Identification of Issues and Opportunities for LVL from NZ Eucalypts

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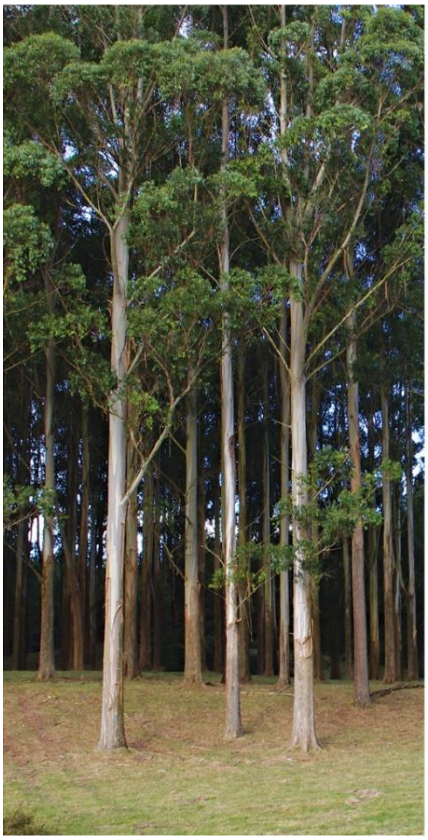

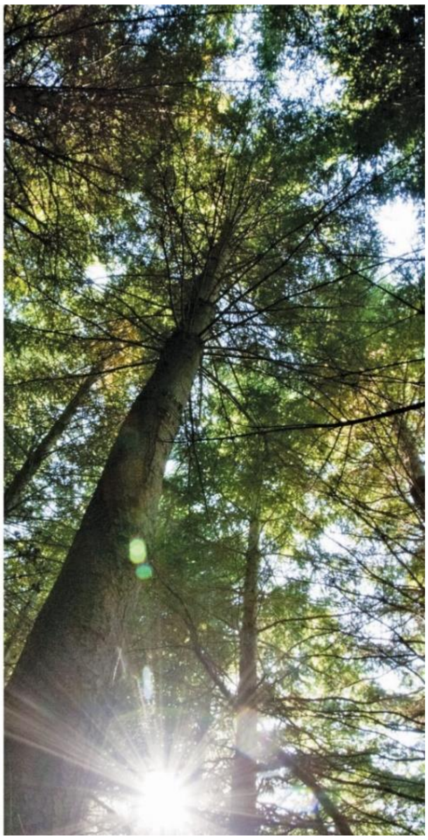

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EXECUTIVE SUMMARY

Information on the opportunities and possible issues for LVL made from eucalypts available or likely to be available in NZ is reviewed and summarised. While it is generally agreed that eucalypt will make good feedstock for LVL despite being mostly planted for pulp production, there is a paucity of information available especially for the species in question. This combination of positive signals mixed with paucity of published information and data extends from big the issues, such as peeling, drying and gluing, down to specific detail such as shear strength, impact bending, water absorption and swelling behaviour.

Opportunities

- The medium-density eucalypts should easily meet the demand for high stiffness product.
- Eucalypt veneers could be used to stiffen pine or other low-density species LVL.
- LVL from early thinnings is a possibility to be investigated.
- There is a possibility that eucalypt LVL may also be superior to softwood LVL in long term performance and thickness swelling.

Issues

- Poor gluing reputation of eucalypts appears confined to high-density tropical eucalypts
- The following require investigation:
    - The best eucalypt log pre-steaming practice before peeling is unknown
    - Shear properties - an instance of poor shear strength has been reported for *Eucalyptus nitens* LVL.
    - Collapse. While collapse-prone eucalypts like nitens meet strength and stiffness requirements, it is not certain that it is achieved through the likely increased glue usage for collapsed veneers or whether higher stiffness grades could have been achieved with non-collapsed veneers.
    - Drying - while few drying problems are reported there is certainly a lack of information in this area, and this could affect profitability.
    - There is sparse information water absorbency, swelling, shear and impact bending. This needs to be remedied in an engineered product.

INTRODUCTION

Objective

The objective of this report is to review information on the opportunities for LVL with eucalypts in general, concentrating on several eucalypt species identified in Cown, et al. (2015) that offer a potential increased value as an alternative to existing well-established species in NZ such as radiata pine. The review focuses on the New Zealand situation but includes other countries that are processing the eucalypts, especially Australia. The results are designed to be collated with a similar reviews that will concentrate on breeding and propagation, silviculture, growth models, products, markets and harvesting.

Description of Search Method

Searches were conducted using key words LVL, Laminated Veneer lumber, EWP, engineered wood products, plywood, veneers AND eucalypts, eucalypts, or sometimes common species name using a range of search engines – mostly Scopus and Google scholar.

Preamble

Laminated Veneer Lumber (LVL) is an engineered wood product made from rotary peeled wood veneers that have been pre-graded for stiffness and to achieve different structural properties. The veneers are glued together using a durable structural adhesive and pressed to form long continuous sections (panels) with the grain running parallel to the main axis. Panels of LVL are cut into structural members made to controlled specifications and is thus stronger, straighter, and more uniform than conventional lumber. Due to its composite nature, it is much less likely than to warp, twist, bow, or shrink. LVL has the following of advantages over other wood-based materials and they will be examined in terms of use of eucalypt feedstock:

- Small logs can be made into large dimension products.
- Long lengths of LVL are available
- The wood resource can be optimised by grading and selecting veneer for different parts of an LVL cross section and making a range of products with different properties.
- Structural properties of LVL are very uniform because the randomised layers of thin veneers are pre-graded for stiffness
- LVL members have high strength because of the low variability and randomised wood properties in thin layers.
- In commercial or industrial structures it is often used as a wood-based alternative to structural steel or reinforced concrete and thus appears to be nicely placed for future trends environmental sustainability in architecture.

As shown by the emergence of Specialty Wood Products Research Partnership (SWPRP) there is renewed interest in the utilisation of eucalyptus species. In several recent reviews (Cown, 2016; Cown, et al., 2015) it is also felt that the profitable processing for solid wood from young eucalypt resources remains a major challenge for the wood processing industry around the world, where current plantations are dominated by the “big nine” species (*E. camaldulensis, E. grandis, E. tereticornis, E. globulus, E. nitens, E. urophylla, E. saligna, E. dunnii*, and *E. pellita,* as well as their hybrids), which together account for more than 90% of Eucalyptus planted forests. In Australia, eucalypt plantation areas have rapidly expanded since 1995 with the total now estimated at 0.98 M ha (most commonly Blue Gum – *E. globulus*, Mountain Ash – *E. regnans* and *E. nitens* (Cown, 2016)). There is thus more research available in the literature on these species. There are also subtropical, denser eucalypts used for veneers and plywood - *E. pilularis, E. cloeziana, E. camaldulensis*, and relevant literature is included.

The eucalypt species grown in New Zealand are from three groups:

- The Eastern Blue Gum group*: E saligna and E. botryoides*
- The Stringybark group*: E. muelleriana, E. globoidea, E. eugenoides, E. microcorys, E. pilularis.*
- The Ash group: *E. delegatensis, E. fastigata, E. regnans, E. obliqua.* + *E. nitens* (not technically an Ash eucalypt). Most research published has been with nitens.

As noted by (Cown, et al., 2015) most of the eucalypt plantation resource is very varied, fragmented and not specifically grown for solid wood products, this may limit the chance of success with LVL. Also in New Zealand, decisions regarding choice of genetic stock, siting and silviculture are often made by landowners, decades ahead of utilisation considerations without solid information on wood properties, technical behaviour etc. This review will thus concentrate on highlighting issues relating to LVL production

LAMINATED VENEER LUMBER

LVL is mostly a structural engineered product and thus concerned with the issues of strength and stiffness in compression, tension and shear. These issues will be influenced by the inherent strength and stiffness of the various species, but also their ability to be efficiently peeled, dried and glued. Visual effects such as colour, form, staining, knots and marks will be of less importance although the engineering issues will be affected by the presence of resins, collapse and other defects. It is also known that eucalypt properties vary quite wildly with species, age, silviculture and genetics, and that required behaviours may be very dependent on their combination.

The indications are that almost any species in NZ will potentially yield strong veneers (Cown, et al., 2015; Hague, 2013; Hamilton, et al., 2015). The limiting factors for commercial success of eucalypt plantations are likely to be plantation growth rates and health, recovery losses due to stresses, collapse, shrinkage and defects, rather than the intrinsic stiffness of the wood (Cown, 2016).

A recent Australian review on the use of plantation eucalypts for engineered wood products (Hague, 2013) indicated information was scarce and that more research had been conducted overseas (South America and Europe) where such material is more widely used (e.g. laminated veneer lumber and plywood, glulam, flake/strand-based products, fibreboard and particleboard). This review indicated that:

- The plantation resource (particularly *E. nitens, globulus,* and *grandis*, often established for pulpwood or biomass) is “perfectly suitable for LVL, strand-board, flake-board, and MDF”.
- The faster-grown low-density species create no problems for adhesive systems with wood densities less than about 650 kg/m^3.
- Further research for solid wood and Engineered Wood Products (EWP) uses should concentrate on genetic selection and silviculture (spacing and pruning) to ensure raw material average density in the range 500 - 550 kg/m^3.

Brazil has been utilizing a range of eucalypts to make LVL for some time (Beadle, et al., 2008; de Carvalho, et al., 2004). There is also a strong trend towards using eucalypts for veneers in China with LVL production set to increase (Arnold, et al., 2013 ; Luo, et al., 2013) while not specifically mentioning LVL reports good veneer recovery from young trees of urophylla, saligna and grandis.

Peeling

Rotary peeling is generally not perceived to be a problem for eucalypts. Early studies, e.g. Hartley (1984), do not consider peeling to be an issue for appearance plywood production from a range of eucalypts (grandis, signata, pilularis, dunii, obliqua, saligna), and recommend which species should be cold or hot peeled. Since grading for appearance plywood is more rigorous, this implies that there should be no unmanageable issues for eucalypt LVL. Steaming pre–peeling has been mentioned as affecting final LVL strength for beech (Çolak, et al., 2007), but no effect has been reported for eucalypts. Since pre-steaming of logs is usually recommended this may need to be checked for each species.

Hartley (1984) considered splitting originating from billets was considered manageable for veneer production from common eucalypts peeled in Australia. Ozarska (1999) mentions problems with peeling small diameter eucalypt logs if traditional methods are used, and obliqua and delegatensis growth stress led to end-splits and breakage of sheets of veneer. Blakemore, et al. (2010) compared nitens 21 year old rotary peelings with 9mm quarter sawn boards and reported no peeling issues. Acevedo, et al. (2012) report research optimising lathe nose bar pressure to reduce lath checks in *E. nitens*. Aydın, et al. (2004) report that *E. camaldulensis* veneer on peeling had a high surface roughness that affected glue usage in LVL production. McKenzie, et al. (2003) mention sheet breakage at the time of peeling of nitens, but this was associated with insufficient peeler log heating. Successful processing of veneer logs evidently depends on preheating logs evenly and using appropriate settings for the lathe. The knots in the second logs made veneer unacceptable for structural plywood when graded visually, but sonic assessment of stiffness led to effective sorting of veneers into stiffness classes for LVL (McKenzie, et al., 2003). Mathieu, et al. (2004) suggest that grandis and saligna veneers can be obtained from very young logs from some clones.

Strength/Stiffness

The strength and stiffness of a final LVL product will be determined by

i. the inherent strength/stiffness of the veneer after drying,
ii. gluing issues
iii. the influence of defects such as collapse, checking and splitting

Inherent strength/stiffness of the veneer

It is generally agreed that eucalypts considered here are suitable for LVL feedstock:

- Australian plantation eucalypts in general (Nolan et al. 2005). McGavin, et al. (2015), have found that Australian plantation eucalyptus have stiffness properties ideal for LVL and that while MOE can be variable it is predictable.
- *E. nitens* (16 years), *E. nitens* (26 years), *E. Globulus* (33 years), *E. regnans* (Farrell, et al., 2011).
- Globulus for plywood in Spain (Vázquez, et al., 2003), in NZ (McKenzie, et al., 2006)
- Grandis in Brazil (Palma, et al., 2011); Grandis from Argentina exceeds strength and stiffness requirements for structural LVL (Saviana, et al., 2009).
- Saligna from Brazil (Iwakiri, et al., 2010)
- All high density subtropical eucalypts report good stiffness properties e.g. - camaldulensis (Islam, et al., 2012)

Blackburn, et al. (2012) performed a large study of *E. nitens* in Tasmania and report that with respect to veneer products there was no reason why tree breeding programs could not be developed to improve nitens veneer production and that that past breeding programs for the improvement of pulp wood properties have not adversely affected wood stiffness, Several NZ studies confirm the acceptability of eucalypts for LVL in terms of stiffness/strength Roper, et al. (2000) found veneer from pruned plantation-grown Eucalyptus species (*E. fastigata* 29 years old from Kaingaroa forest in the North Island) and *E. nitens* (16 years old from Golden Downs forest in the South Island) was of high commercial quality indicating good potential for high-quality products

It is usual in LVL to measure stiffness in individual sheets to optimise sheet position in terms of final panel stiffness. This is usually done acoustically. Gaunt, et al. (2003) showed that veneer peeled from *Eucalyptus nitens* unpruned second logs could be segregated into three stiffness classes using an acoustic test. LVL manufactured with panels from each stiffness class tested. The *E. nitens* LVL had strength and stiffness properties which were higher than those of LVL made from New Zealand-grown *Pinus radiata* veneer. Farrell, et al. (2008) also confirms acoustic grading of sheets improved LVL from 16 yr. old nitens and 33 yr. globulus.

There is also the possibility of using the strength properties of eucalypts to improve LVL made from other species e.g. Grandis (from Turkey) when mixed with poplar gives superior LVL than poplar (MOE, MOR, WA (water absorbency)) (Bal, 2016), Saligna veneers mixed with parica (*Schizolobium amazonicum*) (Iwakiri, et al., 2010).

Impact bending (IB) strength is an important property for LVL but sparse information exists regarding IB with eucalypt LVL The mixing of *E. grandis* veneers to other species and grandis LVL itself has superior IB to poplar (Bal, 2016) and European beech (Bal, et al., 2012)

Pre-classification

Pre-classification has not always enabled greater panel resistance, and this step can be unnecessary if the veneers meant to be used are highly homogenous. In studies carried out by Harding, et al. (1998) on LVL made from *Pinus radiata*, the authors observed that different assembly settings did not significantly influence the physical–mechanical performance of the LVL. Similar results were observed by Palma, et al. (2011) for LVL made from *Eucalyptus grandis*, when the authors did not find evidence for the influence of lower quality veneer placed at the surface layers of the woods panels (de Melo, et al., 2015). This confirmed that *E. grandis* LVL behaved similarly to parica, a common Brazilian hardwood used for LVL. McKenzie, et al. (2003) report with 15 year old nitens, that the knots in the second logs made veneer unacceptable for structural plywood when graded visually, but sonic assessment of stiffness led to effective sorting of veneers into stiffness classes for LVL.

Shear strength

Shear strength in the parallel and perpendicular to face grain directions are important measures for LVL products, measuring strength between fibres. Farrell, et al. (2011) found low values for *E. nitens* despite good results from bending tests (nitens (26 years) would be limited to F7 (~MGP11), with nitens (16years) not making F7). This was attributed to poor bonding and splitting, probably due to poor drying. Poor shear strength was flagged as an issue for future consideration.

Gluing

Historically, there have been problems with gluing eucalypts due to its density, closed cell structure and levels of extractives. High density wood pieces are more difficult to bond together due to their low porosity, and therefore they obstruct the penetration of adhesive and, consequently, the formation of a resistant, high quality glue line (Nolan, et al., 2005; Shukla, et al., 2008). The opposite can occur with low density woods, which may lead to excessive absorption and penetration of adhesive (Ozarska, 1999). It seems to be generally accepted that while high-density eucalypts may be problematic, lower density eucalypts are not problematic with respect to gluing LVL e.g. Shukla, et al. (2008). Farrell, et al. (2011) found that plantation *E. nitens* (16 years old) and globulus (33 years old) were promising for LVL gluing issues but recommended more research gluing of *E. nitens.*

There are many studies on gluing in China e.g. (Li, et al., 2005; Yu, et al., 2007; Zhang, et al., 2007). Zhang, et al. (2007) found that two high density eucalypts, (*Corymbia citriodora* and *E. exserta*) have poor bonding performance, lower-density *E. grandis* and *E. urophylla×E.grandis* showed better performance. Mathieu, et al. (2004) and Carrick (2005) suggest that Blackbutt (*E. pilularis*) veneer is capable of being glued for application as a durable structural LVL. Hopewell (2008) found that higher density subtropical eucalypt, *E. cloeziana and E. pellita* can make good structural products.

Since the 1990's it is generally accepted that plantation low- to medium-density eucalypts are good for veneers/LVL (Shield, 1995). The trend towards using lower density hardwoods is confirmed in a review of research into the use of plantation grown species for LVL (Chen, et al., 2016). Research into gluing eucalyptus veneers for LVL is continuing in China (JIiang, et al., 2011) and Brazil where it is reported *E. grandis, saligna, dunnii, globulus, viminalis, robust*a and *pellita* have great potential when glued with phenol-formaldehyde resin at a weight of 360 g/m² (double line) for use in the production of veneer sheets and plywood panels intended for outdoor use.

Exposure Durability

Durability exposure trials are conducted for glued wooden products to compare the strength of the glue bonds of the laminates in a range conditions. There is a range of tests sometimes called ageing tests used to do this, e.g. EN 321. There is some concern about the applicability of such tests to glued wooden products (Derkowski, et al., 2014). Variable results have been reported on the long term performance of some LVLs in ageing tests. Çolak, et al. (2007) cites Green, et al. (2005) who report that LVL in general may have decreased bending strength in an ageing test after three years. There is sparse information concerning this for eucalypt LVL. Carrick (2005) constructed LVL from veneers of *E. pilularis*, a species considered difficult to laminate. They were subjected to aggressive laboratory aging tests and were found to have performed better than radiata pine LVL and considered suitable for use as a "durable structural LVL". This is a potential area to explore, where some eucalypt LVLs may have an advantage.

Defects

Collapse/ Checking

Some eucalypts, especially nitens and regnans are known to be collapse prone, due to the effects of water tension forces early in drying. These forces are expressed as collapse (wash boarding), or as internal checks. The effect is known to be exacerbated by drying at elevated temperatures and thus must be considered in a LVL context. Blakemore, et al. (2010) showed that with 9mm thick quarter sawn nitens, the expression of water tension is completely via collapse (not checking) and thus collapse in nitens veneers is likely to be more of an issue rather than checking. Information as to whether collapse affects strength or glue quantities is not forthcoming. Unfortunately in this study corresponding veneers were not assembled into LVL so these effects could not be assessed.

Early work e.g. Hartley (1984) mentions collapse with respect to veneer production , but it's usually in the context of appearance grade veneers or loss of volume due to increased shrinkage. Drying at lower temperatures is advised.

Collapse is thus an area that could be looked at in terms of optimising the use of some low density eucalypts. Although that LVL from collapse prone species meets strength and stiffness requirements(Farrell, et al., 2011; McGavin, et al., 2015; Nolan, et al., 2005; Roper, et al., 2000), no references can be found mentioning if the damage done by collapse is compensated for with increased glue usage (as might be expected with the uneven veneer surface), or whether higher grades could have been achieved if the collapse was not present. The poor shear results for nitens of Farrell, et al. (2011) as mentioned above may be related to collapse.

Splitting

This is an often-used term and is often difficult to determine what is being referred to - cracks due to manifestation of growth stress, collapse associated checking or edge crinkling being crushed in rolling or damaged by handling, or drying or even collapse related checks. Splitting is often mentioned as an issue for handling of veneers and calls for correct drying for a range of eucalypts – obliqua, delegatensis, nitens and globulus (Farrell, et al., 2011; Ozarska, 1999).

Drying for LVL

There seems to be few studies that specifically mention drying eucalypt veneers for LVL. Many studies don't include drying details.

Simpson, et al. (1999) undertook a study to determine if fast-grown young *E. nitens* could be successfully peeled for veneer and dried using the techniques that were considered appropriate to produce veneer suitable for LVL. A range of schedules (70 -180°C) were tried with pealed veneers from logs were pre-steamed or hot water soaked before peeling. Pre-steaming affected collapse (reduced collapse) and checking (less and narrower). There was a trend for greater shrinkage from the higher drying temperatures. Veneer dried <110°C had less checking and collapse, but schedules >150°C were still deemed acceptable for LVL.

Farrell, et al. (2008) found significant gains may be achieved through an improved drying approach for plantation nitens veneer quality (and resultant product properties). The study, done in an industrial plant, measured LVL properties from veneers that were produced using a modified (best guess?) obliqua drying schedule that tended to over-dry. This over-drying affected the whole study. This highlights the fact that drying eucalypts for veneers for LVL with different species and age classes will require some work and fine tuning. This is no great surprise - it is the author's observation that often drying becomes the bottleneck in so-called easy-to-dry softwood LVL plants, where drying behaviour is well understood, let alone eucalypt species that aren't as easy to dry, and are less well understood.

If collapse emerges as an issue in terms of LVL panel properties, glue use, or appearance, there will be pressure to dry at reduced temperatures thus affecting throughput. Efforts to reduce collapse in the solid wood sector could also migrate to the LVL sector.

EMC/Water absorption and thickness swelling

As in other areas, there is a paucity of specific information with these parameters regarding eucalypt veneers in general, let alone in an LVL context:

EMC
It is likely that LVL will have a lower EMC than its corresponding solid wood due to the temperature of drying and pressing and the presence of glues (Shukla, et al., 2008). Bal (2016) found the EMC of grandis LVL less than the equivalent solid wood (12% sold wood grandis vs ~9% for grandis LVL). This a large change compared to other species, whose reduction in EMC is often only ~0.5 - <2% (Aydin, 2014). No specific references for the EMC reduction for radiata pine LVL were found, however it is noted that experimenters working with radiata LVL, condition specimens to 12 % at 20°C and 65% (Zarnani, et al.). Lower EMC values are often correlated to increased dimensional stability, due to the wood absorbing less moisture.

Thickness swelling, Water Absorbency

These are likely to be species specific and additionally in an LVL context may depend on veneer thickness (de Melo, et al., 2014). A study comparing particle board made from grandis, saligna and cloeziana found grandis had superior (i.e. reduced) thickness swelling, with saligna superior (i.e. lower) for water absorbency (Junior, et al., 2011). Although this was not done with LVL, it is a possible indicator. Islam, et al. (2012) found that a subtropical eucalypt plywood had low water absorbency.

Thus with regard to EMC, Water absorption and Thickness swelling, with no negative reports found and a few positive reports, no issues are expected with eucalypt LVL

CONCLUSION

Opportunities

From the literature presented here it can be concluded:

- The medium-density eucalypts grown or likely to be grown in New Zealand seem ideally suited to LVL. Since they are of higher stiffness than softwood LVL, eucalypts should easily meet the demand for a high stiffness product.

- Eucalypt veneers could be used to stiffen pine or other low-density species LVL.

- LVL from early thinnings is a possibility to be investigated.

- There is a possibility that eucalypt LVL may also be superior to softwood LVL in long term performance, thickness swelling and water absorbency. These characteristics should be confirmed and could be exploited.

Issues

- The review shows that reputation of eucalypt for EWPs including LVL having gluing issues is mainly due to high-density subtropical eucalypts and that medium-density eucalypts available or likely to be grown in NZ have no known unsolvable gluing issues.
- *Collapse* is an area that could be looked at in terms of optimising the use of some low-density eucalypts. Although LVL from collapse prone species meets strength and stiffness requirements, it is not known what effect collapse has on LVL, whether it effects glue usage or strength and stiffness.
- *Drying -* It is known that many LVL properties including drying behaviour, are species and age class dependent and there is a paucity of detailed information about each eucalypt species, let alone age classes. While there are generally few drying problems reported, there are signals more drying knowledge is needed; especially if optimal production is sought. There are indications that some eucalypt veneers would benefit from a lower drying temperature in terms of collapse, gluing behaviour and splitting. Published knowledge on the drying of individual species and age classes is sparse. It is likely that the opposing demands of throughput versus uniformity encountered in all continuous drying will be present in drying eucalypts for LVL.
- *Splitting/Steaming/Strength loss*- It is known that pre-steaming reduces veneer strength, but is almost always recommended for the peeling of eucalypt veneers in order to improve veneer quality and prevent splitting. This is another area that should be investigated- determining the best pre-steaming times and temperatures and the effect on strength loss and splitting.
- An instance of poor shear strength has been reported for *E. nitens* LVL. This needs to be investigated further.

REFERENCES

Acevedo, A., Bustos, C., Lasserre, J. P., & Gacitua, W. (2012). Nose bar pressure effect in the lathe check morphology to Eucalyptus nitens veneers. *Maderas: Ciencia y Technologia, 14*(3), 289-301.

Arnold, R., Xie, Y., Midgley, S., Luo, J., & Chen, X. (2013). Emergence and rise of eucalypt veneer production in China. *International Forestry Review, 15*(1), 33-47.

Aydin, I. (2014). Effects of veneer drying at high temperature and chemical treatments on equilibrium moisture content of plywood. *Maderas. Ciencia y tecnología, 16*(4), 445-452.

Aydın, İ., Çolak, S., Çolakoğlu, G., & Salih, E. (2004). A comparative study on some physical and mechanical properties of laminated veneer lumber (LVL) produced from Beech (Fagus orientalis Lipsky) and Eucalyptus (Eucalyptus camaldulensis Dehn.) veneers. *Holz als Roh- und Werkstoff, 62*(3), 218-220.

Bal, B. C. (2016). Some technological properties of laminated veneer lumber produced with fast-growing Poplar and Eucalyptus. *Maderas. Ciencia y tecnología*(AHEAD), 0-0.

Bal, B. C., & Bektaş, İ. (2012). The effects of some factors on the impact bending strength of laminated veneer lumber. *BioResources, 7*(4), 5855-5863.

Beadle, C., Volker, P., Bird, T., Mohammed, C., Barry, K., Pinkard, L., Wiseman, D., Harwood, C., Washusen, R., & Wardlaw, T. (2008). Solid-wood production from temperate eucalypt plantations: a Tasmanian case study. *Southern Forests: a Journal of Forest Science, 70*(1), 45-57.

Blackburn, D., Farrell, R., Hamilton, M., Volker, P., Harwood, C., Williams, D., & Potts, B. (2012). Genetic improvement for pulpwood and peeled veneer in Eucalyptus nitens. *Canadian Journal of Forest Research, 42*(9), 1724-1732.

Blakemore, P., Morrow, A., Washusen, R., Harwood, C., Wood, M., & Ngo, D. (2010). *Evaluation of thin-section quarter-sawn boards and rotary veneer from plantation-grown Eucalyptus nitens.* CRC for Forestry Technical Report.

Carrick, J. (2005). Durability of Laminated Veneer Lumber made from Blackbutt (Eucalyptus Pilularis). In *10DBMC International Conference On Durability of Building Materials and Components*

Chen, Z.-x., Lei, Q., He, R.-l., Zhang, Z.-f., & Chowdhury, A. J. K. (2016). Review on antibacterial biocomposites of structural laminated veneer lumber. *Saudi journal of biological sciences, 23*(1), S142-S147.

Çolak, S., Çolakoğlu, G., & Aydin, I. (2007). Effects of logs steaming, veneer drying and aging on the mechanical properties of laminated veneer lumber (LVL). *Building and Environment, 42*(1), 93-98.

Cown, D. (2016). *Review of eucalypt Wood Issues 2016.* Forest Owners' Research Committee.

Cown, D., Pearson, H., Riley, S. G., & Gaunt, D. (2015). *Wood Processing Challenges and Opportunities for Douglas-fir and Several Eucalyptus Species - A Review. Prepared for the Specialty Wood Products Partnership.* Scion, Rotorua.

de Carvalho, A. M., Lahr, F. A. R., & Bortoletto Jr, G. (2004). Use of Brazilian eucalyptus to produce LVL panels. *Forest products journal, 54*(11), 61.

de Melo, R. R., & Del Menezzi, C. H. S. (2014). Influence of veneer thickness on the properties of LVL from Paricá (Schizolobium amazonicum) plantation trees. *European Journal of Wood and Wood Products, 72*(2), 191-198.

de Melo, R. R., & Del Menezzi, C. H. S. (2015). Effects of grading of veneers on properties of LVL made from Schizolobium amazonicum Huber ex. Ducke. *European Journal of Wood and Wood Products, 73*(5), 677-683. doi:10.1007/s00107-015-0939-4

Derkowski, A., Mirski, R., Dziurka, D., & Popyk, W. (2014). Possibility of Using Accelerated Aging Tests to Assess the Performance of OSBs Exposed to Environmental Conditions. *BioResources, 9*(2), 3536-3549.

Farrell, R., Blum, S., Williams, D., & Blackburn, D. (2011). The potential to recover higher value veneer products from fibre managed plantation eucalypts and broaden market opportunities for this resource: Part A Project No: PNB139-0809.

Farrell, R., Innes, T., & Nolan, G. (2008). *Sorting plantation Eucalyptus nitens logs with acoustic wave velocity.*
Gaunt, D., Penellum, B., & McKENZIE, H. M. (2003). *Eucalyptus nitens* laminated veneer lumber structural properties. *New Zealand Journal of Forestry Science, 33*(1), 114-125.
Green, D., & Evans, J. W. (2005). Flexural properties of structural lumber products after longterm exposure to 150 F and 75% relative humidity. In *35th international particleboard composites materials symposium. (*pp. 3-14) Washington State University.
Hague, J. R. B. (2013). *Utilisation of plantation eucalypts in engineered wood products.* Forest & Wood Products Australia. PNB290-1112. Melbourne, Victoria, Australia: Forest & Wood Products Australia Limited.
Hamilton, M. G., Blackburn, D. P., McGavin, R. L., Baillères, H., Vega, M., & Potts, B. M. (2015). Factors affecting log traits and green rotary-peeled veneer recovery from temperate eucalypt plantations. *Annals of Forest Science, 72*(3), 357-365.
Harding, O. V., & Orange, R. P. (1998). The effect of juvenile wood and lay-up practices on various properties of radiata pine laminated veneer lumber. *Forest products journal, 48*(7/8), 63.
Hartley, J. (1984). *The Drying of Hardwood Veneers in New South Wales.* ODC 847:832.20(944). Sydney: N.S.W. timber Advisory Council.
Hopewell, G. P., Atyeo, W. J, McGavin R. L. (2008). *Evaluation of wood characteristics of tropical post-mid rotation plantation Eucalyptus cloeziana and E. pellita: Part (d) Veneer and plywood potential.* Melbourne, Australia.
Islam, M. N., Rahman, K.-S., & Alam, M. R. (2012). Comparative study on physical and mechanical properties of plywood produced from Eucalyptus (Eucalyptus camaldulensis Dehn.) and Simul (Bombax ceiba L.) veneers. *Research Journal of Recent Sciences, 2277*, 2502.
Iwakiri, S., Matos, J. L. M. d., Pinto, J. A., Viana, L. C., Souza, M. M. d., Trianoski, R., & Almeida, V. C. (2010). Production of laminated veneer lumber LVL using veneer of Schizolobium amazonicum, Eucalyptus saligna and Pinus taeda. *Cerne, 16*(4), 557-563.
JIiang, H.-c., Li, N., Tang, X.-m., & Luo, J.-j. (2011). The Application of Response Surface Methodology in Process of Eucalyptus LVL. *Eucalypt Science & Technology, 1*, 003.
Junior, J. B. G., Mendes, L. M., Mendes, R. F., & MoriI, F. A. (2011). Wood paticleboards made from residues obtained in the veneer production of eucalypt species and provenances. *CERNE, vol.17*(no.4).
Li, K.-F., Li, X.-Z., Peng, W.-X., Zhang, H.-H., & Ding, M.-Q. (2005). Research on type I class plywood production technology of timber mountain gum× flooded gum [J]. *Wood Processing Machinery, 6*, 15-20.
Luo, J., Arnold, R., Ren, S., Jiang, Y., Lu, W., Peng, Y., & Xie, Y. (2013). Veneer grades, recoveries, and values from 5-year-old eucalypt clones. *Annals of forest science, 70*(4), 417-428.
Mathieu, K., Carrick, J., & Marosszeky, M. (2004). A method for cleavage fracture testing of hardwood laminated veneer lumber. In *Structural Integrity and Fracture International Conference (*pp. 257-263)
McGavin, R. L., Bailleres, H., Fehrmann, J., & Ozarska, B. (2015). Stiffness and density analysis of rotary veneer recovered from six species of Australian plantation hardwoods. *BioResources, 10*(4), 6395-6416.
McKenzie, H., Gea, L., & Gaunt, D. (2006). Eucalyptus nitens laminated veneer lumber. *Boletín informativo CIDEU*(N. 02 (2006)).
McKenzie, H., Turner, J., & Shelbourne, C. (2003). Processing young plantation-grown Eucalyptus nitens for solid-wood products. 1: Individual-tree variation in quality and recovery of appearance-grade lumber and veneer. *New Zealand Journal of Forestry Science, 33*(1), 62-78.
Nolan, G., Greaves, B., Washusen, R., Parsons, M., & Jennings, S. (2005). Eucalypt Plantations for Solid Wood Products in Australia-A Review 'If you don't prune it, we can't use it'.
Ozarska, B. (1999). A review of the utilisation of hardwoods for LVL. *Wood Science and Technology, 33*(4), 341-351.
Palma, H. A. L., & Ballarin, A. W. (2011). Physical and mechanical properties of LVL panels made from Eucalyptus grandis. *Ciência Florestal, 21*(3), 559-566.

Roper, J., & Hay, E. (2000). Sliced veneer production from pruned plantation grown eucalypts in New Zealand. In *The future of eucalypts for wood products–Proceedings of a IUFRO Conference. (*pp. 106-112)

Saviana, J., Zitto, S., & Piter, J. C. (2009). Bending strength and stiffness of structural laminated veneer lumber manufactured from fast-growing Argentinean Eucalyptus grandis. *Maderas. Ciencia y tecnología, 11*(3), 183-190.

Shield, E. D. (1995). Plantation grown eucalypts: Utilisation for lumber and rotary veneers–primary conversion. *Seminário internacional de utilização da madeira de eucalipto para serraria, 5*.

Shukla, S., & Kamdem, D. P. (2008). Properties of laminated veneer lumber (LVL) made with low density hardwood species: Effect of the pressure duration. *Holz als Roh-und Werkstoff, 66*(2), 119-127.

Simpson, I. G., & Sole, J. (1999). *Eucalyptus nitens pilot veneer peeling and drying study.* Sidney 21525. unpublished: Scion.

Vázquez, G., González-Álvarez, J., López-Suevos, F., & Antorrena, G. (2003). Effect of veneer side wettability on bonding quality of Eucalyptus globulus plywoods prepared using a tannin–phenol–formaldehyde adhesive. *Bioresource technology, 87*(3), 349-353.

Yu, Y., Yu, W., & Wang, G. E. (2007). Manufacturing Technology and Main Properties for Laminated Veneer Lumber of Eucalyptus. *Scientia Silvae Sinicae, 8*, 030.

Zarnani, P., & Quenneville, P. NEW DESIGN APPROACH FOR WOOD BRITTLE FAILURE MECHANISMS IN TIMBER CONNECTIONS.

Zhang, Y.-P., & Fu, F. (2007). Research on the Gluability of Four Plantation Grown Eucalyptus Species [J]. *China Wood Industry, 1*, 008.

APPENDIX OF ABSTRACTS

Acevedo, A., Bustos, C., Lasserre, J. P., & Gacitua, W. (2012). Nose bar pressure effect in the lathe check morphology to Eucalyptus nitens veneers. *Maderas: Ciencia y Technologia, 14*(3), 289-301.

The objective of this study was to evaluate the effect of three nose bar pressure (TC) in the morphology of the lathe checks in Eucalyptus nitens veneers for the manufacture of plywood. Dried veneers were obtained from a peeling process, 1.8 mm thick three nose bar pressure TC1= 0.5%, TC2andTC3= 3.5%= 5%, which were obtained by adjusting the pressure bar and peeling knife of Cremonala the in a plywood plant in southern Chile. Samples were obtained randomly from the three types of veneers processed. Photographs were taken in the veneer thickness for subsequent image processing. In the morphological analysis of the cracks was evaluated: length, area and frequency in the samples for the three nose bar pressure studied. Morphological analysis of images showed that a decrease in the length and depth of the lathe check, as well as the area, when the nose bar pressure increases. Significant differences were found between 0.5%and 5%levels of nose bar pressure. This implies that increasing the nose bar pressure, through a setting that involves a smaller distance between the pressure bar and peeling knife, you get better quality veneers, more rigid and with a reduction of surface cracking in the final plywood.

Arnold, R., Xie, Y., Midgley, S., Luo, J., & Chen, X. (2013). Emergence and rise of eucalypt veneer production in China. *International Forestry Review, 15*(1), 33-47.

China's plywood production grew rapidly over the past 15 years from around 9 M m3 yr−1 in the mid-1990s to over 55 M m3 yr−1 by 2011. Associated with this has been a proliferation of small-scale eucalypt veneer mills processing young (≤ 5 yrs) small diameter logs (mostly ≤ 12 cm small end diameter); by 2011 there were over 5000 such mills in China with a collective capacity to process well over 15.0 M m3 yr−1 of logs.

We review key characteristics of this eucalypt veneer industry with special focus on three key regions for eucalypt veneer production in China. Factors that have spurred and facilitated the rapid growth of this industry are reviewed along with future challenges likely to emerge for China's eucalypt veneer industry.

Aydın, İ., Çolak, S., Çolakoğlu, G., & Salih, E. (2004). A comparative study on some physical and mechanical properties of laminated veneer lumber (LVL) produced from Beech (Fagus orientalis Lipsky) and Eucalyptus (Eucalyptus camaldulensis Dehn.) veneers. *Holz als Roh-und Werkstoff, 62*(3), 218-220.

Laminated Veneer Lumber (LVL) panels made from eucalyptus (Eucalyptus camaldulensis Dehn) and beech (*Fagus orientalis Lipsky*) veneers were tested for physical and mechanical strength properties in this study. Urea formaldehyde (UF) and Polyvinyl acetate (PVA) adhesives were used for eucalyptus LVL panels and UF adhesive for beech LVL panels. The effect of veneer wood species on some physical and mechanical properties was found statistically significant. Also, different glue species caused the differences in strength properties of LVL panels.

Bal, B. C. (2016). Some technological properties of laminated veneer lumber produced with fast-growing Poplar and Eucalyptus. *Maderas. Ciencia y tecnología*(AHEAD), 0-0.

Fast-growing tree species are important due to their short growth time before they are harvested. Both the *Poplar* and *Eucalyptus* species are fast-growing trees. These two species have been cultivated in many parts of the world, and they are used in several ways, including in the pulp and paper industry, as wood-based panels, and as structural composite lumber. In this study, laminated veneer lumbers were produced using different combinations of *Poplar* (*Populus x euramericana* I-214) and *Eucalyptus* (*Eucalyptus grandis*) veneers. Some physical and mechanical properties, including density, thickness swelling, water absorption, modulus of elasticity, modulus of rupture, impact bending, and bonding performance were investigated. According to the test data that were obtained, the mechanical properties of laminated veneer lumbers produced with *Eucalyptus* were greater than those of laminated veneer lumbers produced with *Poplar*. When the two were combined and *Eucalyptus* was used as the top and bottom plies, the mechanical properties also were better than those of *Poplar* laminated veneer lumbers. As a result, it can be said that both *Poplar* and *Eucalyptus* veneers can be used to produce laminated veneer lumbers, and *Poplar* laminated veneer lumbers can be reinforced with *Eucalyptus* veneers

Bal, B. C., & Bektaş, İ. (2012). The effects of some factors on the impact bending strength of laminated veneer lumber. *BioResources, 7*(4), 5855-5863.

Fast-growing tree species are important due to their short growth time before they are harvested. Both the *Poplar* and *Eucalyptus* species are fast-growing trees. These two species have been cultivated in many parts of the world, and they are used in several ways, including in the pulp and paper industry, as wood-based panels, and as structural composite lumber. In this study, laminated veneer lumbers were produced using different combinations of *Poplar* (*Populus x euramericana* I-214) and *Eucalyptus* (*Eucalyptus grandis*) veneers. Some physical and mechanical properties, including density, thickness swelling, water absorption, modulus of elasticity, modulus of rupture, impact bending, and bonding performance were investigated. According to the test data that were obtained, the mechanical properties of laminated veneer lumbers produced with *Eucalyptus* were greater than those of laminated veneer lumbers produced with *Poplar*. When the two were combined and *Eucalyptus* was used as the top and bottom plies, the mechanical properties also were better than those of *Poplar* laminated veneer lumbers. As a result, it can be said that both *Poplar* and *Eucalyptus* veneers can be used to produce laminated veneer lumbers, and *Poplar* laminated veneer lumbers can be reinforced with *Eucalyptus* veneers

Beadle, C., Volker, P., Bird, T., Mohammed, C., Barry, K., Pinkard, L., Wiseman, D., Harwood, C., Washusen, R., & Wardlaw, T. (2008). Solid-wood production from temperate eucalypt plantations: a Tasmanian case study. *Southern Forests: a Journal of Forest Science, 70*(1), 45-57.

Since 1988, there has been a major focus in Tasmania on research for the management of temperate eucalypt plantations for solid wood. This coincided with the formal transfer of large areas of native forest that had previously been part of the production forest estate into reserves, a decision that triggered the establishment of eucalypt plantations for solid wood. This review summarises research on several key areas: silvicultural requirements for solid-wood production; wood properties of plantation-grown eucalypts and the influence of silviculture and genetics on these properties; factors influencing stem defect and decay; balancing silvicultural requirements with maintenance of tree vigour; and issues concerning wood processing and products. We conclude that there are still operational challenges to be confronted in the production of solid wood from plantations. If these can be overcome in the medium term, temperate plantation eucalypts have the potential to provide wood products that meet the requirements for appearance-grade material and that can compete in the same markets as wood from native forests. The bigger challenge at the national level will be to provide the log volumes of suitable material to meet the anticipated demand 25 to 30 years from now.

Blackburn, D., Farrell, R., Hamilton, M., Volker, P., Harwood, C., Williams, D., & Potts, B. (2012). Genetic improvement for pulpwood and peeled veneer in Eucalyptus nitens. *Canadian Journal of Forest Research, 42*(9), 1724-1732.

Abstract: Genetic improvement of wood properties affecting the quality of pulpwood and peeled veneer products is of general interest to tree breeders worldwide. If the wood properties of Eucalyptus nitens (H. Deane & Maiden) Maiden are under genetic control and the correlations between them are favourable, it may be possible to breed to simultaneously improve the plantation resource for both products. Acoustic wave velocity (AWV) measured in standing trees can predict wood stiffness, basic density, and kraft pulp yield (KPY) and therefore has the potential for use in tree breeding programs. From an *E. nitens* progeny trial in Tasmania, 540 trees were selected for rotary peeling. Of the wood properties assessed, there were significant differences among races in diameter, stem straightness, standing-tree, log, and billet AWV, and near infrared predicted cellulose content (CC). All traits displayed significant within-race genetic variation, and genetic correlations between AWV and veneer sheet modulus of elasticity (MOE) and between AWV and KPY and CC were strongly positive and highly significant. A similar relationship was found between veneer sheet MOE and KPY and between diameter at breast height and veneer sheet MOE. Basic density was genetically correlated with AWV and veneer sheet MOE. Results indicate that it should be possible for breeders to simultaneously improve properties in pulpwood and peeled veneer products and that AWV measured in the standing tree shows promise as a breeding selection criterion for both pulpwood and peeled veneer products.

Blakemore, P., Morrow, A., Washusen, R., Harwood, C., Wood, M., & Ngo, D. (2010). *Evaluation of thin-section quarter-sawn boards and rotary veneer from plantation-grown Eucalyptus nitens.* CRC for Forestry Technical Report.

This report presents the findings of two wood processing trials using plantation-grown *Eucalyptus nitens*. One trial explored whether reducing board thickness of quarter-sawn boards (from pruned trees) to 9 mm could completely eliminate internal checking. A small-scale rotary veneering trial was also conducted to evaluate the potential of pruned and unpruned logs for producing appearance-grade veneers.

Objectives

The objectives of the two wood-processing trials described in this report were:

(1) to evaluate whether checking in quarter-sawn boards cut from pruned plantation grown *E. nitens* (shining gum) could be eliminated by reducing board thickness to a very thin section (< 10 mm green-sawn thickness). Surface and internal checking had been identified as significant value-limiting defects in earlier CRC for Forestry processing studies on this species (refer to CRC for Forestry Technical Reports 168 and 200)

(2) to provide a preliminary assessment of the veneer-grade recoveries and the stiffness of veneer sheets cut from pruned and unpruned plantation-grown *E. nitens* logs in a rotary veneer mill.

Methods

Pruned and unpruned logs were harvested from a 21-year-old silvicultural trial in a fast growing *E. nitens* plantation near Lisle, in north-east Tasmania. The best 300 trees per hectare had been pruned to a height of 6.4 m at age six years. Four thinning treatments applied at age nine years gave post-thinning stocking densities of 100, 250 and 600 stems/ha and about 1000 stems/ha, the last an unthinned control treatment. Bush logs from a total of twelve pruned trees from the 100, 250 and 600 stems/ha treatments were transported to the Creswick Timber Training Centre in Victoria, where they were cross-cut to produce two 2.7m sawlogs. Each sawlog was sawn to produce clearwood flitches suitable for re-sawing, with the central knotty core of the log excluded. The flitches were re-sawn to produce quarter-sawn boards of 9 mm green thickness and 75 mm width. Boards were racked and air-dried in a research kiln at CSIRO's Clayton laboratories (Melbourne), using ambient air conditions with fan movement of air after the first four weeks. Following drying to average moisture content of <15%, the boards were cross-cut at mid-length and the cut ends of a total of 1240 boards assessed for the presence of internal checking. One half of each cross-cut board was then steam-reconditioned and dried to final moisture content of 12%. A second cross-cut was then made 50 mm in from the original cross-cut and assessed for internal checking. Bush logs from five pruned and five unpruned trees, all from the 250 stems/ha treatment, were transported to the Ta Ann Tasmania rotary veneering mill near Smithton in northwest Tasmania. Each bush log was cross-cut to produce three 1.91m-long billets, which were processed to produce veneer sheets of 2.4 mm thickness, with dimensions of 1.83 m (longitudinal) × 0.91 m (tangential). Veneer sheets were dried according to standard operational procedures to a moisture content of 12%. All sheets were graded according to AS/NZ Standard 2269:2004, which identifies four veneer grades (A–D) of decreasing quality and rejects sheets that fail to make grade D. Two veneer sheets per billet, one from the inner heartwood and one from the outer heartwood, were taken to CSIRO's Clayton laboratories, where dynamic stiffness was estimated from measurements of specific gravity and acoustic wave velocity.

Key results

(1) Quarter-sawn boards

The quarter-sawn boards were free from surface checking. Levels of internal checking were extremely low, with 94.5% of boards check-free prior to reconditioning and 98.3% of boards having no visible checks following reconditioning. These results represented a marked improvement from the levels of surface and internal checking recorded in previous studies.

(2) Veneer

Percentage recovery of appearance-grade veneer sheets (A and B grade) from pruned logs (12% of green volume) was higher than from unpruned logs (6%), and recovery of all grades (A–D) was also higher for pruned logs at 58% compared with 45% for unpruned logs. Green recoveries were highest from the first 1.9 m billet from the bottom of the logs, progressively reducing for the next two billets, for both pruned and unpruned logs. There was substantial variation in grade recoveries from tree to tree, indicating the need for larger scale trials to reliably estimate green recoveries. Dynamic stiffness of veneer sheets was in the range of 8–11 GPa, increasing significantly from the inner heartwood to the outer heartwood and from the first billet through to the third billet above ground.

Application of results

Surface and internal checking in boards cut from plantation-grown *E. nitens* can be virtually eliminated by quarter-sawing to a thickness of 9 mm (green) and then following appropriate drying and reconditioning schedules. Depending on the sawing system and the final products, an intermediate board thickness in the range of 10-15 mm (finished) might offer an optimum balance between an acceptable level of checking defects, and acceptable recovery and processing costs. Recoveries of useable grades of veneer from *E. nitens* will be higher from pruned than from unpruned plantations. Veneer stiffness from plantation-grown *E. nitens* will be relatively low, compared with veneers cut from native forest eucalypt logs.

Further work

Whether there is an economic application for defect-free thin-section quarter-sawn boards cut from pruned plantation-grown *E. nitens* will need to be determined by industry. Studies on the manufacture of plywood products from veneer of plantation-grown *E. nitens* and on the properties of these products are warranted, although such work is outside the scope of the CRC for Forestry research program.

Carrick, J. (2005). Durability of Laminated Veneer Lumber made from Blackbutt (Eucalyptus Pilularis). In *10DBMC International Conference On Durability of Building Materials and Components*

Blackbutt (*Eucalyptus Pilularis*) is a common plantation hardwood in New South Wales, Australia, highly regarded for its strength and durability but considered difficult to laminate for "engineered timber" because of chemicals present in the timber (extractives). While previous work by State Forests New South Wales pointed to a viable lamination method using phenolic tannin glues, plywood made from Blackbutt has shown glue failure in exterior applications. At the University of New South Wales (UNSW), a lamination technique was investigated for Blackbutt Laminated Veneer Lumber (LVL) and a cleavage fracture toughness method was adapted to quantify the toughness of its glue-lines. The durability of Blackbutt LVL with differing extractive content was explored by assessing fracture toughness of glue-lines after exposure to one of three artificial weathering environments and a marine inter-tidal zone. Specimens subjected to the most aggressive laboratory environment and those immersed in the inter-tidal zone showed some loss of fracture toughness with increasing exposure, however Blackbutt LVL was shown to be much more durable than Pine LVL. Exposure to the adverse environments had not compromised the nature of the glue-lines and the mean toughness values remained relatively high at approximately 400 J/m2. The results suggest that Blackbutt veneer is capable of being glued for application as a durable structural LVL. ., (Carrick, 2005)

Chen, Z.-x., Lei, Q., He, R.-l., Zhang, Z.-f., & Chowdhury, A. J. K. (2016). Review on antibacterial biocomposites of structural laminated veneer lumber. *Saudi journal of biological sciences, 23*(1), S142-S147.

In this review, the characteristics and applications of structural laminated veneer lumber made from planted forest wood is introduced, and its preparation is explained, including various tree species and slab qualities, treatments for multiple effects and reinforced composites. The relevant factors in the bonding technology and pressing processes as well as the mechanical properties, research direction and application prospects of structural laminated veneer lumber made from planted forest wood are discussed.

Çolak, S., Çolakoğlu, G., & Aydin, I. (2007). Effects of logs steaming, veneer drying and aging on the mechanical properties of laminated veneer lumber (LVL). *Building and Environment, 42*(1), 93-98.

In this study the effects of steaming and drying condition on the mechanical properties and durability of laminated veneer lumber (LVL) and solid sawn lumber were investigated in a comparative way. Steamed beech and steamed and non-steamed spruce logs were used and two different veneer drying temperatures (20 and 110 1C) were selected for this aim. Aging test was applied according to EN 321 to determine the durability of LVL and solid wood samples. Steaming decreased considerably all investigated strength properties of LVL panels and the least affected was the compression strength. The compression strength and the static bending strength values of both beech and spruce LVL panels were higher than those of the solid wood groups obtained from the same logs. The impact strength values of LVL panels, unlike the static bending strength and the compression strength, were lower than those of the solid samples, which were not steamed and aged.

Cown, D. (2016). *Review of eucalypt Wood Issues 2016.* Forest Owners' Research Committee.

Cown, D., Pearson, H., Riley, S. G., & Gaunt, D. (2015). *Wood Processing Challenges and Opportunities for Douglas-fir and Several Eucalyptus Species - A Review. Prepared for the Specialty Wood Products Partnership.* Scion, Rotorua.

de Carvalho, A. M., Lahr, F. A. R., & Bortoletto Jr, G. (2004). Use of Brazilian eucalyptus to produce LVL panels. *Forest products journal, 54*(11), 61.

Brazil stands out on the international eucalyptus pulp market, with large areas planted with this species, approximately 3,000,000 ha, mainly to supply the demands of this industrial sector. Several species are perfectly adapted to the country's environmental and climatic conditions, constituting a raw material with excellent silvicultural productivity, with trees reaching diameters of up to 30 cm at the base in a period of 8 years. Recent research has evaluated the diversification of the final use of this wood with the idea of obtaining other products from it, such as sawn planks and panels. The purpose of this study is to evaluate the potential of this raw material in the production of LVL panels, to characterize eucalyptus-based LVL, and to spark the interest of Brazilian companies (particularly plywood manufacturers) in this product, which is still nonexistent in Brazil's domestic market. LVL panels of structural dimensions were built in the laboratory using 3-mm-thick sheets. The panels were evaluated through static flexure tests, showing satisfactory results compared to technical information on LVL panels made of other raw materials and sold on the international market. Eucalyptus showed good potential for the manufacture of panels.

de Melo, R. R., & Del Menezzi, C. H. S. (2015). Effects of grading of veneers on properties of LVL made from Schizolobium amazonicum Huber ex. Ducke. *European Journal of Wood and Wood Products, 73*(5), 677-683. doi:10.1007/s00107-015-0939-4

The work aimed at evaluating the influence of pre-classification of veneer made from paricá (*Schizolobium amazonicum Huber ex. Ducke*) plantation trees on Laminated Veneer Lumber (LVL) properties. This species is native to the Amazonian and is fast growing with low density. For LVL production, veneers were separated into four classes according to the density or dynamic modulus of elasticity. LVL was produced considering three different strategies of assembly—random veneers assembly; assembly using veneers with greater EMd placed at the surface layer with gradual reduction up to the centre of the panels; assembly using veneers with greater density placed at the surface layer and gradual reduction into the centre of the panels. The following mechanical and physical properties were then evaluated: static bending modulus of elasticity (E M), modulus of rupture (f M), compression strength parallel to grain (f c0), shear strength parallel to glue-line (f v0), shear strength perpendicular to glue-line (f v90), water absorption and thickness swelling for 2 and 24 h of water immersion. Physical properties of LVL were not found to be influenced by different pre-classification strategies, while for mechanical properties only bending strength at flatwise position was influenced by pre-classifying veneers.

Derkowski, A., Mirski, R., Dziurka, D., & Popyk, W. (2014). Possibility of Using Accelerated Aging Tests to Assess the Performance of OSBs Exposed to Environmental Conditions. *BioResources, 9*(2), 3536-3549.

The work aimed at evaluating the influence of pre-classification of veneer made from paricá (*Schizolobium amazonicum Huber ex. Ducke*) plantation trees on Laminated Veneer Lumber (LVL) properties. This species is native to the Amazonian and is fast growing with low density. For LVL production, veneers were separated into four classes according to the density or dynamic modulus of elasticity. LVL was produced considering three different strategies of assembly—random veneers assembly; assembly using veneers with greater EMd placed at the surface layer with gradual reduction up to the centre of the panels; assembly using veneers with greater density placed at the surface layer and gradual reduction into the centre of the panels. The following mechanical and physical properties were then evaluated: static bending modulus of elasticity (E M), modulus of rupture (f M), compression strength parallel to grain (f c0), shear strength parallel to glue-line (f v0), shear strength perpendicular to glue-line (f v90), water absorption and thickness swelling for 2 and 24 h of water immersion. Physical properties of LVL were not found to be influenced by different pre-classification strategies, while for mechanical properties only bending strength at flatwise position was influenced by pre-classifying veneers.

Farrell, R., Blum, S., Williams, D., & Blackburn, D. (2011). The potential to recover higher value veneer products from fibre managed plantation eucalypts and broaden market opportunities for this resource: Part A Project No: PNB139-0809.

The objectives of this Part A of the study were to:
1. Provide baseline data on veneer quality and plywood properties of fibre-managed plantation *E. nitens* grown in Tasmania.
2. Identify the genetic parameters that affect quality of rotary-peeled veneer and plywood to guide selection of families for future breeding programs and to examine the compatibility of breeding for potentially conflicting objectives.
3. Assess the effectiveness of an acoustic sorting strategy and potential gain from segregation of logs for veneer and plywood production. The key outcomes, industry benefits and indication to future work included:
1. This project presents Australia's first large scale peeling trial for plantation *E. nitens* providing significant baseline data on plywood properties and veneer quality and the genetic parameters that underpin them. Results will help guide future breeding programs and direct research towards key processing parameters most likely to improve veneer quality and recovery and therefore commercial opportunities for peeled products from this resource.
2. Glue bond tests (for exterior use) were generally promising. Further work is required to improve and understand bond quality issues in younger (16yr) *E. nitens* resource.
3. Shear properties were poor for all resources tested at UTAS and EWPAA facilities, limiting F-Grade classification to F8 and below. Assuming shear strength could be increased beyond the observed limiting levels through process optimisation the resources tested would classify with F-Grades of F34 (*E.glob*), F17 (E.ni26), F17 (TasOak/E.ni16), F17 (TasOak/P.rad)and F11(E.ni16).
4. Significant gains in veneer quality (and resultant product properties) may be achieved through appropriate drying of the plantation veneer.
5. Log steaming prior to peeling also needs to be evaluated to establish veneer quality (and end product) implications.
6. Plywood panels with optimised veneer sheet layup increased resultant panel stiffness by 18%.
7. Viable processing of short-rotation (16yr) unpruned *E.nitens* will depend on increasing average stiffness properties through genetic selection of superior families, use of acoustic sorting strategies to exclude low stiffness logs, process optimisation and recovery improvements as well as stiffness grading and alignment of veneers in panel construction.
8. High stiffness (and strength) values for *E. nitens* 26yr plywood panels (>14GPa, i.e. ≥F17), suggest opportunities for *E. nitens* resource on longer rotations (i.e. 20-25yrs). Further work is needed to analyse this potential including recovery of face grade veneers from pruned *E.nitens* logs.
9. Very high stiffness (and strength) values for the *E. globulus* resource indicate opportunities to utilise this species for peeled structural products. Further work is needed to examine material

harvested from younger rotations i.e. 10-20yrs, (noting the 33yr material in this project was opportunistic).
10. Acoustic correlations at log level (5.4m) were similar to those at billet level (2.4m) and were sufficient to indicate potential for acoustic segregation of long logs prior to merchandising.
11. The large dataset gathered for the 16yr *E. nitens* was useful in correlating AWV to veneer stiffness facilitating the segregation of logs into three stiffness classes. The practical benefit from an acoustic segregation strategy is likely to be the ability to identify low and high stiffness logs at the extremes of the stiffness distribution and utilise them appropriately.
12. Final engineered wood product (e.g. plywood and LVL) stiffness from plantation *E. nitens* could be improved through selectively breeding for higher standing tree AWV.
13. There were no adverse estimated genetic correlations between studied objective traits, indicating a breeding objective could be developed to include traits that would simultaneously improve desired properties in both pulpwood and RPV engineered wood products.
14. Implications for industry. The grade recovery into face material suitable for plywood was zero. This makes the resource as a stand - alone option unsuitable for plywood production. It may be suitable to supplement supplies of core veneer however industry usually has an over-supply of lower quality veneers and struggles to find uses for it. Commercial grade recovery is 80% C-D, 20% D-D plywood (which is later sold at marginal price). With no face grade ply, there is no commercial viability. For LVL production this is not as critical however there are limited LVL opportunities currently in Australia (only one LVL plant).

Farrell, R., Innes, T., & Nolan, G. (2008). *Sorting plantation Eucalyptus nitens logs with acoustic wave velocity.*

Sawn lumber from plantation-grown *Eucalyptus nitens* displays significant variation in stiffness and strength. Diversion of low-strength material to non-structural timber production and separation of high strength material for premium value structural applications will improve resource utilisation and enterprise profitability. Acoustic wave velocity (AWV) was evaluated as a direct measure of wood stiffness using two age classes of *Eucalyptus nitens.* The two age-classes (8 years and 13-15 years) from a total of five sites provided material representative of the resource currently being directed to the structural market. Standing trees and felled logs were measured before and after harvest using readily available stress wave timing tools (FAKOPP and Hitman). Logs were sawn, dried and finished according to normal structural processing requirements. One sample board per log was then tested for stiffness, bending strength and hardness. Log samples were also collected to determine green and basic density, and relationships between the evaluated wood properties and AWV measurements in trees and logs were determined. The AWV along logs provided the strongest correlation with wood stiffness facilitating the segregation of logs into stiffness classes. AWV cut-off values were identified to batch logs into three stiffness classes with an average MOE of 12, 10 and less than lOGPa. Although AWV measurement on logs provided the single best correlation with an R^2=0.54 (n=155), it was observed that both AWV on logs and trees provided highly significant positive correlation with board stiffness. The correlation between tree AWV and stiffness was sufficiently good (R^2=0.36, n=l55) to allow trees to be batched to segregate the higher value structural material. One cut-off AWV was identified to batch material into two. Stiffness classes with an average MOE of 12 and 10GPa. Given that AWV and wood property values were significantly different among sites this study indicates that acoustic assessment of *E. nitens* plantations could provide some indication of the resource value for the structural market. A weaker but still highly significant positive correlation was found between stiffness and hardness indicating that segregation based on increasing stiffness would also improve hardness values.

Gaunt, D., Penellum, B., & McKENZIE, H. M. (2003). *Eucalyptus nitens* laminated veneer lumber structural properties. *New Zealand Journal of Forestry Science, 33*(1), 114-125.

Veneer peeled from *Eucalyptus nitens* (Deane & Maiden) Maiden unpruned second logs was segregated into three stiffness classes using an acoustic test. Laminated veneer lumber (LVL) was manufactured using sheets from each stiffness class tested. Strength tests showed that the sheets

were successfully segregated by the acoustic stiffness test. The *E. nitens* LVL had strength and stiffness properties which were higher than those of LVL made from New Zealand-grown *Pinus radiata* D.Don veneer.

Green, D., & Evans, J. W. (2005). Flexural properties of structural lumber products after longterm exposure to 150 F and 75% relative humidity. In *35th international particleboard composites materials symposium. (*pp. 3-14) Washington State University.
Wood strength decreases when heated. Design guidelines indicate that for limited exposure of temperatures up to 150°F, this immediate effect of temperature is reversible; that is, the member will recover essentially all lost strength when the temperature is returned to normal. Prolonged heating at temperatures over 150°F can cause a permanent loss in strength. Virtually all research on permanent loss in strength is based on heat exposure of small, clear specimens of solid wood for limited periods of time. This paper presents results on permanent loss in flexural properties for solid-sawn and structural composite 2-by 4-ft. Lumber, heated in air at 150°F and 75 percent relative humidity (RH), for periods of up to 6 years. The results presented here will show that for 2 to 3 years of continuous exposure, the reduction in bending strength of laminated veneer lumber (LVL) is similar to that of solid-sawn spruce, pine, and fir (SPF) lumber. After 3 years of exposure, the bending strength of LVL decreased faster than that of solid-sawn SPF lumber. The bending strength of laminated strand lumber was found to be more sensitive to duration of temperature exposure than was bending strength of solid-sawn SPF lumber or LVL.

Hague, J. R. B. (2013). *Utilisation of plantation eucalypts in engineered wood products.* Forest & Wood Products Australia. PNB290-1112. Melbourne, Victoria, Australia: Forest & Wood Products Australia Limited.
This document reviews and summarises available information on the utilisation of plantation Eucalypts in engineered wood products (EWPs). The primary focus of the review was on *Eucalyptus globulus* (southern blue gum) and *E. nitens* (shining gum), which comprise the majority of the Australian hardwood (Eucalypt) plantation estate, but other plantation Eucalypt species were also considered where information was available. The EWPs covered in the review included laminated veneer lumber (LVL) and plywood, glulam, flake/strand-based products, fibreboard and particleboard. Key findings:
The available information on the suitability of Australian-grown plantation Eucalypts for EWPs is scarce. Furthermore, that which does exist is typically based on limited replication within given studies.
It is evident that significantly more research has been conducted overseas, particularly in South America and South-western Europe. Furthermore, it is apparent that wood processing industries in these regions have been utilising plantation Eucalypt resources for some time for a variety of EWPs.
Fast-grown, lower density Eucalypts generally present no major difficulties with respect to adhesion; any of the adhesive systems conventionally used by the EWP industry could in all likelihood be used by Australian EWP manufacturers to produce fit-for-purpose products from plantation Eucalypt resources with air-dry densities less than 650 kg/m3.
Based on available published research data and current practices in the global EWP industry, it is believed that much of the current Australian plantation Eucalypt resource (i.e. that originally planted for wood chip and pulp), and in particular *E. globulus*, *E. nitens* and *E. grandis*, would be suitable for use as a feedstock for LVL, selected strand/flake-based EWPs and medium density fibreboard.
Further research efforts should primarily be directed towards tree breeding and improved silvicultural practices e.g. breeding for optimum density (500 to 550 kg/m3) and pruning to reduce the incidence of defects. This would potentially open up opportunities for utilisation of the plantation Eucalypt resource for plywood and glulam, as well as further increasing opportunities for utilisation in other EWP markets.

Hamilton, M. G., Blackburn, D. P., McGavin, R. L., Baillères, H., Vega, M., & Potts, B. M. (2015). Factors affecting log traits and green rotary-peeled veneer recovery from temperate eucalypt plantations. *Annals of Forest Science, 72*(3), 357-365.

Key message: High levels of percentage green veneer recovery can be obtained from temperate eucalypt plantations. Recovery traits are affected by site and log position
in the stem. Of the post-felling log traits studied, outof- roundness was the best predictor of green recovery.
Context Eucalyptus globulus and Eucalyptus nitens are widely planted in temperate regions of the globe but few studies of rotary peeling have been documented.
Aims This study aims to examine differences among sites and log positions in post-felling log traits and green veneer recovery traits and determine the extent to which log traits explain variation in recovery traits.
Methods Log traits and green rotary-peeled veneer recovery traits from six temperate eucalypt plantations were studied. Selected plantations encompassed different age, site productivity, silvicultural and species classes in south-eastern Australia. Differences in log and recovery traits among sites and between lower and upper logs were examined, as was the extent to which log traits explained variation in recovery traits.
Results Differences among sites for percentage recovered green veneer were non-significant, despite significant differences for peelable billet volume, roundup loss, residual core diameter and all post-felling log traits: small end diameter, sweep, taper, out-of-roundness, end splitting and dynamic modulus of elasticity (MOEdyn). The lower log exhibited more sweep, taper and out-of-roundness but lower MOEdyn and less recovered green veneer. Out-of-roundness was the best predictor of recovery traits (R2=13–21 %, P<0.001).
Conclusion Recovered green veneer was high across all sites and log positions (78 % overall).

Harding, O. V., & Orange, R. P. (1998). The effect of juvenile wood and lay-up practices on various properties of radiata pine laminated veneer lumber. *Forest products journal, 48*(7/8), 63.

Laminated veneer lumber (LVL) was produced in seven different configurations, including current industry practice, all juvenile, all mature, mixed juvenile and mature, deep lathe check, and an alternative lay-up, which glued the loose face to the loose face, and a control. The all juvenile lay-up did not decrease the stiffness (E p min) of the LVL significantly compared to many other patterns. The juvenile wood component seemed to perform at least as well as current industry practice. The juvenile LVL was found to have more twist and bow, and no difference in crook compared to the mature lay-up pattern. The deep lathe checks did not decrease the stiffness of the LVL, but did show an increase in distortion compared to most of the other lay-up configurations. The alternative configuration of matching the loose face to the loose face increased the average stiffness of the resulting LVL studs. It also had significantly lower crook and bow, although this alternative lay-up did increase the amount of twist. Overall, the LVL fell within allowable parameters of distortion according to the governing lumber-grading rules. For twist, 90 percent of the LVL studs were below 2.5 mm, one-fourth of the allowable limit of 10 mm. For both crook and bow, over 99 percent of the studs were below one-fourth of the allowable limits of 10 mm and 20 mm, respectively. The radiata pine veneer produced a median structural grade of F5, and 93 percent of the studs were F5 and better. There were no F11 studs found in the LVL. The amount of reject material was low: 2.9 percent of the total number of studs.

Hartley, J. (1984). *The Drying of Hardwood Veneers in New South Wales.* ODC 847:832.20(944). Sydney: N.S.W. timber Advisory Council.

Information about the drying of hardwood veneers in New South Wales is reviewed. Sources were published and unpublished reports, and N.S.W. industrial experience. Aspects discussed are types of drier, drying rates, shrinkage, collapse, dried quality, control and measurement of dried veneer moisture content, and aspects of drier operation. Information is given about the drying of some particular species, and aspects for further investigation are discussed.

Hopewell, G. P., Atyeo, W. J, McGavin R. L. (2008). ***Evaluation of wood characteristics of tropical post-mid rotation plantation Eucalyptus cloeziana and E. pellita: Part (d) Veneer and plywood potential.*** **Melbourne, Australia.**

Representative logs from two hardwood plantations located in north Queensland were peeled to enable assessment of the veneer and plywood potential of fast-grown tropical plantation eucalypts. After visual grading and veneer recovery calculations, selected veneers were assembled to produce plywood panels which were then tested for mechanical properties and glue bond strength. These tests were chosen to provide the best indications of the utility of young, fast-grown, tropical eucalypts for panel product applications.

On 20 March 2006, Cyclone Larry crossed the north Queensland coast near Innisfail and caused extensive damage to buildings, agricultural crops, forests and timber plantations. Salvage logging in the area subsequently provided forty-two 19-year-old Gympie messmate *(Eucalyptus cloezia na)* stems and thirty-two 15-year-old red mahogany *(Eucalyptus pellita)* stems for processing and product research. The donor stands were approximately 60 km apart and growing on different soil types. From this sample, 14 Gympie messmate and 12 red mahogany billets (one per tree in each case) were used for peeled veneer and plywood trials.

The north Queensland region has a rich history of veneer and plywood production, with many rainforest species achieving popularity with joiners and architects, both in Australia and abroad, since the 1930s. With much of the production rainforest area in the region now listed as World heritage sites, local forest product processing activities have diminished during the past 20 years. During this period, a new series of trial plantings of rainforest and eucalypt species have been established to investigate the potential for substitute timber production. The region includes areas of highly productive land with suitable soil types and high annual rainfall encouraging several private forestry companies to establish plantation projects in the area in recent years.

The plantations accessed during the Cyclone Larry salvage operations reflect typical target age classes and candidate species for thinning and near-rotation harvesting for commercial plantations and therefore presented an excellent opportunity to evaluate the potential of these resources through veneer production and plywood manufacturing processes and testing protocols.

Representative samples of each test population were measured for a range of attributes including volume and taper. Billets were stored under cover within damp hessian shrouding to delay drying degrade between harvesting and processing. Although this mode of storage was effective in preventing drying degrade, the red mahogany billets developed end splits as a consequence of growth stress release.

Although the red mahogany was only 15 years old, the billets obtained from selected logs had ideal geometries for peeler logs, with an average taper ratio similar to the older Gympie messmate. It should be noted however, that ages 15 and 19 the material used in these research trials was considerably younger, and therefore smaller in dimension, than traditional peeler logs, sourced from native hardwood forests and older plantations. It should also be noted that the billets used for this trial were 1.31 m in length which is a standard cross band dimension, not the conventional 2.5 m length used for production of long bands.

Veneer was produced through standard industry steaming, peeling and drying processes. The dried veneer was visually graded in accordance with Australian Standards and then batched for lay-up into structural panels. Type A and Type B bond adhesives were used and a total of ten 1200 mm x 1200 mm Gympie messmate and six red mahogany panels were manufactured in commercial production facilities. Additionally, eight panels comprised of plantation hardwood outer layers over plantation softwood cross band substrates were produced.

End splits impacted the production of full veneer sheets from the young red mahogany; however the Gympie messmate produced a reasonable quantity of veneer sheets. Several of the red mahogany billets contained white picket rot, generally associated with knots and the juvenile core. This limited the available peeling fraction from affected billets and often left a large residual core. Further work is recommended in the areas of decay prevention in the plantation, the development of low splitting families or clones and the assessment of post-harvest techniques to minimize the development of growth stress-related end splits. It was not possible to determine whether the extent of end splitting was influenced by the Cyclone in addition to growth stress release.

Several methods of assessing the grade quality for each species were used, including the distribution of visual grades and calculation of grade scores to provide a relative value for the grade quality. The Gympie messmate produced significantly more veneer per cubic metre of log and achieved higher scores for quality than the younger red mahogany. Industry representatives witnessing the peeling operations commented that the Gympie messmate had the appearance of a high quality hardwood veneer, despite the relatively young age of the source trees.

While the low number of test panels available for each species precluded the formal allocation of stress grades, the mechanical tests suggested that both species in their respective age classes can attain stress grades equal to standard commercial structural plywood products. These data provide an indication of the potential of the species and age class only and should be used with caution. Based on the test sample (n=6 panels), the 15 year old red mahogany panels may achieve stress grades ranging from F11 to F14. This result indicates that correctly graded veneers could produce a structural product in the range typical for commercially available softwood plywood products. From an appearance quality perspective, it was noted that the red mahogany also exhibited good red colouration, despite the young harvest age of the material.

The Gympie messmate panel sample (n=10 panels) may achieve stress grades between F22 and F27 which indicates that the 19 year old material could produce veneer quality typical of the higher end of the commercial range of F17 to F27 hardwood plywood currently available in domestic markets.

Despite higher total extractives content than the older Gympie messmate, the 15 year old red mahogany performed better in the glue bond assessment. The panels manufactured by commercial production facilities achieved a 100% pass rate and the laboratory scale tests achieved a 90% pass for Type A bonds. The commercial facility-produced Gympie messmate Type A panels achieved an 80% pass rate but only 42% for the laboratory scale glue bond tests. This may be attributed to the lower density of the red mahogany veneer which typically allows for strong bonding between adherends. Both species failed to produce satisfactory Type B bonds in either the industry prepared plywood panels or laboratory scale tests. The results for the Type A bond tests provide optimism for future product development for exterior grade engineered wood products using plantation-grown eucalypts. However, there is a need for further investigations into use of Type B bond plywood manufacture from young plantation-grown eucalypts in order to explain the unexpected results attained during these trials.

Islam, M. N., Rahman, K.-S., & Alam, M. R. (2012). Comparative study on physical and mechanical properties of plywood produced from Eucalyptus (Eucalyptus camaldulensis Dehn.) and Simul (Bombax ceiba L.) veneers. *Research Journal of Recent Sciences, 2277*, 2502.

Plywood becomes very important material for various structural purposes in Bangladesh and used as a substitute of solid wood. Therefore, the objective of this study was to determine and compare the physical and mechanical properties of plywood produced with veneers of eucalyptus and simul tree. The commercial urea formaldehyde resin was used for fabricating the panels. Physical properties i.e., density, moisture content, water absorption and thickness swelling; and mechanical properties i.e., modulus of elasticity (MOE) and modulus of rupture (MOR) of the panels were determined according to the procedure of ASTM standards. It was found that the density of eucalyptus and simul plywood was 879 and 536 kg/m3 respectively. Further, it was also observed that MOE and MOR of eucalyptus plywood were almost 2 and 2.5

times higher respectively than those of simul plywood. These differences were attributed to the variation in properties of veneer wood species and the effect of veneer wood species on some physical and mechanical properties of plywood was *found statistically different.*

Iwakiri, S., Matos, J. L. M. d., Pinto, J. A., Viana, L. C., Souza, M. M. d., Trianoski, R., & Almeida, V. C. (2010). Production of laminated veneer lumber LVL using veneer of Schizolobium amazonicum, Eucalyptus saligna and Pinus taeda. *Cerne, 16*(4), 557-563.

This research evaluated the quality of laminated veneer lumber - LVL manufactured with veneers of Schizolobium amazonicum (paricá), Eucalyptus saligna and Pinus taeda. The LVL panels were manufactured in the laboratory conditions composed by seven veneers, 2,0 mm thickness, with different structural compositions, using phenol-formaldehyde resin. The veneers of Schizolobium amazonicum- paricá- were pre-classified by using stress wave machine. The veneers of Eucalyptus saligna and Pinus taeda were disposed in the face layer to reinforce the structural strength of LVL panels. The LVL quality was evaluated using glue line shear strength and static bending test (MOE and MOR, edge and flat). Grading of paricá veneers based on MOEd did not affected significantly the results of the glue line shear strength and MOE and MOR edge. For the MOE and MOR flat, the use of veneers of MOEd grade 1 contributed significantly to increasing the average values of these properties. In the same way, using the Eucalyptus saligna veneers on the face of LVL resulted in higher average values of MOE and MOR, edge and flat.

JIiang, H.-c., Li, N., Tang, X.-m., & Luo, J.-j. (2011). The Application of Response Surface Methodology in Process of Eucalyptus LVL. *Eucalypt Science & Technology, 1*, 003.

The influence of veneer thickness and glue spread on mechanical property of laminated veneer lumber(LVL)of eucalyptus wood was investigated by response surface methodology(RSM).The results showed that veneer thickness and glue spread had significant effects on modulus of rupture(MOR) and modulus of elasticity(MOE).The determination coefficient(R2) of predicted values and experiment values were 0.72,0.79,0.59,0.69 respectively. The optimum parameters in experiment: veneer thickness 2.0 mm, glue spread 233 g·m-2.The MOR and MOE of laboratory products reached the level of 1st-class product and 140 E indicated in national standard(GB/T 20241-2006).

Junior, J. B. G., Mendes, L. M., Mendes, R. F., & Mori, F. A. (2015). Plywood boards of eucalyptus: a case study of species and provenances. *Cerne, 15*(1), 010-018.

This work aimed at evaluating 15 provenances of Eucalyptus cloeziana, Eucalyptus grandis and Eucalyptus saligna for multi-laminated plywood boards manufacturing. Six boards for each provenance were made. Phenol-formaldehyde adhesive with 320g/m^2 glue content was used. The utilized pressing cycle was of 15kgf/cm^2, at the temperature of 150ºC during 10 minutes. From the results obtained regarding the physical properties, the species of Eucalyptus cloeziana and Eucalyptus saligna performed better. In the mechanical tests, MOE presented itself above the demands of the norm with the exception of provenance 7785 of Eucalyptus saligna, in which stress was performed parallel to the cover fibres. For parallel MOR, only the provenances 9789 and 10695 of Eucalyptus grandis and 97852 of Eucalyptus cloeziana managed to reach the demands of the norm ABNT 31:000.05-001/2. For shearing stress
and failure in wood, all the provenances and species showed themselves above the demands, with the exception of 10634; 48 and 9753 of Eucalyptus grandis.

Junior, J. B. G., Mendes, L. M., Mendes, R. F., & Moril, F. A. (2011). Wood paticleboards made from residues obtained in the veneer production of eucalypt species and provenances. *CERNE, vol.17*(no.4).

This work aimed the evaluation of 15 (fifteen) provenances of three eucalypt species: Eucalyptus cloeziana, Eucalyptus grandis and Eucalyptus saligna. The trees were 31 years old and the test was developed in the campus of the Universidade Federal de Lavras. Six particleboards for each provenance were made by using the residues generated in the veneer production of this material. It was used urea-formaldehyde at 8% resin level and paraffin at 1%, both according to their respective solid content. The boards were produced by using a pressing cycle with temperature of 160 ºC, specific pressure of 40kgf/cm2 and pressing time of 8 minutes. From the results, it was concluded that the specie Eucalyptus saligna was the best one in terms of water absorption. The 43 provenance of Eucalyptus grandis showed the best development of thickness swelling. Superior results of compression and elastic modulus were found to Eucalyptus cloeziana. The provenance of number 10695 of the specie Eucalyptus grandis presented the best results for elastic and rupture modulus. In general, the provenance 10695 and species of Eucalyptus grandis showed the greatest potential for production of particleboard.

Li, K.-F., Li, X.-Z., Peng, W.-X., Zhang, H.-H., & Ding, M.-Q. (2005). Research on type I class plywood production technology of timber mountain gum× flooded gum [J]. *Wood Processing Machinery, 6*, 15-20.

Using orthogonal testing method, this article studies how the veneer glue quantity, thermo-compression temperature, thermo-compression time - three factors influences type 1 class plywood production technology of Timber Mountain Gum × Flooded Gum, and has obtained the superior production technology. The result shows: veneer glue quantity , thermo-compression temperature, and thermo-compression time affects the bond strength of Timber Mountain Gum × Flooded Gum plywood significantly, and thermo-compression time influenced biggest, thermo-compression temperature next, veneer glue quantity smallest; and the better production technology is veneer glue quantity 320g/m2, thermo-compression time 1.2mm/min, thermo-compression temperature 135 ℃.

Luo, J., Arnold, R., Ren, S., Jiang, Y., Lu, W., Peng, Y., & Xie, Y. (2013). Veneer grades, recoveries, and values from 5-year-old eucalypt clones. *Annals of forest science, 70*(4), 417-428.

Context: Processing young, small eucalypt logs into veneer is a burgeoning industry across southern China. However, plantations supplying these logs were mostly established for pulpwood; little information is available on variation and election among commercial eucalypt clones/varieties in regards to suitability for veneer production.

Methods: Tree growth and log form were assessed on 11 eucalypt clones from a 5-year-old trial in southern China. Logs from these were rotary peeled for veneer; recovery percentages plus a range of quality and value traits were assessed on the outturn.

Results: Tree volumes, green veneer recovery ratios (%), veneer quality grades, log value, and value m^{-3} varied significantly among both clones and log positions up the stem. The clone with the best veneer recovery ratio (50.5 %) provided nearly twice that of the poorest clone (28.4 %). Average veneer value log^{-1} by clone ranged from RMB 6.7 (US$1) up to RMB 15.1 (US$2) and average value m^{-3} by clone ranged from 589 $RMBm^{-3}$ (US$88) up to 925 $RMBm^{-3}$ (US$139). Overall, sweep was the key factor influencing veneer recovery ratio and value. Knots, especially dead knots, holes and splitting were major factors influencing veneer quality grade. Middle and upper logs had significantly higher veneer recoveries, grades, and values m^{-3} than the lower logs.

Conclusions: Excellent potential exists for selecting among eucalypt clones, and even among log positions within trees, for optimizing veneer production.

Mathieu, K., Carrick, J., & Marosszeky, M. (2004). A method for cleavage fracture testing of hardwood laminated veneer lumber. In *Structural Integrity and Fracture International Conference (*pp. 257-263)

Blackbutt (Eucalyptus Pilularis) is a common plantation hardwood in New South Wales which is highly regarded for its strength and durability but is difficult to laminate. A method was developed to test Blackbutt Laminated Veneer Lumber (LVL) glue-lines for mode I fracture toughness – comparisons were made to similar work in the USA and Australia. The cleavage test method is demonstrated to be more suitable for assessing LVL bond quality than the currently-used Australian Standard chisel test. The test shows that Blackbutt veneer is capable of being glued for application as a durable structural material.

McGavin, R. L., Bailleres, H., Fehrmann, J., & Ozarska, B. (2015). Stiffness and density analysis of rotary veneer recovered from six species of Australian plantation hardwoods. *BioResources, 10*(4), 6395-6416.

The Australian hardwood plantation industry is challenged to identify profitable markets for the sale of its wood fibre. The majority of the hardwood plantations already established in

Australia have been managed for the production of pulpwood; however, interest exists to identify more profitable and value-added markets. As a consequence of a predominately pulpwood-focused management regime, this plantation resource contains a range of qualities and performance. Identifying alternative processing strategies and products that suit young plantation-grown hardwoods have proved challenging, with low product recoveries and/or unmarketable products as the outcome of many studies. Simple spindle-less lathe technology was used to process 918 billets from six commercially important Australian hardwood species. The study has demonstrated that the production of rotary peeled veneer is an effective method for converting plantation hardwood trees. Recovery rates significantly higher than those reported for more traditional processing techniques (e.g., sawmilling) were achieved. Veneer visually graded to industry standards exhibited favourable recoveries suitable for the manufacture of structural products.

McKenzie, H., Gea, L., & Gaunt, D. (2006). Eucalyptus nitens laminated veneer lumber. *Boletín informativo CIDEU*(N. 02 (2006)).

Eucalyptus nitens is a rapidly growing species which was little planted in New Zealand due to severe defoliation caused by a beetle, *Paropsis charybdis*. In 1987 Forest Research released a parasitic wasp, successfully controlling the pest. Since then, *E. nitens* has been planted in the Bay of Plenty/Taupo and Southland regions for local kraft pulp and export chip respectively. There may be a wider role for the species in New Zealand if it can be demonstrated that it can produce quality solidwood products. The Forest Research Management of Eucalypts Cooperative is collecting growth and wood quality information from most regions of the country and performance is being monitored in pulpwood plantations. A Forest Research sawing trial based on a 30-year-old stand showed there were some problems with sawn timber such as internal checking. The opportunity to extend the research to trees from another stand was provided by a unique stand of pruned fifteen-year old *E.nitens* in a Forest Research trial at Golden Downs Forest, Nelson. Whilst the butt logs were suitable for sawing, a structural product, laminated veneer lumber (LVL) was considered a likely appropriate use of the heavily branched second logs. This note summarises the main results of the LVL study.

McKenzie, H., Turner, J., & Shelbourne, C. (2003). Processing young plantation-grown Eucalyptus nitens for solid-wood products. 1: Individual-tree variation in quality and recovery of appearance-grade lumber and veneer. *New Zealand Journal of Forestry Science, 33*(1), 62-78.

A New Zealand stand of *Eucalyptus nitens* (Deane and Maiden) Maiden was pruned up to height 8 m and grown for 15 years at low stocking to 57 cm diameter at breast height. This stand provided 15 trees, preselected for a range of wood density. Lumber and veneer were cut from the 5-m butt logs, veneer was peeled from the second logs from height 7 to 13 m, and each tree was evaluated for production of appearance-grade lumber and rotary-peeled veneer. Butt-log quality was good as pruning had effectively restricted the knotty core, and there was little decay from branches in either butt logs or veneer billets. Longitudinal growth stresses varied widely among trees, resulting in log end-splitting and saw-log flitch movement during sawing (spring), which led to crook in sawn timber, substantially reducing timber conversion in some trees. Collapse and internal checking were prevalent in air-dried lumber, and numbers of checks varied widely among trees. Face-checking was found in boards from all trees after kiln-drying and reconditioning, and even those with very few face checks had internal checks. Veneer thickness varied unacceptably, caused probably by incorrect knife and pressure-bar settings. Veneer splitting also varied among trees, and was worse in butt-log than in second-log veneers. Unsatisfactory pre-heating of billets before peeling may have exacerbated splitting. Knots severely downgraded structural plywood veneer grades, <8% of sheets from the second logs being acceptable compared with 87% of sheets from the pruned butt logs. Stiffness of veneer sheets was successfully measured using a sonic device (Pundit) to sort veneers for manufacture of laminated veneer lumber.

Nolan, G., Greaves, B., Washusen, R., Parsons, M., & Jennings, S. (2005). Eucalypt Plantations for Solid Wood Products in Australia-A Review 'If you don't prune it, we can't use it'.

This review explores influences and impediments that impact a solid products industry's ability to profitably process a plantation hardwood resource over time. That is, operating as a sustainable industry. For this study, solid wood products include natural rounds, sawn timber and veneer products but exclude products reconstituted from wood chips or fibre.

Significant eucalypt plantations exist around the world and some are being milled for solid wood products. However, Australia does not currently have a solid wood products industry that profitably processes plantation eucalypts. Australia's hardwood product industry is a mature industry that depends on harvesting native forest for its resource. It generates considerable regional economic activity and employment, producing about $1 billion of sawn timber in 2003-04, and generating at least as much again in further processing and other products. About 32,500 people are directly employed nationally in hardwood forest management, harvesting, sawmilling and timber processing. However, the industry has been in transition for at least fifteen years driven by reduction in harvests from native forest and competition from lower priced plantation softwood products. In response, the hardwood industry has moved from producing low value unseasoned products to higher value, seasoned appearance and niche structural items.

Eucalypts have performance characteristics in these areas that most softwoods cannot match. As such, they are not true commodity products but differentiated ones that can sustain a higher price.

Products, markets and processing

Hardwood consumption has steadily declined since the 1960s to about 1.1 million m3 in 2003. Softwood consumption has increased to about 3.5 million m3 and it now dominates the structural timber market. The proportion of hardwood used in appearance application has increased progressively with demand that is underpinned by its natural visual appeal.

Eucalypt hardwood plantations do not bring a new or different solid wood product to the market. They will supplement the supply of hardwood logs from native forests. So the opportunities and constraints that apply to current solid hardwood products are likely to continue for those milled from a plantation resource. The major products groups are:

Natural rounds: debarked and often preservative treated logs used as piles, posts, poles, landscape elements and beams. Natural rounds provide a substantial potential market for plantation eucalypt thinings. Studies have found that they are fit for purpose and industry has begun to introduce them into the market.

Sawn hardwood: boards used as an appearance, structural, or industrial product in building, furniture or general construction. This is the major market area of solid hardwood products and studies have found that a suitably grown plantation resource can provide a useful feedstock for each product area. While there are differences between species and the age of the plantation, knots and other defects associated with branches are the major causes for down grade of products for both appearance and structural applications. Early pruned logs appear to provide substantially improved recoveries and product quality in all species.

Veneer: thin slices of material used for appearance and structural applications.

This could be a major market area except for price competition with softwood and imported products. Studies have found that a suitably grown plantation resource can provide a useful feedstock for veneer, plywood and laminated veneer lumber (LVL) production but knots and other defects can lead to significant down grade. Technological advances can influence the productivity and profitability of growing and processing eucalypt hardwoods by potentially increasing recovery of usable product and reducing the unit cost of production. However, technological advances are unlikely to negate the two most important market drivers for solid hardwood products: the dominant demand for wood without significant natural feature, such as knots and gum vein; and the cost competitiveness of exotic softwood products in the commodity structural market.

Log availability

Australia had 676,000 ha of hardwood plantations in 2003 with an estimated 107,000 ha, or about 17.4%, managed specifically for saw-log production. A significant proportion of these saw-log plantations is owned by or established in cooperation with state agencies.

These plantations are also young, with 62% planted since 1995 with expected rotation length of 20-35 years. Some have proposed that plantations can soon replace log supply from native forests. Others hope hardwood plantations will increase log supply to a growing regional industry.

However, under current policies, the estimated sustainable hardwood log availability from Australia's public forest is expected to fall by 36% or 776,000 m3 between 2001 and 2039 and by 25% or 115,000 m3 from private forests. If policies change and more native forests are reserved, these falls could be more extreme. By 2035, log availability from hardwood plantation is estimated to reach only about 376,000 m3. So, by 2035, plantation logs are likely to make up:

· less than 15% of the 2001 native forest supply level
· only about 18% of total estimated log availability in 2035
· less than half of the estimated log availability lost from public native forest between 2000 and 2035.

It is unlikely that existing plantations being managed for fibre production will:

· yield significant saw-log suitable for most profitable solid wood products
· respond to late silvicultural treatment (after about age 4) in a way that improves log quality for solid wood products significantly.

Silviculture

Logs suitable for solid wood products probably have the longest growth cycle of any renewable resource. Growing a suitable resource for solid wood products involves:

· selecting species that have growth and wood quality characteristics suited to producing solid wood products on relatively short rotation times
· planting selected trees on high quality sites at a relatively high initial stocking
· pruning the trees several times from an early age (about age 2 to 3) to reduce the size of the knotty core and encourage the growth of clear wood
· thinning the number of trees on the site severely before canopy closure to about 150-250 stems per hectare
· grow the trees to a suitable market diameter. This takes 20 to 35 years depending on the characteristics of the trees and the site.

This process provides the widest possible opportunity for marketing the logs as it focuses on producing a resource for:

· appearance grade recovery for the sawn timber, with a fall-down market of structural and industrial timber
· appearance and high quality structural veneer, with fall down into internal laminates, and strand material.

Economics

To be sustainable, producing solid wood products must be economically viable for each sector of the industry: the solid wood producer; the plantation grower; and as only some part of any tree or plantation will be suitable for solid wood products, producers of complementary wood products.
Solid wood producers generally make their highest returns from appearance material with little natural feature. Returns from high feature structural products are limited by competing commodity products, especially softwood. Studies on mill profitability are rare but producers have indicated that if the recovery of appearance and low feature material from the available resource falls below a threshold level, the feasibility of processing the material at all is in doubt.
Profitability models for growing plantation hardwoods are more developed. They show that growing a plantation for high value saw-logs can provide suitable long term returns.
However, these projections are sensitive to log price, site productivity, rotation length and land costs. Generally, a mean annual increment at age 10 of at least 20 to 25 m3/ha is required for operations to be profitable.

Conclusions

Eucalypt plantations have been established to provide industry with a supplementary source of wood fibre. Significant development work has been done into species selection and silviculture, particularly when growing for fibre. With continuing restrictions on access to native forests, in past decades government programs have sought to encourage or establish hardwood plantations specifically for solid wood products. This review assessed the current status of Australia's plantations, their suitability for solid wood product and industry's capacity to use them. It found that:

· The vast majority of the current hardwood plantation estate will not produce logs suitable for a profitable solid wood products industry.
· It is highly likely that a solid wood products industry can profitably process and sell material from a future plantation hardwood resource if that resource includes a high proportion of high quality logs with significant clear wood.

· This industry's production strategy will likely focus on supplying a high quality and high value appearance hardwood market. Structural and other products will likely supply niche markets only.
· The general parameters of growing and processing suitable logs are known but there is considerable uncertainty in the sensitivities of the boundaries of practice.
· Unless more plantations managed for hardwood saw-logs are established in the near future, Australia will have to meet its demand for high quality hardwood appearance timber for building and furniture with increased imports.

Recommendations

For the solid wood products industry, the major issues to be addressed in moving to a plantation hardwood resource are log availability and improved production optimisation techniques. The primary areas that require research are:
· determining the growing cost and value of logs grown specifically for high value solid wood products
· improved understanding of market structures, the impact of particular wood characteristics on product value and related economic aspects
· improved log availability modelling from the plantation and native forest estate
· increasing value from the current hardwood plantation resource by optimising processing to minimise degrade, especially during drying
· exploring the mechanisms and control of growth stress and tension wood effects
· refining understanding of the interactions of site, species and silviculture
· improvement of log output and quality through tree breeding.

Work in these areas should be deliberate comparative studies, operating across species to a standard methodology that integrates growing and milling results, and provides improved assessment data for plantation inventory and economic modelling.

Ozarska, B. (1999). A review of the utilisation of hardwoods for LVL. *Wood Science and Technology, 33*(4), 341-351

This review on the use of hardwoods for the production of LVL revealed that a large number of research studies have been carried out, particularly in North America and three Asian countries (Japan, Malaysia and China). However, the studies have been restricted to species of low to medium density, i.e. 290 to 693 kg/m3. Two major potential uses of hardwood LVL have been investigated in these studies: domestic and industrial structures, and various furniture components. The production of structural LVL in North America and Asia was based predominantly on low density hardwoods. A study currently carried out in Europe aims at using medium density hardwoods for structural LVL. The LVL used for furniture components was produced from medium density hardwoods. No work has been undertaken outside Australia on the use of high density species for LVL. In Australia, studies undertaken on the production of LVL and hardwood plywood from eucalypts revealed that there were significant problems in gluing the dense raw material which often had a high level of extractives. Peeling low quality, small diameter eucalypt logs also created problems when the traditional plywood processing techniques were used.

Palma, H. A. L., & Ballarin, A. W. (2011). Physical and mechanical properties of LVL panels made from Eucalyptus grandis. *Ciência Florestal, 21*(3), 559-566.

This paper mainly aimed to evaluate the physical and mechanical properties of LVL panels made from Eucalyptus grandis check for this species in other resources , from reforestation at the region of Sengés, in Paraná state, Brazil. LVL panels were manufactured using 23 veneers (2,4mm thick each one) in commercial dimension of 2.500 mm long and 1,200 mm wide. The properties of static bending were analyzed (strength and rigidity) in beams of the LVL, in the flatwise and edgewise positions. The properties of compression parallel to grain and shear parallel in the plans L-X and L-Y and density in this LVL panels were also analyzed according to ASTM-D 5456/4761 and ASTM-D 198 codes. The mean values to flatwise bending MOE and MOR were 13114 MPa and 88.76 MPa, respectively, and for edgewise bending MOE and MOR were 15871 MPa and 88.63 MPa, respectively. The density (12%) of the LVL panels and of the veneers were 690 kg/m3 and 649 kg/m3. The mean values to parallel compression MOE and MOR were 16856 MPa and 58.05 MPa, respectively. The mean values of the maximum resistance to shear parallel in the plans L-X and L-Y were 5.96 MPa and 591 MPa, respectively. All these values reached partially or they passed the medium limits of reference (normative codes, researches and commercial catalogs) established for LVL panels and original solid wood, attesting overall the quality of those panels produced with this wood.

Roper, J., & Hay, E. (2000). Sliced veneer production from pruned plantation grown eucalypts in New Zealand. In *The future of eucalypts for wood products– Proceedings of a IUFRO Conference. (*pp. 106-112)

Recent utilisation studies conducted by ***Forest Research*** in New Zealand have included young fast-grown trial plantation stands of *Eucalyptus fastigata* (29 years old from Kaingaroa forest in the North Island) and *Eucalyptus nitens* (16 years old from Golden Downs forest in the South Island). Both these trial plantations were pruned at young ages and thinned to low stockings to allow rapid growth of clearwood outside the knotty core. When these trees were felled, the pruned logs were sawn for lumber. A sample of the clear dimension boards was taken for green slicing on a *Marunaka Slicing Lathe* and sliced veneer of thickness 0.6mm was produced and dried to current commercial standards. The resulting veneer was of high commercial quality indicating good potential for high-quality veneer from pruned plantation-grown *Eucalyptus* species

Saviana, J., Zitto, S., & Piter, J. C. (2009). Bending strength and stiffness of structural laminated veneer lumber manufactured from fast-growing Argentinean Eucalyptus grandis. *Maderas. Ciencia y tecnología, 11*(3), 183-190.

The present paper reports the results of an investigation regarding the determination of bending strength and stiffness in specimens of laminated veneer lumber (LVL) manufactured from Argentinean *Eucalyptus grandis* and tested edgewise according to European standards. For this purpose an empirical research project with one sample containing 44 specimens with nominal sizes of 24.3 mm in width, 100 mm in depth and 2.44m in length was carried out. The characteristic strength value was 74 % and 118 % higher, respectively, than those adopted by Argentinean standards for the best strength class of sawn and glued laminated timber of the same species. It was similar to that reported for LVL of Norway spruce and lower than that published for LVL made from Uruguayan *Eucalyptus grandis* even though in the latter case the reported value was not obtained according to European standards. The modulus of elasticity mean value was 22 % and 14 % higher, respectively, than those adopted by Argentinean standards for the best strength class of sawn and glued laminated timber of the same species. Modulus of elasticity also exhibited a mean value 22 % and 53 % higher, respectively, than those published for LVL manufactured from Norway spruce and Uruguayan *Eucalyptus grandis*. A relatively low variation of results was found for both strength (COV = 9 %) and modulus of elasticity (COV = 10 %) and the particularly high stiffness/density relation previously published for sawn timber of this Argentinean deciduous species was confirmed by the results of this study. The coefficient of determination (R2) between density and modulus of elasticity was equal to 0.67 whereas R2 reached 0.37 between modulus of elasticity and strength and 0.19 between density and strength.

Shield, E. D. (1995). Plantation grown eucalypts: Utilisation for lumber and rotary veneers– primary conversion. *Seminário internacional de utilização da madeira de eucalipto para serraria, 5*.

There is great appeal in a maturing stand of planted Eucalypts. To most, this appeal is aesthetic and to the uninitiated, it extends to the assumption that the trees have great utility. However, on a global basis thus far, for most species of Eucalypts, that utility has been largely limited to pulping and use as firewood. On a global scale, there is not yet a substantial utilisation of plantation grown Eucalypts for primary conversion into, for example, higher value products such as lumber and rotary veneer. The first part of this paper examines why this is so. The second part is devoted to an examination of special techniques required to maximise the success with which this raw material can be converted into lumber and rotary veneer.

Shukla, S., & Kamdem, D. P. (2008). Properties of laminated veneer lumber (LVL) made with low density hardwood species: Effect of the pressure duration. *Holz als Roh-und Werkstoff, 66*(2), 119-127.
Cross-linked polyvinyl acetate (PVAc) adhesive and thin veneers of three low density wood species, namely silver maple, yellow poplar and aspen, were used to produce LVL engineered wood products using different press durations. Density, water absorption, thickness swelling, flexural strength and surface hardness were evaluated. Internal bond strength, tensile shear and block shear strengths were tested in dry, accelerated (boiling and dry) and cyclic (wet and dry) conditions. LVL made using cross-linked polyvinyl acetate and silver maple with a platen temperature of 38 ◦C for 5 minutes exhibited the best properties. LVL of silver maple veneers showed improved properties as compared to yellow poplar and aspen. Silver maple can be used suitably in laminated veneer flooring
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Simpson, I. G., & Sole, J. (1999). *Eucalyptus nitens pilot veneer peeling and drying study.* Sidney 21525. unpublished: Scion.
A pilot study was conducted to determine suitable drying schedules for drying Eucalyptus nitens veneer for LVL production. Drying temperatures between 50 and 180°C were evaluated. The drying schedules at 90°C and 110°C were recommended based on the level of collapse and checking. The effect of log preheat or pre steam on collapse and checking reported

Vázquez, G., González-Álvarez, J., López-Suevos, F., & Antorrena, G. (2003). Effect of veneer side wettability on bonding quality of Eucalyptus globulus plywoods prepared using a tannin–phenol–formaldehyde adhesive. *Bioresource technology, 87*(3), 349-353
The influence of rotary peeling on the different behaviour of tight and loose sides of Eucalyptus globulus veneers has been studied.The presence of lathe checks on the loose sides favours wettability, the contact angle decreasing more rapidly on these sides than on tight sides. Additionally, pine bark tannins improved wettability due to their surfactant character. Bonding quality tests carried out on plywoods prepared using a tannin–phenol–formaldehyde adhesive showed that fracture almost invariably occurred in a glue line with at least one loose side, where wood failure appeared. This behaviour, confirmed by analysing the glue lines by means of fluorescence microscopy, was due to the large surface alterations of the loose sides which reduced mechanical strength but allowed greater penetration of the adhesive giving rise to high wood failure.

Yu, Y., Yu, W., & Wang, G. E. (2007). Manufacturing Technology and Main Properties for Laminated Veneer Lumber of Eucalyptus. *Scientia Silvae Sinicae, 8*, 030.
The hot-press temperature curves were researched and effects of hot-pressing temperature,thickness of veneer and the numbers of layer on mechanical properties of laminated veneer lumber(LVL)were analyzed with emphasis in the paper.Results showed that there was positive relationship between hot-pressing temperature and modulus of elastic(MOE);the modulus of rupture(MOR)of LVL was best when manufactured at 160 ℃.When the thickness of veneers was 3.25 mm the LVL usually destroyed due to veneer tearing;while when the thickness of veneers was 1.70 mm it easily splited in adhesive layer;the mechanical properties of LVL were best when the thickness of veneers was 1.70 mm;the 3 multinomial degrees of fitting the numbers of layers with MOE and MOR of Eucalyptus LVL matched very well,the R2 value were 0.951 6 and 0.981 2,respectively.

Zhang, Y.-P., & Fu, F. (2007). Research on the Gluability of Four Plantation Grown Eucalyptus Species [J]. *China Wood Industry, 1*, 008.
This paper analyzed and tested the gluability of glued laminated lumber by four plantation grown Eucalyptus species focusing on gluing pressure and adhesive consumption. The results showed that two high density species of Eucalyptus (E.citriodora and E.exserta) have poor bonding performance with lower wood failure.The other two Eucalyptus species (E.grandis and E.urophylla×E.grandis) with lower density showed better performance.