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Life cycle assessment and life cycle cost implication of residential buildings—A review

Hamidul Islam, Margaret Jollands, Sujeeva Setunge *

School of Civil, Environmental and Chemical Engineering, RMIT University, 124 Latrobe St, Melbourne 3000, VIC, Australia

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ABSTRACT

The aim of this article is to report a comprehensive review of life cycle assessment (LCA) and life cycle cost (LCC) implication on residential buildings. It discusses the contemporary issues, and its relationship and significance of system boundary, assumptions, and reports how it effects on economic and environmental impacts. The tools, frameworks and processes of LCA and LCC of buildings are also discussed. It critically illustrates the existing LCA and LCC studies on residential house designs to determine the causes for the widely varying results of numerous previous studies. It evaluates life cycle cost and life cycle environmental impacts of a case study building, and compares with very similar LCA and LCC studies. Finally, it reports the implications and perspectives of LCA and LCC studies on building designs.

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* Corresponding author. Tel.: +61 3 9925 2182; fax: +61 3 9639 0138.
E-mail address: sujeeva.setunge@rmit.edu.au (S. Setunge).

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1. Introduction

A residential building utilizes a variety of building components in its assemblage designs. The assemblages involve a complex arrangement of material fabricated with various technologies, meeting legislative requirements. The assemblages are produced from a wide range of resources using energy intensive processes, from raw material extraction to final disposal. Energy intensive processes consume a large amount of resources for the generation of power, and produce significant emissions and solid waste. The environmental impacts associated with building assemblages also include operational use of the residence with its heating and cooling, as well as their maintenance and disposal. These systems also have a significant economic cost. Assessing the environmental impact and cost of a whole building over its lifetime is a complex exercise, as it requires assessment of all its elements and life cycle stages. Life cycle assessment (LCA) and life cycle costing approaches evaluate the life cycle environmental impacts and life cycle cost (LCC), respectively.

This paper focuses two goals. First, this paper provides a comprehensive review of LCA and LCC studies of residential house design. The tools, frameworks and processes of LCA and LCC of buildings are also discussed in the next. The limitations and gaps are identified and summarized. Second, life cycle cost and life cycle environmental impacts of a case study building is reported, and compared with similar LCA and LCC studies. Finally, it reports the implications and future perspectives of LCA and LCC studies on building designs.

2. Literature review

2.1. Overview of LCA studies of buildings

LCA has been used in the building sector since 1990 [1]. There have been a large number of LCA studies of residential buildings in Europe, North America and Australia. The aims of the studies are generally to.

2.1.1. LCA tools and inventory

Various LCA software tools have been developed in different regions, such as *GaBi* and *SimaPro* in Europe, and *ATHENA* in the United States (US) and Canada. LCA software uses life cycle inventory (LCI) database for evaluating environmental impacts. There are many LCI databases such as ATHENA, Eco-Invent and AusLCI. Examples of LCA tools and region specific LCI databases are shown in Table 1.

ATHENA is the most suitable for use in US and Canadian studies, as it contains the most comprehensive database of Canadian and US products and processes [2,3]. Eco-invent contain Swiss and European product and process data. AusLCI contains Australian product and process data.

Technology in the building industry has a high rate of change due to hi-tech improvements, so data quality in LCA studies on buildings is a major concern. The age, regional origin and accuracy of the inventory data affect the accuracy and validity of studies [2,4,5]. A major focus over the last two decades in Europe, Canada and the USA has been to produce region specific life cycle inventory (LCI) database [6]. An initiative to develop an Australian database was followed [7].

2.1.2. LCA study assumptions

A summary of LCA studies conducted on residential buildings is shown in Table 2. Many LCA software packages and region specific life cycle inventory databases have been used in previous studies. While any LCA software can be used, the preference in recent studies is to use region specific LCI data. For example, several recent Australian LCA studies were conducted using *SimaPro* software and the Australian region specific database AusLCI [8–10]. One UK study was conducted using *GaBi* software and region specific data [11]. Two recent North American studies were conducted using *ATHENA* software and North American region specific data [12,13]. The

Table 1
LCA software tools and LCI databases around the world.

LCA software tools		LCI database			
Name	Focus	Name	Description		
			Source	Region	Focus
SimaPro	Generic LCA tool; Evaluate environmental performance of products and services; its Ecoinvent contain 2500+ process database	**Eco-Invent**	Primary, BUWAL, ETH-ESU	Swiss and Western Europe	Generic; over 2500+ processes; includes uncertainty data and infrastructure
ATHENA	Contain North American database; specifically developed for buildings; allow user for comparisons among alternative	**Athena's database**	Primary	Canada and North America	Construction industry; 90+ processes—wood, steel, concrete and structural products
GaBi	Generic LCA tool; process-based LCA; widely adopted tool integrated with Economic cost	**USA National LCI**	Primary, Eco-Invent 2000	USA and North America	Basic processes to build upon in LCA studies
LISA	Australian based freely available streamlined tool; not allow users to add new case studies	**Australian LCI**	Primary, various databases	Australia	Mostly AusLCI and LCA studies at RMIT University/centre for design and others
LEGOE	Use by architects and engineers; integrated with a CAD tool	**Canadian database**	Primary	Canada and North America	Basic materials: aluminium, glass, plastics, steel and wood
BEES	US based building material specification tool; applicable to LCA and LCC; not transparent	**Inventory of Carbon & Energy (ICE)**	Secondary	Global	Inventory of embodied energy and carbon coefficient for building materials

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