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Carbon footprint and embodied energy consumption assessment of building construction works in Western Australia

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Abstract

The Australian Green Infrastructure Council (AGIC) is currently leading a new approach to the delivering and operating of infrastructure through a more careful examination of the carbon footprint of construction activities. Using a life cycle assessment (LCA) methodology, this paper presents life cycle greenhouse gas (GHG) emissions and energy analysis of the Engineering Pavilion (hereinafter referred to as Building 216), at Curtin University Western Australia. The University utilises a Building Management System (BMS) to reduce its overall operational energy consumption.

This LCA analysis employed a 'mining to use' approach, in other words, the analysis takes into account all of the stages up to the utilisation stage. The life cycle GHG emissions and embodied energy of Building 216 were calculated to be 14,229 tonne CO_2-e and 172 TJ, respectively. This paper identified the 'hotspots', or the stages in production and operation of Building 216 that were the cause of the majority of the GHG emissions. From this, proposals for further improvements in environmental management may be made. The usage stage of the building produces 63% less GHG emissions than the University average, due to the implementation of the BMS. This system has played a significant role in reducing the total embodied energy consumption of the building (i.e., 20% less than the University average).

Keywords: LCA; Building; BMS; GHG emissions; Embodied energy

1. Introduction

In general, buildings contribute approximately 30% to total global GHG emissions (UNEP, 2009). In efforts to reduce global warming, GHG reductions in this area would make a significant contribution (UNEP, 2009). According to the Intergovernmental Panel on Climate Change (IPCC), there are three areas to focus on in reducing emissions from buildings: reducing energy consumption and building embodied energy, switching to renewable energy, and controlling non CO_2 emissions (Levine and Urge-Vorsatz, 2007). In Australia, regulation is already reshaping the built environment, with mandatory disclosure of the National Australian Built Environment Rating System driving higher levels of energy efficiency in commercial buildings. The carbon price also encouraged more informed decision-making across the economy (GBCA, 2013), although this is no longer the case due to change in government in 2013.

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Australia's per capita greenhouse gas emissions are the highest of any OECD country and are among the highest in the world (Garnaut, 2008). The nation's built environment is experiencing enormous pressure due to its population increase, economic growth, and the government's existing energy and environmental policies (Department of Environment, 2011). Almost a quarter (23%) of Australia's total GHG emissions are the result of the energy demand from the building sector (Department of Environment, 2009). The building sector, comprising residential and commercial buildings, drives a large proportion of Australia's economic activity (Electrical Solutions, 2008). The building sector's contribution to GHG emissions is mainly driven by its end use of, or demand for, electricity (operational energy). For example, there are approximately 21 million square metres of commercial office space in Australia, spread across 3980 buildings (The Parliament of the Commonwealth of Australia, 2010). However, in the main, these offices have not been designed to consider energy efficiency or solar passive design or their long-term environmental and social impact (Department of Climate Change and Energy Efficiency, 2012; Property Council of Australia, 2008).

Along with GHG emissions, energy consumption is often used to measure the environmental performance of buildings. Recent studies have highlighted the importance of both embodied energy and operational energy use attributable to buildings over their lifetime (Biswas et al., 2008). Embodied energy is the energy consumed by processes associated with the total production of a building, from the acquisition of natural resources from processes including mining and manufacturing, through transport and other functions, and finally, the operational energy, involving the energy utilised by the building's operations and use (air conditioning, heating and lighting, office and kitchen equipment).

The building industry has now acknowledged its environmental shortcomings, and through the Australian Green Infrastructure Council (AGIC) will lead a new approach to the delivering and operating of infrastructure by undertaking a more detailed examination of the carbon footprint (the total sets of greenhouse gas emissions caused by product life cycle stages) associated with construction activities.

Life cycle assessment (LCA) for green building design has recently been developed around the understanding that there is a shortage of holistic environmental assessment tools in the building industry (Horne et al., 2009). The life cycle assessment brings benefits to the decision-making process in that it can be used to review sustainability initiatives throughout the entire life cycle of the building, including the design, detailing, delivery and deconstruction phases. A number of studies in North America, Europe and Japan have used LCA as a useful tool for determining the carbon footprint and embodied energy consumption in assessing the environmental performance of buildings (Lemay, 2011; Bribián et al., 2009; Junnila and Horvath, 2003; Junnila et al., 2006; Suzuki and Oka, 1998). In 2000, Fay et al., applied the LCA in evaluating alternative design strategies for an energy efficient Australian residential building. Since then, no LCA study has yet been published which assesses the environmental impact from modern buildings in the public sector in Australia.

Energy consumption in Western Australia grew at an annualised rate of 6 per cent between 2008 and 2012, faster than the average increase across Australia of 1.1 per cent, linked to economic growth (CCA, 2013). This paper, thus, assessed the embodied energy and associated carbon GHG saving benefits of the use of an energy efficient building in Western Australia.

The new Building 216 "Engineering Pavilion Complex" at Curtin University in Western Australia comprises two building wings located around an exhibition plaza. Using an LCA methodology, this paper presents a life cycle GHG emissions and energy analysis of Stage 2 of Building 216 (Fig. 1). This paper identified the 'hotspots', or the stages which are the cause of most of the GHG emissions from the building construction and operational phases, so that further environmental management improvements can be made.

2. Methodology

Following Biswas (2014), this LCA is best termed as "streamlined" LCA (SLCA), as it does not take into account the recycling of building materials or their disposal into landfill. This SLCA that was employed followed the ISO14040–44 guidelines (ISO, 2006) in calculating the life cycle GHG emissions and embodied energy of Stage 2 of Building 216. The LCA is divided into four steps: (1) goal and scope definition; (2) inventory analysis; (3) impact assessment; and (4) interpretation (as presented in the 'Results' section of this report). This LCA has limited its focus to two impact categories only (Finkbeiner et al., 2011); global warming impact, or carbon footprint, and embodied energy. Finally, this LCA is process-based, where the input data, in the form of energy and chemicals for each of the processes of the building's life cycle, has been utilised in assessing global warming and embodied energy consumption impact.

2.1. Goal and scope definitions

The goal of this research is to assess the environmental performance of Building 216 in terms of carbon footprint and embodied energy consumption. Carbon footprint is the total sets of greenhouse gas emissions caused by building life cycle stages, including mining, manufacturing, transport and the use. In the current analysis, the embodied energy includes the energy consumed by processes associated with the production of the building, from the acquisition of natural resources to final consumption including mining, manufacturing, transport and the use of building. In this current research, energy consumption associated with the demolition and transportation to landfill have not been considered. This LCA is limited to three stages: