

ENVIRONMENT DESIGN GUIDE

LIFE CYCLE ASSESSMENT OF FOREST AND WOOD PRODUCTS IN AUSTRALIA

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Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

- Impacts of the production of forestry and wood products on the Australian environment have to date not been well understood due to a lack of detailed information on inputs and outputs of Australian forestry and wood products.
- The establishment of an industry standardised Life Cycle Inventory (LCI) is needed to allow for the comparison on environmental grounds of timber against other building products.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGE actions. In these circumstances, designers should at least consider the following:

- The study which is the subject of this paper forms the first rigorous national Life Cycle Inventory (LCI) of representative Australian forestry and wood products, and is being incorporated into the national AusLCI database. Comparison of building products can be made once the AusLCI database has been completed.
- The study used ISO Standards to develop a methodology for the LCI. The methodology can be used as a guide for other building product sectors.

Cutting EDGE Strategies

- The study uses a 'cradle-to-grave' analysis for LCI, i.e. the environmental impacts are studied from seedling generation to being ready for distribution as finished products.
- Undertaking Life Cycle Assessments (LCA) relies on the use of LCI information such as that generated by this project for environmental assessment.

Synergies and References

- The Australian Life Cycle Inventory Database Initiative (AusLCI): www.auslci.com
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- CORRIM, 2005, *Life Cycle Environmental Performance of Renewable Building Materials in the Context of Residential Construction*, Consortium for Research on Renewable Industrial Materials (CORRIM Inc.), Seattle, USA.
- Pöyry, J, 1999, 'Usage and Life Cycle of Wood Products', *National Carbon Accounting System Technical Report No. 8*, Australian Greenhouse Office, Canberra.
- Tharumarajah, A, 2005, *Australian National Life Cycle Inventory Database: A Preparatory Framework for Development*, Discussion paper, CSIRO.

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Sustainability imperatives are starting to drive business decisions and government policies. As solutions are sought to developing environmental assessments, it is important to know how much energy, water or chemical has gone into manufacturing a product, and what greenhouse gas emissions or other emissions to the environment have been released in the process. The first national rigorous Life Cycle Inventory (LCI) of representative Australian forestry and wood products and processes was developed by CSIRO to allow the environmental impacts of the production of common timber products and systems to be quantified and evaluated from 'cradle-to-gate'. This paper outlines the development of the Life Cycle Inventory of Australian forestry and wood products and provides some results and benefits.

Keywords:

Life cycle inventory, forestry, wood products



Figure 1 Sawlogs in softwood plantation forest await collection and distribution, South Australia

(Source: CSIRO, 2008)

1.0 INTRODUCTION

Over recent years there has been a growing recognition that consumption of manufactured products affects both resources and the environment (RMIT Centre for Design, 1997) and that the production of a product impacts the environment, beginning with the extraction of raw materials, through processing, subsequent manufacturing, use and disposal, as well as all necessary transportation. Business decisions and government policies (Australian Government, Business Roundtable

on Sustainable Development 2008) are starting to be driven by such sustainability imperatives. Governments are increasingly incorporating consideration of environmental impacts and sustainable development in policy decisions and are also increasingly holding product manufacturers accountable for their actions. Environmental assessments of products require details of how much energy, water or chemical has gone into manufacturing a product, and what greenhouse gas emissions or other emissions to the environment have been released in the process.

There is little verified life cycle information available on forestry and wood products; and Life Cycle Inventory (LCI) information for wood products is the least well defined in any current Australian Life Cycle Inventory database. To date there have been a number of sources of LCI information for timber in Australia, however some of these have not been in the public domain, and regardless, the scope of data gathered has been inconsistent. Thus, wood products are at a distinct disadvantage compared to other products, such as steel and concrete, as there is no detailed database to provide strategic insight for use in pro-active environmental marketing, process improvement, comparison for product substitution, and, importantly, supply of information for building evaluation tools.

Organisations such as CORRIM (the Consortium for Research on Renewable Industrial Materials) in North America have worked with a variety of stakeholders over several years to produce an extensive publicly available LCI of forestry and wood products in the United States (Wilson, 2005). Of the available LCI data for wood products used in Australia, few are based upon detailed analysis of the Australian forestry and wood products industry. The LCI database generated for this project will ensure the content is compatible with international standards and with an Australian National Life Cycle Inventory Database whose specifications are currently being determined.

A thorough and detailed approach to a LCI for forestry and wood products was undertaken to provide a LCI database of representative wood products and processes used in Australia. Direct detailed input from forest managers, distributors and product manufacturers was obtained to confirm the processes and values used in creating a LCI database of forestry and wood products. This paper outlines the development of the LCI of Australian forestry and wood products and provides some results and benefits.

The LCI database covers five categories of forestry and wood products:

- softwood plantation and hardwood native forests
- softwood framing and hardwood timbers
- veneer, plywood and LVL (Vertical Laminated Lumber)
- particleboard and MDF
- glulam and engineered I-beams

The coverage target was to obtain data on at least 50 per cent of Australian production in the defined categories to create a LCI for a wider range (over 60) of commercial forestry and wood products.

In this analysis, CSIRO only considered regrowth native forest and plantations that were managed on a sustained yield basis with above and below-ground carbon stocks in a state of equilibrium. Thus it was assumed that over an entire rotation there would be no net change in carbon stocks in the soil. This is consistent with current knowledge and modelling using the carbon accounting model Fullcam. As the vast majority of wood production from native forests in

Australia is now from regrowth forests, not old growth forests, scenarios involving land-use change were not considered as part of this project.

2.0 LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is described as an objective process to evaluate the environmental burdens associated with a product or process over its life cycle by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those energy and materials uses and releases on the environment, and to evaluate and implement opportunities to effect environmental improvements (Consoli et al. 1993). "Life cycle" refers to all activities from acquisition of raw materials through to product manufacturing, and to the enduse of these products and their eventual disposal or recycle, i.e. from "cradle-to-grave". Thus, Life Cycle Assessment quantifies the flow of materials and energy into and out of a system, as shown in Figure 2.

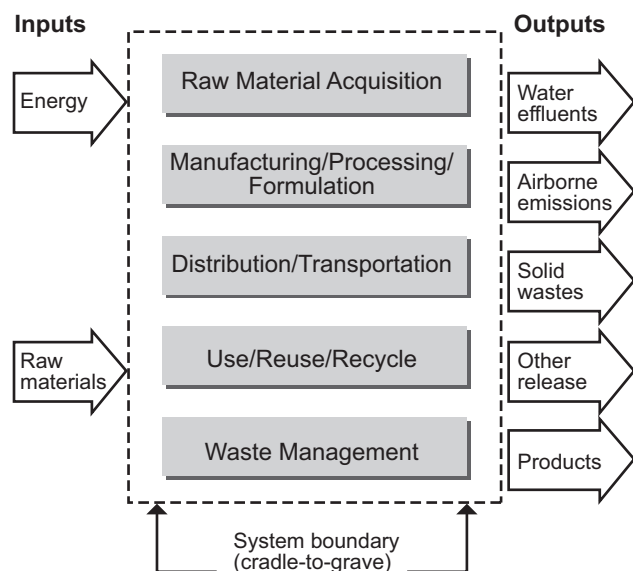


Figure 2 Life cycle assessment flow diagram showing indicative inputs and outputs

According to the ISO 14040 guidelines (ISO 14040 1998) to the Life Cycle Assessment methodological framework, a Life Cycle Assessment shall include four elements:

- goal and scope definition
- inventory analysis
- impact assessment
- interpretation of results

The key component for performing a Life Cycle Assessment is the information obtained from a data inventory which contains the values of all the inputs and outputs for relevant activities undertaken to produce a product. This inventory is known as a LCI database and these have information which provides a quantitative basis for comparison of the environmental impacts of building products.

The scope of a typical LCI includes the inputs and outputs up to the factory gate, i.e. up to when a product is produced for a market. This allows the environmental impact of a product's production to be understood, though the impact of the use of the product will vary significantly depending on the use of that product. A LCA that considers the life of a product up until the end of its life, and the recycling/decay/disposal at that point is called a 'cradle-to-grave' analysis. This requires a much more detailed analysis that is customised for each individual use of each product with a projection of what will happen at the end of its life, and how it will be disposed of, and is not covered by this study.

The development of a thorough forestry and wood products inventory results in the industry benefiting through a more advanced understanding of the life cycle of its products and processes. It is most important to create a LCI for wood products thoroughly for each type of product to ensure a quality database both for the forestry and wood products industry and for the industries which produce products which compete with wood products. There are established guidelines for creating a LCI database in the form of the ISO 14040 series of international standards (ISO 14040 1998). Currently there is work on setting standards for a wide-ranging Australian National LCI database known as AusLCI (Tharumarajah, 2005) and all activities on a LCI for wood products (as noted in the 5 categories above) are compatible with this approach.

2.1 Life Cycle Inventories

Countries in Europe and North America have completed detailed 'cradle-to-gate' analysis of forestry and wood products in close collaboration with industry and timber research organisations (e.g. Wilson 2005) as have Asian countries such as Japan (e.g. Tsuda et al 2006). Major international research studies conducted on the forest resource (i.e. production of logs) and major wood products relate principally to the timber framing of houses and wood building construction (e.g. Seppala et al. 1998 and Kakita et al. 2006)]. Many other countries have adopted their own national standards, as well as developing guidelines for specific industries, an example of which is the American Forest and Paper Association user's guide for the US forest industry (American Forest and Paper Association 1996).

In Australia, there have been few Life Cycle Assessment studies undertaken for construction and packaging materials. Moreover, these studies did not so much include a full Life Cycle Assessment of wood or timber products but focused on embodied energy for timber products (e.g. Lawson 1996). Todd and Higham (1996) reviewed Life Cycle Assessments of forestry and wood products. Some researchers have tried to compare environmental impacts of wood products with other alternatives using a Life Cycle Assessment method (e.g. Taylor and van Langenberg 2003). However, these Life Cycle Assessment and Life Cycle Inventories have had very limited work on the detail of forestry and

wood products in Australia, which led in part for the need for the research project that is the subject of this paper.

One of the key distinctions between Australian and international LCI efforts has been the lack of coordination, the minimal representation of industry and the insubstantial detail of the final output in Australian databases, almost all of which are held in-house and not made public so that the data collection processes lack coordination and documentation is variable. In other countries, the process of effectively engaging industry has not only led to a comprehensive LCI database, the process of data collection has also informed industry of the value and use of a LCI database. As a result the LCI database becomes a useable resource for industry.

3.0 AUSTRALIAN LIFE CYCLE INVENTORY OF FORESTRY AND WOOD PRODUCTS

The overall objective of this project was to create the first national rigorous LCI of representative Australian forestry and wood products to enable evaluation and benchmarking of the environmental impacts of wood products for comparison with selected competing products.

3.1 Overview

A LCI database for forestry and wood products aimed to be of high quality, contain a range of representative products, and be consistent, credible, and demonstrably independent. This project was supported in part by FWPA, and steered by an independent committee.

Practicalities such as focusing on a limited but representative range of wood products, availability of resources, and availability of data meant that many decisions were made on what would constitute a satisfactory LCI database. The content was compatible with international standards and with an Australian National LCI database (AusLCI) whose specifications were being determined concurrently.

The underpinning principle was to obtain substantial industry input into a forestry and wood products LCI database to confirm the processes and values used in creating a LCI database of timber products. The target was to obtain data from those producing between them at least 50 per cent of Australian production in the defined categories. The range of data collected was, of necessity and lack of unlimited resources for its collection, restricted by what data industry had available or was willing to provide (commercial confidentiality being a concern for some manufacturers) or what could be obtained from existing sources. The cooperation of the industry was excellent and resulted in good quality data and desired industry coverage but data collection was slower than anticipated.

The Australian LCI database covers the following categories of forestry and wood products: softwood plantation and hardwood native forests; softwood

framing and hardwood timbers; veneer and plywood, and LVL; particleboard and MDF; and glulam and engineered I-beams.

The data collection was up to the consumption phase for the wood products when sold to a consumer (known as a cradle-to-factory-gate study). This provides an accurate database of Australian wood products for various users to examine a wood product and consider its production history. Most importantly, it provides industry with a reference of production practices and the ability to benchmark and monitor performance over time. A cradle-to-gate study is a practical point to collect data for a LCI database. For example, beyond this point, the useful life and maintenance requirements of wood products used in a building will depend upon a number of factors, including the exposure to various elements and the use and type of preservatives and paints, all highly variable and not within the responsibilities of producers and manufacturing plants.

While the original aim was to develop Life Cycle Inventories for generic wood products, the detailed data was sufficient to provide information on common categories of the generic products. Table 1 shows the original categories of products and the expanded (more specific) range of products developed for the Australian timber products LCI database.

2006) and ISO/TS14048 Life cycle assessment – Data documentation format (ISO/TS 14048 2002).

CORRIM generally followed these guidelines in developing a Life Cycle Assessment methodological framework for their studies of North American timber products, but concluded that it is essential to provide very detailed information on every aspect of data collection and process modelling to ensure consistency, compatibility and credibility in meeting the objectives of a LCI database. Thus, the plan for developing an LCI database included a preliminary step where standards are set and strict guidelines developed. The development of the Australian LCI for forestry and wood products was no different.

ISO 14044:4.2.3.1 clearly states that the scope of a LCI study shall specify the following items: product system to be studied; functions of the product system; functional unit; system boundary; allocation procedures; data requirements; assumptions; limitations; data quality requirements; type of critical review, if any; and type and format of the report required for the study. A quality assurance plan was put in place and data documentation spreadsheets developed with accompanying checklists to ensure documentation met ISO standards. Documents setting out the specific guidelines, quality assurance and documentation procedures and the LCI database relating to the development of the Australian LCI were

Products in the Life Cycle Inventory database	
Category	Products
Logs - Softwood	Peeler log (straight logs used for 'peeling' ply from), High quality saw log, Low quality saw log, Pulp log, Chips
Logs - Hardwood	Peeler log, Saw log, Pulp log
Sawn timber - Softwood and Hardwood	Rough sawn green timber, Rough sawn kiln dried timber, Planed kiln dried timber, Bark, Chips (as sawmill co product)
Plywood	Veneer, Interior Plywood, Exterior Plywood, Formply, T&G Flooring, Structural Plywood (each 3 thicknesses)
LVL	LVL (3 thicknesses)
Particleboard	Raw and Decorated (each 3 thicknesses)
MDF	Raw and Decorated (each 3 thicknesses)
Glulam	Pine
I-beams	OSB (Oriented Strand Board) web and pine flanges, Plywood web and LVL flanges

Table 1 Products in the Life Cycle Inventory database

3.2 Guidelines, Documentation and Quality Assurance

Established guidelines exist for creating an LCI database in the form of the ISO 14040 series of standards (ISO 14040 1998), including ISO 14044 Life cycle assessment – Requirements and guidelines (ISO 14044

prepared. An example of the detailed specifications is the system boundaries as shown in Figure 3.

The raw materials in Figure 2 are the materials obtained directly from the environment. The inputs between the LCI boundary and the module boundary are common or pre-defined processes which can be called upon by

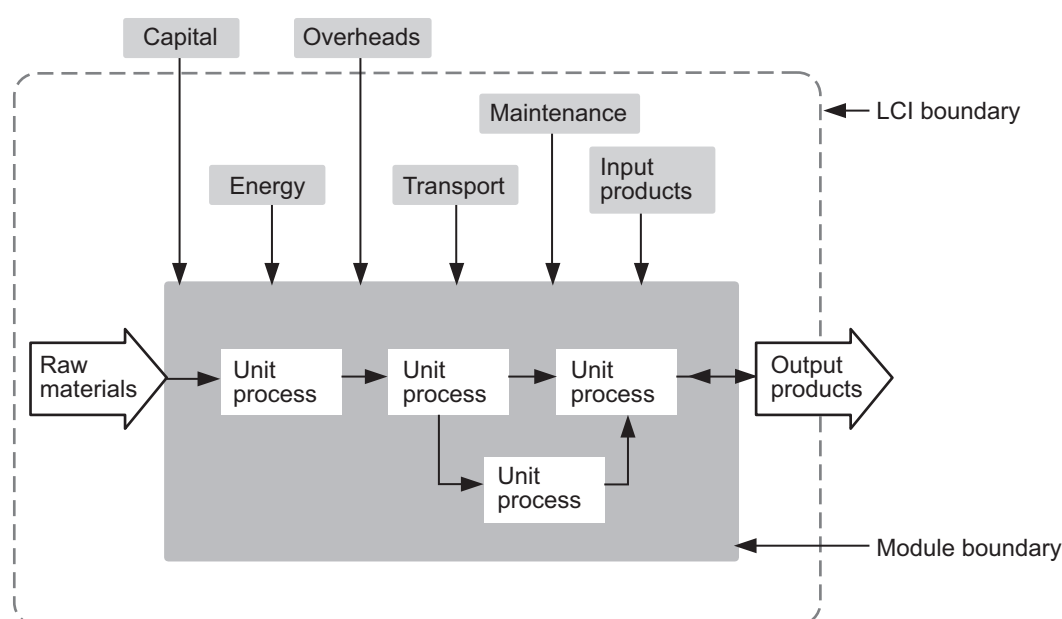


Figure 3 System boundaries for the LCI Timber project

any of the inventory product models. The common processes include logs from forests, glues, imported products and materials (glues and timber products such as oriented strand board), energy supplies (electricity, gas, etc), transport modes (ships, aeroplanes, rail, trucks, cars etc) and equipment. The output products include the main product, by-products and wastes.

3.3 Data Collection

Survey forms identifying all required data were developed in collaboration with relevant industry input from each of the five areas: forests, sawmills, veneers and plywood, particleboard and MDF, glulam and engineered I-beams. From a comprehensive list of Australian forests, sawmills and wood product manufacturing plants, a list of the industry providers of forestry and wood products which would be sufficient to achieve a target of 50 per cent (considered a good level of sampling given the broad array of manufacturing technologies) of Australian production was drawn up and approached for participation in the surveys. Typical forests, mills and plants were visited for visual inspection, initial data collection and identification and understanding of processes.

Six case study regions were selected to ensure coverage of the main production areas of Australia – softwood plantations in the three major regions of Australia; and hardwood native regrowth forests also in three States of Australia became the representative sources of forest data. A seventh softwood plantation area was added later in a different Australian state.

Because of the large number and widely varying scale of sawmill operations, a sampling procedure was set up to capture data from as many as possible of the larger sawmills (approximately 22 softwood mills and 66 hardwood mills) using detailed data surveys. A simplified data form was sent randomly to a large number of the small sawmills to ensure that data from a full cross section of sawmills was included. For

the remaining plants manufacturing wood products in Australia, in any one category, there are less than ten plants producing almost all of the production in Australia. For these sufficient plants were approached so that up to 80 per cent of Australian production was covered. Where clear differences in processes among the competing plants could be identified, effort was made to include representatives of each identified type. The resulting coverage is shown in Table 2 for each category of forestry and wood product. Cooperation levels were generally very high and some very detailed data was made available thus ensuring a thorough understanding of the processes, their inputs and outputs and comprehensive maps of the processes.

Coverage of Australian production

Category	Approximate proportion of Australian production
Forests – softwood plantation areas	60%
Forests – hardwood regrowth forest areas	30%
Sawmills – softwood	40%
Sawmills – hardwood	30%
Veneer and plywood manufacturing plants	90%
LVL plants	50%
Particleboard manufacturing plants	60%
MDF plants	80%
Glulam plants	53%
I-beam plants	65%

Table 2 Coverage of Australian production by the research project

3.4 Environmental Impact Modelling

The data inputs and outputs per reference unit (e.g. usually m³ or m² of a standard product) were then averaged for input into models developed in the SimaPro life cycle assessment software (PRé Consultants, 2008). Within the software, 'models' are created which draw on various data inputs for different production processes. Each element of the production process, such as peeling a log to make plywood for example, is called a 'unit process'. Unit processes for plywood manufacture for example would be; glue mixing, glue spreading, hot pressing, scarffing, trimming, sanding and packaging. As each manufacturer's production method varies, several of these processes are aggregated to simplify data collection. The SimaPro software cross-references data entered by multiple parties at different stages of production which might apply to several products.

From the visits to forests, mills and plants, comprehensive process maps were drawn up for each product. Then related individual processes were aggregated into a small number of processes which became the unit processes required of a LCI. The selection of unit processes was based on clearly defined steps in the process of producing the output products and influenced by the availability of data (or inability to disaggregate available data). These unit processes were modelled in an integrated SimaPro model to calculate the resulting inputs and outputs per reference unit (e.g. cubic metre of log or sawn timber or square metre of a plywood or particleboard) including all raw materials from growing forests and common processes such as Australian energy sources. The result is an LCI of all inputs and outputs for the products listed in Table 1.

4.0 SOME OUTCOMES

4.1 Forestry

The forestry process includes the establishment, growing and management of forests, harvesting of trees and transportation of logs to processing facilities.

Inputs considered in the forest production systems included: land, water, fuel/energy, chemicals and other materials (other resources, consumables and infrastructure). Averaged over the forest production cycle, land use efficiencies ranged from 0.05-0.08 ha m⁻³ for softwoods and 0.11 ha m⁻³ to 0.98 ha m⁻³ for hardwoods over the production cycle. This cycle covers seedling generation and planting to harvesting the forest. Estimated water use ranged from 0.3 to 0.7 Ml m⁻³ for softwoods compared with 1-10 Ml m⁻³ for native hardwoods. These differences were largely a result of the lower management and harvesting intensity of native forests compared with plantations.

Direct energy use varied from 198 MJ m⁻³ in softwood plantations to 464 MJ m⁻³ in hardwood native forests. Virtually all (>99 per cent) energy use was associated with combustion of diesel in vehicles and machinery. The greater energy usage in hardwood native forests

was largely due to greater fuel usage during harvesting. For softwood plantations, the largest contributor to energy inputs was haulage (51 per cent), followed by harvesting (28 per cent) and management (18 per cent). For hardwoods, the highest contributor was harvesting (61 per cent) followed by haulage (25 per cent) and management (10 per cent).

Assumed CO₂ sequestered by the forest and stored in wood products averaged 756 kg m⁻³ for softwood products and 1013 kg m⁻³ for hardwood products.

CARBON AND OTHER EMISSIONS

Direct emissions include both CO₂ and non-CO₂ emissions from operations under the control of the forest owner or contractor (e.g. from fertiliser, burning or vehicle and machine use). Direct CO₂ emissions averaged 10 kg CO₂ m⁻³ for softwood plantations and 21 kg CO₂ m⁻³ for hardwood native forests. Major non-CO₂ emissions included CH₄, N₂O and NO_x. Using IPCC emission factors of 23 for CH₄ and 196 for N₂O, these non-CO₂ greenhouse gasses (GHGs) effectively contributed 7 kg CO₂-e m⁻³ from softwood plantations and 21 kg CO₂-e m⁻³ from hardwood native forests. Thus, total GHG emissions were 17 kg CO₂-e m⁻³ from softwood plantations and 42 kg CO₂-e m⁻³ from hardwood native forests.

SimaPro modelling was used to estimate total direct plus indirect emissions (associated upstream processes such as fuel, energy and fertiliser production and transport) arising from wood production. Preliminary results for total GHG emissions associated with growing, harvesting and hauling of an average log were 26 kg CO₂-e m⁻³ for plantation softwood compared with 60 kg CO₂-e m⁻³ for native hardwood logs.

These emissions were allocated to wood products based on the total value of each product. For products from softwood plantations, total GHG emissions varied from 17 kg CO₂-e m⁻³ for pulplogs to 30 kg CO₂-e m⁻³ for large sawlogs. These represented between 2 and 4 per cent of the total CO₂-e sequestered in the logs.

Portion of GHG emissions by activity

Category	Proportion of GHG emissions
SOFTWOOD PLANTATIONS	
Burning and fertiliser application	37%
Log transport	32%
Timber harvesting	24%
Forest management operations	7%
NATIVE HARDWOOD FORESTS	
Burning	50%
Log transport	13%
Timber harvesting	31%
Forest management operations	6%

Table 3 Portion of GHG emissions by activity

For hardwood logs, there was wider variation in allocation of CO₂-e emissions as a result of the greater variation in product value. Thus, CO₂-e emissions varied from 38 kg CO₂-e m⁻³ for low quality sawlogs and pulplogs or 3 per cent of the total CO₂ sequestered to 146 kg CO₂-e m⁻³ for other logs (poles pile and girders) or 13 per cent of the total CO₂ sequestered. Thus, the net amount of CO₂-e sequestered in plantation softwood products varied from 726 kg CO₂-e m⁻³ for large sawlogs to 740 kg CO₂-e m⁻³ for pulplogs and that for native hardwood products varied from 911 kg CO₂-e m⁻³ for other logs to 1017 kg CO₂-e m⁻³ for pulplogs.

It is thus critical that there is recognition given to the longer-term storage of carbon in forest products. If this occurs, forestry will be reflected as a long-term sink for carbon in terms of net carbon storage in the logs harvested, otherwise forestry will be counted as a small source of carbon emissions.

4.2 Softwood Framing and Hardwood Timbers

The data collection provides a new benchmark for sawn timber building products in Australia. The results presented draw upon data collected from 24 sawmills from across Australia. In comparison, CORRIM collected data from eight sawmills for its data collection for sawmills. The data collection covers all Australian States and captures a significant proportion of total production.

The recovery rate is the term used to describe the rate of volume of sawn logs compared to the resultant volume of timber product created. The recovery rate reported for softwood primarily relates to dried and dressed radiata timber building products, with a particular focus on timber house framing, which is the dominant building product. The recovery rate of 45 per cent for softwood building products fits in the middle of a wide range of rates previously reported, 45 per cent (Pöyry 1999) and 47 per cent (Ximenes) as well as recovery rates reported by CORRIM of 42 per cent (hemlock) and 58 per cent (Douglas fir) (Milota 2004).

The fuel mix in the softwood sample shows a very high reliance on the use of wood residues material to fire the kiln drying process. Approximately 80 per cent of the heating energy in the study is from wood residues compared to approximately 58 per cent in CORRIM (Milota, 2004) and this is reflected in the emissions profile reported.

Water is used during the kiln drying process to recondition timber in order to give more even moisture content throughout the 'stack' of wood that is being dried. This use of water for kilns in Australia was higher than in the CORRIM North American studies. However, CORRIM reported high water usage in the log yards due to sprinkling logs with water during storage. As a result the water usage in Australia for softwoods was much lower.

4.3 Veneer, Plywood and LVL

Data for veneer, plywood and LVL has been collected from 80 per cent of Australian plywood and LVL mills making this the most comprehensive analysis of these products undertaken, providing a new Australian benchmark. The plywood and LVL processes were compared and considered similar which enabled the use of plywood data in the LVL model. The results are for average Australian veneer, plywood and LVL. The veneer process has four unit processes within the system boundary: Preparation, Conditioning, Green Veneer, Dry and Finish. The plywood and LVL processes both have three unit processes: Manufacture, Finish, and Packaging

Inputs

The main inputs to manufacture 1 m³ of structural plywood include: 80 kg A-bond glue (which includes resins, flours, fillers, catalyst, etc.); 0.43 m³ of hardwood veneer; 0.84 m³ of softwood veneer; 0.0039 kg Alkaline Copper Quaternary (ACQ) preservative. There are other inputs; however they are in non-registering quantities. It takes 2.1 m³ of logs to produce the veneer to make 1 m³ structural ply. The average results show that the yield of veneer from logs is approximately 40 per cent compared to 50 per cent estimated by CORRIM but varies between mills, with small labour intensive mills reporting higher recovery rates. The main source of energy is the boiler which is mainly used in the veneer drying process. The electricity input is 165 kWhm⁻³; LPG is 3.37 lm⁻³; and natural gas 0.351 GJm⁻³. These energy sources are mainly used in the drying process (40 per cent). 640 lm⁻³ of water is also consumed.

Emissions

The most significant emission factor was due to boilers. Boilers accounted for almost half of the emissions from the system for LVL and plywood and about 60 per cent for veneer. The total impact for plywood per cubic metre as measured by the SimaPro 'Eco-indicator 99' environmental indicator was very similar to those for LVL.

4.4 Glulam and Engineered I-beams

Australian average glulam requires 501 MJ of energy to manufacture 1 m³ of glulam. To manufacture 1 linear metre of I-beam, OSB web and pine flanges requires 9.3 MJ and 8.9 MJ for plywood web and LVL flanges, respectively. Table 4 shows an example of the timber and energy used in Australia in comparison to the CORRIM values for glulam. As seen in this table, to manufacture 1 m³ of glulam in Australia, 668 kg of sawn timber is required and 64.8 kg of shavings and trimmings and 63.4 kg of sawdust including wood waste are generated respectively. Wood recovery for glulam in terms of wood input as sawn timber and output as glulam was estimated at 81 per cent, the rest being shavings and trimmings and sawdust (Table 4), which is similar to CORRIM's data (82 per cent for

Glulam product yields comparison			
Wood Mass Balance (weighted average)	FWPA Australian glulam weight averaged	CORRIM (PNW) (Pacific North West)	CORRIM (SE) (South East)
Input timber densities vary dependent on forests studied	668 kg/m ³	592 kg/m ³	676 kg/m ³
Output – Glulam	540 kg/m ³	483 kg/m ³	551 kg/m ³
Output – shaving, trimming & sawdust	128+ kg/m ³	89 kg/m ³	119 kg/m ³
Output – wood waste	128+ kg/m ³	20 kg/m ³	6 kg/m ³
Recovery of wood	81%	82%	82%
Energy consumption	501 MJ	893 MJ	1420 MJ

Table 4 Glulam product yields comparison

PNW and SE).. Manufacture of Australian glulam consumes a little more electricity, requiring 364.6 MJ comparing to CORRIM's 304 MJ for PNW and 356 for SE, but the balance of other energy sources such as natural gas, or diesel are considerably less for Australian glulam. The data collection for glulam and I-beam products provides a new benchmark for building products in Australia.

5.0 BENEFITS

A major benefit for the industry of the LCI of forestry and wood products is to have a credible quantitative basis for comparison of competing timber products and non-timber alternatives. Collection, enhancement and verification of data provide the industry with reliable environmental impact information to improve the environmental bottom line as well as providing data for assessing choice in building products on the basis of environmental impacts. Now that this project has established a uniform protocol for collecting LCI data on timber in Australia, the future potential in obtaining this information for the forestry and wood products industry means greater acceptance of wood as an environmental material choice, gives wood products a greater prominence in evaluation tools, and greater understanding by the industry of future growth areas, such as recycling opportunities, service provision potential, and take back schemes, which would greatly add to the bottom-line in the future market place. As well, the establishment of these protocols will potentially enable other industries to mimic the process in assessing the LCI for their particular products.

The project has produced the first national LCI database on Australian forestry and wood products production with benefits including:

- The compilation of a common database for the wood industry.
- An objective and quantitative basis for comparison of competing wood products and non-wood alternatives.

- An objective and quantitative basis for comparing systems which incorporate wood products to those systems which use alternative materials, for example, complex composite products or whole houses.
- A method of comparing the environmental impacts of wood products from improved production processes.
- A database for use with Life Cycle Assessments of wood products and the buildings in which they are used.
- Provision of up-to-date credible industry based LCI information for life cycle assessment of wood products from Australian manufacturers.
- Support to manufacturers on environmental performance and impact assessment measures so environmental improvements can be addressed.
- Facilitating communication of environmental information to customers and other stakeholders.
- Setting a benchmark for carbon sequestration in wood products.
- Setting an industry standard for handling of environmental data.

6.0 CONCLUSIONS

The development of an LCI for Australian forestry and wood products is a major step forward in the provision of quality data on the environmental impacts of wood products used in building. The quality assurance procedures, in following the ISO Standards procedures and documentation, have set a high level for all following contributions to the developing Australian LCI database (AusLCI). The wide forestry and wood industry coverage also makes the resulting LCI very representative of Australian wood products and an excellent basis for assessing the environmental impacts of any application of wood products.

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The papers included in the World SB08 Proceedings, Volume 2, have been reviewed in its entirety and deemed to be worthy of inclusion in the conference program and proceedings by at least two, and in many cases three, independent and qualified experts drawn from Australia and internationally, including members of the International Scientific Committee. These reviews were not 'blind' however.

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