Sensitivity (+/- 5% change)

	Thermally Modified Wood
Feedstock	5.3%
Labour	0.3%
Pricing	7.3%
Energy	0.3%
Capital	0.5%

Pulp & Paper – Market Pulps

	BCTMP (300,000* t)	Kraft (200,000* t)	Kraft (300,000* t)	Kraft (1,000,000* t)
ROCE	3	3	4	5
Market	3	4	4	4
Technology	5	5	5	5
EBITDA	2	3	3	5

*admt of product

Technology Overview

Market pulp is a precursor to tissue, paper and packaging products. It is a fibre based product that forms the sheet, and different market pulps perform different purposes within a sheet. For example, Northern Bleached Softwood Kraft is used primarily as a reinforcement sheet for strength, while Bleached Chem-Thermo Mechanical Pulp (BCTMP) is usually used to provide bulk.

Individual companies can optimise their production within a range dictated by the feedstock (fibre quality) and the process they are using to meet the needs of the customer. There are three primary ways of producing a market pulp: Kraft or sulphate pulping; sulphite pulping; and thermo mechanical pulping (TMP). In the WoodScape model. Kraft and TMP pulping were examined. Sulphite pulping was excluded as it is very rarely used.

Kraft pulping is a chemical process that removes lignin while leaving the primary fibres in a complete form. Its advantage lies in its chemical recovery processes which see an extremely high level of chemicals being recycled. This process also has the ability to produce excess power in the right configuration.

BCTMP, or TMP, pulping is a mechanical pulping process which uses refiners to mechanically force the fibres apart. It requires large amounts of electricity and is normally found in jurisdications with low energy costs. This pulping technology can include a chemical stage (C) and a bleaching stage (B) to try and remove as much lignin as possible. It produces a high yeild - lower cost fibre, however it can not remove the same amount of lignin as the Kraft pulping process, meaning that it can not produce the high bright papers that Kraft can. TMP pulps are often used in applications where paper use is immediate and short term, such as newspaper.

Market Overview

Global production of chemical wood pulp is some 130 million tonnes pa. Of this, approximately 45 million tonnes is produced as market pulp. Market pulp demand is driven by the end-use demand. In some cases this market is growing, albeit at a slow rate, and in others, declining. Tissue and packaging grades are growing while newsprint, printing and writing grades are declining.

Changes in global paper consumption (%)

World Apparent Consumption	1996-2001	2001-2006	2006-2011
Coated Papers		5%	-2%
Folding Boxboard		6%	2%
Household+Sanitary Paper	4%	4%	4%
Newsprint	2%	0%	-4%
Printing+Writing Paper	3%	3%	0%
Paper and Paperboard + (Total)	3%	4%	1%
Paper+-Board Ex Newsprnt + (Total)	3%	4%	2%
Pulp for Paper + (Total)	1%	2%	-1%

Source: FAOSTAT

This picture changes slightly when considering the growth in Asia separately from the rest of the world. General growth in Asia is stronger, however comparing 2001-2006 to 2006-2011, growth has slowed. This could simply be a factor of the global economy in the second half of this period, but it could also show a longer term movement in the demand for pulp and paper.

Changes in Asia paper consumption (%)

Asia Apparent Consumption	1996-2001	2001-2006	2006-2011
Coated Papers		5%	3%
Folding Boxboard		13%	5%
Household+Sanitary Paper	5%	8%	8%
Newsprint	2%	5%	1%
Printing+Writing Paper	4%	7%	6%
Paper and Paperboard + (Total)	3%	8%	6%
Paper+-Board Ex Newsprnt + (Total)	3%	8%	7%
Pulp for Paper + (Total)	2%	4%	3%

Source: FAOSTAT

The other concern in the market outlook is that newer paper machines require different recipes which are focused on low cost fibres - predominately hardwood resources which New Zealand does not have.

In the immediate term, there is no market shortage for pulp from either BCTMP or Kraft processing. Longer term, a detailed market analysis addressing these issues should be conducted before investing significantly.

WoodScape Model Performance

In the WoodScape model, the BCTMP process had a ROCE of 1% while the Kraft processes had ROCE’s ranging from 7 - 18%. It is important to note that the performance of the largest Kraft facility may be no better than smaller scale facilities depending on the extra cost needed to secure sufficient fibre to feed the facility. This premium would be necessary to transport fibre from a wider catchment and possibly of a higher grade. The impact of this can be seen on the large-scale Kraft mill sensitivity.

The very large plant would require a feedstock supply of 5Mt pa. This could only be achieved in the central North Island and would have a significant impact on existing facilities.

ROCE Sensitivity (+/- 5% change)

	BCTMP (300,000 t)	Kraft (200,000 t)	Kraft (300,000 t)	Kraft (1,000,000 t)
Feedstock	0.7%	0.5%	0.6%	1.2%
Labour	0.2%	0.1%	0.1%	0.1%
Pricing	2.4%	1.1%	1.3%	2.3%
Energy	0.4%	0.0%	0.0%	0.0%
Capital	0.1%	0.2%	0.3%	0.4%

Pulp & Paper – Dissolving Pulp (Retrofit to existing Kraft mill)

	Dissolving Pulp 170,000 t product
ROCE	5
Market	4
Technology	5
EBITDA	5

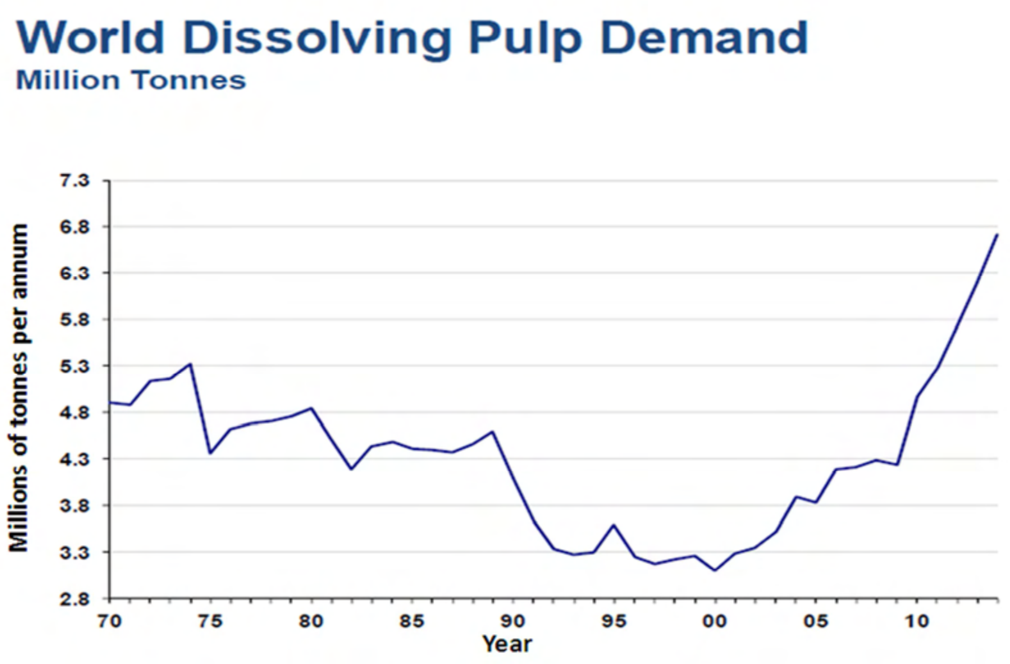
Technology Overview

Dissolving pulp (DP) is a process in which the pulp fibre is further reduced to a pure cellulose state, which is then used for the development of textiles. Historically, DP is produced using a sulphite process, however due to recent increases in demand, many Kraft mills are being converted to produce a standard grade of DP. Key to this conversion is a pre-hydrolysis stage placed before the main hydrolysis stage, the two-stage process removing any remaining hemi-celluloses. This model is based on the conversion of a Kraft mill.

At present, the market is pushing producers to produce higher grades, which requires further capital investment. Existing sulphite producers are investing further to drive the production to alpha cellulose, and it is expected that recent conversions will follow suit. The model does not reflect this second stage of conversion.

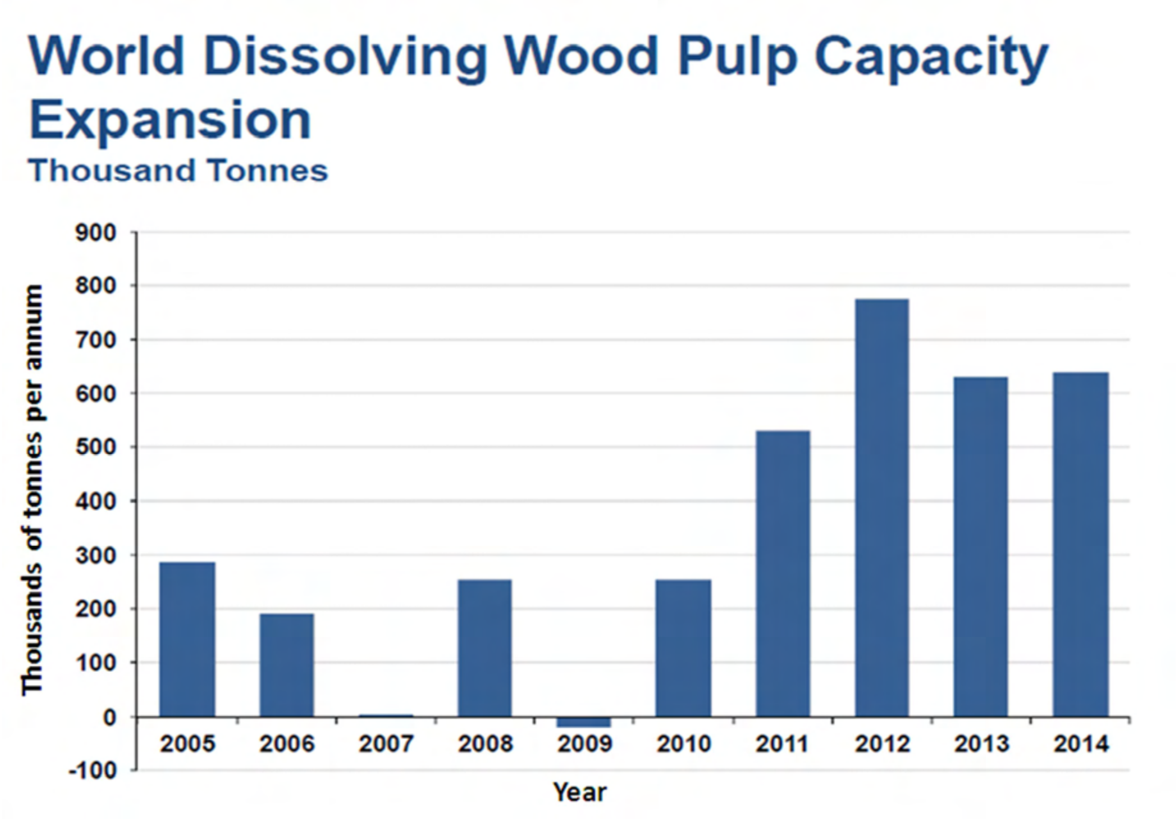
Market Overview

DP is raw material for various products, the largest volumetric market of which is for textiles (60%), including rayon. The global DP market is about 4 million tonnes pa, and it is growing 4 - 5% pa. This should be compared to the cotton and fossil oil based textile market grown mainly in Asia, which is about 70 million tonnes in total. This is an important consideration; the recent growth in DP supply comes online due to the shortfall in cotton production.



Source: RISI – October 2012

As a result of the shortfall in fibre supply, there has been significant capacity additions for DP announced. The bulk of these expansion announcements have been from Asia and equal to over 500,000 admt pa for the last couple of years.



Based on the amount of capacity additions, the recent high pricing is not expected to continue long term. This high pricing, reaching over $1,500 / admt, has been driving significant returns in the recent past. Recent forecasts project a lower price closer to $1,150 / admt.

> "Lowering Our Commodity DP Deck – We have reduced our commodity DP forecast in FY13E from $1,000/tonne to $975/tonne and for Trend from $1,200/tonne to $1,150/tonne. Commodity DP prices ended last week at US$890/tonne and have averaged US$873/tonne YTD. There are over 3 million tonnes of new commodity DP capacity slated to come online from 2012-2014. We estimate existing commodity-grade capacity at the end of 2011 was 4.0 million tonnes; adding that much capacity will likely take commodity DP operating rates down from 88% in 2011 to a possible low of 59% in 2014."

Source: RBC Dominion Securities, Inc. Fortress Paper research note, January 23, 2013

WoodScape Model Performance

In the WoodScape model, the current ROCE of DP lies in the 20% range. This is driven by the foreign exchange advantage for New Zealand producers (current pricing in the WoodScape model is NZ$1,329/admt). The Royal Bank of Canada recently forecast a drop of $50/admt, which would represent just under a 3% decline in the ROCE (correlating to approximately a 5% drop in pricing). While DP is one of the highest rated technologies in WoodScape, significant effort is required to answer the market issues.

ROCE Sensitivity (+/- 5% change)

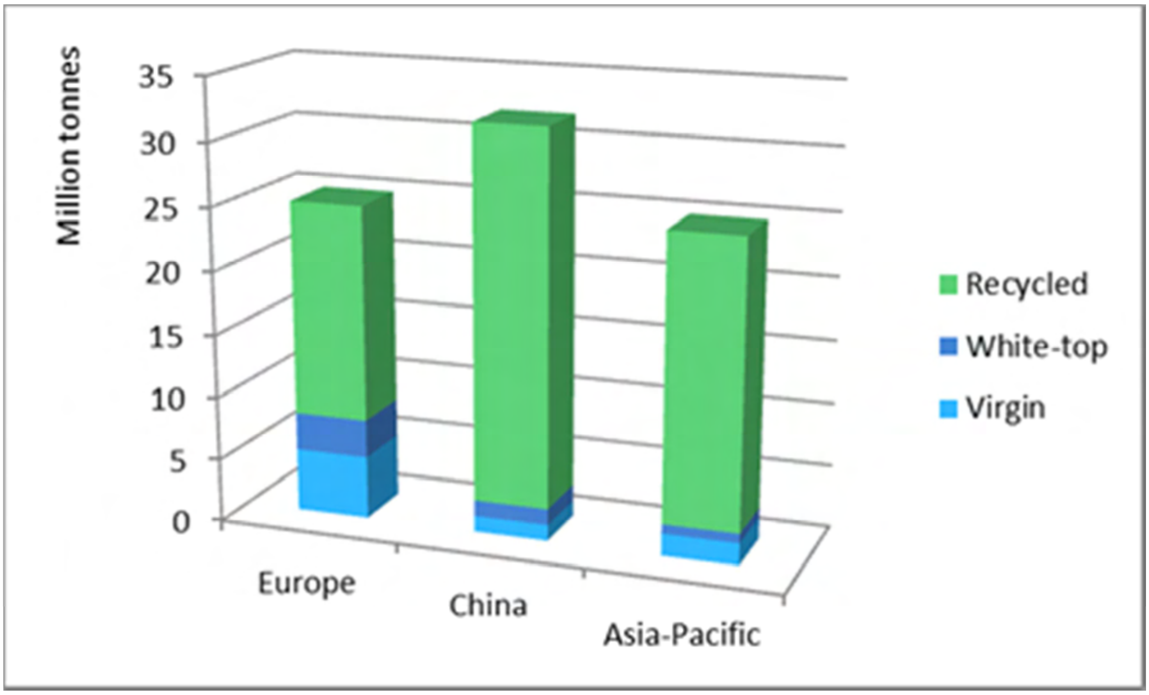
	Dissolving Pulp
Feedstock	1.1%
Labour	0.3%
Pricing	3.1%
Energy	0.1%
Capital	0.1%

Pulp & Paper – Linerboard

	Linerboard 300,000 t product
ROCE	5
Market	5
Technology	5
EBITDA	3

Technology Overview
Linerboard and corrugated medium (fluting) are used to produce containerboard. They are generally produced from a range of pulp including low value pulp for bulk, and high value pulps for printability and brightness. Linerboard can be put together in different layers for different market applications. The technology is well established with large OEM's (original equipment manufacturers) capable of providing complete installations. In today's market place, scale is the key to producing linerboard on a globally completive level.

Market Overview
The global container board market is currently some 210 million tonnes pa. Linerboard makes up 70% of this, or 150 million tonnes. The key growth market is Asia, and strong demand growth is expected in this area. However, the majority of this growth will be supplied by predominantly recycled grades. Average annual growth of 3.5% pa is expected for the next ten years in Asia.



Source: Indufor

New Zealand demand is expected to rise, driven by an expansion in the export of food products. This is further assisted by the expected growth in processed products, typically requiring more packaging.

There is potential for New Zealand to expand production, however it will be important that any expansion be globally competitive and it is likely that the producer will need to be focused on high quality and more specialised grades.

WoodScape Model Performance
Linerboard performed well in the WoodScape model with ROCEs in the 10% range. The technology takes advantage of the foreign exchange but it is sensitive to the pulp in-feed cost. It is also sensitive to energy and labour, so appropriate siting will be critical for long term success.

ROCE Sensitivity (+/- 5% change)

	Linerboard
Feedstock	6.7%
Labour	2.2%
Pricing	3.5%
Energy	2.5%
Capital	2.4%

Pulp & Paper – Newsprint

	Newsprint 300,000 t product
ROCE	1
Market	3
Technology	5
EBITDA	2

Technology Overview
Newsprint is a paper generally produced from mechanically produced (ground wood) pulp and/or recycled paper. It is produced in several grades ranging in brightness or density of the sheet. Directory papers are also generally considered to fall into this category. As newsprint is made from mechanical grades of pulp, it is generally off-white and susceptible to discolouration. As a result, the market for this type of paper is short term use.

Market Overview
Total global demand for newsprint is estimated at some 37 million tonnes pa and declining dramatically. The decline of the newsprint market is primarily due to the rapid development electronic media becoming increasingly available and devices such as tablet computers. Although global demand for newsprint is expected to decline, the fall is likely to be more moderate in Asia. New Zealand's and Australia's demand for newsprint is unlikely to expand, as electronic media is becoming increasingly popular.

WoodScape Model Performance
Newsprint did not perform well in the WoodScape model and it had a slightly negative ROCE. The technology option is very sensitive to pricing but the long term outlook for the market is very weak. Any future market opportunities are contingent on the Asian market and the long term trend of this market is uncertain.

ROCE Sensitivity (+/- 5% change)

	Newsprint
Feedstock	0.4%
Labour	0.2%
Pricing	1.8%
Energy	0.5%
Capital	0.0%

Heat & Power – Combined Heat and Power

	CHP (20 MWe)	CHP (60 MWe)	Power (60 MWe)	Gasification to Power (17 MWe)
ROCE	1	3	1	1
Market	4	4	4	4
Technology	5	5	4	4
EBITDA	2	3	1	1

Technology Overview

Combined heat and power (CHP) is simply combustion in one form or another, directed to create a mix of heat and electricity. In general, there is low technology risk and low market risk with these technologies. For the most part they can be bought off the shelf, with service packages from vendors, and they cover a range of scales. Large scale CHP technologies from 20 MWe up to 60 MWe were considered in the WoodScape model, in addition to the option of pure power production over producing both heat and power for sale.

Market Overview

CHP adoption around the world has been driven primarily by policy. This is especially true in Europe where high costs, climate change and geo political concerns drive energy policy. In North America, where energy security and costs are much less, the adoption of CHP has been significantly slower.

In New Zealand, three factors drive the economics of these technologies: the current cost of power; the cost of feedstock; and the current cost of heat. The technologies at this scale produce a significant volume of heat, from which they derive 60% of their revenue.

Average electricity and heat (e.g. gas) prices for industrial users are expected to remain reasonably stable over the next few years. The WoodScape model assumes that generated electricity is sold to the grid, with a sell price set at 6.7 c/kWh.

There are other opportunities for CHP in New Zealand, such as where there is a low or negative cost for biomass, or where an investor is interested in meeting their own energy demand (the buy price of electricity is closer to 9.3 c/kWh). There are also opportunities in regions with constrained electricity supply.

WoodScape Model Performance

In the WoodScape model, the smaller scale Combined Heat and Power options and the Power options both had negative returns. The larger scale CHP (60 MWe) was profitable, around 8%. However it would need a large demand for steam heat to achieve these numbers. If the right feedstock agreement can be made and a market for the heat found, there is a chance that this technology might be used selectively within New Zealand.

This technology is important to monitor, as it is one of the few technologies relatively insensitive to many factors. If a long term pricing contract can be developed for the technology, it is relatively robust in terms of shocks to feedstock, labour and energy use.

ROCE Sensitivity (+/- 5% change)

	CHP (20 MWe)	**CHP (60 MWe)**	**Power (60 MWe)**	**Gasification to Power (17 MWe)**
Feedstock	0.2%	0.2%	0.4%	0.2%
Labour	0.1%	0.1%	0.1%	0.3%
Pricing	0.6%	1.0%	0.6%	0.5%
Energy	0.0%	0.0%	0.0%	0.0%
Capital	0.1%	0.6%	0.1%	0.3%

Heat & Power – Syngas (Replacement of Natural Gas)

	Lime Kilns 170,000* m^3	Lumber Kilns 230,000* m^3	Combined Heat and Power (8 MW_{th} 112,000* m^3)
ROCE	1	1	1
Market	4	3	4
Technology	2	3	4
EBITDA	1	1	1

*Log input volume

Technology Overview
The production of syngas to provide a natural gas replacement for lime, lumber or combined heat and power, is a relatively simple process in which the details make or break the technology.

The WoodScape model of this technology is based on the Nexterra system. This technology is nearing commercialisation for combined heat and power applications. It is currently providing heat to a plywood mill and is at the pilot stage for lime kilns. It is a well-designed process with capital efficiency at its core. It produces a syngas that can be direct fired although it has a lower calorific value than natural gas.

The technology is based around gasifying woody biomass in a fixed bed system and then either direct firing or co-firing the syngas. The Nexterra system is fully optimised and process controlled such that it can be turned up or down easily. The base technology is now being demonstrated at the University of British Columbia to produce power from an internal combustion engine. Key to the success of this demonstration will be Nexterra's ability to clean up the gas before firing in the internal combustion engine.

http://www.nexterra.ca/

Market Overview
In the New Zealand context, the market for this technology is somewhat limited. As natural gas prices in this country are low, the technology is not competitive against direct fire options using natural gas. Where the technology will excel will be in regions without access to natural gas, and in areas where biomass costs are low or disposal is a problem. As the technology has a small form factor and is very capital efficient, there may be niche opportunities within New Zealand.

WoodScape Model Performance
The returns for this technology are negative due to the low price of natural gas in New Zealand, and the high price of residue biomass (and hog fuel). As a result, this technology should be looked at when there is a negative cost of biomass (net costs to dispose of biomass/hog fuel due to shipping or land filling costs). The ability to apply carbon credits might make a minor improvement in the economics of the technology.

ROCE Sensitivity (+/- 5% change)

	Lime Kilns	Lumber Kilns	Combined Heat and Power (8MW)
Feedstock	0.4%	0.3%	0.2%
Labour	0.2%	0.8%	0.2%
Pricing	1.0%	1.2%	0.5%
Energy	0.0%	0.0%	0.1%
Capital	0.1%	0.1%	0.5%

Heat & Power – Fast Pyrolysis

	Combined Heat and Power ($3MW_e$) 320,000* m^3	Pyrolysis to Boiler Fuel 230,000* m^3
ROCE	1	3
Market	3	2
Technology	3	4
EBITDA	2	3

* Log input volume

Technology Overview
Fast pyrolysis (typified by Ensyn) is the process of rapidly heating biomass to a certain temperature for a short time, to turn the biomass into a liquid. There are several different ways to complete this; however the WoodScape model is based on the Ensyn process, considered one of the more advanced companies working in this area. At this stage of development, Ensyn has built smaller scale pyrolysis plants and is working on commercial scale plants for heat and power, and demonstration plants for upgrading bio oil to a transportation fuel (or refinery feedstock).

This technology has excellent yields compared to some of the other fuel targeted technologies; however there are challenges with the final product in terms of water content and oxygen content. In the model the drop-in fuel option is not considered, only the options of providing heat and power and of using pyrolysis oil as a boiler fuel replacement.

Although this model is based on the Ensyn process, there are other processes available. Ensyn and Metso both have programmes using uncatalysed fast pyrolysis, while companies like KiOR propose using a catalyst fast pyrolysis approach.

The advantage of the uncatalysed fast pyrolysis approach is that it has higher initial yields which then need upgrading to fuels. The advantage of a catalysed approach is that the product is converted directly to a drop-in fuel without the upgrading step. The disadvantage is in yield and the complexities of managing the catalyst.

If a company is considering a fast pyrolysis option they should understand the range of approaches being used in the industry, and their advantages and disadvantages. Within the broad concept of fast pyrolysis, there are a number of different developers and technologies:

Type Metso/Forum
The chips are pyrolysed to produce pyrolysis oil. In this system, the pyrolysis unit is integrated to a power boiler, which, in addition to firing biomass, fires the pyrolysis gases and tar residues.

Type Envergent Technologies (Ensyn / Honeywell UOP)
The biomass (wood waste, forest residues etc.) is liquefied by fast pyrolysis (one to two seconds). The resulting pyrolysis gas is condensed as pyrolysis oil. The oil contains 30% water and its heat value is about half that of fossil fuel oil. To use pyrolysis oil for transportation purposes, the oil has to be further refined. The optimal setup would be to have several pyrolysis plants to feed a common refinery.

http://www.ensyn.com
http://www.kior.com

Market Overview
Although this technology is in its early stage, pyrolysis oil could have a market in New Zealand; the challenge is which option to consider for a market.

There would be limited use for combined heat and power applications with the availability of cheap power and heat for large parts of New Zealand, making the technology uncompetitive. There may be a niche opportunity as a replacement for boiler fuel (bunker C types of fuel).

Pyrolysis oil direct to fuels would be the best path, although the economics were not modelled in this case. However the challenge in New Zealand is two-fold: a producer using a catalysed approach, going directly to a drop-in fuel, would have to invest significant effort into market acceptance of the product; if using an uncatalysed approach, partnering with a refinery would be of critical importance.

WoodScape Model Performance
The fast pyrolysis option for CHP has a negative ROCE (-1%), while the option to produce boiler fuel has a positive ROCE (5.8%). This is primarily driven by the low cost of power and heat in New Zealand versus the price of fuel. However, as this is a heavy fuel option, clear markets and customers would have to be identified as part of the due diligence on the technology.

This application has been tested in a couple of instances, however the use of pyrolysis oil as a boiler fuel may require the customer to change lines or nozzles in their system to use the product.

At this stage, no carbon credit or offset has been assumed for this product.

ROCE Sensitivity (+/- 5% change)

	Combined Heat and Power	**Boiler Fuel**
Feedstock	0.2%	0.2%
Labour	0.1%	0.2%
Pricing	0.7%	1.0%
Energy	0.1%	0.1%
Capital	0.2%	0.5%

Heat & Power – Wood Pellets

	Wood Pellets (70,000* odt)	Wood Pellets (160,000* odt)	Wood Pellets (500,000* odt)
ROCE	4	3	3
Market	4	4	4
Technology	4	4	4
EBITDA	2	2	2

*product out

Technology Overview

The wood pellet process is a simple technology. Essentially, biomass of various qualities is hammered and milled down to a 3mm particle size and then pressed into a pellet mould. Key to the process is the target market and the feedstock going into the facility.

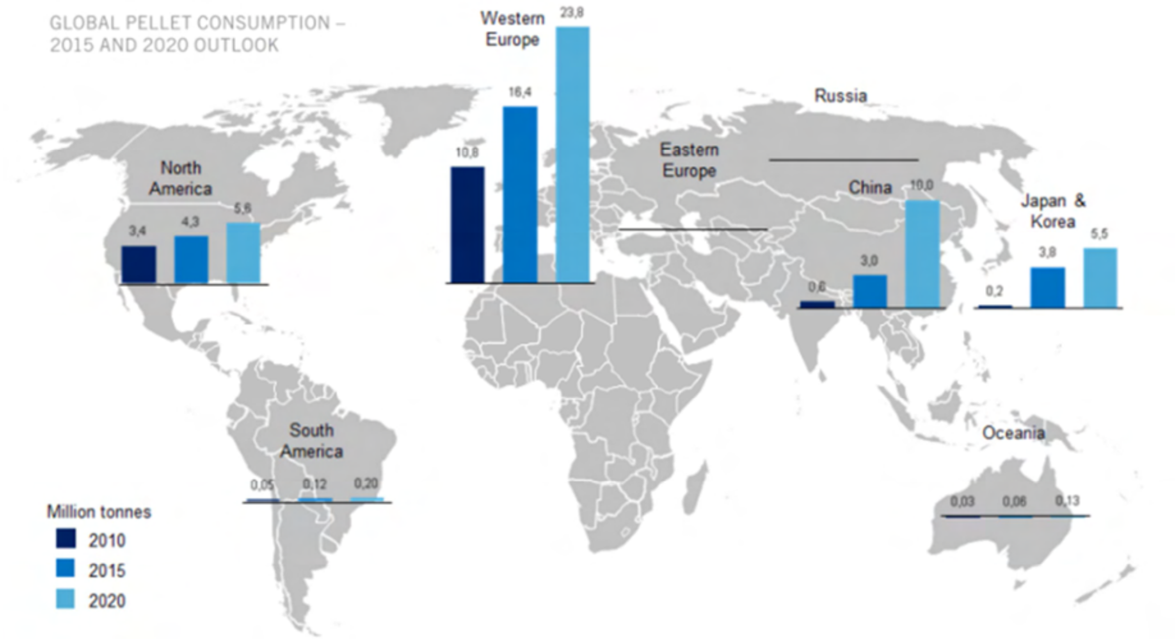
If the target market is residential pellets, then a whitewood pellet is required which produces little or no ash when burned. If the market is an industrial power generator, more ash is acceptable within limits. This allows for a wider range of feed material into the process.

The WoodScape model is based on three sizes of pellet mills. These sizes were picked to show the scale impact, however users should be aware that pellet mills come in many sizes sufficient to match the facility or business.

Market Overview

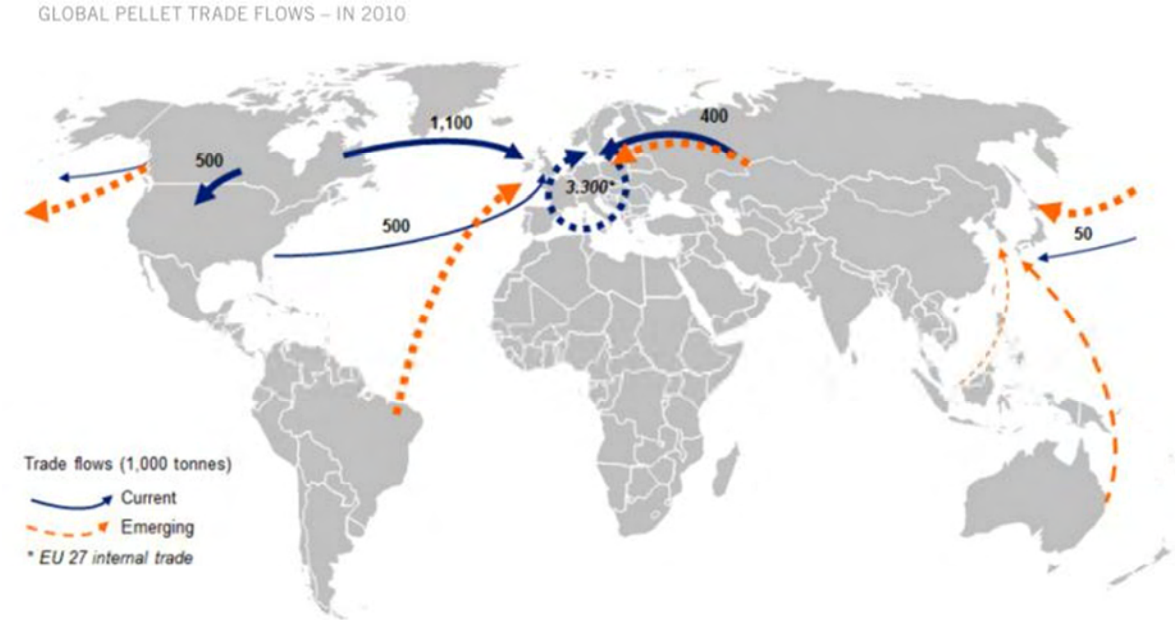
The global market for pellets has had relatively little impact from the global recession. Driven in Europe by climate change goals and energy security issues, pellet co-firing in power utilities has led the way. Substantial growth in the demand for pellets is predicted by most analysts, from approximately 15 million tonnes pa to 40 million tonnes pa, at an estimated 11% growth rate.

The two primary regions of opportunity are Europe, and Japan and Korea. Although China is projected to be a top consumer, it is expected that it will produce its own pellets. Europe is forecasted to continue the current trend of importation, with South America playing a larger role than in the past. Japan and Korea are expected to need imports from North America or from the Oceania regions.



Source: Poyry – Global pellet market outlook to 2020.

This can be seen in the figure below, where the emerging trade flows are projected to come from North America (western Canada), and Australia and New Zealand.



Source: Poyry – Global pellet market outlook to 2020.

These forecasts come with considerable risk due to their reliance on government policy and behaviour around renewable fuels. The subsidies that drive the adoption of pellets, such as a higher cost source of power, may reduce and significantly alter this forecast. Also in the longer term, the viewpoint of biomass as a renewable fuel, or the issue of exportation of carbon from one jurisdiction to another, may come into debate. As a result, companies looking at these opportunities should be aware of the market risk and adopt an approach to minimise that risk.

WoodScape Model Performance

The WoodScape model considered New Zealand shipments of wood pellets to Europe as a base case, being the current market for pellets. The ROCE ranged from 12% to 6% to

4% for the smallest mill to the largest mill. Although this is counter intuitive, the main driver behind larger facilities having lower returns is the incremental cost of fibre. The small pellet mill consumed hog fuel, while the large pellet mill consumed pulp logs or slab wood.

The financial model for wood pellets is highly sensitive to this feedstock price and to the pellet price. This pellet price is driven by shipment cost and foreign exchange. The high cost of shipping to Europe drives the results down considerably, as does the volatility of the New Zealand dollar against the Euro.

ROCE Sensitivity (+/- 5% change)

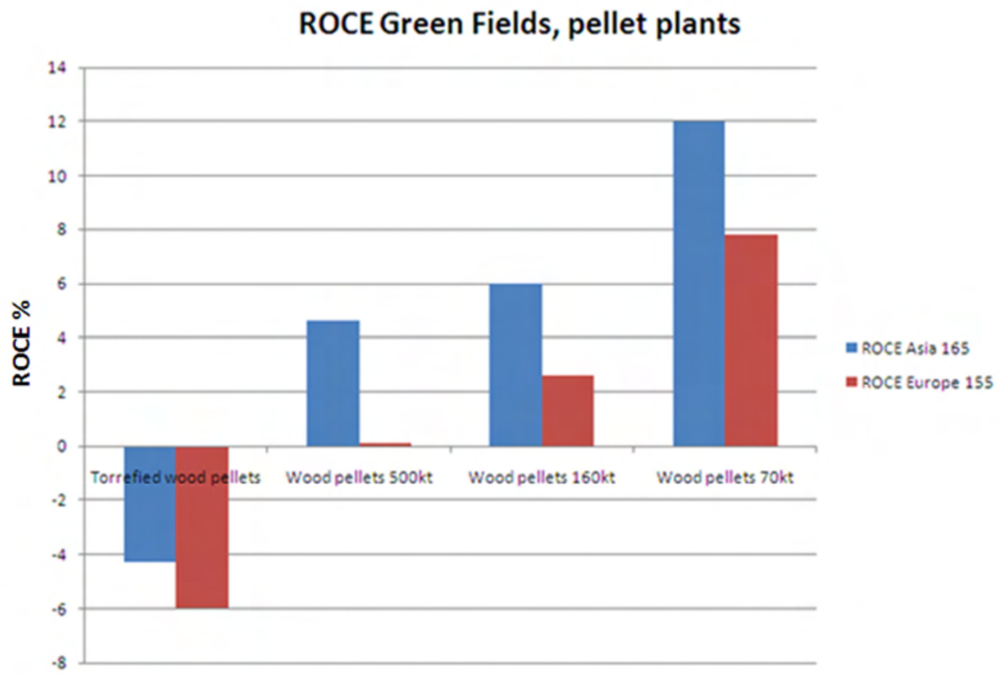
	Wood Pellets (70,000 odt)	**Wood Pellets (160,000 odt)**	**Wood Pellets (500,000 odt)**
Feedstock	1.2%	1.9	2.9%
Labour	0.7%	0.6	0.2%
Pricing	3.4%	3.5	3.6%
Energy	0.3%	0.3	0.5%
Capital	0.9%	0.6	0.1%

European versus Asian market delivery

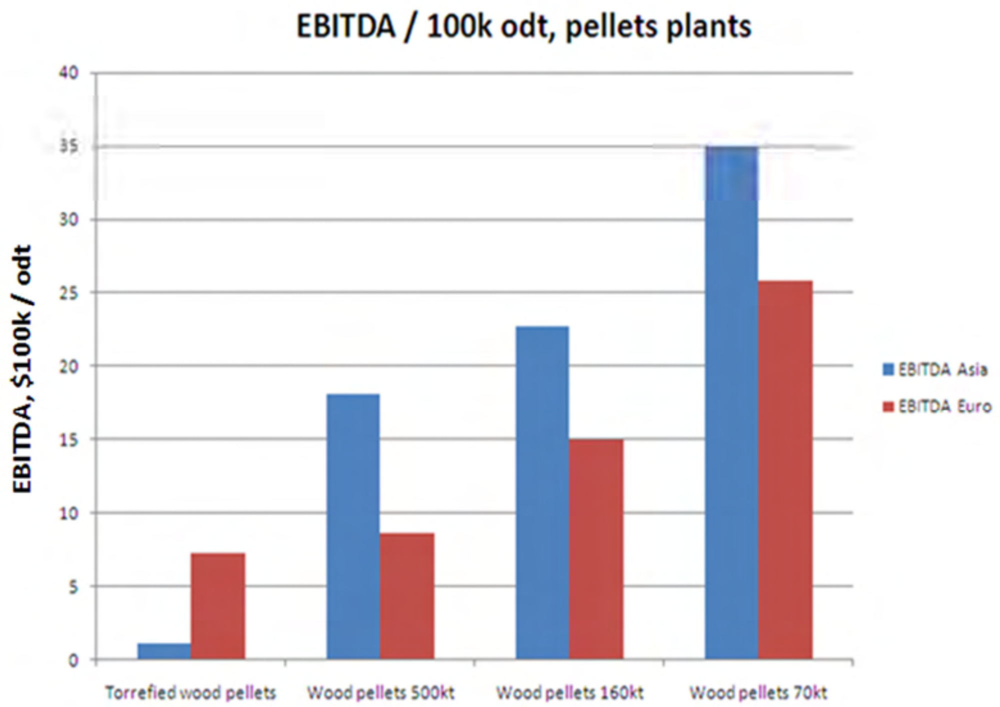
A second scenario was calculated based on the market outlook of rapid growth in Japan and Korea, with these countries being the target market. To evaluate this option, the product price was kept equal but the freight cost adjusted to reflect break bulk shipment to Japan. This provided a financial benefit of $10/t which goes directly to the bottom line, thereby increasing the ROCE. See graph below.

Companies interested in pellets should monitor the situation in Japan and Korea. Both countries have renewable fuel targets and are net importers of energy, but the price they are willing to pay for pellets may be dictated by government policy.

Since wood pellets are primarily driven by cheap feedstock, freight and foreign exchange, the key to success will be managing risk on price and foreign exchange through contracts, and locating the facility where there is a current imbalance in cheap feedstock and good port infrastructure. It is also important to recognise that there are significant synergies with other producers when it comes to shipping infrastructure. Silos at the wharf can be shared and larger (cheaper $/tonne) ships can fill up more regularly, meaning lower shipping rates. This is a key advantage for Canadian producers who ship along rail lines into shared facilities and shared ships.



ROCE Green Fields, pellet plants
ROCE %
14
12
10
8
6
4
2
0
-2
-4
-6
-8
Torrefied wood pellets
Wood pellets 500kt
Wood pellets 160kt
Wood pellets 70kt
ROCE Asia 165
ROCE Europe 155



EBITDA / 100k odt, pellets plants
EBITDA, $100k / odt
40
35
30
25
20
15
10
5
0
Torrefied wood pellets
Wood pellets 500kt
Wood pellets 160kt
Wood pellets 70kt
EBITDA Asia
EBITDA Euro

Source: Wood Pellet Association of Canada

Heat & Power – Torrefied Wood Pellets

	Torrefied Pellets 50,000 odt product
ROCE	1
Market	3
Technology	3
EBITDA	2

Technology Overview
One of the challenges of wood pellets is their shipment cost per unit of energy. As a result, there is significant interest in torrefied wood pellets. A torrefied wood pellet is one that has been heated from 200^0 to 300^0 Celsius in a non-combustible environment, to drive off the hemi-cellulose component of the biomass. This increases energy density (energy per unit of weight), increases the water resistance of the pellet and improves its ability to be co-fired with coal. This has value for the customer and has positive impacts on the supply chain. One downside of torrefied material, however, is the possibility of pellets breaking down in transit, or in handling; the increased levels of dust create a risk for explosion.

At the present stage of development there are several demonstration plants around the world producing small volumes of torrefied materials. The approach and the recipe are not standardised, and a manufacturer would need to have agreement with their consumer to make this technology practicable. Efforts are ongoing around standards. There is a level of optimisation between increased energy density versus loss of biomass and decreased yield.

Market Overview
Most pellet producers view torrefied pellets as the next generation of pellets, and are closely monitoring progress. Amongst consumers, however, there is a split between those that who already made the investment in wood pellets (including weather proofing) and those who have not. This may not affect the market for the end product, but a company should ensure it has discussed the torrefication recipe and result with potential customers as part of its due diligence.

If a company is considering entry into the wood pellet market, it would be advisable to monitor the current situation with torrefied pellets. With shipping being one of the most significant costs to a manufacturer, increasing the energy density per unit would reduce its relative importance.

For the purpose of this model product pricing has been based on the energy equivalent price of wood pellets.

WoodScape Model Performance
The current performance in the WoodScape model is not positive due to the capital cost and yield impact of the process modelled. As this is not the only torrefaction technology available, the economics may improve, but investors in this technology need to pay careful attention to the yield of pellets, (a factor of how far the torrefaction is pushed) and the capital required.

ROCE Sensitivity (+/- 5% change)

	Torrefied Pellets 50,000 odt
Feedstock	0.6%
Labour	0.4%
Pricing	1.4%
Energy	0.1%
Capital	0.1%

Fuels & Chemicals – Syngas to Chemicals

	Ethanol 275,000* m^3	Methanol 270,000* m^3	Acetate 275,000* m^3
ROCE	2	2	4
Market	4	5	3
Technology	3	2	2
EBITDA	4	2	4

Log input volume

Technology Overview
This technology involves first gasifying biomass, and then converting the syngas to a chemical or fuel. This technology is in demonstration in Edmonton, Canada, and the plant has come online in 2012. The technology is adaptable to produce ethanol, methanol and acetate. It should be noted that the technology being demonstrated is based on municipal solid waste not biomass.

www.enerkem.com

Market Overview
The market for the ethanol, methanol and acetate is varied although all three are mainstream chemicals:

1. Ethanol - the market is primarily as a fuel additive. In most jurisdictions this is mandated by government as a primary component of a renewable fuel strategy. Ethanol is also used in other applications including as a commercial alcohol.
2. Methanol - also a primary chemical used in many applications. It is primarily produced from natural gas from major refineries, and a renewable source may have a niche market opportunity.
3. Acetate - another main stream chemical which, although a much smaller market than methanol or ethanol, is a higher value market. In terms of global pricing, acetate is the highest and methanol the lowest.

WoodScape Model Performance
Within WoodScape, the syngas to chemicals option performed moderately with ROCE ranging from 0.5% to 11% for acetate. Although this level of performance is respectable when ranked against other technologies, the degree of technical risk with these options suggests a need for a higher return to offset that risk.

These technologies have a medium sensitivity to pricing. As all three chemicals are globally traded and often priced on that basis, companies exploring this option should be concerned with variabilities in foreign exchange and commodity price.

ROCE Sensitivity (+/- 5% change)

	Ethanol	Methanol	Acetate
Feedstock	0.2%	0.2%	0.2%
Labour	0.3%	0.2%	0.3%
Pricing	1.8%	1.4%	1.9%
Energy	0.2%	0.2%	0.2%
Capital	0.6%	0.3%	0.7%

Fuels & Chemicals – Catalytic Pyrolysis (Aquaflow)

	AquaFlow (350,000* m^3)	AquaFlow (700,000* m^3)
ROCE	4	5
Market	4	4
Technology	2	2
EBITDA	5	5

* Log volume going in

Technology Overview

Catalytic pyrolysis technology takes biomass, which has been reduced to small particles, and uses pyrolysis in the presence of catalysts (varying on the biomass being processed) to produce a mix of hydrocarbon products. Some of the combustible gases are used to provide energy in the process, and the key products are synthetic diesel and jet fuel. The technology can also be used on algae and other biomass feedstocks, such as grasses and straws. This technology is still in development and demonstration stage and is not fully proven at commercial scale.

http://www.aquaflowgroup.com/

Market Overview

The principle products are drop-in diesel and jet fuel, which have a large, well established and growing market as long as the New Zealand fuel standards can be met. Consistent quality standards are critical to liquid fuels. The market price in New Zealand will be benchmarked by the price of oil and New Zealand's currency strength, usually measured against the USD when purchasing oil. Current oil prices are expected to remain high for the foreseeable future with no substantial drops in price being predicted.

WoodScape Model Performance

The catalytic pyrolysis technology performed well in the WoodScape model in terms of ROCE and EBITDA/odt. ROCE ranged from 12 -16% depending on the scale of the plant, with the larger plant providing economies of scale. These ROCEs ranked well against most other technologies, taking a similar feedstock, such as pulp logs or chip, and are in the upper quartile of the overall rankings. There is still some technology risk which would need to be taken into account in an investment.

ROCE Sensitivity (+/- 5% change)

	Aquaflow (350,000)	Aquaflow (700,000)
Feedstock	0.6%	0.7%
Labour	0.1%	0.0%
Pricing	1.9%	2.2%
Energy	0.1%	0.1%
Capital	0.9%	1.0%

Fuels & Chemicals – Ethanol via Fermentation

	Ethanol via Fermentation 1.6M m^3 of log in
ROCE	1
Market	4
Technology	2
EBITDA	1

Technology Overview

Ethanol via fermentation is the process of breaking down the wood with a pre-treatment and then converting the released sugars through fermentation. It is essentially the same high level process as corn to ethanol fermentation, although the conditions and enzymes change. The biggest challenge facing this technology is the effective separation, or breakdown, of the wood into a form that the enzymes can efficiently convert to sugar.

This area of technology has been perhaps the most studied of all the biofuels / bio chemical processing technologies, with research being carried out globally. Significant progress has been made with the efficiency of enzymes and cost of the process.

The technology modelled in WoodScape is based on that considered originally by FPInnovations and then updated with the NREL estimates in 2010. This model only sells ethanol and any residue created is used for heat and power within the facility.

Market Overview

The largest market for ethanol is the United States, for fuel. Fuel ethanol is added as a renewable component in fuels, and government policies around the world are driving the demand. The United States' Renewable Fuel Standards in particular, have set significant targets for renewable fuels from cellulosic biomass.

As a result, global supply has increased dramatically especially in the United States and regions like Brazil. The United States' supply comes mainly from corn; in regions like Brazil it is sugar cane; and in China it is corn, cassava or sweet potatoes. As ethanol can be fermented from any sugar source the price of the base feedstock is exceptionally important to be globally competitive.

Ethanol can also be used as an alcohol for beverages, a smaller mature market, or for the production of ETBE (Ethyl tert-butyl ether), a gasoline additive. There has recently been a shift in the Brazilian market and supply for ethanol, as plastics manufacturers are looking at a bio-based ethanol as a feed-in chemical for plastics manufacture. The final plastics are no different than those from a petroleum feedstock, but are sourced from a renewable feedstock.

As seen in the table below (Ethanol Demand and Supply), global growth of the ethanol market is forecasted to grow to 120,950 million litres by 2015. This represents a growth rate of 4.7%, which is expected to increase demand beyond supply if no new added capacity is brought online. However, based on the number of companies looking at opening bio-based ethanol capacity, there should be no expectation of a shortage of supply in the near future.

Specifically, most Asian countries are forecasted to be net importers of ethanol, with the clear exception of China and India, the two largest markets. Growth rates in Asia are stronger (5-6%) than global growth rates (4.7%). Japan and the Phillippines will be the two most interesting markets if cost effective production can be maintained.

In New Zealand, ethanol is used as a fuel additive (Gull and Mobil) and is sold at 10% blends with petrol. This proportion of the fuel is exempt from excise tax. Currently most of New Zealand's ethanol comes from dairy whey.

Ethanol Demand and Supply

(millions of litres)	Capacity	Consumption 2010	Consumption 2015	Average Annual Growth Rate 2010-2015 (%)
China	10,989	7,426	9,600	5.9%
India	3,000	2,109	2,680	5.4%
Japan	181	396	438	2.1%
Philippines	150	302	500	13.1%
Taiwan		61	100	12.8%
Thailand	1,084	657	1,000	10.4%
Rest of Asia	604	779	1,014	6.0%
Australia	450	336	400	3.8%
New Zealand	25	18	30	13.3%
Rest of World	97,794	85,877	105,200	4.5%
World Total	**114,277**	**97,961**	**120,962**	**4.7%**
Operating Rate		86%	106%	

Source: IHS Chemical Economic Handbook - Ethanol

WoodScape Model Performance

At ethanol prices of NZ$0.85/litre this technology operates with a negative ROCE. The challenge facing this technology is two-fold. Firstly, the technology requires a whitewood source of fibre. As a result, the technology is modelled with chips which are the only source of pure whitewood available. If the technology could tolerate a lower quality feedstock, that includes bark contamination, then a cheaper feedstock could be used, significantly improving the results.

Secondly, the amount of capital needed to implement this type of technology at scale. Ethanol requires both pre-treatment and fermentation stages, which equates to a significant amount of capital. An order of magnitude reduction is required before significant improvements to ROCE occur.

The final issue with ethanol is price. This technology option is very sensitive to commodity pricing. In some jurisdictions, subsidies can help make this technology viable; the downside is that those subsidies need to be in place for the long term.

ROCE Sensitivity (+/- 5% change)

	Ethanol via Fermentation
Feedstock	0.8%
Labour	0.1%
Pricing	1.3%
Energy	0.0%
Capital	0.2%

Fuels & Chemicals – Fischer-Tropsch Diesel (DOE)

	Fisher-Tropsch Diesel (DOE) 1.6M m^3 log in
ROCE	3
Market	4
Technology	2
EBITDA	3

Technology Overview
Fischer-Tropsch (FT) diesel is based on the well-established technology developed during the Second World War and subsequently used in South Africa. The original technology was based on coal as a primary feedstock, and has been adapted to use on biomass feedstocks. Dry chipped biomass is gasified and then a catalysis step FT takes the gas to a liquid hydrocarbon, typically a synthetic diesel.

Gasification of biomass has more challenges than coal and the FT process is sensitive to scale, with a very large plant being preferred. Gasification of biomass with FT to liquids is not commercially proven due to the economies of scale needed. The products from FT-biodiesel synthesis can be refined to diesel oils, gasoline, jet fuel and other oil products.

Lignocellulosic raw material, or biomass, is first dried and gasified. The crude synthesis gas contains mainly carbon monoxide and hydrogen, but also carbon dioxide, water, methane and other impurities. The gas then has to be purified before feeding to the FT (synthesis reactor). In the synthesis, carbon monoxide and hydrogen combine in long chain hydrocarbons with the aid of cobalt or iron catalysts. Various synthesis products in gaseous, liquid and wax form result from this step of the process, which will be further reformed, ideally in an existing fossil oil refinery.

Temperature in gasification is about 1200^{o}C, compared with pyrolysis at 250-300^{o}C and plasma conversion, 7000^{o}C. (Ciferno and Marano, 2002).

Other versions of gasification and FT technology are currently under investigation, including micro-channel FT at the University of Canterbury. These technologies were not included in the model due to insufficient data on CAPEX and OPEX, and should be included in future studies as they have the potential of being viable at a smaller scale.

Market Overview
The primary product produced from this technology is a drop-in substitute for diesel, or possible jet fuel, with some chemical by-products (naphtha, waxes). It is also likely that the plant will generate substantial heat which will be used to generate steam and electricity. This will be used to drive the plant's processes rather being sold. The market for diesel is large and growing with the price set by international oil and refined diesel prices, as well as the strength of the NZ$ versus other major currencies. The quality of the product is critical to market acceptance; established distributors will need assurance that the product will consistently meet current standards.

In the facility modelled for WoodScape, the output of diesel was approximately 107 million litres with another 53 million litres of gasoline. New Zealand's consumption in 2011 was 2,700 million litres of diesel and 3,200 million litres of gasoline. This facility would therefore be able to provide approximately 4% of New Zealand's demand for diesel and 3% of its demand for gasoline. It would consume approximately 675,000 odt's of wood, or

1.7 million m^3 of wood. Putting this into perspective, this is within the scale of the current pulp production at Kinleith.

The principle product is a drop-in substitute for diesel.

WoodScape Model Performance

The FT DOE model has a ROCE in the 2-3% range. It is a very large plant in terms of fibre consumption. It is feasible in the central North Island, although it will have a significant impact on other users in the area. This technology is interesting to explore further, as it puts a drop-in fuel into the market and offsets New Zealand imports of fuels.

Further scenarios with this technology should be explored, such as its potential under future oil prices and foreign exchange. In addition, the issue of carbon has not been built into this model. This may incrementally increase the returns on these technologies.

ROCE Sensitivity (+/- 5% change)

	FT Diesel DOE
Feedstock	0.7%
Labour	0.0%
Pricing	1.3%
Energy	0.0%
Capital	0.4%

Fuels & Chemicals – Fischer-Tropsch Diesel (Davy Process Technology)

	Fischer-Tropsch Diesel (DPT) 1.0M m^3 log in	Fischer-Tropsch Diesel (DPT) 5.0M m^3 log in
ROCE	3	4
Market	4	4
Technology	2	2
EBITDA	4	4

Technology Overview
This version of the gasification plus Fisher Tropsch synthesis is based on a technology developed by Davy Process Technology. This technology has higher yield than the DOE model of the previous section. Refer to previous section for more general details on the gasification plus Fisher Tropsch technology.

http://www.davyprotech.com

Market Overview
See previous section.

WoodScape Model Performance
There are three versions of the FT diesel process within the WoodScape model. Their ROCEs ranged from 2.6% through 5.4% to 8.5%. The New Zealand models perform better than the DOE version as they incorporate higher yields of fuels. This is a mid-range performance. The ROCE results are sensitive to scale, with a very large plant (feedstock demand of 5.0 million m^3) giving the better result. These results would not preclude the technology from further, more detailed investigation of its suitability.

ROCE Sensitivity (+/- 5% change)

	FT Diesel (Small)	FT Diesel (Large)
Feedstock	0.4%	0.9%
Labour	0.0%	0.0%
Pricing	1.1%	1.8%
Energy	0.0%	0.0%
Capital	0.5%	0.7%

Fuels & Chemicals – Lignin Polymers (Solvent Rescue)

	Lignin Polymers 0.62M m^3 log in	Lignin Polymers 1.25M m^3 log in
ROCE	4	5
Market	2	2
Technology	2	2
EBITDA	4	5

Technology Overview
The Lignin Polymers technology, developed by Solvent Rescue, is based on a supercritical water reaction process. Finely ground biomass is treated in water at very high pressure and high temperature (water's supercritical point). The biomass breaks down into a mix of lignin, which is claimed to be very high value (in excess of $1000 per tonne) and a biocrude suitable for processing into liquid hydrocarbon fuels. The technology has been developed to pilot scale but is still under development. There are other similar approaches also under development elsewhere in the world.

http://www.solventrescue.co.nz/

Market Overview
The key product from the process is lignin, which has a very high value. Currently, lignins derived from other process fetch up to US$800 per tonne, and have a range of end uses in the chemical industry, with developing uses in the plastics and oil industries.

The biocrude product could be refined into fuels such as diesel, with the exact route not determined. It is possible that it could be blended with crude oil and put through an oil refinery, or specialist refining at a local level might also be possible; neither route is commercially proven. The biocrude product is priced on its energy equivalence to crude oil.

WoodScape Model Performance
The Lignin Polymers technology performs well in terms of ROCE compared to other options in the model. There are two scale options, with the larger scale performing better (21% versus 15%). There is still a substantial degree of risk associated with this technology as it is still at pilot scale, and markets and market prices for the products are not fully established. Its performance in the model indicates that it is worth further development and investigation.

The results are highly sensitive to the price for the lignin product and this process is looking for a price premium over that of ligno-sulphonates, based on its product characteristics (no sulphur, natural state, etc.)

ROCE Sensitivity (+/- 5% change)

	Lignin Polymers	Lignin Polymers
Feedstock	1.2%	1.4%
Labour	0.1%	0.1%
Pricing	2.4%	2.9%
Energy	0.1%	0.1%
Capital	1.0%	1.2%

Fuels & Chemicals – Organosolv Pulping (Lignol)

	Organosolv Pulping 0.83M m^3 log in
ROCE	1
Market	2
Technology	2
EBITDA	2

Technology Overview

The Organsolv process in the WoodScape model is based on the Repap process originally designed and built in eastern Canada. This technology is now controlled by Lignol, and is based on pulping chips with ethanol, then fermentation to produce additional ethanol from the sugars in the wood. The significant difference to the usual Organosolv process is that Lignol extracts the lignin for eventual sale. This lignin is described as significantly different from the ligno-sulphonates currently on the market, allowing for a wider range of opportunities in new markets. Success with the lignin is a key component of Lignol's strategy, as without obtaining a higher value for the lignin, the facility is not commercially viable.

This technology is currently in a pilot plant stage (continuous processing) and the company is looking for opportunities to build a demonstration model. One aspect not covered in this analysis is the potential for Lignol to custom ferment the sugars to another chemical. The modelling is presently based on Lignol producing ethanol; however it may be possible for them to produce another biofuel, such as Butanol, which may provide higher income and improve the economics of the process.

http://www.lignol.ca

Market Overview

The market for ethanol has already been reviewed in the Ethanol via Fermentation technology pages. The market for lignin could be considered significantly underdeveloped at this stage. Although there is a significant market for ligno-sulphonates, there is no confirmed market for the pure 'lignin' that this technology makes.

Ligno-sulphonates are used in adhesives, binders, dyes and various products like asphalt. The total market is about 1.2 million tonnes. New entrants looking to capitalise on the properties of their 'native lignin' are targeting opportunities like foundry resins, phenolic panels or animal feed. These markets are untested, although they show some promise especially where the lignin may be a substitute for phenol which has seen significant price increases in the past five years. Partnerships with these potential downstream customers will be crucial for success.

Ligno-sulphonate Markets (volumes in 1000's of tonnes)

	Annual Capacity (year-end)	Consumption 2010	Consumption 2015	Average Annual Growth Rate, 2008-2013
North America				(percent)
Total	**426**	**313**	**314**	**0.1%**
Central and South America	36	42	46	1.8%
Western Europe	477	287	267	-1.4%
Central and Eastern Europe	393	251	304	4.2%
Africa	165	14	18	4.6%
Middle East	-	47	75	11.6%
Asia				
China	380	186	230	4.7%
India		22	26	3.3%
Indonesia	-	8	8	0.0%
Japan	65	63	55	-2.4%
Korea, Republic of	-	42	39	-1.4%
Malaysia	-	7	7	0.0%
Philippines	-	3	3	0.0%
Singapore	-	2	2	0.0%
Taiwan	-	18	18	0.0%
Thailand	-	7	7	0.0%
Other	-	9	10	4.0%
Total	**445**	**367**	**405**	**1.9%**
Oceania				
Australia	-	7	7	0.0%
New Zealand	-	1	1	0.0%
Total	**-**	**8**	**8**	**0.0%**
Total	**1,942**	**1,330**	**1,437**	**1.4%**

Source: The Chemical Economics Handbook.

It should be noted that even if these other opportunities begin to provide sales there is still significant risk on the market side. This is technology was to be implemented it would add 75,000 odt's of lignin to the overall market. Care must be taken in implementation of this type of facility to ensure that both the lignin and the ethanol are sold.

WoodScape Model Performance

The Organsolv facility was slightly negative in terms of ROCE, not a sufficient return given the technology and market risk. Pricing is a key component, which puts the technology on challenging grounds in face of the uncertainty in lignin pricing for new markets. The technical risks also need to be addressed, both in the process and also with the customer. Companies considering this technology need to spend as much time understanding the technical risk with consumers as they do on the plant and process. Companies should also be aware that building these customer partnerships will take time.

ROCE Sensitivity (+/- 5% change)

	Organosolv
Feedstock	0.5%
Labour	0.0%
Pricing	1.3%
Energy	0.3%
Capital	0.2%

Fuels & Chemicals – Tannin Hot Water / Sulphate

	Tannin Hot Water 28,000 t bark	Tannin Sulphate 28,000 t bark
ROCE	1	2
Market	2	2
Technology	2	2
EBITDA	1	3

Technology Overview
There are two tannin extraction technologies in the model; hot water and sulphate. The feedstock is bark (Radiata pine), and the extraction processes used historically, vary widely, depending on the feedstock and the end use. There are well established processes and markets for the products, however, processes and feedstocks are end use specific and new variations are being developed. These are still at pilot scale. Yields of product are low on a kg per kg of feedstock basis. This technology is based on a Scion developed process.

Market Overview
The tannins extracted from the bark are used in a wide range of industries: tanning, resin and glue, medical and food. The tannins extracted are viewed as being very high value, and there are an increasing number of uses for tannins and chemicals extracted from bark.

WoodScape Model Performance
The ROCEs of the tannin technologies were at the lower end of the scale of the others in the WoodScape model. The hot water process did not rank as well as the sulphate process. The tannin technologies were comparatively high in capital cost in relation to volume of feedstock being processed and product being created. The greatest sensitivities are to product pricing and feedstock costs.

ROCE Sensitivity (+/- 5% change)

	Tannin Hot Water	Tannin Sulphate
Feedstock	0.4%	0.4%
Labour	0.2%	0.2%
Pricing	0.5%	0.9%
Energy	0.1%	0.1%
Capital	0.2%	0.2%

Acknowledgements

The authors wish to acknowledge the New Zealand wood processing industry for the assistance, data and review of the WoodScape model and reports.

REFERENCES

Cicerno J.P. and Marano J. J. (2002). Benchmarking Biomass Gasification Technologies for Fuels, Chemicals and Hydrogen Production. U.S. Department of Energy National Energy Technology Laboratory

Indufor 2012. Wood Products Market Report – Confidential to WoodScape study

Biopathways 2010; FPInnovations – BioPathways study

Random Lengths – Weekly lumber and panel market newsletter

Japan Lumber Journal.

Global Trade Services.

[1] Techno-Economic Analysis of Biochemical Scenarios for Production of Cellulosic Ethanol, NREL/TP-6A2-46588 June 2010

WoodScape model results.

Glossary

Admt	Air dry metric tonne
BCTMP	Bleached Thermo-mechanical Pulp
CHP	Combined Heat & Power
CHH P&P	Carter Holt Harvey Pulp and Paper
CLT	Cross laminated timber
CNI	Central North Island
Cm	centimetre
CO2	Carbon Dioxide
D. Fir	Douglas fir
Euc.	Eucalyptus
FAOSTAT	Food & Agriculture Organisation Statistics
GDP	Gross Domestic Product
Glulam	laminated lumber beams and columns
ha	Hectare
k	thousand
m	metre
M	Million
m^3	cubic metre
MDF	Medium density Fibre board
Min.	Minimum
MW	Megawatt
MW_e	Megawatt electric
MW_{th}	Megawatt thermal
NBSK	Northern Bleached Softwood Kraft
NBHK	Northern Bleached Hardwood Kraft
LVL	Laminated Veneer Lumber
odt / ODT	Oven dry tonne
OEL	Optimised Engineered Lumber
OEM	original equipment manufacturer
OSB	Oriented strand board
pa	per annum
P. Rad	Pinus radiata
RBC	Royal Bank of Canada
ROCE	Return on Capital Employed
Radiata	Pinus radiata
sed	small end diameter
SWP	Solid wood processing
SWOT	Strengths, Weaknesses, Opportunities & Threats
TMP	Thermo-mechanical pulp
t	tonne
Wood pellets	pelletised wood from sawdust – used for fuel
Wood fibre dice	wood fibre similar to MDF formed into dice – used in plastics reinforcing

A Grade	Saw log; unpruned, min. sed 30 cm, max. knot 10 cm, min length 3.7 to 6.1 m
K grade	Sawlog; unpruned, min. sed 20 to 34 cm, max. knot 15 cm, lengths vary 3.6 to 12 m.
S grade	Sawlog, unpruned, min. Sed30 to 40 cm, max. knot 6 cm, lengths 4.1 to 6.4 m

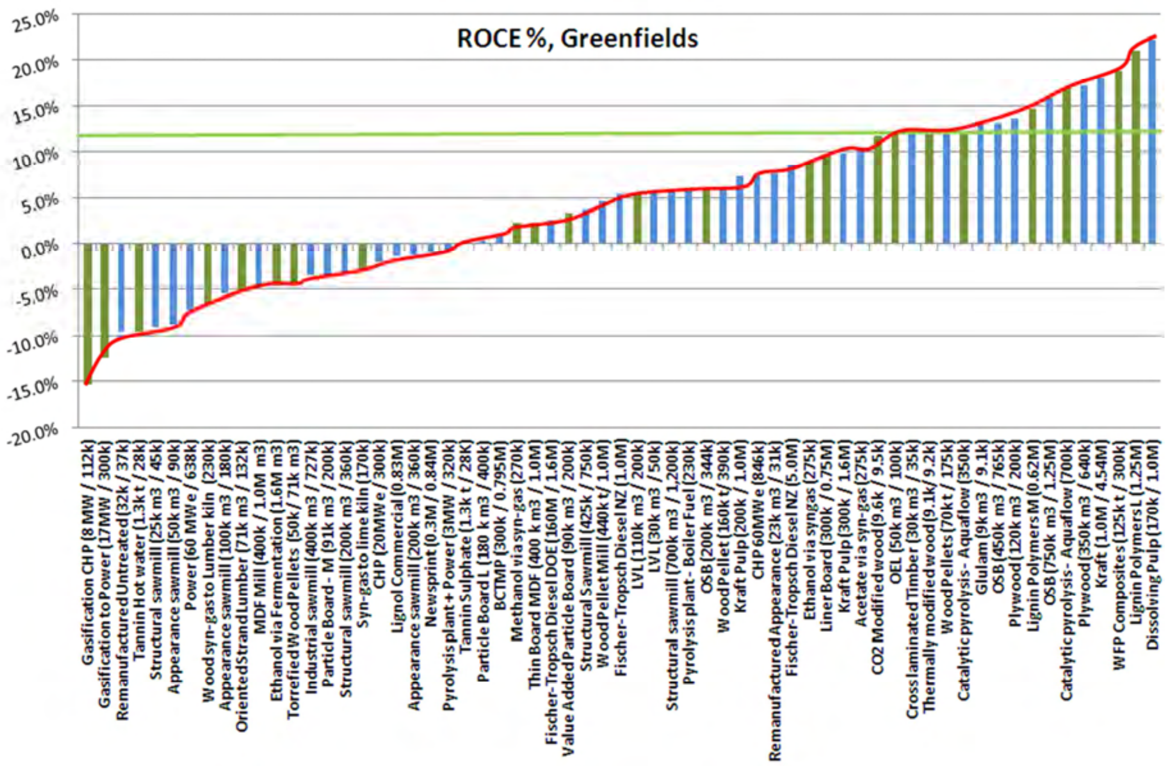
Appendix A – Log Price assumptions (Agrifax, 2012)

Wood Price	$/odt	$/m3
Peeler log	323.80	129.53
Sawlogs	267.00	100.77
Industrial logs	235.20	88.77
Post and Poles	224.20	82.07
Pulpwood	141.80	51.25
Chips	148.80	56.16
Hog fuel	35.00	12.31
Bark - Coarse	115.56	47.96
Sawdust	50.00	18.87
Shavings	50.00	18.87

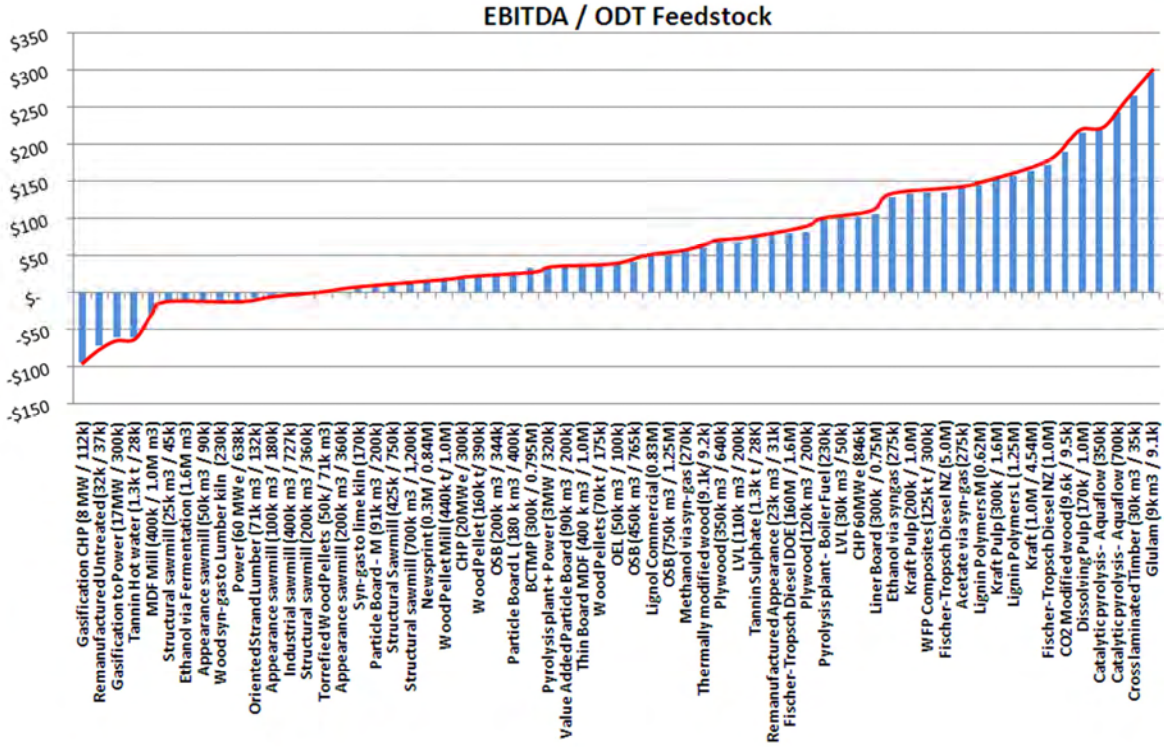
Appendix B – ROCE graphs

The red line on the graphs indicates the base case results

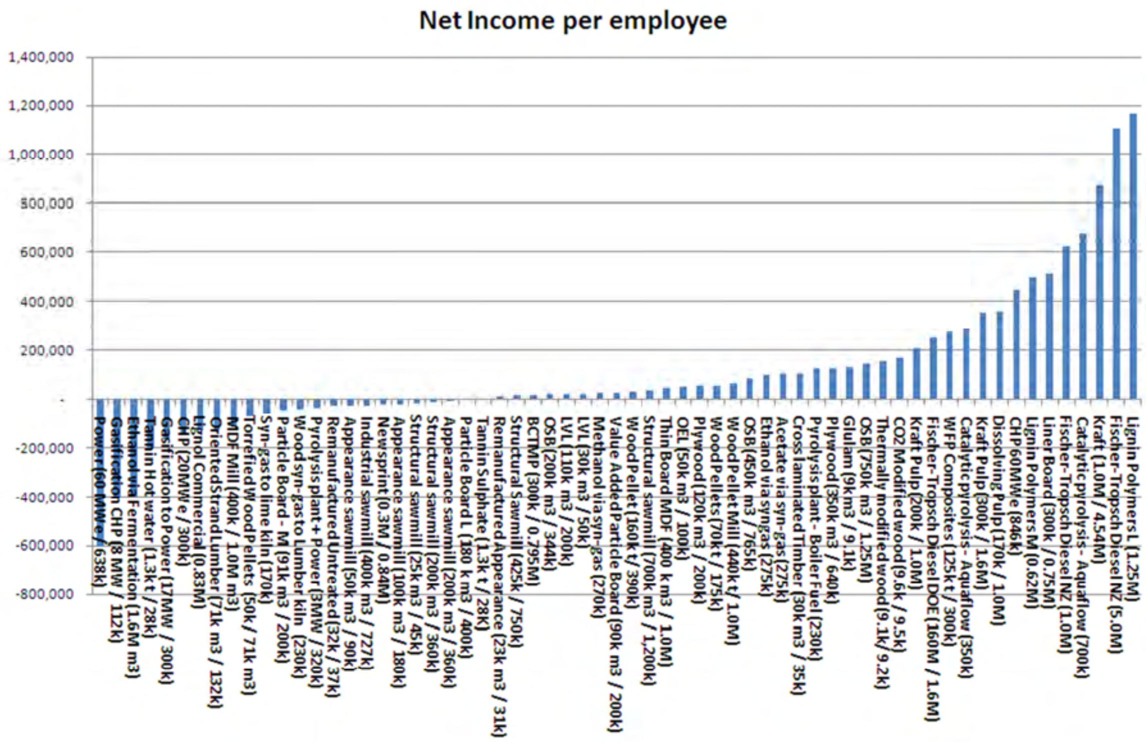
1. Base Case



EBITDA
Base case



Net Income per employee
Base Case



APPENDIX C – TECHNOLOGY LIST

Fuel & Chemical	Tannin Hot water (1.3k t / 28k)
Fuel & Chemical	Wood syn-gas to Lumber kiln (230k)
Fuel & Chemical	Ethanol via Fermentation (1.6M m3)
Fuel & Chemical	Syn-gas to lime kiln / 170k
Fuel & Chemical	Lignol Commercial / 0.83M
Fuel & Chemical	Tannin Sulphate (1.3k t / 28K)
Fuel & Chemical	Methanol via syn-gas / 270k
Fuel & Chemical	Fischer-Tropsch Diesel DOE (160M / 1.6M)
Fuel & Chemical	Fischer-Tropsch Diesel NZ (1.0M)
Fuel & Chemical	Fischer-Tropsch Diesel NZ (5.0M)
Fuel & Chemical	Ethanol via syngas (275k)
Fuel & Chemical	Acetate via syn-gas (275k)
Fuel & Chemical	Catalytic pyrolysis - Aquaflow (350k)
Fuel & Chemical	Lignin Polymers M / 0.62M
Fuel & Chemical	Catalytic pyrolysis - Aquaflow / 700k
Fuel & Chemical	Lignin Polymers / 1.25M
Fuel & Chemical	Dissolving Pulp (170k / 1.0M)
Power & Heat	Gasification CHP (8 MW / 112k)
Power & Heat	Gasification to Power (17MW / 300k)
Power & Heat	Power (60 Mwe / 638k)
Power & Heat	Torrefied Wood Pellets (50k / 71k m3)
Power & Heat	CHP (20MWe) / 300k
Power & Heat	Pyrolysis plant + Power 3MW / 320k
Power & Heat	Wood Pellet Mill (440k t/ 1.0M)
Power & Heat	Pyrolysis plant - Boiler Fuel / 230k
Power & Heat	Wood Pellet (160k t/ 390k)
Power & Heat	CHP 60MWe (846k)
Power & Heat	Wood Pellets (70k t/ 175k)
Pulp & Paper	Newsprint 0.3M / 0.84M
Pulp & Paper	BCTMP (300k / 0.795M)
Pulp & Paper	Kraft Pulp (200k / 1.0M)
Pulp & Paper	Liner Board (300k / 0.75M)
Pulp & Paper	Kraft Pulp (300k / 1.6M)
Pulp & Paper	Kraft (1.0M / 4.54M)
Recon & panel	Oriented Strand Lumber (132k m3 / 71k)
Recon & panel	MDF Mill (400k / 1.0M m3)
Recon & panel	Particle Board - M 91k m3 / 200k
Recon & panel	Particle Board L (180 k m3 / 400k)
Recon & panel	OEL (50k / 100k)
Recon & panel	Thin Board MDF (400 k m3 / 1.0M)
Recon & panel	Value Added Particle Board (90k m3 / 200k)
Recon & panel	LVL (110k m3 / 200k)
Recon & panel	LVL (30k m3/ 50k)
Recon & panel	OSB (200k m3 / 344k)
Recon & panel	Cross laminated Timber (30k m3 / 35k)
Recon & panel	OSB (450k m3 / 765k)
Recon & panel	Plywood (120k m3 / 200k)
Recon & panel	OSB (750k m3 / 1.25M)
Recon & panel	Plywood (350k m3 / 640k)
Recon & panel	WFP Composites (125k t / 300k)
Sawmilling	Structural sawmill (25k m3 / 45k)
Sawmilling	Appearance sawmill (50k m3 / 90k)
Sawmilling	Appearance sawmill (100k m3 / 180k)
Sawmilling	Industrial sawmill (400k m3 / 727k)
Sawmilling	Structural sawmill (200k m3 / 360k)
Sawmilling	Appearance sawmill (200k m3 / 360k)
Sawmilling	Structural Sawmill (425k / 750k)
Sawmilling	Structural sawmill (700k m3 / 1,200k m3)
Secondary SWP	Remanufactured Untreated (32k / 37k)
Secondary SWP	Remanufactured Appearance (23k m3 / 31k)
Secondary SWP	CO2 Modified wood (9.6k / 9.5k)
Secondary SWP	Thermally modified wood (9.1k/ 9.2k)

APPENDIX D – NEW ZEALAND WOOD FLOW