Review

Timber as a Building Material - An environmental comparison against synthetic building materials

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SYNOPSIS

This paper is an introduction to the use of sustainable timber products and how they compare to the use of synthetic materials such as steel and aluminum, for building purposes.

The paper focuses on the Life Cycle Assessment approach to building materials, exploring indicators and actual comparisons between wood and others.

The results of a study conducted in Germany for the Food and Agricultural Organisation, clearly demonstrate that wood is the superior building material on environmental cirteria.

INTRODUCTION

Wood has been used throughout the history of mankind. From the very first housing, bridges and tools, timber has provided humans with a broad range of building products and materials for construction. However, with the modernisation of the construction industry and efforts to minimise costs, new construction materials have come to the fore. Synthetic products such as concrete and steel have redefined the construction industry.

However, just how effective are these alternative materials, especially in regards to their overall environmental impact. Each type of building material has a different 'embodied energy'. 'Embodied energy' is the amount of energy used to fabricate particular building materials, and is calculated in MJ/m^2 (Mega Joule per Meters Squared).

It is imperative to note that the following results are based on Australian materials and environmental conditions.

EMBODIED ENERGY

The following tables represent the indicative Embodied Energy values for common building materials, in four different construction areas; floors, walls, windows and roofs.

TABLE 0.1 — FLOORS (INCLUDING FLOORING, FRAMING, FOOTING ETC.)

Timber suspended, timber sub-floor enclosure	740 MJ/m^2
Timber suspended, brick sub-floor wall	1050 MJ/m^2
Concrete slab on ground	1235 MJ/m^2

TABLE 0.2 — WALLS (INCLUDING FRAMING, INTERNAL LINING, INSULATION ETC.)

Weather board, timber frame	410 MJ/m^2
Brick veneer, timber frame	1060 MJ/m^2
Double brick	1975 MJ/m^2

TABLE 0.3 — WINDOWS (INCLUDING 3MM GLASS)

Timber frame	880 MJ/m^2
Aluminum frame	1595 MJ/m^2

TABLE 0.4; — ROOFS (INCLUDING PLASTERBOARD CEILING, R2.5 INSULATION, GUTTERS ETC.)

Concrete tile, timber frame	755 MJ/m^2
Concrete tile, steel frame	870 MJ/m^2
Metal cladding, timber frame	1080 MJ/m^2
Clay tile, timber frame	1465 MJ/m^2

(Tables 0.1 – 0.4 sourced from National Timber Development Council, 2001, Environmentally Friendly Housing using Timber – Principles, p10)

While this approach considers the energy consumed during the production of building components, consideration must be made to the amount of carbon released in the manufacture of building materials compared to the amount stored in the material itself. Demonstration of these comparisons and environmental advantages of wood over other synthetics are recorded in Table 0.5 below.

TABLE 0.5

Material	Carbon released (kg/m^3)	Carbon stored (kg/m^3)
Sawn timber	15	250
Steel	5320	0
Concrete	120	0
Aluminum	22000	0

(Sourced from Forests & Wood Products Research and Development Corporation, (1997) Environmental Properties of Timber, p5)

Further details of the energy efficiency ratings of various roof/ceiling, wall and flooring construction elements are available online at www.timber.org, the authoritative report entitled “R-values”.

LIFE CYCLE ANALYSIS

From the resources used as inputs for manufacturing, to their use in construction and through to the ‘death’ of the product, a new scientific assessment process has been developed. This process is called “Life Cycle Assessment or Analysis” (LCA).

The LCA approach balances a range of factors

- Forest utilization
- The generation of by-products
- Disposal of waste
- Resource depletion
- Global Warming
- Landfill
- Ozone hole extension
- Eutrophication (the growth of water based life forms)
- Synthesis of compounds responsible for acid rain

LCA is important, because if valid assessment is to be made then the environmental impacts of a product must be assessed during *all* stages of the life cycle of the building material. This entails assessing procedures such as product manufacturing, CO_2 emissions, transport and maintenance. Therefore, a ‘cradle to grave’ approach is used to assess the life long impacts of the materials use.

The basis for providing LCA results are,

- To assist government decision making in regards to resource use, availability and industry support policies;
- To assist long-term strategic planning for the industry, in terms of potential market drivers;

- To assist with product design or identifying improvements in the environmental aspects of the building material manufacturing process;
- To market wood as an environmentally sustainable and competitive resource; and
- To improve the recognition of wood as an environmentally superior building product throughout the value chain.

THE FAO REPORT

This paper explores the findings of a report prepared for the Forestry Products Division, of the Food and Agriculture Organisation of the United Nationals (FAO, 2002) in Germany. The report provides a summary of recent studies on LCA according to the standard ISO 14040. The Standard requires that the goal and scope be clearly defined at the beginning of all LCA studies. Additionally, the standard also requires that building and construction materials be compared on the basis of using the same functional units of measurement.

The report was designed to compare the ecological benefits of using wood based products in house construction in comparison to synthetic materials. A 'cradle to grave' life cycle assessment of building products indicates the environmental advantages of wood over concrete, steel, synthetics, ceramics and glass.

Results of identified environmental advantages of using wood-based products for construction purposes over a number of building alternatives were obtained from the GaBi 3.0 software program (IKP, 1999) to provide a set of key indicators, as follows:

- Global Warming Potential (GWP) in kg CO_2 equivalents.
- Acidification Potential (AP) in kg SO_2 equivalents.
- Eutrophication Potential (EP) in kg phosphate equivalents.
- Photochemical Ozone Creation Potential (POCP) in kg Ethene equivalent.

Although the report is not based on the Australian forestry and building industry, it does indicate the potential environmental benefits that could be obtained from a greater utilisation of timber and wood-based products in the international construction industry. As the sustainability indicies for Australia's building industries are developed, the research outcomes will be made available through the NAFI web-site www.nafi.com.au.

Net benefits from timber become even greater when the proper thermal utilisation of waste or scrap wood is included as part of the ongoing LCA process.

Environmental and energy balances were used as the key indicators to compare the lifetime impacts of using various building products through practical applications, of the following dwellings:

- Single family housing
- Simple large building
- Sheds
- Window frames
- Flooring materials

RESULTS

Single family house (80 year life-span)

Two different forms of house construction were compared in this study – timber frame and brick. Importantly both houses were designed with approximately the same heat transition co-efficient (K-Value)

Life cycle inventory of inputs to build the houses	
Timber frame	34 250 kWh
Brick House	41 100 kWh

(Sourced from FAO, 2002, Environmental and Energy Balances of Wood Products and Substitutes p17-18)

Examples of what timber and forestry residues and by-products are derived from are: thinning and harvesting operations, sawmill residues, furniture production, building site rubbish, timber from demolition and waste paper for recycling.

For the life cycle assessment, the report's authors (from the University of Hamburg) investigated the thermal utilisation of forestry, processing, and end of life cycle wood waste for wood generation. The comparisons between timber and brick can be seen in Tables 1.1 and 1.2.

A key finding is that increasing the proportion of timber used in a single-dwelling construction reduces the environmental impacts for all the indicators and is further enhanced when the thermal utilisation of wood is considered (see tables 1.1 and 1.2).

TABLE 1.1 — ZERO THERMAL UTILISATION OF WOOD WASTE

	Timber Frame	*Brick*
GWP	94 852	114 980
AP	212	256
EP	18	22
POCP	5	7

TABLE 1.2 — WITH THERMAL UTILISATION OF WOOD WASTE

	Timber Frame	*Brick*
GWP	79 248	108 400
AP	177	242
EP	15	21
POCP	5	6

(Tables 1.1 & 1.2 sourced from FAO, 2002, Environmental and Energy Balances of Wood Products and Substitutes p18-19)

Further information on the LCA of houses can be found in the National Timber Development Council's (NTDC) publication "Environmentally Friendly Housing using Timber" (2001). The NTDC publication describes the LCA of different houses and includes an indication of the total CO_2 emissions based on various forms of heating and cooling.

Comparison of three-story buildings

These tables display the difference between building two three-story buildings, both constructed over and area of 9 750m², with different materials. The buildings were;

- Building 1, made from 1 000t wood + 60t steel; and
- Building 2, made from steel only.

TABLE 2.1 — NO THERMAL UTILISATION OF WOOD WASTE

	Building 1	Building 2
GWP	1.1m	3.4m
AP	2 445	7 613
EP	208	648
POCP	63	196

TABLE 2.2 WITH THERMAL UTILISATION OF WOOD WASTE

	Building 1	Building 2
GWP	- 1.5m	3.4m
AP	- 3 264	7 613
EP	- 278	648
POCP	- 84	196

(Tables 2.1 & 2.2 sourced from FAO, 2002, Environmental and Energy Balances of Wood Products and Substitutes p23-24)

The above data from the comparison of the two multi-story building constructions clearly demonstrates the environmental benefits for timber over the use of steel.

Sheds constructed out of wood, steel and concrete

A comparison was made of basic shed construction using three different materials, over the same sized area incorporating the following factors;

- Covered area of 1000m² and an average height of 6m.
- Impacts include the cost associated with demolition plus production, transportation and operation over a twenty-year period.
- Assume thermal utilisation of the wood by-product.

TABLE 3.1 COMPARISONS OF SHED CONSTRUCTION LCA

	Wood	Steel	Concrete
GWP	0.8m	1.3m	1.6m
AP	1849	2946	3582
EP	158	250	305
POCP	48	76	92

(Table 3.1 sourced from FAO, 2002, Environmental and Energy Balances of Wood Products and Substitutes p25-29)

Again, the research clearly demonstrates that wood is a more efficient building product in environmental terms, than synthetic equivalents, when the full LCA is undertaken on the building structures and thermal utilisation of wood by-product is obtained.

Comparisons of LCA in Aluminum, PVC and wooden window frames

The comparisons are as follows (assuming thermal utilisation of wood by-products)

- Including the production of two-wing windows (1650mm by 1300mm)
- Including a lifetime of 30 years

TABLE 4.1 COMPARISONS OF WINDOW FRAME BUILDING MATERIALS IN TERMS OF LCA

	Aluminum	PVC	Wood
GWP	1089	996	906
AP	5.1	4.6	2.2
EP	0.3	0.3	0.2
POCP	2.3	2.7	1.6

(Table 4.1 sourced from FAO, 2002, Environmental and Energy Balances of Wood Products and Substitutes p35-36)

Wood returned the best results once again. Most interesting is the extreme difference between the Acidification Potential (AP) of Aluminum and PVC, and that of wood. While other indicators do not have a large disparity the AP indicators for materials other than wood are more than double the figures of timber.

LCA of flooring materials, wood, PVC and Lino

NB::

- Lino includes wood and cork
- PVC contains chlorine and ethylene
- Functional units = 1 m^2
- Results take into account varying product lifetimes (lino = 25 years, PVC = 20 years, solid wood = 40 years)

Results are as follows,

TABLE 5.1— LCA OF FLOORING PRODUCTS

	Lino	Vinyl	Wood
GWP	1600	4174	424
AP	13	31	24
EP	2	1	4
POCP	2	1	0

(Table 5.1 sourced from FAO, 2002, Environmental and Energy Balances of Wood Products and Substitutes p45-47)

Table 5.1 above indicates that in this instance, lino has the best LCA

CONCLUSION

There is potential in the future to use the results of LCA cradle to grave analysis to provide sustainability ratings on dwellings similar to the Energy Efficiency Ratings that currently apply on such items as household white goods.

Timber should be the preferred building product on environmental grounds across the life of the various building products. To demonstrate the difference between wood and other building products it is essential to take into account thermal utilisation of wood waste. Therefore it is critical that the Renewable Energy Regulations support the use of wood waste as an effective and efficient bio-energy resource.

The LCA work is starting to be combined with information about the nature and source of manufacturing inputs as the basis for developing sustainability indicies. On these grounds there may be an ideal opportunity for the timber industry to regain lost markets or to address new markets in the building industry. Identification of innovative building designs and new applications for timber as a construction material for the future must include the combination the outputs of cradle to grave or even cradle to cradle LCA research with cost analysis to increase the use of timber products in construction.

REFERENCES

FAO (2002) *Environmental and Energy Balances of Wood Products and Substitutes*. Rome: FAO

Forest & Wood Products Development Corporation (1997) *Environmental Properties of Timber*. NSW: FWPRDC

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