Identifying processing opportunities for key specialty tree species; - processing options analysis using the WoodScape model

Authors: Peter Hall, Rosie Sargent and Steve Riley

Date: May 2019

Publication No: SWP-T073

TABLE OF CONTENTS

Scion reference number; SIdney No.

EXECUTIVE SUMMARY

The Specialty Wood Products Research Partnership wish to know where there are opportunities to develop processing of Douglas-fir, Cypress and Eucalyptus species (nitens and fastigata).

A previous report covers the long-term supply of these species at a regional level. Whilst there are substantial volumes available in some locations typically volumes are more modest (<10,000 m^3 per annum) and show a decline in volume available over time. A summary of the long run volumes estimated to be available is presented.

Log and wood product prices for the three target species were identified from industry sources.

Product prices were worked back from retail prices to ex-mill prices. Conversion factors from logs to products were derived from industry sources to generate a weighted or blended ex-mill lumber price. Cypress logs and Eucalyptus logs were found to have lower conversions from logs to products than Douglas-fir.

The costs of drying these specialty wood products were calculated for conventional kilns, low temperature kilns, solar kilns and air drying with low temperature kiln finishing.

The log prices, ex-mill blended lumber prices and drying costs were then used in the WoodScape model to determine the financial performance of some wood processing opportunities; small scale sawmilling and OEL™.

The best performing sawmilling options were;
- Cypress logs, particularly with a solar kiln and a small sawmill
- Eucalyptus with a solar kiln, but only at lower log prices.

Making OEL™ from cheaper lower grade *Eucalypt nitens* logs is also viable

OEL™ was only viable on cheaper logs, which will be in limited supply as they will only be 20 to 25% of the total log supply. This would limit its application on specialty tree species unless a larger mill was to run on a mix of species.

INTRODUCTION

The Speciality Wood Products (SWP) Research Partnership wishes to know what opportunities there are for processing of their species of interest, in comparison to *P. radiata* processing based on estimates of financial returns. The focus of this work is on Douglas-fir, Cypress and Eucalyptus species.

The Ministry of Primary Industries (MPI, 2016) National Exotic Forest Description (NEFD) figures were used to identify where the wood resource is located (Hall et al, 2018).

In 2012 Scion conducted the WoodScape study, which developed a model (WoodScape). This study was prompted by the Woodco strategic goal of increasing on-shore wood processing, reducing log export volumes and adding $6 billion to NZ's export earnings. The model developed for the WoodScape project enables comparison of financial returns from a wide range of wood processing options off a common basis. The model currently has 135 wood processing options, including 65 different processing types along with some scale variants. Further, new processing types and scale can be added to the model, as long as there is sufficient data available (capital and operating costs, log and product prices etc.).

Logs from specialty species are sometimes exported as there is no, or limited, onshore market and prices are often lower than radiata prices simply because the species is unfamiliar to the dominant Chinese log market. A driver for this study is to get the maximum value from the specialty species estate by determining financially viable wood products, with a focus on Douglas-fir, Cypress and *Eucalyptus nitens.*

The intent of this work is to identify the size and location of the specialty species resource, now and into the future (2050) and then determine which wood processing types, products and scales fit with these resources and have attractive financial metrics (ROCE, NPV, IRR).

This work will include the following species:

- Douglas-fir
    - Douglas-fir production thinnings
- *E. nitens* – focussed on Otago and Southland resource
- Cypresses (macrocarpa and lusitanica)

The analysis of the log resources is reported separately (Hall, Sargent and Riley 2018), with a summary table from that work presented here.

Glossary

ROCE — Return on capital employed;

- a financial ratio that measures a company's profitability and the efficiency with which its capital is employed. **ROCE** is calculated as: **ROCE** = Earnings Before Interest and Tax (EBIT) divided by Capital Employed

NPV — Net present value;

- the difference between the present value of cash inflows and the present value of cash outflows over a period of time.

IRR — Internal rate of return;

- a metric used in capital budgeting to estimate the profitability of potential investments. The internal rate of return is a discount rate that makes the net present value (NPV) of all cash flows from a project equal to zero.

EBIT — Earnings before Interest and Tax

Objectives

The objectives of this work are to;

1. Summarise the long run supply volume of Douglas-fir, Cypress and *Eucalyptus nitens* and *fastigata* logs by district.
2. Establish current and historical prices for Douglas-fir, Cypress and Eucalyptus logs
3. Identify wood products that Douglas-fir, Cypress and Eucalyptus can be manufactured into, and prices for these products.
4. Gather data on technologies (very small sawmill, portable sawmill, solar kilns etc.) we wish to analyse that are not already included in the WoodScape model and add them to the model. A list of technologies already in WoodScape can be found in Appendix 1.
5. Identify technologies that can viably be used on a small scale Douglas-fir, cypress and Eucalyptus wood resources.

Using the log volume and price data in the WoodScape model, identify the key financial metrics (ROCE, IRR, NPV) of these processing options for the different species.

Then using with the regional supply volumes, identify regions where these technologies could be applied.

The following technologies and products to be added to the WoodScape model:

Technologies

- Sawing appearance grade products with a portable mill (Woodmizer)
- Solar kiln drying
- Small (<50k m^3 p.a.) appearance grade sawmill
    - With small conventional temperature (<90°C) kiln

Products

Cypress

- Decking timber (cypress heartwood)
- Cladding (cypress heartwood).
- Cypress Utility
    - Outdoor furniture (cypress heartwood)
    - Raised garden beds (cypress heartwood)

Douglas-fir

- Structural lumber
- Appearance lumber
- OEL™

Eucalyptus

- Flooring
- Stair treads
- OEL™

METHODS

The study was carried out using the following approach;

1. Summary of regional wood supply data was derived from the previous report. This information indicates the scale of the processing opportunity at a regional level.

2. Prices were searched out (internet, industry contact, literature) for Douglas-fir, Cypress and Eucalyptus logs to establish typical prices and variations in price.

3. Products (traditional and new) for which Douglas-fir, Cypress and the Eucalyptus species of interest are suitable were identified.

4. Where these products (prices) and processes were not already in the WoodScape model data was gathered (internet, industry, literature) to expand and populate the model.

5. The WoodScape model was used to determine the financial metrics of milling and drying these species at a small-scale.

6. Summarise the results with a focus on the financial performance (return on capital employed (ROCE), Internal rate of return (IRR), Net present value (NPV)) of the wood processing options.

The data from the WoodScape modelling was subject to sensitivity analysis.

RESULTS

Wood availability

Summary of long run log supply volumes

To be able to determine the type and scale of processing that is appropriate for a region / species, there needs to an understanding of the volume of wood that is available on a consistent basis over the long term (30 to 40 years) (Hall et al, 2018).

Log supply by region and species (without new plantings)

Douglas-fir is the most plentiful of the target species, with long run resources of >50,000 m^3 per annum in 5 regions (Table 1).

The only region with a significant long-term resource of Cypress is the West Coast. All other regions have only a few thousand cubic metres per annum. It is understood (P. Millen & M. Lausberg, *pers comm*) that the quality of West Coast cypress is poor, so the useable volume of logs will be lower than that reported here.

Only Waikato and Southland have significant long-term resources of Eucalypts. Most other regions only have very small quantities.

The small amounts of wood available in the long term restrict the processing options available, as these quantities are too small to supply many of the processing options available. Even with very small mills there is likely to be a need to be able to process a range of species within a speciality mill to keep it supplied. A portable sawmill is capable of processing up 10,000 m^3 per annum.

Table 1 – long run supply volume (no new planting)

Region	Douglas-fir	Cypresses	Eucalypts
Northland	-	1,500	1,200
Waikato	75,000	9,000	26,000
Bay of Plenty	25,000[1]	2,000	3,000
Gisborne	2,000	2,000	400
Hawkes Bay	4,000	3,000[4]	1,000
SNI West	400	3,000	200
SNI East	20,000	200	100
Tasman Nelson	7,000	200	-
Marlborough	20,000	3,000	300
West Coast	100,000[2]	20,000	-
Canterbury	100,000	3,000[5]	300
Otago	200,000[3]	4,000	3,000
Southland	90,000[3]	2,000	63,000

1 = after 2033, 2 = after 2028, 3 = after 2035 volumes increase to 400,000 in Otago and 150,000 in Southland, 4 = after 2038, 5 = after 2033

Based on the data in the 2017 National Exotic Forest Description (MPI, 2018) it is not possible to differentiate between *Eucalyptus nitens* and *Eucalyptus fastigata*. However, it is known that the majority of the Otago and Southland eucalyptus resource is *E. nitens*. Further, *E. nitens* does not perform well in warmer climates and the Eucalyptus resource in the CNI is mostly *E. fastigata* along with some area of other Eucalyptus species.

Log prices

Given the small total volumes of logs, the volume of pruned logs was expected to be very low (but unknown) so the average prices were based off unpruned grades.

Douglas-fir

Prices for Douglas-fir logs are presented in Table 2. These prices are typically slightly higher than for Radiata pine logs of similar physical dimensions. An average log price for use in the model was derived from these prices. Average saw log price for the base case was $192 per m^3, high average prices were $207 per m^3.

Table 2 - Douglas-fir log prices

Grade	Min. SED	Low	High	Mid
Pruned	40	$ 385	$ 450	$415
Pruned	30	$ 190	$ 230	$210
Small knot (<6cm)	30	$ 190	$ 205	$197
Small knot (<6cm)	20	$ 150	$ 185	$167
Large knot (<10cm)	n. a.	$ 135	$ 165	$150
Firewood	n. a.	$ 50	$ 55	$52

Cypress

Log prices for cypress are shown in Table 3. There is no pulp market for low quality logs and so these are sold for firewood (as is slabwood from sawmilling). Average saw log price for the base case was $168 per m^3, high average prices were $195 per m^3.

Table 3 – Cypress log prices

Grade	Min. SED	Low	High	Mid
Pruned	40	$200	$375	$288
Pruned	30	$170	$190	$180
Small branch (knot <6cm)	50+	$150	$276	$213
Small branch (knot <6cm)	30	$140	$183	$162
Small branch (knot <6cm)	20	$100	$133	$117
Large branch (knot <10cm)	n. a.	$100	$118	$109
Firewood	n. a.	$ 60	$ 78	$ 69

Eucalypts

Log prices for Eucalypts are shown in Table 4. Average saw log price for the base case was $190 per m^3, high average prices were $268 per m^3.

Table 4 – Eucalypt log prices

Grade	Min. SED	Low	High	Mid
Pruned	>30cm	$120	$295	$208
Pruned	>20<30cm	$100	$273	$187
Small branch (knot <6cm)	30	$120	$279	$195
Small branch (knot <6cm)	20	$100	$257	$180
Large branch (knot <10cm)	20	$ 90	$110	$100
Firewood	10	$ 75	$100	$ 88

Product prices

A wide range of products are created from the target species. Some of these (e.g. laminated bench tops, stair treads) retail for very high prices (Table 5).

Table 5 – product prices for specialty wood products

Products	Species	Grade	Low	High
Chip	all species			$ 75
Firewood	all species		$ 75	$ 100
Sawdust	all species		$ 25	-
Cladding	Cypress	Heartwood	$ 2,391	$ 2,544
Decking	Cypress	Heartwood	$ 1,440	$ 1,564
Garden beds	Cypress	Heartwood	$ 777	$ 948
Interior panelling	Cypress			$ 2,740
Laminated benchtops	Cypress	Clear	$ 8,454	$ 10,870
Laminated stair treads	Cypress	Clear	$ 4,187	$ 7,609
Cladding	D. fir	Heartwood		$ 3,083
CLT	D. fir		Same as radiata	
Glulam	D. fir		Same as radiata	
Interior panelling	D. fir		$ 1,279	$ 1,514
Structural timber	D. fir		Same as radiata	
Flooring	*E. nitens*	Feature	$ 795	
Flooring	*E. nitens*	Select	$ 1,170	$ 2,800
Flooring	*E. nitens*	Standard	$ 919	
Glulam	*E. nitens*		2x radiata	
Interior panelling	*E. nitens*			$ 2,130
Laminated benchtops	*E. nitens*	Clear		$ 4,141
Rough sawn timber	*E. nitens*		$ 1,495	$ 3,125
	Cypress		$ 989	$ 1,157
	D. fir		Same as radiata	
Structural timber	Cypress?			

The WoodScape model works on ex-mill prices. Therefore, the retail prices need to be converted to ex-mill prices. This was done by removing retail margin and transport costs.

Further, any individual log produces a range of lumber or product grades. Data was obtained from processors on conversion factors and grade recoveries. These were used to derive a blended lumber price.

Many of the products require remanufacturing (dressing, finger jointing, laminating and treating) and the cost of this was deducted from the product price, as appropriate, to get back to an ex-mill price. These remanufacturing costs are several hundreds of dollars.

Blended Lumber Prices

The conversion factors and the ex-mill blended lumber prices are shown below.

Douglas-fir

Mills cutting Douglas-fir were assumed to produce;

- Sawdust 10%
- Off cuts 3%
- Slabwood 29%
- Lumber 58%

The split in lumber grades, their associated ex-mill process and a weighted / blended lumber price is shown for two types of mill; Table 6 - structural products and Table 7 - specialty products.

Table 6 – Blended lumber price - Douglas-fir Structural mill

Product	% of lumber volume	Price $ per m^3	Volume Weighted price
SG 8	56	$ 400.00	$ 224.00
No 2 Framing	16	$ 280.00	$ 44.80
Merch.	13	$ 310.00	$ 40.30
Industrial	11	$ 220.00	$ 24.20
Green packaging	4	$ 191.26	$ 7.65
TOTAL	100		**$ 340.95**

Table 7 – Blended lumber price - Douglas-fir Speciality products mill

Product	% of lumber volume	Price $ per m^3	Volume Weighted price
Cladding	56	$ 401.00	$ 224.56
Cladding	16	$ 360.00	$ 57.60
Merch.	13	$ 310.00	$ 40.30
Industrial	11	$ 220.00	$ 24.20
Green packaging	4	$ 191.26	$ 7.65
TOTAL	100		**$ 354.31**

Cypress

Mills cutting Cypresses were assumed to produce;

- Sawdust 10%
- Off cuts 3%
- Slabwood 38%
- Lumber 49%

The split in lumber products and prices for Cypress are shown in Table 8. A blended lumber price of $458 was derived.

Table 8 – Blended lumber price - Cypresses

Product	% of lumber volume	Price $ per m^3	Volume Weighted price
Dressing Heart	26%	$856.50	$226.81
Dressing sap	11%	$381.00	$ 43.24
Merchantable	30%	$388.50	$117.63
Box	32%	$220.00	$ 70.16
TOTAL	100		**$457.84**

Eucalypts

Mills cutting Eucalyptus were assumed to produce;

- Sawdust 10%
- Off cuts 3%
- Slabwood 28%
- Firewood 15%
- Lumber 43%

The split in lumber products and prices for *Eucalyptus fastigata* are shown in Table 9. A blended lumber price of $567 was derived.

Table 9 – Blended lumber price – *Eucalyptus fastigata*

Product	% of lumber volume	Price $ per m^3	Volume Weighted price
Select/clears for flooring	81	$613	$497
Standard flooring	7	$361	$25
High feature flooring	5	$238	$12
Lamination stock	4	$648	$26
Box	3	$220	$7
TOTAL	**100**		**$567**

The split in lumber products and prices for *Eucalyptus nitens* are shown in Table 10. A blended lumber price of $522 was derived. *E. nitens* tends to have higher degrade during drying and therefore has a higher percentage going into box grade and a lower blended lumber price (Table 10).

Table 10 – Blended lumber price – *Eucalyptus nitens*

Product	**% of lumber volume**	**Price $ per m^3**	**Volume Weighted price**
Select/clears for flooring	70	$613	$429
Standard flooring	6	$361	$22
High feature flooring	4	$238	$10
Lamination stock	4	$648	$26
Box	16	$220	$35
TOTAL	**100**		**$522**

Timber drying costs

The cost of drying timber was estimated for a range of kiln types, species and lumber dimensions.

Timber drying costs at radiata mills can vary from $40 to $70 per cubic metre, depending on the scale and efficiency of the system. A typical average mill is likely to have drying costs of $45 to $50 per m^3. For large mills where a modern continuous counter flow kiln is appropriate, these will be more efficient and cost less. However, these are too large for consideration here.

Some of the specialty timber species cannot be dried in the same way as radiata and needs a lower temperature and slower regime.

The scale of operations being considered was also low, with the mills in some cases being mobile, as the resource is small and dispersed. The target volume per annum was 10,000 m^3.

The types of drying considered were;

- Conventional kiln (Douglas-fir only)
- Low temperature kiln
- Solar kiln
- Air drying with finishing in a low temperature kiln.

The costs of drying using the different approaches were calculated (Table 11)

Table 11 – drying costs ($ per cubic metre)

Species	**Thickness, mm**	**Conventional kiln**	**Low temperature kiln**	**Solar kiln**	**Air drying +low temp**	**Air drying**
Douglas-fir	25	53	73	60	n. a.	n. a.
Douglas-fir	50	79	100	99	n. a.	n. a.
Douglas-fir	All	66	86	79	n. a.	n. a.
Cypress	25	n. a.	79	65	97	40
Cypress	50	n. a.	107	106	139	39
Cypress	All	n. a.	93	85	118	40
Eucalyptus*	25	n. a.	118	70	97	40
Eucalyptus	50	n. a.	144	111	139	39
Eucalyptus	All	n. a.	131	90	118	40

**Eucalyptus nitens* was assumed to be sawn to no more than 25mm thickness as degrade during drying is more severe on boards thicker than this.

The average (All) drying costs was used in the WoodScape analysis as mills are likely to produce a range of lumber dimensions to maximise volume and value recovery.

WoodScape modelling

The key inputs to the model are, log prices, product prices and information specific to the type and scale of the wood processing technologies. The model covers a wide range of wood processing options; from very large scale (Kraft pulp) to very small (Portable sawmill). Within a type of processing (e.g. sawmilling) there are several types and scales of mills (super mills at 1.0M m^3 of logs in and small appearance mills at 50k m^3 of logs in).

Technologies which use of residuals for bioenergy are also included. The full list of technologies in WoodScape is included in Appendix 1. For this study we added; a portable sawmill, a variant of a small appearance mill with air drying and a solar kiln for finishing the drying, and OEL™ made from non-radiata species (Douglas-fir and Eucalyptus lumber). Key financial metrics for all species studied are presented in Tables 12 (high log process) and 13 (average log process).

Table 12 – results from financial analysis, portable sawmill by timber species and various drying options (high log prices)

Species	Type	Kiln drying type	ROCE %	EBITDA, $k p.a.	NPV, $k p.a.	IRR %	Margin on sales %
D Fir	Structural	Conventional	-2.3	-5	-1132	-	-0.2
D Fir	Specialty	Conventional	4.3	65	-703	-1.1	2.6
D Fir	Structural	Low Temp	-11.6	-105	-1924	-	-1.4
D Fir	Specialty	Low Temp	-5.0	35	-1387	-	-1.4
D Fir	Structural	Solar	-8.4	-70	-1647	-	-2.9
D Fir	Specialty	Solar	-1.8	0	-1110	-	0
Cypress	Specialty	Low Temp	18.8	257	149	12.6	7.6
Cypress	Specialty	Solar	22.0	297	373	15.1	8.8
Cypress	Specialty	Air + LT	8.8	132	-548	4.2	3.9
Euc. fas.	Specialty	Low Temp	-27.8	-398	-4,584	-	-10.6
Euc. fas.	Specialty	Solar	-14.5	-193	-2,961	-	-5.2
Euc. fas.	Specialty	Air + LT	-23.7	-333	-4,096	-	8.9
Euc. nit.	Specialty	Low Temp	-19.9	-243	-3,971	-	-1.9
Euc. nit.	Specialty	Solar	-5.3	-53	-2,072	-	-1.5
Euc. nit.	Specialty	Air + LT	-13.6	-188	-3,140	-	-2.7

*Euc. fas. calculations use dryings averaged fir 25 and 50mm boards as it assumes a mill will cut a mix of thicknesses. For Euc nit. The costs of drying 25mm boards is used. The drying costs for 25mm boards is lower (Table 11) hence the improved returns for *E. nitens*.

Table 13 – results from financial analysis, portable sawmill (5,000 m^3 per annum out) by timber species and various drying options (average log prices)

Species	Type	Kiln drying type	ROCE %	EBITDA, $k p.a.	NPV, $k p.a.	IRR %	Margin on sales %
D Fir	Structural	Conventional	10.2	124	-354	5.62	5.1
D Fir	Specialty	Conventional	17.0	194	19	11.27	7.9
D Fir	Structural	Low Temp	0.5	24	-913	-11.91	1.0
D Fir	Specialty	Low Temp	7.2	94	-539	2.5	3.8
D Fir	Structural	Solar	3.9	59	-717	-1.81	2.5
D Fir	Specialty	Solar	10.5	129	-343	5.9	4.9
Cypress	Specialty	Low Temp	53.1	655	2,373	37	19.5
Cypress	Specialty	Solar	56.8	695	2,597	39.7	20.6
Cypress	Specialty	Air + LT	41.9	530	1,675	29.2	15.7
Euc. fas.	Specialty	Low Temp	42.3	578	1,844	29.6	15.4
Euc. fas.	Specialty	Solar	59.5	783	2,990	41.7	20.8
Euc. fas.	Specialty	Air + LT	47.7	643	2,207	33.4	17.1
Euc. nit.	Specialty	Low Temp	33.1	519	1,321	23.1	15.0
Euc. nit.	Specialty	Solar	50.8	759	2,662	35.6	22.0
Euc. nit.	Specialty	Air + LT	40.7	624	1,907	28.5	18.1

Sensitivities of the ROCE's to changes in the key inputs were calculated (Tables 14 and 15). The ROCEs were highly sensitive to changes in product prices.

Table 14 – ROCE Sensitivities to costs (high log prices)

Species	Type	Kiln drying type	Labour	Product Pricing	Energy	Capital
D Fir	Structural	Conventional	-11.4%	-20.0%	-12.0%	-11.7%
D Fir	Specialty	Conventional	-11.2%	-20.1%	-11.8%	-11.4%
D Fir	Structural	Low Temp	-11.3%	-19.9%	-11.8%	-11.8%
D Fir	Specialty	Low Temp	-11.2%	-20.0%	-11.7%	-11.5%
D Fir	Structural	Solar	-11.3%	-19.9%	-11.9%	-11.7%
D Fir	Specialty	Solar	-11.2%	-20.0%	-11.7%	-11.5%
Cypress	Specialty	Low Temp	-7.3%	-16.4%	-7.8%	-7.7%
Cypress	Specialty	Solar	-7.4%	-16.5%	-7.8%	-7.7%
Cypress	Specialty	Air + LT	-7.3%	-16.3%	-7.7%	-7.8%
Euc. fas.	Specialty	Low Temp	-4.6%	-13.2%	-5.1%	-5.1%
Euc. fas.	Specialty	Solar	-4.7%	-13.4%	-5.1%	-4.9%
Euc. fas.	Specialty	Air + LT	-4.7%	-13.3%	-5.1%	-5.0%
Euc. nit.	Specialty	Low Temp	-5.3%	-14.0%	-5.9%	-6.2%
Euc. nit.	Specialty	Solar	-5.4%	-14.2%	-6.0%	-6.1%
Euc. nit.	Specialty	Air + LT	-5.3%	-14.0%	-5.9%	-6.1%

The sensitivities of the ROCE's to changes in yield and utilisation were also calculated. The changes in ROCE for a 1% change in product yield or utilisation are shown in Table 15. The Cypress and Eucalypt operations were more sensitive to changes in yield.

Table 15 – ROCE sensitivities to changes in yield and utilisation (high log prices)

Species	Type	Kiln drying type	Yield	Utilisation
D Fir	Structural	Conventional	17.0%	-14.0%
D Fir	Specialty	Conventional	16.8%	-13.7%
D Fir	Structural	Low Temp	16.9%	-14.0%
D Fir	Specialty	Low Temp	16.7%	-13.7%
D Fir	Structural	Solar	16.9%	-14.0%
D Fir	Specialty	Solar	16.7%	-13.7%
Cypress	Specialty	Low Temp	22.6%	-10.6%
Cypress	Specialty	Solar	22.6%	-10.6%
Cypress	Specialty	Air + LT	22.4%	-10.7%
Euc. fas.	Specialty	Low Temp	27.3%	-8.5%
Euc. fas.	Specialty	Solar	27.6%	-8.4%
Euc. fas.	Specialty	Air + LT	27.4%	-8.5%
Euc. nit.	Specialty	Low Temp	13.1%	-8.1%
Euc. nit.	Specialty	Solar	13.7%	-7.9%
Euc. nit.	Specialty	Air + LT	13.6%	-8.0%

Figure 1 shows the ROCE data from Table 12. The combination of solar kilns with Cypresses and Eucalypts and higher product prices showed promising results where the log prices were lower. The results are highly sensitive to log prices.

Figure 1 – ROCEs for portable sawmill and various drying types

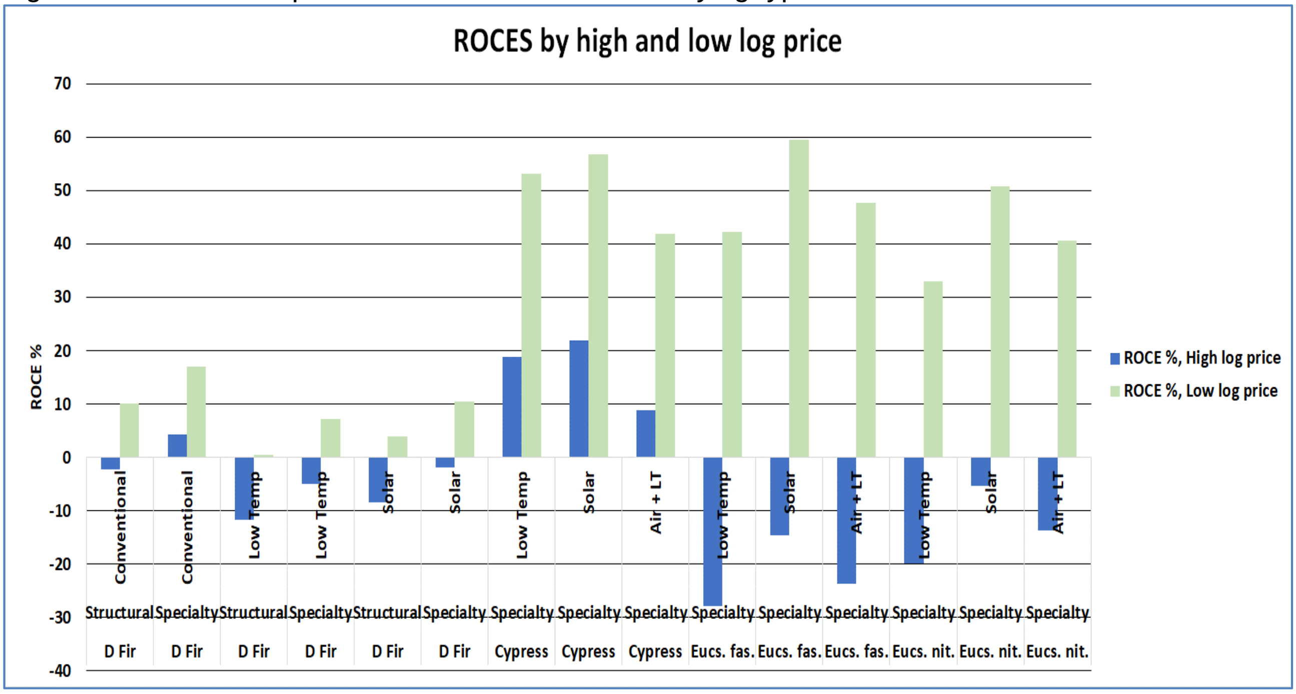


Figure 2 shows the EBITDA's from Table 11. The results are highly sensitive to changes in log price.

Figure 2 – EBITDA for portable sawmill and various drying types

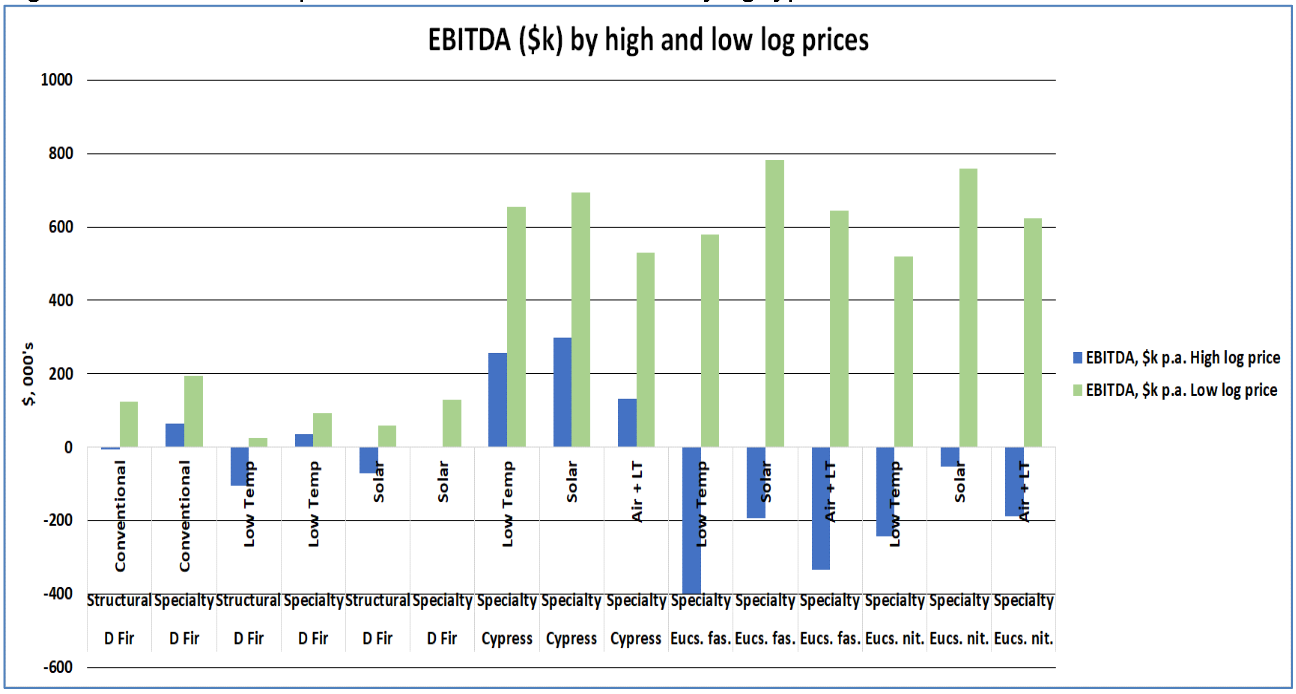
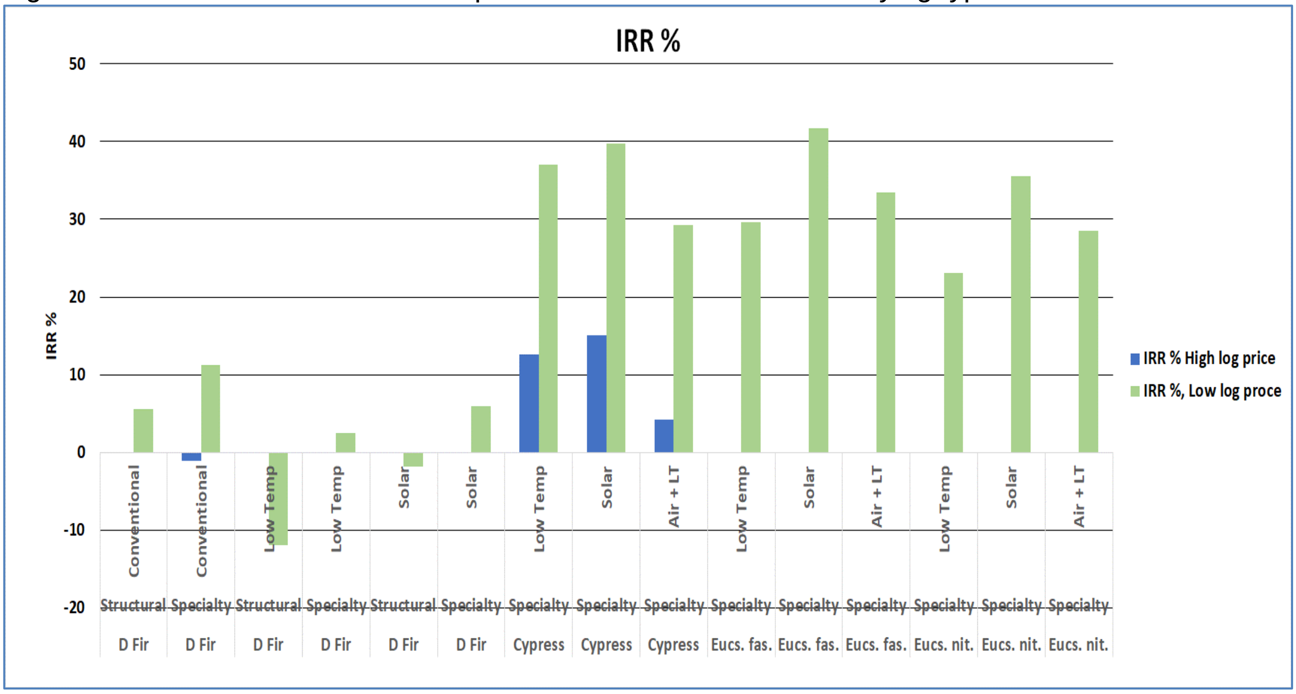


Figure 3 shows the IRR's from Table 13 (average log prices). At high log prices many of the options have poor financial performance and IRR's cannot be calculated.

Figure 3 - Internal rates of return for portable sawmill and various drying types



The impact of product prices on ROCE was also assessed. The approach taken was assuming the higher log prices, what product price was required to get to a ROCE of 20%. The results of this assessment are presented in Table 16.

Table 16 – Blended lumber price required to get a ROCE of 20% by species and drying method for a small sawmill

Tree Species	**High log price $/m^3**	**Drying type**	**Blended ex-mill lumber price required**	**Difference to assumed lumber price**
Douglas-fir	$207	Solar	$480	+$126 per m^3
Douglas-fir	$207	Low temp.	$487	+$133 per m^3
Douglas-fir	$207	Conventional	$465	+$111 per m^3
Cypress	$195	Solar	$458	+$ 1 per m^3
Cypress	$195	Low Temp.	$467	+$ 10 per m^3
Cypress	$195	Air + Low temp	$494	+$ 37 per m^3
Eucalyptus fas.	$268	Solar	$625	+$ 56 per m^3
Eucalyptus fas.	$268	Low Temp.	$668	+$155 per m^3
Eucalyptus fas.	$268	Air + Low temp	$655	+$ 86 per m^3
Eucalyptus nit.	$268	Solar	$604	+$ 35 per m^3
Eucalyptus nit.	$268	Low Temp.	$605	+$ 85 per m^3
Eucalyptus nit.	$268	Air + Low temp	$632	+$ 63 per m^3

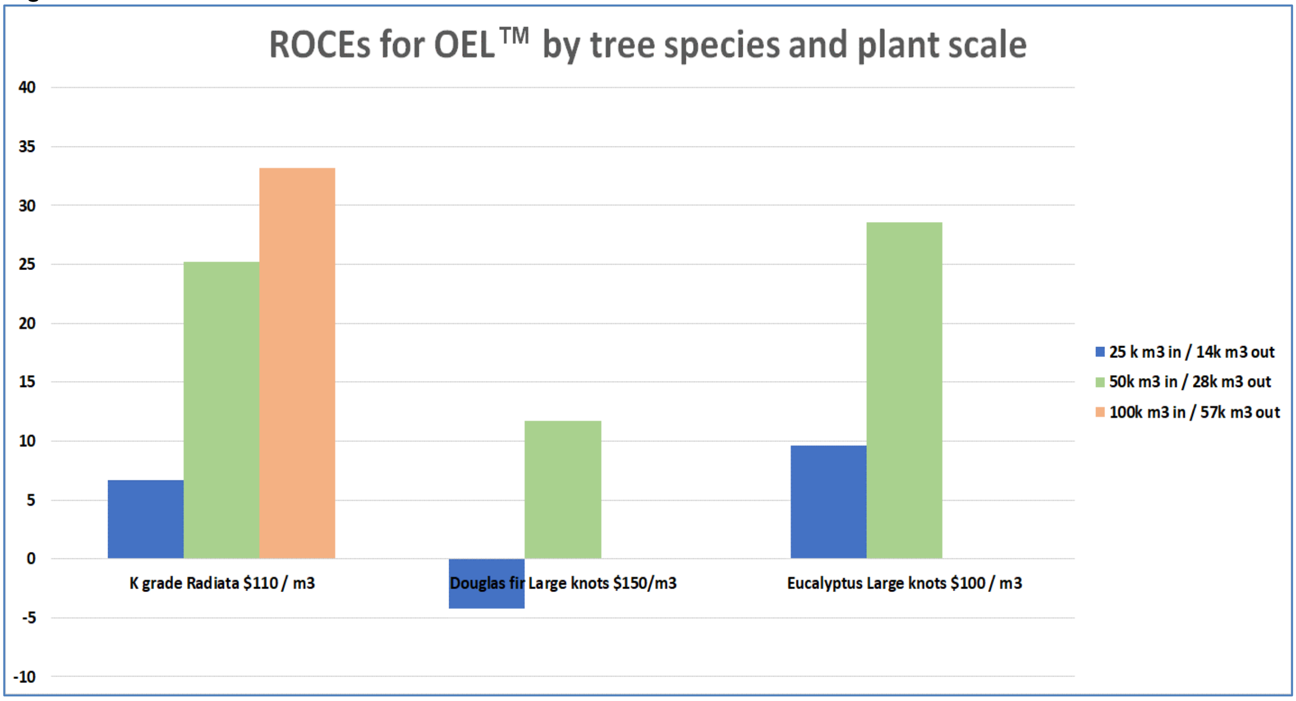
For Cypress the differences between the product prices required to get a 20% ROCE and what is currently paid are small. The differences are larger for the Eucalypt and Douglas-fir milling options.

<u>Other products</u>

Optimised Engineered lumber (OEL™)
OEL™ has successfully been made from Douglas-fir and *Eucalyptus nitens* (Gaunt 2016 a & b). Figure 4 shows the ROCE's for making OEL from radiata, Douglas-fir and Eucalyptus logs.

Only Pinus radiata can be used at the larger scale as the other species are generally insufficient in volume to allow the larger plant (given that the analysis is based on using only the lower quality logs). Eucalyptus based OEL has slightly better ROCE's than using radiata as the log price assumed is slightly lower.

Figure 4 – ROCEs for OEL



Small sawmill (15,000 m^3 per annum out)
The assumptions on the log prices (lower) and lumber prices were the same as above. The mills capital and operating costs were adjusted to account for the different approaches to drying.

The mill would most likely have to run on a mix of log species, as in many locations the supply of one species would be insufficient to supply a mill of this size. The financial metrics (Table 17) do not look attractive except for milling Eucalypts and using a solar or low temperature kiln. Overall this does not appear to be an attractive proposition as it would only make money when running on Eucalypts.

Table 17 – Financial metrics for a small sawmill with different drying options (average log prices).

Species	Log cost	Drying type	ROCE %	EBITDA $M	IRR %
Douglas fir	$192	Solar	-33.0	-$3.498	-
Douglas fir	$192	Low Temperature	-39.0	-$3.673	-
Douglas fir	$192	Conventional	-31.0	$3.173	-
Cypress	$168	Solar	-1.2	$0.017	-
Cypress	$168	Low Temperature	-3.0	-$0.182	-
Cypress	$168	Air + Low temperature	-8.7	-$0.807	-
Eucalyptus fas.	$190	Solar	13.7	$1.692	6.9
Eucalyptus fas.	$190	Low Temperature	5.2	$0.677	-1.6
Eucalyptus fas.	$190	Air + Low temperature	7.0	$0.992	0.8
Eucalyptus nit.	$190	Solar	7.9	$1.017	1.8
Eucalyptus nit.	$190	Low Temperature	-2.9	$0.182	-
Eucalyptus nit.	$190	Air + Low temperature	1.8	$0.342	-

Only Waikato and Southland would have sufficient resource to support a sawmill of this size operating on Eucalypts only, in the long term.

CONCLUSIONS

Unpruned log prices were found to be;
Douglas-fir $192 to $207 per m^3
Cypress $168 to $195 per m^3
Eucalyptus $190 to $286 per m^3

Eucalyptus logs have the greatest variation between average and high prices, and therefore have a larger shift in ROCE and other financial matrices when the log prices are changed between these.

Blended ex-mill lumber prices were determined to be;
Douglas-fir $354 per m^3
Cypress $457 per m^3
Eucalyptus fastigata $569 per m^3
Eucalyptus nitens $522 per m^3

The ROCE of small scale sawmilling (5,000 m^3 per annum out) and drying for the target species is highly sensitive to log price;
- at average log prices operations are financially attractive for Cypresses and Eucalypts.
- at higher log prices only cypress milling remains attractive

These ROCEs are also highly sensitive to product pricing.

OEL™ using lower grade ($100 per m^3) Eucalyptus logs is financially and technically viable. OEL™ is not as attractive using Douglas-fir logs due to higher log prices ($150 per m^3). OEL™ was only viable on cheaper logs which will be in limited supply as they will only be 20 to 25% of the total log supply. This would limit its application to specialty tree species unless a larger mill was to run on a mix of species.

Moving to a larger saw mill (15,000 m^3 per annum out) did not greatly improve the financial metrics. The mill is of a size that it would have to run on a mix of log species, and as the returns on some of these is negative the overall proposition is unattractive.

The drying costs for the different kiln types showed that a conventional kiln had the cheapest costs, but these cannot be applied to Cypress and Eucalypt species. Of the slower drying options required for these species the solar kilns were the cheaper option.

Air drying had the lowest costs – but the lumber is not sufficiently dry and needs to be finished in a low temperature kiln.

The combination of air drying and finishing in a low temperature kiln was estimated to be lower cost than a low temperature kiln on its own cost for Eucalyptus species. However, for Cypresses the low temperature kiln was better than air drying and finishing in a low temperature kiln.

The best performing options were;
- Cypress logs, particularly with a solar kiln and a small sawmill
- Eucalyptus with a solar kiln, but only at lower log prices.

ACKNOWLEDGEMENTS

Several people have assisted with this study, Scion and the authors would like to acknowledge the Specialty Wood Products Research Partnership generally and specifically;

- Mark Dean
- Dean Satchel
- Doug Gaunt
- Paul Millen

REFERENCES

Jack M., Hall P., Goodison A. and Barry L. (2013). WoodScape Study – Summary Report. Scion contract report for the Wood Council of New Zealand (Woodco). Scion SIDNEY No. 50738. http://www.woodco.org.nz/strategic-plans/woodscape

Hall P., Sargent R. and Riley S. (2018). Identifying processing opportunities for key specialty tree species – resource analysis. Scion contract report for Specialty Wood Products Research Partnership. Scion SIDNEY No. 61652.

Ministry of Primary Industries (2018). A national exotic forest description – as at 1 April 2017. https://www.teururakau.govt.nz/news-and-resources/open-data-and-forecasting/forestry/new-zealands-forests/

Ministry of Primary Industries (2014). Wood availability forecasts (Various regions). https://www.teururakau.govt.nz/news-and-resources/open-data-and-forecasting/forestry/new-zealands-forests/

Neumann A. and Perley C. (1991). National Exotic Forest description – Yield tables as at 1 April 1991. Ministry of Forestry Wellington New Zealand.

New Zealand Farm Forestry Association (2007). Best Practice with Farm Forestry Timber species. NZFFA Electronic Handbook Series No. 1: Cypresses. Ian Nicholas, Editor.

New Zealand Farm Forestry Association (2007). Best Practice with Farm Forestry Timber species. NZFFA Electronic Handbook Series No. 2: Eucalypts. Ian Nicholas, Editor.

Gaunt D. (2016 a) *Eucalyptus nitens* Optimised Engineered Lumber (OEL™) trial.

Gaunt D. (2016 b) Douglas-fir Optimised Engineered Lumber (OEL™) trial.

APPENDICES

Appendix 1 - Technologies currently in the WoodScape model

Industry Segment	Technology (Product out / feedstock in)	Product
Sawmilling	Appearance sawmill (50k m3 / 90k m3)	Kiln dried boards
Sawmilling	Appearance sawmill (100k m3 / 180k m3)	Kiln dried boards
Sawmilling	Appearance sawmill (200k m3 / 360k m3)	Kiln dried boards
Sawmilling	Structural sawmill (25k m3 / 45k m3)	Kiln dried framing
Sawmilling	Structural sawmill (200k m3 / 360k m3)	Kiln dried framing
Sawmilling	Structural Sawmill (425k m3 / 750k m3)	Kiln dried framing
Sawmilling	Structural sawmill (700k m3 / 1,200k m3)	Kiln dried framing & boards
Sawmilling	Industrial sawmill (210km3 / 400k m3)	Industrial lumber green
Sawmilling	Industrial sawmill Dry (210k m3 / 400k m3)	Dry industrial lumber
Sawmilling	Lumber Industrial small (15k m3 / 25k m3)	Industrial lumber
Sawmilling	Big Squares (17k m3 / 25k m3)	Big Squares
Sawmilling	Big Squares (700k m3 / 1000k m3)	Big squares
Secondary SWP	Remanufactured Untreated (32k m3 / 37k m3)	Reman. mouldings
Secondary SWP	Remanufactured Appearance (23k m3 / 31k m3)	Treated mouldings
Secondary SWP	Glulam (9k m3 / 9.1k m3)	Laminated beams
Secondary SWP	Thermally modified wood (9.1k m3 / 9.2k m3)	Heat modified wood
Secondary SWP	CO2 Modified wood (9.6k m3 / 9.5k m3)	CO2 modified wood
Secondary SWP	Acetylated 2.5km3	Acetylated wood
Secondary SWP	Acetylated 10km3	Acetylated wood
Secondary SWP	Acetylated 22km3	Acetylated wood
Secondary SWP	Acetylated 159km3	Acetylated wood
Secondary SWP	Remanufactured Appearance (50k m3 / 66k m3)	Treated mouldings
Recon & panel	Oriented Strand Lumber (71k m3 / 132k m3)	Thick OSB
Recon & panel	MDF Mill (400k m3 / 1.0M m3)	Medium density fibre board
Recon & panel	MDF Mill (125k m3 / 320k m3)	MDF S
Recon & panel	MDF Mill (250k m3 / 640k m3)	MDF M
Recon & panel	Thin Board MDF (400 k m3 / 1.0M m3)	MDF
Recon & panel	Particle Board - M (91k m3 / 200k m3)	Flooring etc.
Recon & panel	Particle Board L (180k m3 / 400k m3)	Flooring etc.
Recon & panel	Value Added Particle Board (90k m3 / 200k m3)	Coated particle board
Recon & Panel	Hardboard (90k m3 / 260k m3)	Hard Board M
Recon & panel	LVL (110k m3 / 200k m3)	Laminated Veneer Lumber
Recon & panel	LVL (30k m3 / 50k m3)	Laminated Veneer Lumber
Recon & panel	OSB (100km3 / 175km3)	Oriented Strand Board
Recon & panel	OSB (200k m3 / 344k m3)	Oriented strand Board
Recon & panel	OSB (450k m3 / 765k m3)	Oriented strand board
Recon & panel	OSB (750k m3 / 1.25M m3)	Oriented Strand Board
Recon & panel	Plywood (120k m3 / 200k m3)	Plywood
Recon & panel	Plywood (350k m3 / 640k m3)	Plywood
Recon & panel	WFP Composites (125k t / 300k t)	Wood fibre plastics
Recon & panel	OEL (50k m3 / 100k m3)	Optimised Engineered lumber
Recon & panel	Chip mill (250k m3 in / out)	Chip
Recon & panel	Cross laminated Timber (30k m3 / 35k m3)	Cross Laminated Timber

Recon & panel	Cross laminated Timber (60k m3 / 70k m3)	Cross Laminated Timber
Pulp & Paper	Newsprint (0.3M adt / 0.84M m3)	TMP Newsprint
Pulp & Paper	BCTMP (300k adt / 0.795M m3)	TMP plus heat and power
Pulp & Paper	Kraft Pulp (200k adt / 1.0M m3)	Kraft pulp + heat and power
Pulp & Paper	Kraft Pulp (300k adt / 1.6M m3)	Bleached Kraft Pulp + H&P
Pulp & Paper	Kraft (1.0M adt / 4.54M m3)	SKP + H&P
Pulp & Paper	Liner Board (470k adt/ 0.5M adt)	Packaging
Power & Heat	Gasification CHP (8 MW / 112k t)	1 MWe Power
Power & Heat	Gasification to Power (17MW / 300k t)	Power
Power & Heat	Power (60 MWe / 638k)	60 MWe Power
Power & Heat	CHP (20MWe / 300k)	Heat and power
Power & Heat	CHP 60MWe (846k m3)	Heat and power
Power & Heat	Pyrolysis plant + Power (3MW / 320k)	Pyrolysis oil + power
Power & Heat	Pyrolysis plant - Boiler Fuel (70k t /230k t)	Pyrolysis oil
Power & Heat	Wood Pellets (20k t / 50k)	Wood pellets
Power & Heat	Wood Pellets (40k t / 100k t)	Wood pellets
Power & Heat	Wood Pellets (70k t / 175k m3)	Wood pellets
Power & Heat	Wood Pellets (160k t/ 390k m3)	Wood pellets
Power & Heat	Wood Pellets (440k t / 1.0M)	Wood pellets
Power & Heat	Torrefied Wood Pellets (50k t / 152k m3)	Torrefied wood pellets
Power & Heat	Bark Briquettes (2.4k t / 6k t)	Bark briquettes
Power & Heat	Bark Briquettes (20k t / 50k t)	Bark briquettes
Power & Heat	Heat (5MW / 9.6 k m3)	Heat as LP steam
Power & Heat	Heat (10MW / 19.2k m3)	Heat as LP steam
Power & Heat	Heat (20MW / 38.4 k m3)	Heat as LP steam
Power & Heat	Heat (30MW / 57.6k m3)	Heat as LP steam
Fuel & Chemical	Activated carbon (28k t / 258k t)	Activated carbon
Fuel & Chemical	Tannin Hot water (1.3k t / 28k t)	Tannin
Fuel & Chemical	Tannin Sulphate (1.3k t / 28k t)	Tannin
Fuel & Chemical	TanninHW & BarkBriq (20k in)	Tannin & Briquettes
Fuel & Chemical	TanninHW & BarkBriq (60k in)	Tannin & Briquettes
Fuel & Chemical	Biomass+FCC (49.1M l / 450k m3)	Syn-diesel
Fuel & Chemical	Biomass+ FCC Large (98.2 M l / 900k m3)	Syn-diesel
Fuel & Chemical	Wood syn-gas to Lumber kiln (190k GJ / 28k m3)	Syn-gas
Fuel & Chemical	Syn-gas to lime kiln (782k GJ / 170k m3)	Syn-gas
Fuel & Chemical	Ethanol via Fermentation (206M l / 1.6M m3)	Ethanol
Fuel & Chemical	Lignin Organosolv Commercial (77k t / 0.83M m3)	Ethanol & chemicals
Fuel & Chemical	Fischer-Tropsch Diesel DOE (160M / 1.65M m3)	Syn-diesel
Fuel & Chemical	Fischer-Tropsch Diesel 2012 (136M l / 1.0M m3)	Syn-diesel
Fuel & Chemical	Gasification + FT diesel (682M l / 5.0M m3)	Syn-diesel
Fuel & Chemical	Gasification + FT Diesel (150Ml / 1.0M m3)	Syn-diesel
Fuel & Chemical	Super critical water M (110m l / 0.62M m3)	Biocrude
Fuel & Chemical	Super critical water L (220M l / 1.25M m3)	Biocrude
Fuel & Chemical	Thermal process + H upgrade (138M m3 / 938k m3)	Syn-diesel
Fuel & Chemical	Methanol via syn-gas (42k t / 270k m3)	Methanol
Fuel & Chemical	CDP Diesel (24.9M l / 155k m3)	Syn-diesel
Fuel & Chemical	CPD Diesel Large (50M l / 311K M3)	Syn-diesel
Fuel & Chemical	Catalytic Pyrolysis (60M l / 460k m3)	Syn-diesel

Fuel & Chemical	Catalytic Pyrolysis (118M l / 910k m3)	Syn-Diesel
Fuel & Chemical	Catalytic Hydrothermal Large (150 m l / 944k m3)	Syn-diesel
Fuel & Chemical	Catalytic Hydrothermal Biocrude (75.6M l / 475k m3)	Biocrude
Fuel & Chemical	Thermal Process + H upgrade (275M l / / 1.89M m3)	Syn-diesel
Fuel & Chemical	Upgrading pyrolysis oil	Drop-in fuel
Fuel & Chemical	Ethanol via syngas (46M l / 275k m3)	Ethanol
Fuel & Chemical	Acetate via syn-gas (33k t / 275k m3)	Acetate
Fuel & Chemical	Dissolving Pulp (170k adt / 1.0M m3)	Bleached wood pulp
Fuel & Chemical	Terpenes & Pellets (445t & 70kt / 168k m3)	Terpenes & Pellets
Fuel & Chemical	Terpenes & chip (2.3k & 329k / 875k m3)	Wood Terpenes
Fuel & Chemical	Resins & chip (1.6k & 332k / 875k m3)	Wood Resins
Fuel & Chemical	Resins & Terpenes (3.9kt & 300kt / 875k m3)	Wood Resins &Terpenes
Fuel & Chemical	Resins & Pellets (310t & 70kT / 187k m3)	Resins & Pellets
Fuel & Chemical	Resins & Terpenes & Pellets (779t & 67kt / 175k m3)	Resin Terpene & Pellets
Fuel & Chemical	Resins & Terpenes & TMP (3.9kt &315k t / 875k m3)	Resins & Terpenes & TMP