31 July 2003

CEMENT & CONCRETE ASSOCIATION OF AUSTRALIA

The Chairman
Standing Committee of Public Works
Parliament House
Macquarie Street
SYDNEY NSW 2000

Dear Sir

ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS

Thank you for the opportunity to contribute to the inquiry into the energy consumption in residential buildings.

Our submission addresses the terms of reference relating to the operations of rating tools, new technology and other strategies.

It is our belief that when dealing with energy efficiency, environmental impact and sustainability of buildings that a holistic strategy should be adopted. That is, to assess a building throughout its life cycle; from cradle to grave. Such a strategy can be implemented through Life Cycle Assessment (LCA) methodology and tools.

The attached document (Attachment 1) provides an overview of the LCA methodology and provides examples of how it can be utilised by the building industry through case studies.

It should be noted that in the case study presented the design of the house remained the same with no attempt to optimise the design with respect of the materials and the construction system used. Further benefits can be obtained through passive solar design and proper utilisation of thermal mass to effect thermal efficiency in buildings. These concepts are presented in the attached document (Attachment 2).

We will be more than happy to discuss the above concepts further and provide additional information as required.

Yours faithfully

KEN SLATTERY
Chief Executive Officer

Att.

LIFE CYCLE ASSESSMENT – AN OVERVIEW

1. INTRODUCTION

In Australia, there is a clear and definite commitment by the Government to ensure that the construction industry moves towards ecological sustainability. There is an increasing awareness among practitioners (designers and builders) that there are many environmental issues that need to be considered in the design, construction and operation of buildings to ensure that the built environment is sustainable.

With the overall increase in environmental consciousness, decisions regarding the choice of type of construction and of construction materials can no longer be made solely from technical and economic points of view but are becoming increasingly influenced by environmental aspects. The traditional criteria for selecting a particular structure type have been engineering requirements, initial and life cycle costs, experience with and availability of the materials and technology, aesthetics and the ability to build the structure under the local conditions. In the event of alternatives having identical technical performance characteristics the cost would have been, generally, the decisive factor. In contrast to this there is a call today for sustainable construction, that is resource-conscious and environmentally friendly structures. This implies that the overall most favourable alternative from the technical, economical and ecological points of view will be used.

Whereas the technical and economical characteristics of a structure are comparatively easy to quantify, an assessment from the ecological point of view is more difficult to carry out. To address the latter the concept of Life Cycle Assessment (LCA) has been evolving. This paper presents an overview of LCA methodology and discusses its relevance and application in the construction industry.

2. LIFE CYCLE ASSESSMENT

2.1. General

LCA is a method that systematically assesses the environmental effects of a product, a process or activity holistically, by analysing its entire life cycle. This includes identifying and quantifying energy and materials used and waste released to the environment, assessing their environmental impact and evaluating opportunities for improvement.

The entire life cycle of a product generally consists of three phases: production, usage and disposal. These phases can be subdivided further depending on the product and its function. The life cycle of construction products, for example, ranges from raw materials acquisition through manufacturing, construction, use, maintenance, to demolition and treatment of waste, see Fig. [1].

The benefits of LCA are summarised as follows [1]:

- identifying opportunities to improve the environmental aspects of products at various points in their cycle;
- decision-making in industry, governmental or non-governmental organisations (eg strategy planning, priority setting, product or process design or redesign);
- selection of relevant indicators or environmental performance, including measurement techniques; and

- marketing (eg an environmental claim, ecolabelling scheme or environmental product declaration).

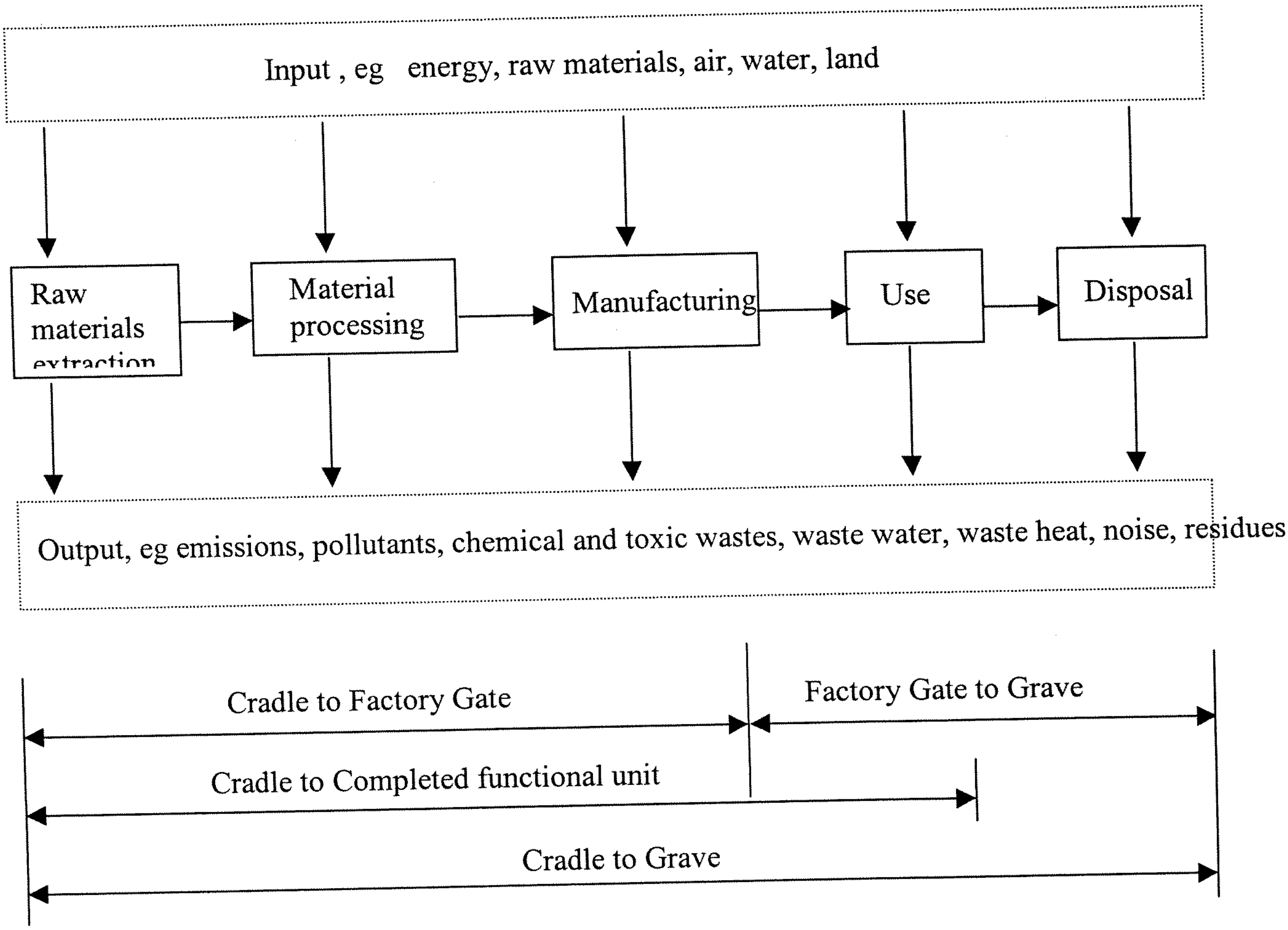

Fig. [1]: Scope of life cycle assessment

2.2. LCA Methodology

LCA methodology comprises a number of stages or phases which are briefly described below and shown in Fig. [2].

2.2.1 Initiation/definition of goal and scope

This is a critical phase since it is at this time that the purpose of the assessment and the scope of the study are established. The boundary conditions for the study are established in this phase. The boundary conditions define the type and amount of information that will be collected in the following phases.

2.2.2 Inventory analysis

A process of quantifying materials and energy, which enter (input) or leave (output) a product system over its life cycle. Inventory analysis involves compilation of quantitative data on energy, water, all materials requirements, air emissions, waterborne effluent, solid waste and other environmental releases that occur during the life cycle of a product.

2.2.3 Impact assessment

A technical, quantitative and qualitative process to characterise and assess the effects of the environmental burdens identified in the inventory analysis phase. One of the early efforts to classify the environmental effects has been the Dutch LCA methodology [2], which suggested 14 environmental parameters to be investigated. Eco indicators 95 have been suggested by the European based organisation SETAC (The Society of Environmental Technology and Chemistry). A list of these parameters and indicators is given in the Appendix.

These parameters or measures address resource depletion, ecosystem health, human health and social health considerations. It is important to note that it is not possible to add together the effect of these parameters to achieve an overall score. Each parameter is assessed separately thus producing an environmental profile of a product. Also, the goal, scope and boundaries of an LCA study should determine the relevant environmental parameters to be investigated and need to be considered in the context of the location of the impact.

2.2.4 Interpretation/improvement assessment

The findings of the inventory analysis or the impact assessment or both are combined to reach conclusions and recommendations within the goal and scope of the LCA study. The recommendations may include both qualitative and quantitative aspects of potential improvements such as a change in product design, raw materials usage optimisation, consumer use guidelines, waste management practices etc.

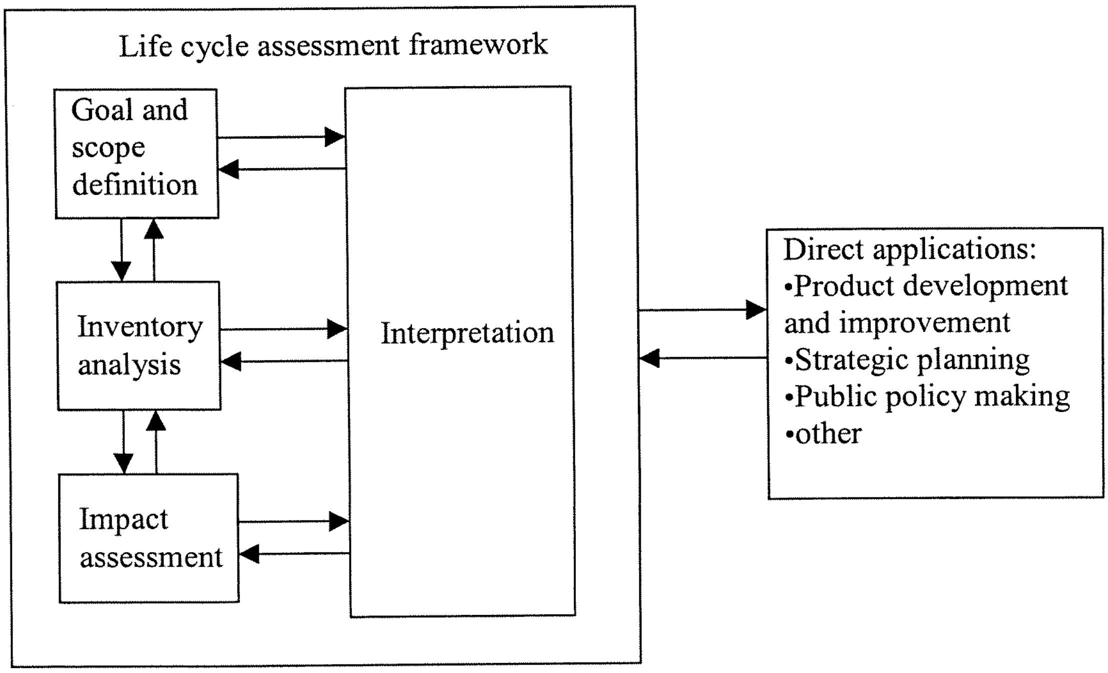

Fig. [2]: Phases of an LCA [1]

As can be seen LCA is an iterative process, which could effect progressive and effective improvement in a product or a system.

2.3 LCA and Embodied Energy

In the early 90's some studies brought attention to the energy embodied within the fabric of the building. One definition of embodied energy is the total energy required by the processes of producing a product, from initial extraction of raw materials to final delivery [3].

The interest in embodied energy of materials and products has increased in recent years as a result of concerns for the environment. Of the various parameters, which may be used to assess the effects of materials and products on the environment, energy consumption and carbon dioxide emissions are probably the most easily estimated. Carbon dioxide emissions arising from the production of materials could be made from knowledge of the embodied energy. It is true that CO_2 emission is an urgent global problem and must be mitigated, but it cannot be used in isolation from other environmental impacts. Because of the ease of evaluation, CO_2 is sometimes chosen by itself as the criteria in the environmental assessment of two products or systems. This could lead, in some cases, to incorrect conclusions.

Within the scope of LCA shown in Fig. [1], embodied energy covers a limited and in some instances an unclearly defined path. The energy embodied in a material or a product is only part of what may be attributed to buildings over their lifetimes. Life Cycle Assessment provides a more comprehensive means of analysing the energy requirements and environmental impact of buildings.

2.4. Life-cycle Assessment Models and Tools

The concept of LCA has only emerged on a wide scale since the late 1980's. A number of government institutions, universities, consulting firms and industries have developed LCA systems in an attempt to create an accepted standard or to demonstrate the particular benefits of their products or a combination of these.

Internationally, there is a considerable effort focused on LCA methodology with various countries and organisations developing tools and models based on the principles and framework of LCA set out by SETAC and/or ISO 14040 series [1,4-6]. With some exceptions, most of the LCA tools developed cover mainly inventory analysis of part or all of the life cycle, embodied energy and CO_2 emission and/or calculation of operating energy of a building.

In Australia, the Environmental Services Group of the NSW Department of Public Works and Services, developed an LCA software LCAid™. LCAid™ is a computer modelling for environmental assessment which takes the guesswork out of sustainable building design. It allows ideas and options to be scientifically tested, while they are in the conceptual or design stages. It has the advantage of being integrated with 3D computer aided design software. Thus LCAid™ can be used to optimise design solutions.

The Commonwealth Scientific Industrial Research Organisation (CSIRO) has developed a 3D-CAD based prototype to calculate, direct from 3D-CAD drawings, embodied energy, CO_2 emissions and mass for all materials in a house [7]. CSIRO has also developed a software program for calculating operating energy in single dwellings (CHEENATH) and in commercial buildings (BUNYIP). To make use of these software programs in the context of life cycle assessment some major work is required, firstly to cover the whole of the life cycle, and secondly to provide the necessary "seamless" integration between the existing software to achieve userfriendliness. The Cement & Concrete Association of Australia (C&CAA) has provided funds to support CSIRO in integrating existing modules into a life cycle energy assessment tool that is also capable of being extended to provide the broader environmental assessment in the future.

3. LIFE CYCLE ASSESSMENT OF BUILDINGS – CASE STUDIES

A series of case studies utilising LCA methodology and using LCAid™ as a tool has been conducted with the following objectives:

- To introduce and raise awareness in the construction industry of the "whole of life cycle" concept as applied to environmental impacts of buildings and their materials.

- To demonstrate LCA as a tool for assessing and comparing building materials and products and entire buildings over their life cycle.

The study included various types of buildings. For the purpose of this submission the study of a detached house (a typical 3-4 bedroom house) is included.

A number of forms of construction were considered as shown in Table [1].

For each case study, assessment was made for three life cycles; 50, 75 and 100 years. A number of assumptions were made regarding building occupancy, on-site construction practices, recycling, lighting and other electricity usage. These assumptions are documented for each case study.

Table [1]: Detached house – construction options

	Floor	External Walls	Internal Walls	Roof
Case 1:	Timber floorboards	Timber/stud/plaster-board	Plasterboard	Prepainted steel roof
Case 2:	Concrete slab on ground	Brick veneer	Plasterboard	Terracotta tiles
Case 3:	Concrete slab on ground	Double brick	Rendered concrete bricks	Concrete tiles
Case 4:	Concrete slab on ground	Tilt-up panel with plasterboard and battens	Tilt-up panel	Concrete tiles
Case 5:	Concrete slab on ground	Tilt-up panel	Tilt-up panel	Concrete tiles

Life Cycle Inventory (LCI) data used for the case studies has been sourced from the LCI data collected by DPW&S over the last five years. The data has been attained from information provided by manufacturers, describing manufacturing processes and raw material inputs. Site visits were carried out to see the processes used to assist in LCI development.

The LCI for cement was supplied by the C&CAA. It was developed in accordance with ISO standards [4].

The study has clearly shown that:

- For the house studied, there was no significant difference between the different forms of construction in terms of energy and greenhouse gas emissions over the three life cycles considered. This was due to the fact that operation was the most important phase of the life cycle for energy usage as can be noted from Figure 4 for the detached house. It should be noted that the decision of the house remained the same for all forms of construction.

- Significant differences were observed in the performance of different forms of construction in terms of other environmental categories, such as ozone depletion and heavy metals.

- Environmental assessment of a building should not be based on just one or two indicators (eg energy and greenhouse gas).

- Life Cycle Assessment provides a broader view and offers a more balanced appraisal of the environmental performance of buildings.

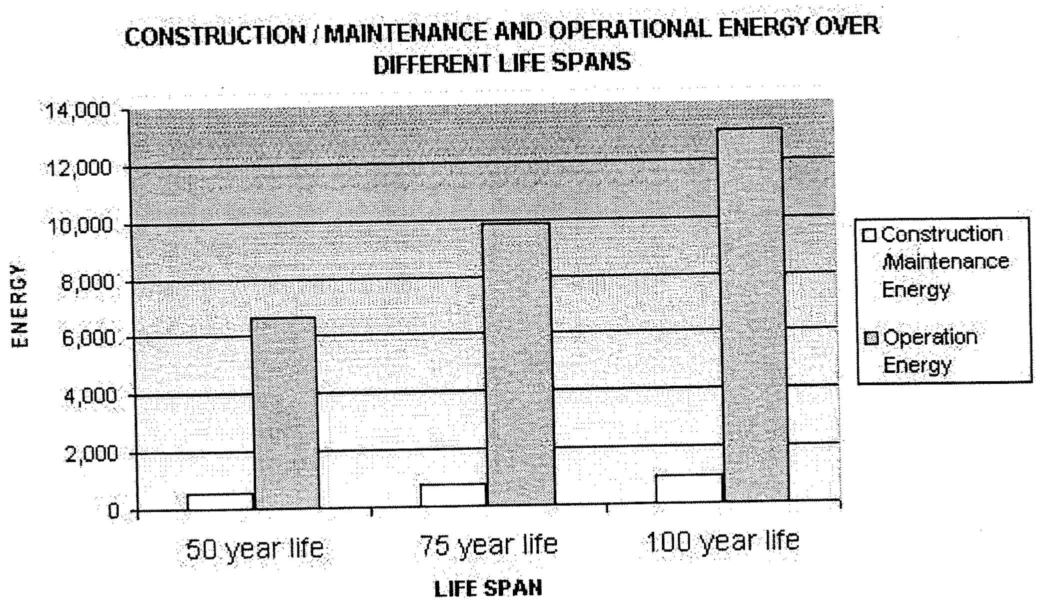

Fig. [4]: Construction and operation energy for the detached house studied

4. CONCLUSION AND RECOMMENDATIONS

True and relevant environmental assessment of a product necessitates the evaluation of the product in its function (ie functional unit). The functional unit defines amongst other things the size, service life, maintenance and possibilities of reuse.

Life Cycle Assessment (LCA) is developing as an acceptable methodology for assessing the environmental impact of a building throughout its life cycle encompassing extraction and processing of raw materials, manufacturing, transportation and distribution, use/reuse/maintenance, recycling and final disposal. An LCA assessment involves:

- defining and describing the product or process establishing fully the context in which the assessment is being made;

- identifying the life cycle stages being covered evaluating and quantifying the energy, water and materials usage and the environmental releases at each stage:

- determining the impacts of the releases and developing opportunities to effect environmental improvements.

The outcome of an LCA study of different building types with various forms of construction has shown that the use of one parameter or indicator is inadequate to describe or assess the environmental performance of a building (a functional unit).

On the other hand, environmental assessment as developed in an LCA study should be used as part of a more comprehensive decision process or used to understand the broad or general trade-offs. Comparing results of different LCA studies is only possible if the assumptions and context of each study are the same and these assumptions should be explicitly stated.

In an era of heightened sensitivity to the environmental impact of building products and the manufacturing processes behind them, the building industry is faced with the challenge of reaching beyond the assessment of specific building materials/products to assessment of the building itself as a functional unit.

However, the building and the construction industry at large needs to be supported in the adoption of LCA through:

- Pooling of resources (Government and Stakeholders) towards further development of LCA methodology in Australia. In particular the area of environmental impact categories relevant to Australia.

- Availability of tools and models based on the principles of ISO 14040 standards which are user friendly and capable of being fully integrated in the design process.

- Better appreciation by all involved that energy efficiency is one component of sustainable development.

5. REFERENCES

[1} AS/NZS ISO 14040:1998 Environmental Management – Life Cycle Assessment – Principles and Framework. Australia/New Zealand Standard. (1998).
[2] Cembureau Concrete: the benefit to the environment, 6. Sustainability of Concrete. January 1995.
[3] Lawson, W.R. LCA and Embodied Energy; Some Contentious Issues. Proceedings of the, Embodied Energy: the current state of play, seminar held at Deakin University, Woolstores Campus, Geelong, Australia. 28th –29th November (1996). Deakin University (1998) pp73-76.
[4] AS/NZS ISO 14041:1999 Environmental Management – Life Cycle Assessment – Goal and scope definition and inventory analysis. Australian/New Zealand Standard. (1999).
[5] AS/NZS ISO 14042:2000 Environmental Management – Life Cycle Assessment – Life cycle impact assessment. Australian/New Zealand Standard. (2000).
[6] AS/NZS ISO 14043:2000 Environmental Management – Life Cycle Assessment – Life cycle interpretation. Australian/New Zealand Standard. (2000).
[7] Tucker, S.N. and Ambrose, M.D. Evaluating Embodied Energy in Construction Using a 3D CAD Based Model. Proceedings of the, Embodied Energy: the current state of play, seminar held at

Deakin University, Woolstores Campus, Geelong, Australia. 28th –9th November (1996), pp 95-103.

APPENDIX

In the classification process a number of standard parameters are investigated (Ref 2):

(1) ABIOTIC DEPLETION: the depletion of abiotic raw materials compared with the total available resource. This is obviously relevant to the manufacture of concrete products.

(2) BIOTIC DEPLETION: the depletion of biotic raw materials compared with the total reserves and the reserves/production ratio.

(3) GREENHOUSE EFFECT: a measurement of the substances contributing to Global Warming Potential (GWP), measured as equivalent Carbon Dioxide weight.

(4) OZONE DEPLETION: a measurement of the substances contributing to Ozone Depletion Potential (ODP), measured as equivalent CFC-11 weight.

(5) HUMAN TOXICITY: an assessment of acceptable daily intakes of toxic substances by humans, measured as the equivalent body weight exposed to the toxicologically acceptable limit.

(6) AQUATIC OR TERRESTRIAL ECOTOXICITY: an assessment of substance with an eco-toxic effect on species in the ecosystem. Measured as volume of polluted water, or weight of polluted soil.

(7) OXIDANT FORMATION: Photochemical ozone creation potential of substances measured as equivalents weight of ethylene.

(8) ACIDIFICATION: Acidification potential of substances are measured as SO2 equivalents by weight.

(9) NUTRIFICATION: Nutrification potential of substances are measured as Phosphate equivalents by weight.

(10) AQUATIC HEAT: Waste heat emissions into water are measured as energy.

(11) MALODOROUS AIR: Odour thresholds are measured in terms of volume of polluted air

(12) NOISE: Noise is measured as an effect over time.

(13) SPACE: Use of space is measured as area over time.

(14) VICTIMS: The measurement of the numbers of human fatalities directly attributable.

Eco indicator 95

Eco indicator 95 was produced for the National Reuse of Waste Research Programme (NOH) in the Netherlands and includes the following impact categories.

- Greenhouse effect (Atmospheric pollution)
- Ozone Depletion (Atmospheric pollution)
- Heavy Metals (Water & Air pollution)
- Nutrification (Water & Land pollution)
- Acidification (Water & Land pollution)
- Carcinogenesis (Human health)
- Summer smog (Air pollution)
- Winter smog (Air pollution)

Additional indicators added to LCAid™ include energy and water consumption and solid wastes. This is to compare human consumption with the corresponding atmospheric and pollutant impacts.