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GHG emission reduction performance of state-of-the-art green buildings: Review of two case studies

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ABSTRACT

Driven by the current green building standards, previous studies focused much more on energy efficiency (especially the operation phase) than greenhouse gas (GHG) emission reduction during the life cycle of buildings. Few studies adopted a life cycle measure to assess GHG emission reduction performance of green buildings. The relationship between GHG emission reduction and defined green buildings remained unclear. The authors first develop a life-cycle GHG measure with its definitions. Two state-of-the-art green buildings located in China and Australia are studied to present the relationship between low GHG buildings and green buildings. It is found that although defined green buildings could have better GHG emission reduction performance than conventional buildings because of the excellent energy performance, and sometimes can even achieve the goal of Net Zero Emission Building, green buildings do not necessarily indicate low GHG buildings from the life-cycle perspective. The main reason is that the criteria for green building rating tools usually don't include GHG emission performance. Perusing sustainability, the authors suggest that life-cycle GHG emission reduction should be taken into account in the evaluation of green buildings. This paper outlines the suggestions on improving the green building rating tools to encourage GHG emission reduction performance of green buildings.

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1. Introduction

Climate change, leading to seriously deteriorated living environment, disease, etc., is considered as one of the most significant challenges to the development of human society [1]. Excessive greenhouse gas (GHG) emission is recognized as a key factor of climate change and global warming [2]. Many countries have been trying to make great efforts to reduce GHG in the years to come [3]. Many studies concluded that the building industry is the main contributor to GHG emissions. For instance, during their life cycle, buildings contribute 43% of the national CO_2 (the main GHG) emissions in the US [4], and more than 50% in China [5]. Buildings are estimated to be responsible for more than 50% of GHG emissions in UK [6], and 23% in Australia [7] over the whole life cycle. GHG emission reduction in the building sector are considered to be the most cost-efficient when compared with all the other sectors [8,9]. Therefore, GHG emission reduction in buildings has been widely recognized as one of the most important and effective ways to eliminate the negative impact of climate change [9–15].

Although a variety of policy instruments reducing GHG emissions from buildings have been proposed and implemented in many countries, direct policies which aimed at building related GHG mitigations are rarely put into practice [16,17]. Many of the policies promote the development of green buildings or building energy efficiency, which mainly focus on operational energy and corresponding GHG emissions in building's operation phase, such as energy consumption from air conditioner, lighting, heating, etc. [18,19]. Building energy consumptions in operation phase indeed have great influence on the GHG emissions of buildings, but not all of them. Embodied GHG emissions during the production, transportation and assembling (construction) of building materials and components also take non-negligible proportion of the total GHG emissions [16,17]. Meanwhile, the types of construction materials, HVAC, etc. may determine construction approaches and building operation modes during the whole life cycle of the buildings, which directly generate GHG emissions in various amounts. Thus, simply just considering GHG emissions in the operation phase of the building may be biased for the assessment of green buildings. Therefore, it is critical to measure the GHG emissions in a green building from life cycle perspective. The understanding of GHG emission performance of green buildings can help improve the reasonability of green building standards /rating systems.

Empirical evidence and case studies are the fundamental methods in the research of green buildings, building energy efficiency or GHG emission reduction in buildings to obtain data, experience and best practices for the validation of proposed management models [11,20,21]. Case study is one of the key approaches to validate the effectiveness of the practices of GHG emission reduction in buildings. Meanwhile, pilot projects of green buildings or low carbon buildings serve as effective benchmarks for the promotion of policies and kick-starting of the green building market [12,17]. Many scholars have conducted case studies on energy performance of various kinds of buildings, such as residential and commercial buildings in different countries and regions [22–26]. A number of studies have compared the life-cycle energy consumption of the cases and validated energy-saving of different approaches of building energy saving [27–30]. Some scholars proposed various methods for the assessment of GHG emissions over the life-cycle of buildings with case studies [31–36]. However, few researches adopted a life cycle measure to assess the GHG emission performance of green buildings. Evidence of the status of GHG emissions from green buildings is still rare, even in the form of case study.

This paper investigates the distribution of GHG emissions during the whole life cycle of two state-of-the-art commercial green buildings, Nanhaiyiku 3 and the Pixel Building, which are located in Shenzhen, China and Melbourne, Australia respectively. There are two reasons for choosing these two case studies. Firstly, both buildings were awarded the highest rating of their national green building rating systems and standards, respectively, and their detailed information is presented in Table 1. The two cases could represent the status of state-of-the-art commercial green buildings in China and Australia. Secondly, both buildings were developed and operated by their developers. As the two cases are the outstanding prototype work of the developers, they are both used as head offices of their developers. It is critical for the researchers to easily collect the complete life cycle data from the developer both in buildings' construction phase and operation phase. Data collectability limited the research to be case study, but not statistical research. GHG emission reduction performance of the two cases are analysed to disclose the implications and effect of GHG emission reduction under the current operational energy efficiency and green building oriented policy circumstance. Based on the results, this paper tries to disclose the possible loopholes and provide the suggestions on improving Chinese and Australian green building rating tools to encourage GHG emission reduction performance of green buildings.

2. Methodology

2.1. GHG auditing boundary and inventory data

Life cycle assessment (LCA) is the most prevalent methodology adopted in the previous studies and caters to energy consumption or GHG emissions analysis of buildings [29,30,37–39]. ISO 14040:2006 provides a series of LCA principles and frameworks [40]. The four phases defined in ISO 14040:2006 for LCA approaches include goal and scope definition, inventory analysis, impact assessment and interpretation. For a LCA study based on ISO 14040, the GHG auditing boundary and inventory data are the prerequisites. In general, LCA accounts for GHG emission for

Table 1
General information of Nanhaiyiku 3 and the Pixel Building.

General information	Nanhaiyiku 3	The Pixel Building
Location	Shenzhen, China	Melbourne, Australia
Developer	China Merchants Property Development Co.	Grocon Pty Ltd.
Built year	2008	2010
Building type	Office building	Office building
Structure type	Reinforced concrete frame	Reinforced concrete frame
Number of floors	5 floors with a underground garage	4 floors
Height	21.5 m	15.98 m
Floor area	250,23.9 m^2	1136.4 m^2
Air-conditioning area	16,259 m^2	1082.3 m^2
Award	3 star green building (GB50387-2006, Ministry of Housing and Urban-Rural Development, China)	6 star green building (Green Star, Green Building Council of Australia)