Research & Development

James Hardie International

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"TOWARDS GREENER SHEETS"

AN ENVIRONMENTAL PROFILE OF JAMES HARDIE FIBRE-CEMENT PRODUCTS

ESD & THE BUILDING INDUSTRY

It is James Hardie's policy to conduct its business in an environmentally sound manner, and to provide the management systems and operating procedures necessary to identify, monitor, control and reduce the impact of its operations on the environment. As such, the Company is committed to Ecologically Sustainable Development (ESD) principles.

The best known definition of ESD comes from a 1987 report entitled "Our Common Future" by the United Nations World Commission on the Environment and Development:

"(Ecologically) sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The first step towards ecologically sustainable design is energy conservation since the generation and use of energy is responsible for many of the environmental impacts.

In the case of the building industry, the materials of construction can be high in embodied energy as it includes all energy required to extract and process the raw materials into finished building elements, to transport them to site and the energy used in the construction process.

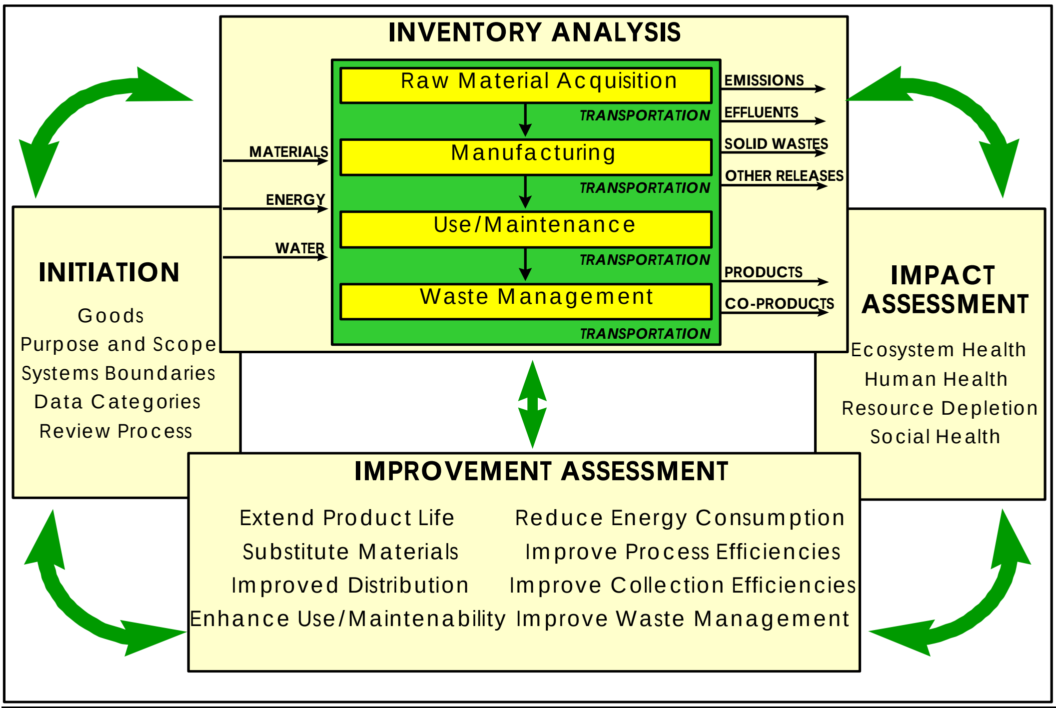


FIGURE 1: A Generic Life Cycle Assessment Model

Studies have shown that the energy embodied within the fabric of buildings is significant and, in the case of large commercial buildings, can be greater than the lifetime operational energy requirement.

Despite much work by researchers, there remains a lack of accurate data in the industry. This is particularly so since most manufacturers are reluctant to publish figures which may reveal confidential formulations or ingredients, or expose their products to undue environmental criticism.

James Hardie, as a responsible building products manufacturer, has conducted its own research into these matters and with this publication shares some of the findings.

THE THEORY OF LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) was identified by James Hardie as the most powerful modern tool to assess the environmental issues associated with its products. LCA is an auditing mechanism that provides data on embodied energy and a host of other parameters that identifies environmental impacts of products or production processes.

As shown in Figure 1, LCA attempts to measure the total environmental effects of a process or product taking into account all stages of its entire life cycle (often referred to as the "cradle to grave" cycle) including all environmental by-products in each of the following:

- Raw material extraction, processing and transportation.
- Product design, manufacture and distribution.
- Use and maintenance.
- Recycling and/or final disposal.

A number of software packages required for this purpose were investigated by James Hardie and the **SimaPro** Model developed in the Netherlands by PRe' Product Ecology Consultants was selected.

There is a huge amount of output from such software, but ultimately the results allow the user to identify where energy savings and other improvements may be made.

The SimaPro Model uses eleven parameters of environmental impact, namely the greenhouse effect, ozone layer depletion, acidification, eutrophication, heavy metals, carcinogens, winter and summer photochemical smogs, pesticides, energy consumption and solid waste emissions.

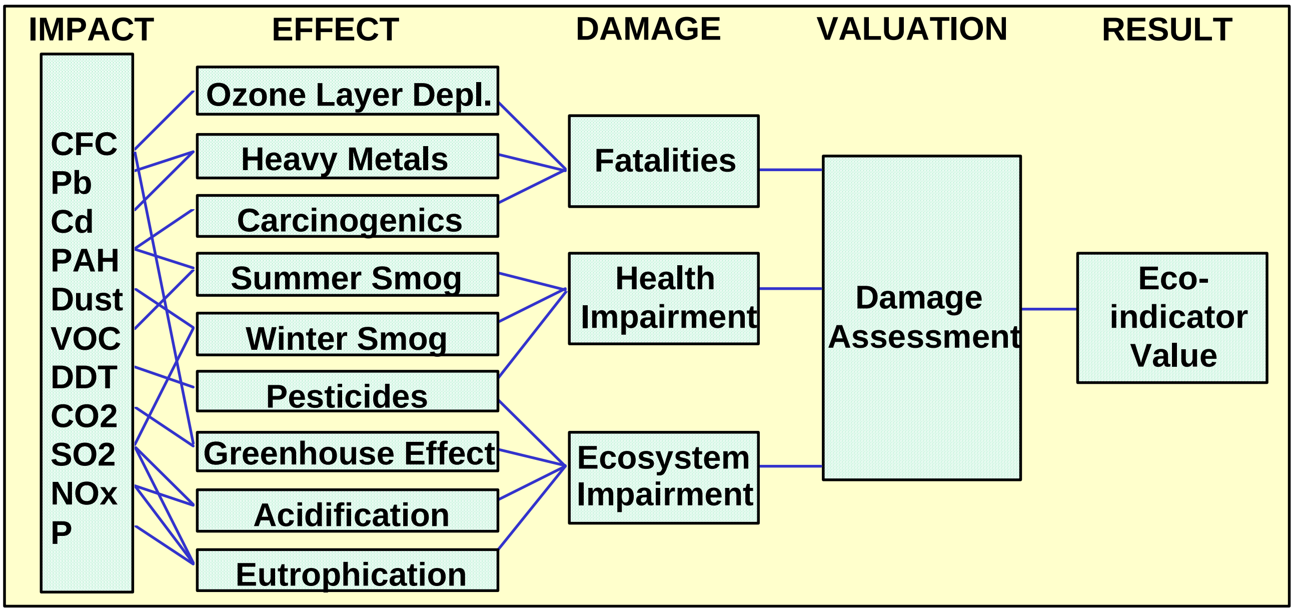


FIGURE 2: Eco-Indicator Weighting Principle
Source: The Eco-indicator 95, Manual for Designers, PRe', NOH.

Other software uses slightly different parameters and weightings (relevant to the local ecology) so, when comparing competing products, it is very necessary to know the method used and assumptions employed.

To make the data easier to comprehend, scores on individual parameters may be combined into groups such as Fatalities, Health Impairment and Ecosystem Impairment. Finally, an overall score or **Eco-Indicator** value may be determined as shown in Figure 2.

The software developers, however, caution against comparisons between products unless they have been studied within the exact same parameters. This complicates the selection of competing products on a comparative basis.

THE JAMES HARDIE LCA STUDY

Scope & Inventory Database

The LCA study was conducted on products manufactured at the NSW Rosehill plant in Australia and involved five of the most commonly used fibre-cement (FC) products:

- 6.0mm Villaboard™ sheet
  (known as Hardibacker® in the USA)
- 4.5mm Hardiflex™ sheet
- 9.0mm Hardipanel™ Compressed sheet
- 7.5mm Hardiplank™ board
- 9.0mm PrimeLine™ board

When a manufacturer receives raw materials from other manufacturers, the environmental impact of those constituents are inherited. In order to obtain credible and accurate results, there was a need to develop an environmental inventory database for fibre-cement that would cover the constituent materials' life cycle from extraction to manufacture and final disposal. The majority of the database on the inputs is 'primary' or original data, sourced directly from the suppliers.

This means that separate LCA studies of the raw materials listed below had to be done to generate data that could be fed into the main analysis for our products. The majority of our suppliers were fully cooperative and the results of the studies have since allowed them to review their own operations for improvements.

Where information on a process input was not provided by a supplier, then average data was obtained either from the SimaPro LCI database, or from literature reviews.

Raw Material Inputs

The raw materials used by James Hardie in the manufacture of fibre-cement products are renewable and abundant, and are as follows:

- Cellulose fibre - unbleached plantation pine wood pulp (*Pinus Radiata*);
- Ordinary Portland cement;
- Ground sand or quartz rock (silica);
- Small amounts of additives as required for specific product properties;
- Water;

Environmental Impact Statements (EIS) exist for all areas from which our raw materials are being extracted. These are held by our suppliers.

The Fibre-Cement Production Process

James Hardie's fibre-cement products are manufactured using the Hatschek Process. The factory process is presented in Figure 3.

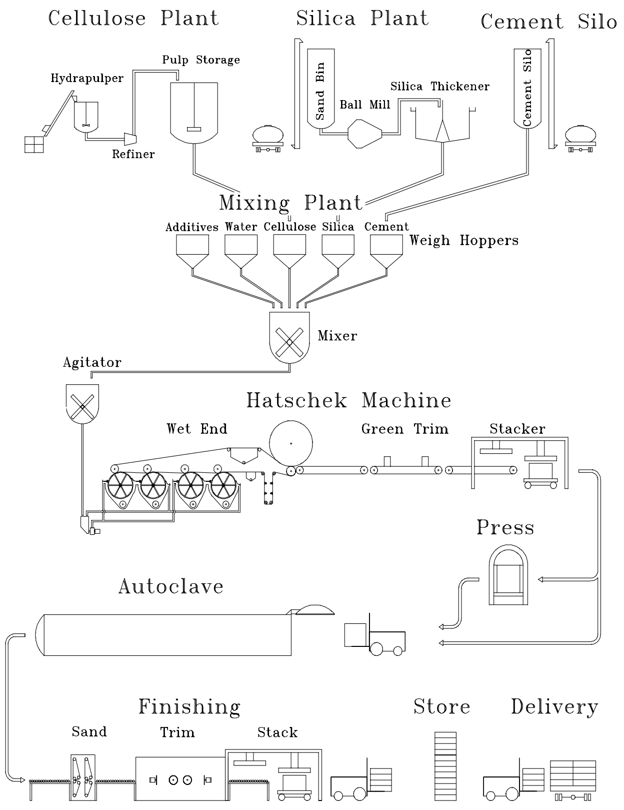


FIGURE 3: An Overview Of The Fibre-Cement Manufacturing Process

Within the manufacturing process, James Hardie is attempting to recycle as much of the waste products as is practical:

- An appreciable amount of the waste mix slurry from the Hatschek process is being recycled back into the fresh fibre-cement mixes;
- The process water is being recycled at least four times before it is treated and released, thereby significantly reducing the overall water demand of the process which currently relies on just 25% of town water;
- Much effort is expended on recycling solid and liquid wastes such as oil, packaging, steel consumables and scrap "green" sheets, thus sending the least possible amount of it to landfill.

RESULTS OF OUR LCA STUDY

Ecological Profiles of Raw Materials

As expected, cement contributes the major share of the environmental impacts of fibre-cement products because of its relatively high process energy requirements and the gaseous emissions associated with cement manufacture. The cellulose fibre ranks second followed by the sand, a distant third, then the additives and finally the water.

Eco-Indicator Method Results

Figure 4 is known as the "normalised" graph and indicates the relative contributions of the raw materials to the eleven environmental impacts measured in the LCA. It shows that the fibre-cement process and related activities contribute predominantly to the greenhouse effect, ecotoxicity (ie an aggregation of acidification, eutrophication, heavy metals), smog and energy use. Compared to the other environmental problems, the contribution of the fibre-cement processes to the ozone layer depletion, carcinogenic substances and solid waste emissions are almost negligible and no pesticides are involved.

Once the weighting occurs, namely considering the relative importance of each impact, the graph is "evaluated" and it was found that after weighting the ecotoxicity effect becomes the most prominent.
Figure 5 is known as the Indicator Graph in which the environmental effects are

aggregated with respect to the raw materials, thus giving a good idea of the relative contribution of the various materials and processes to the environmental impact of the product.

The indicator analysis revealed that cement contributes up to 35% to the overall environmental impacts, energy generation contributes 33%, with all the other processes collectively contributing 32%, made up of 12.1% for sand, 11.2% for cellulose fibre, 7.6% for refinery steam and 1.3% for the other process activities including natural gas usage and solid waste transport from the fibre-cement plant.

The LCA Indicator analysis found a total eco-indicator value of 2.24 millipoints for each kilogram of Villaboard™ sheet (equivalent to 20.9 millipoints per square metre). Again it is cautioned that this figure is not valid for comparative purposes unless the alternative material has been assessed on exactly the same basis and also by the SimaPro model.

The LCA Indicator value is, however, of great value to James Hardie because it sets a benchmark against which future products and processes can be measured in the continued effort to improve environmental performance.

Embodied Energy of FC Products

The contribution by the major process inputs to the embodied energy values of our fibre-cement products is shown in Table 1, revealing that cement is the most prominent input, followed by process steam raising, electrical energy generation, cellulose fibre, additives and sand.

The embodied energy values found for the five selected fibre-cement products are shown in Table 2 (per square metre) which are summaries of various LCA output data.

The commonly used Villaboard™ product is the most energy efficient of the James Hardie range. Although having a very similar mix formulation to Hardiplank™ board, the energy content of the Primeline™ weatherboards is increased considerably by its factory-applied surface coating.

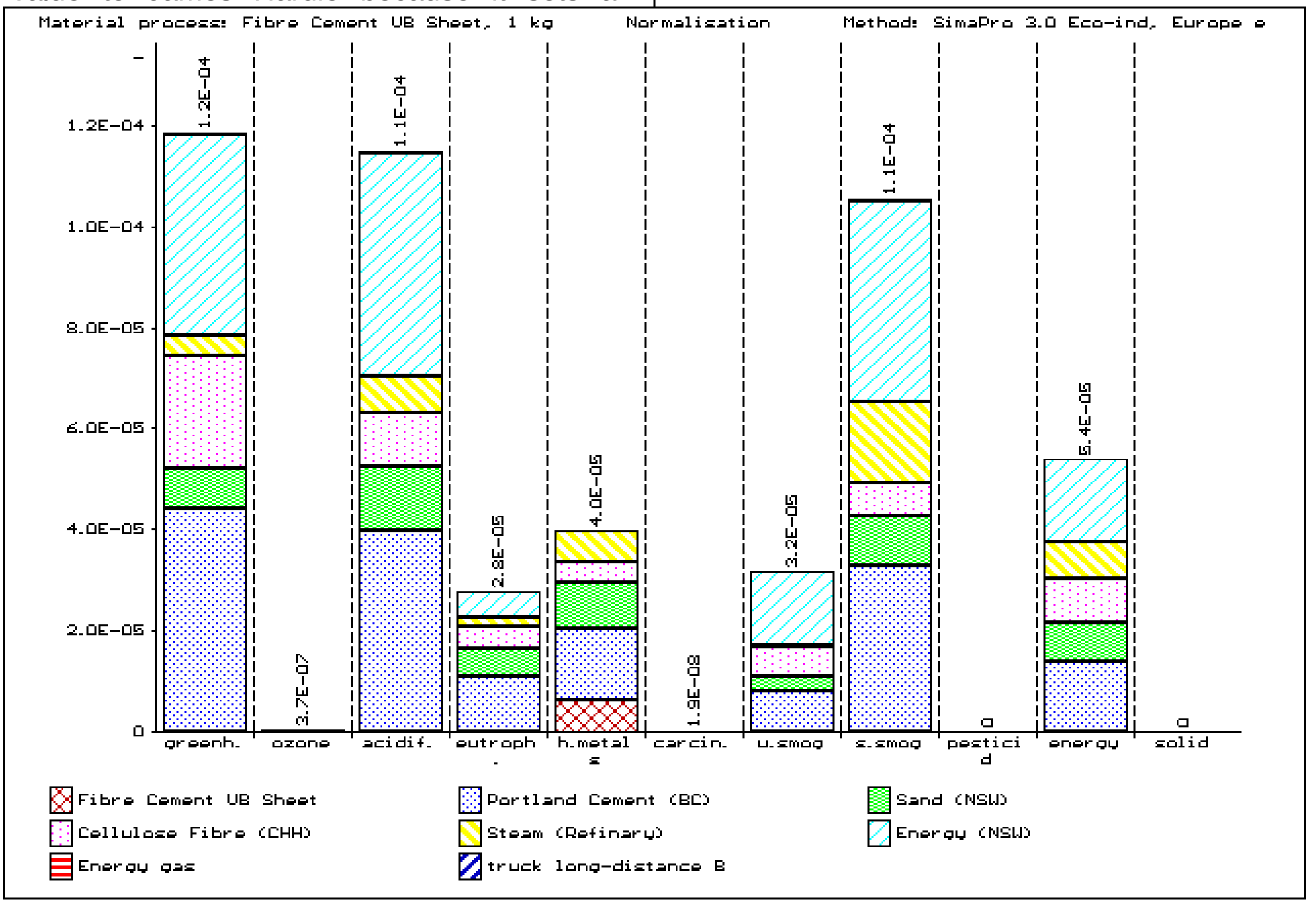


FIGURE 4: Normalisation Graph for Production of 1kg of FC

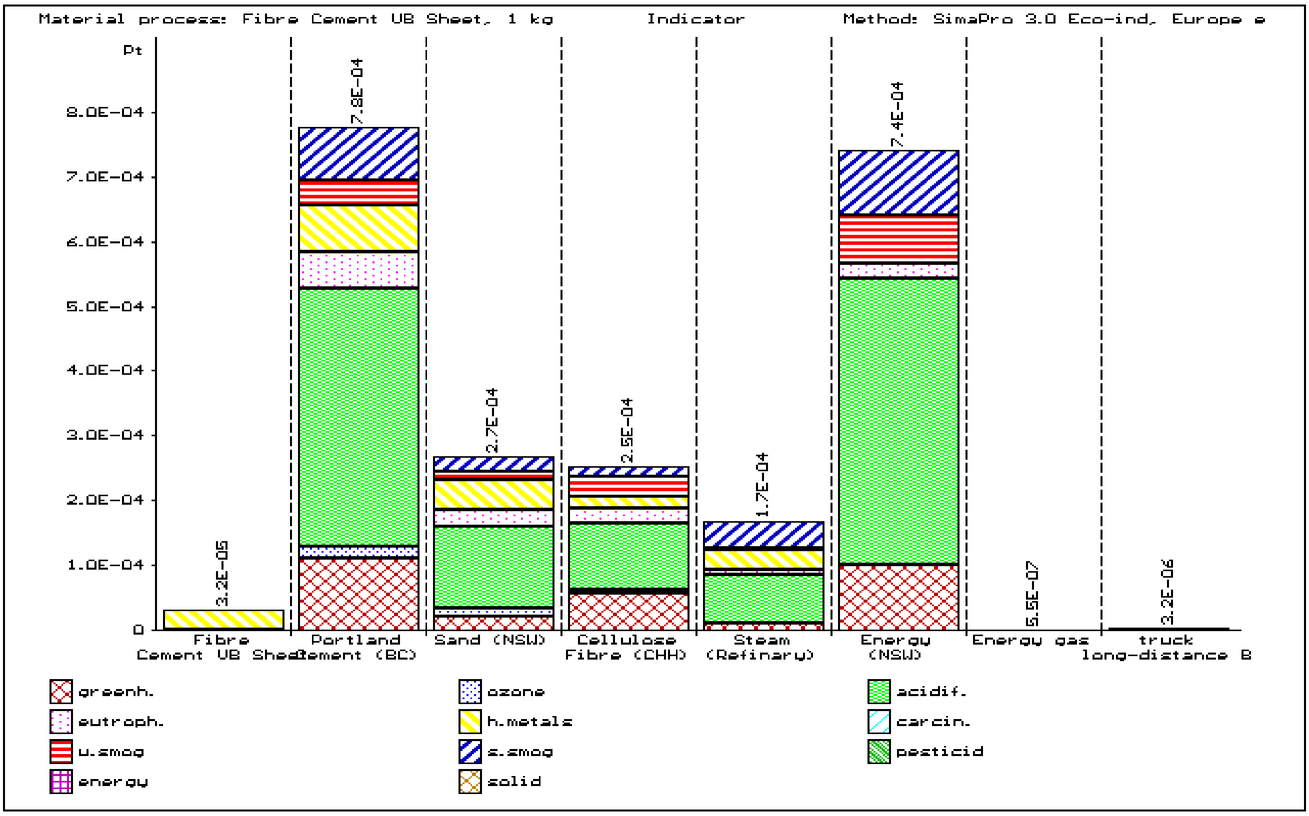


FIGURE 5: Indicator Graph for Production of 1kg of FC

TABLE 1: Contribution of Process Inputs to Embodied Energy of FC

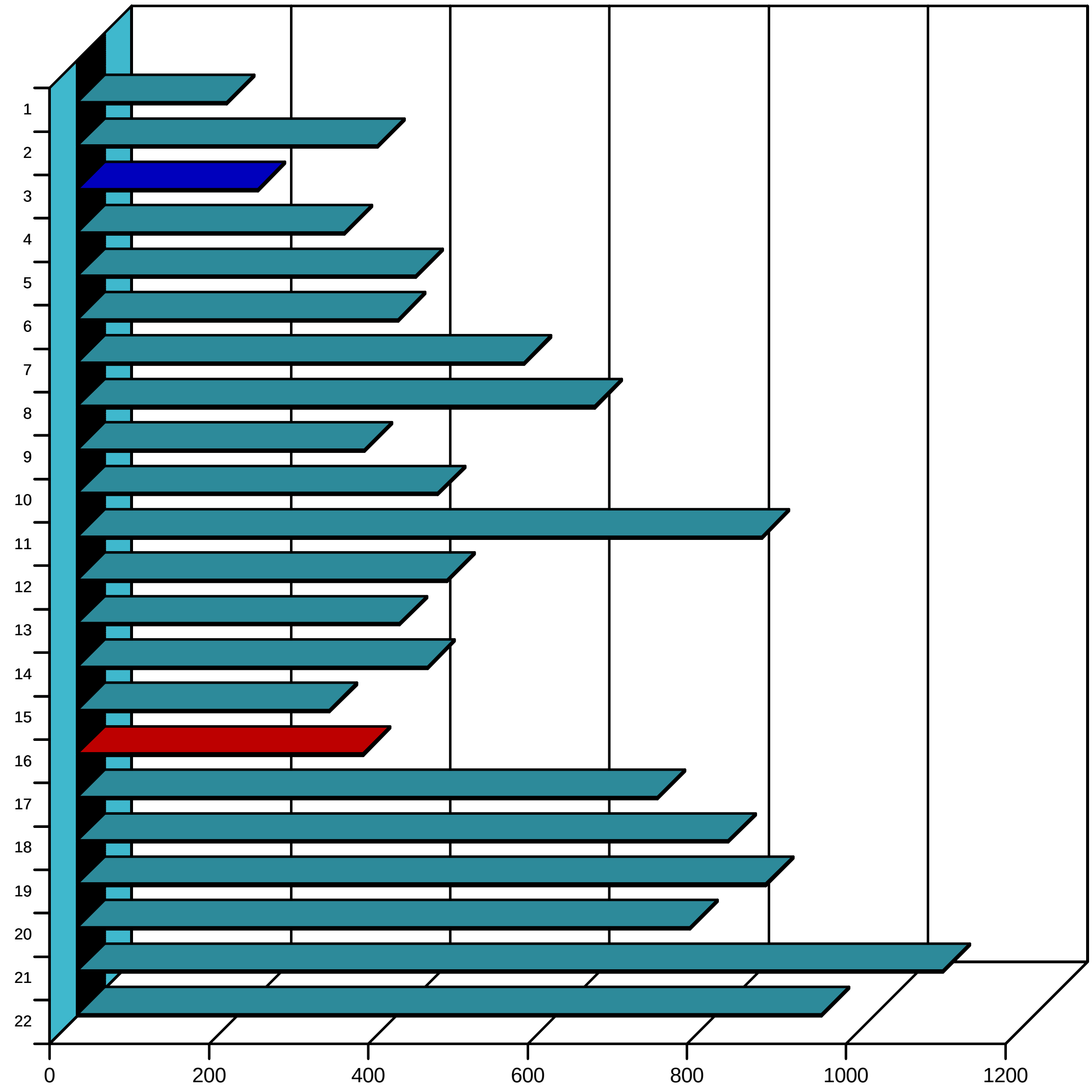
Process Input	6 mm Villaboard™ Sheet	4.5 mm Hardiflex™ Sheet	9 mm Compressed Sheet	7.5 mm Hardiplank™ Board	9 mm PrimeLine™ Board
Cement	27.4%	28.4%	35.3%	32.1%	28.0%
Refinery Steam	24.5%	22.0%	20.0%	20.6%	17.9%
Electrical Energy	17.4%	15.6%	14.0%	14.6%	12.7%
Cellulose Fibre	13.2%	11.8%	12.2%	12.6%	11.0%
Additives	2.9%	9.7%	8.7%	9.1%	7.9%
Sand	8.0%	6.7%	4.8%	5.5%	4.8%
Other process inputs (incl fuel energy)	4.2%	3.7%	3.0%	3.5%	16% (incl 13% for paint)
Solid waste transport	2.4%	2.1%	2.0%	2.0%	1.7%

TABLE 2: Summary of the LCA Study Parameters of Five James Hardie Fibre-Cement Building Products Per Square Metre of Product

ENVIRONMENTAL PARAMETER	6mm Villaboard™ Sheet	4.5mm Hardiflex™ Sheet	9mm Compressed Sheet	7.5mm Hardiplank™ Board	9mm PrimeLine™ Board
Embodied Energy (MJ)	45.9	37.7	101.8	76.9	99.3
Eco-Indicator (millipoints)	20.9	16.2	45.5	33.5	37.7
CO2 Air Emissions (kg)	11.9	11.5	31.6	23.7	31.2
NOx Air Emissions (g)	80.9	103.8	271.4	206.8	250.5
SOx Air Emissions (g)	65.1	47.9	149.6	97.2	149.6
CxHy Air Emissions (g)	26.9	31.2	84.4	63.4	80.8
CH4 Air Emissions (g)	2.4	2.0	4.8	3.8	4.3
Dust Air Emissions (g)	28.9	25.8	72.6	23.6	79.2
Solid Waste Emissions (kg)	6.8	5.7	16.2	11.9	13.4
Water Resource Depletion (L)	101.7	75.7	195.5	153.5	172.5
Wastewater Discharge (L)	81.7	59.5	149.6	120.2	135.0

NOTES:

- The Embodied Energy includes the energy content of all the process inputs and transportation energy;
- Air emissions include those of energy generation, inputs manufacture and transportation emissions;
- Solid waste emissions include those of the fibre-cement process, fibre-cement process energy generation and raw materials manufacture, but do not include the solid waste emissions resulting from the generation of required energy to produce raw materials or resulting from transportation;
- Water resource depletion relates to the manufacture of fibre-cement products, the fibre-cement process energy generation and raw materials manufacture;
- Wastewater discharge is for fibre-cement process, cement and cellulose fibre production and sand mining;



	LEGEND	MJ/m²			MJ/m²
1	Timber Frame, Timber Weatherboard Wall.	188	12	Cavity Concrete Block Wall.	465
2	Timber Frame, Reconstituted Timber Weatherboard Wall	377	13	Single Skin Stabilised Rammed Earth Wall.	405
3	**Timber Frame, Fibre Cement Weatherboard Wall. . .**	**227**	14	Single Skin Autoclaved Aerated Concrete Block (AAC) Wall	440
4	Timber Frame, Steel Clad Wall.	336	15	Single Skin Cored Concrete Block Wall.	317
5	Steel Frame, Steel Clad Wall.	425	**16**	**Steel Frame, Compressed Fibre Cement Clad Wall. . . .**	**359**
6	Timber Frame, Aluminium Weatherboard Wall.	403	17	Hollow-core Precast Concrete Wall.	729
7	Timber Frame, Clay Brick Veneer Wall.	561	18	Tilt-up Precast Concrete Wall.	818
8	Steel Frame, Clay Brick Veneer Wall.	650	19	Porcelain-Enamelled Steel Curtain Wall.	865
9	Timber Frame, Concrete Block Veneer Wall.	361	20	Glass Curtain Wall.	770
10	Steel Frame, Concrete Block Veneer Wall.	453	21	Steel Faced Sandwich Panel Wall.	1087
11	Cavity Clay Brick Wall.	869	22	Aluminium Curtain Wall.	935

FIGURE 6: Embodied Energy (MJ/m^2) of Wall Construction Systems.

Source: Building Materials Energy And The Environment, Towards Ecologically Sustainable Development, (Table 6.2, p 59; Appendix B), Dr Bill Lawson, 1996. The figures for fibre-cement have been updated with approval of the author on the basis of the LCA study conducted by James Hardie.

Considering the figures given in Table 3, it is seen that fibre-cement sheet has a very favourable embodied energy value compared to many other building materials. The advantage that FC sheet has over some alternative materials becomes more apparent when its use in walling systems is considered as shown in Figure 6. This is because of the better coverage (or mass per unit area) of the fibre-cement products.

TABLE 3: Process Energy Requirement (PER) for Common Building Materials

Material	Embodied energy (MJ/kg)
Air dried sawn hardwood	0.5
Stabilised earth	0.7
Concrete blocks	1.4
In-situ concrete	1.7
Precast tilt-up concrete	1.9
Kiln dried sawn hardwood	2.0
Clay bricks	2.5
Gypsum plaster	2.9
Kiln dried sawn softwood	3.4
Autoclaved aerated concrete (AAC)	3.6
Plasterboard	4.4
Fibre Cement (Villaboard™ Sheet)	**4.8**
Cement	5.6
Local dimension granite	5.9
Particleboard	8.0
Plywood	10.4
Glue-laminated timber	11.0
Medium density fibreboard (MDF)	11.3
Glass	12.7
Imported dimension granite	13.9
Hardboard	24.1
Mild steel	34.0
Zinc	51.0
Acrylic Paint	61.5
PVC	80.0
Plastics general	90.0
Copper	100.0
Synthetic rubber	110.0
Aluminium	170.0

(Source: Building Materials Energy And The Environment, Towards Ecologically Sustainable Development, by Dr Bill Lawson, 1996. The originally published figure was 7.6MJ/kg based on data provided by James Hardie at that time. The updated figure is based on the more reliable data of this study and has been endorsed by Dr Lawson.)

Using fibre-cement as cladding material in a timber-framed wall system has a total embodied energy of 227 MJ/m^2, which is:

- 20% higher than a timber weatherboard wall;
- 40% lower than a reconstituted w'board wall;
- 32% lower than a steel cladding wall;
- 44% lower than an aluminium cladding wall;
- 60% lower than a clay brick veneer wall;
- 50% lower than a concrete block veneer wall;

A steel-framed facade wall system using Hardie Compressed sheet as cladding material has a total embodied energy of 359 MJ/m^2, which is:

- 15% lower than a steel clad wall;
- 45% lower than a clay brick veneer wall;
- 21% lower than a concrete block veneer wall;
- 59% lower than a steel curtain wall;
- 53% lower than a glass curtain wall;
- 67% less than steel-faced sandwich panel wall
- 61% lower than an aluminium curtain wall;

Gaseous Emissions

Table 2 provides information as to the quantities and types of gases that are emitted into the air during the whole of the fibre-cement life-cycle except for demolition and final disposal.

Table 4 shows where the carbon dioxide emissions arise. Of that contributable to the additives, more than 90% is due to the road transportation of the material. Additive A, however, is not used in the common Villaboard™ product (known as Hardibacker® in the USA).

TABLE 4: Maximum Contribution of Process Inputs to CO_2 Emissions of FC Products

Process Input	Max CO_2
Cement	37.6 %
Additive (A)	24.2 %
Electrical energy generation	22.0 %

Cellulose fibre	21.9 %
Acrylic paint	14.5 %
Sand	7.7 %
Additive (M)	5.6 %
Autoclave steam	4.1 %
Steel balls for silica plant	1.9 %
Packaging (timber gluts, pallets, etc.)	1.3 %
Fossil fuels (Diesel, LPG, Natural Gas)	0.2 %

Water Resource Depletion

The estimated water consumption values for each product are given in Table 2. The LCA analysis finds that cellulose pulp manufacture is the major influence (namely up to 60%) on water usage attributable to fibre-cement products. Second is sand mining which takes up 22% of the water resources. Third is the fibre-cement factory process itself with 14%, followed by cement manufacture with up to 8%.

Earlier it was stated that James Hardie has been recycling its process water so as to limit the intake of fresh town-water. About 75% of the water demand of approximately 1.45 litres/kg of product is met by recycled water.

Emissions to Water

During the recycling process, the process water is treated and returned into the system, but after at least four cycles the lignin content becomes too high for further recycling. At this point the wastewater is then neutralised to a target pH of 7.8 with 1kg of CO_2 gas per cubic metre and discharged into the sewer. The carbon dioxide is obtained as a waste product from other industries.

The effluent from all James Hardie plants is continually monitored by environmental authorities and heavy fines would be incurred if it did not meet the agreed standards. A new biological wastewater treatment plant is currently under development. This will enable the process water to be recycled further and will also treat the effluent to a much higher quality than is currently being discharged.

As with other environmental impacts, James Hardie has inherited a certain amount of the impact from its raw material suppliers in that pulp manufacture accounts for 62% of the total effluent, and sand mining 27%. The fibre-cement factory process accounts for merely some 16%. Since the cement is manufactured in a dry process, it contributes just 0.6% of the total effluent.

Solid Waste Emissions

Despite our recycling efforts, solid wastes totalling some 300kg per tonne of product are generated in the manufacture of fibre-cement products, as presented in Table 5.

TABLE 5: Composition of Solid Waste Emissions during Manufacture of FC Products

Waste Material	kg / tonne
Autoclave dry scrap (reject sheets, interleaves, etc) plus non-autoclave dry scrap	76
Fine solids from surface finishing; grinding, trimming and sanding	48
Process sludge - a slurry of waste raw materials and calcium carbonate	36
Other process wastes - felts, sanding belts, timber scrap, packaging waste, synthetic bulk bags, paper, empty drums and cans etc	140

This represents 32-42% of the overall solid waste since the amount of solid waste generated in the procurement of the raw materials has to be considered too. It has been estimated and added to the factory waste to give the figures shown in Table 2. Cement is responsible for the majority of the "inherited" solid waste.

So as to facilitate handling and minimise dust emissions into the atmosphere during transport and disposal, the dust is mechanically collected and conveyed into collection bins before being treated with water and acrylic emulsifiers to bind the fine particles.

In the production process, the silica produced by milling quartzitic sand or rock is continually held within an aqueous slurry and hence there is no release of silica dust. In the fibre-cement product silica is in its respirable dust form and in sufficient quantity can be hazardous to health. Over time, usually a number of years, regular exposure to silica may result in bronchitis, silicosis, and lung cancer.

The I.A.R.C. (International Association for Research on Cancer) has determined that silica is a known human carcinogen and in its rating system has nominated it as a Class A1 carcinogen. Consequently the following procedures have been adopted to warn fibre-cement users of this hazard:

- The working instructions section of the company's technical brochures contain a section called "Recommended Safe Working Practices" which details the means by which dust generation may be minimised and/or appropriate protective equipment be used.

- Also, the material safety data sheet for fibre-cement contains complete details of the hazards posed by respirable silica and means of controlling these.

- In addition to the above, each product, or pack of product, also contains a warning, drawing the user's attention to the need to follow the safe working procedures for the product.

The excess process sludge is dewatered to approximately 50% water and 50% solids by weight. The fibre-cement dry waste, dust and solid sludge waste are transported by road in separate bulk waste bins and is disposed of at a municipal landfill, where it is considered environmentally safe for disposal since it is chemically inert or non-reactive in nature and does not emit harmful vapours.

Potential uses of dry fibre-cement solid waste such as scrap and fine particles is being investigated by James Hardie.

- Recycling of post-consumer fibre-cement waste in the manufacture of new fibre-cement products is not possible at this time because of the contamination by paint or surface finishings which would hinder the process or adversely affect the chemical and physical properties of new product.

- There is some potential for use in crushed concrete road base and low-strength recycled concrete, or in special agricultural uses as a soil conditioner or in soil amendment.

Disposal at End of Life Cycle

Almost all fibre-cement building products are fixed by nails or screws to lightweight structural systems such as timber or steel frames. During refurbishment or at demolition stage, it would be possible to remove the fibre-cement materials in an organised manner for potential reuse, recycling or else landfill disposal without any special treatment. Currently only the fine dust from our factories requires such treatment.

In 1988, Brown & Caldwell Consulting Engineers of California, USA, carried out laboratory analysis which confirmed that fibre-cement solid waste material can be designated as non-toxic or non-hazardous to the environment and is safe for disposal in a municipal landfill. The material is chemically inert and much like concrete demolition waste.

JAMES HARDIE & THE FUTURE

Environmental Stewardship

James Hardie is arguably the world market leader in the manufacture of fibre-cement building products and the development of related building systems. During the 1980s, the company pioneered the technology for using cellulose as the reinforcing fibre as an alternative to asbestos in Australia and in 1990 became the first manufacturer of FC products in the USA. Our investment in fibre-cement process technology, product development – and indeed environmental strategy – is set to continue.

Management strategies and programs are continually being implemented in the areas of:

- water and resource conservation;
- energy consumption and management;
- use of renewable resources as raw materials;
- avoidance of environmentally damaging materials;
- waste minimisation by recycling of process materials;
- pollution reduction and protection of the natural environment;

These programs have resulted in a considerable improvement in the resource and energy efficiency of our operations and ensure an ongoing improvement in the environmental performance of our products. We are glad to report that our raw material suppliers too are implementing similar programs of their own.

The LCA study has given us a new perspective of the manufacturing of fibre-cement products and has identified where the major environmental impacts and potential savings are. Fibre-cement has emerged as a competitive building material on the environmental playing field.

The Shift Towards Greater Environmental Awareness

There was a time not so long ago that for most of us the concept of environmental issues meant saving forests, rivers or other natural features, reducing litter and even preserving historical buildings. The tireless work of countless activists and educators has been fruitful. By now our awareness has grown considerably and we know that continued large-scale consumption of energy derived from fossil fuels and depletion of natural resources may have serious global and local environmental and ecological consequences.

"The rivers are our brothers. They quench our thirst. They carry our canoes and feed our children. So you must give to the rivers the kindness you would give to any brother.

"Will you teach your children what we have taught our children? That the earth is our mother? What befalls the earth befalls all its offspring.

"The earth does not belong to man. Man belongs to the earth. All things are connected like the blood which unites us all. Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, so he does to himself."

From a speech by Chief Seattle, 1855

James Hardie intends to be part of the solution and not part of the problem. Our LCA study has been an important step in the right direction and will enable us continually to improve our performance and thus not to compromise the life comfort of future generations.

ANY ENQUIRIES SHOULD BE DIRECTED TO

JAMES HARDIE INTERNATIONAL
P O BOX 219, GRANVILLE NSW 2142, AUSTRALIA
PHONE (02) 9849-0529
FACSIMILE (02) 9684-6199

VISIT OUR INTERNET WEBSITE
www.jameshardie.com