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Replacement scenarios for construction materials based on economy-wide hybrid LCA

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Abstract

As part of the Integrated Carbon Metrics project, which comprehensively quantifies embodied GHG emissions related to the built environment in Australia, this contribution evaluates construction material replacement scenarios at the economy-wide scale. We investigate the potential use of Engineered Wood Products (EWPs) in new building stock to assess the carbon outcomes of a potentially significant shift in the use of construction materials. This becomes increasingly relevant as Australia moves forward with augmenting the National Construction Code to allow the construction of mid-rise buildings utilizing timber. The selection of low-carbon and sustainable building materials is crucial in reducing the built environment's carbon footprint. The main objective of the replacement scenario analysis is to assess the potential reduction in future GHG emissions by replacing the use of reinforced concrete with EWPs. The scenarios include the comparison of mid-rise buildings (10-story) with standard reference buildings (using reinforced concrete) at the national scale. The analysis considers the full cradle-to-gate carbon footprint of construction materials embedded in buildings. Since the scenarios are implemented in an input-output model of the Australian economy, changes in the use of construction materials can also be evaluated with respect to indirect effects on industries involved in the production chain of these materials as well as their respective GHG emissions.

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Keywords: construction materials; construction industry; engineered wood products; input-output modelling; residential and non-residential buildings

1. Introduction

Whilst the construction industry in Australia directly accounts for only about 2% of total national greenhouse gas emissions, the carbon footprint of construction products such as buildings and infrastructure contributes 18% to the

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total national carbon footprint [1]. This is because the production of construction materials is an energy- and carbon-intensive process particularly for bulk materials such as concrete and steel. The carbon footprint of construction takes into account the life-cycle emissions of all these materials and of all other goods and services used in the supply chain of buildings and other construction products [2, 3]. In 2013, the Australian carbon footprint was 23.8 Mt CO_2e for residential building construction, 16.8 Mt CO_2e for non-residential building construction, and 57.1 Mt CO_2e for non-building construction (which includes road and bridge construction with 9.8 Mt CO_2e) [1]. Within the building sector, construction materials are widely known to be a key contributor of embodied emissions with concrete, cement, plasterboard, limestone, brick and other ceramics accounting for the highest amount of embodied emissions (39.2%), whilst other large contributors include other minerals (24.2%), iron and steel (9.8%), timber (9.3%) and other metals (9.2%) [1]. The results of Yu et al. [1] corroborate those of other studies which show that concrete and steel account for the most embodied emissions in the building sector, including a study by Giesekam et al. [4] who found that 44% of industrial emissions were derived from cement and steel, whilst a study by Yan et al. [5] found that concrete or reinforced steel contributed to 94-95% of embodied material emissions. For domestic houses in Sydney, Ximenes et al. [6] calculated that a house design with the maximum use of timber could result in almost half the greenhouse gas emissions (GHGE) – around 30t CO2e – compared to a reference house by swapping the floor components including the sub-floor and floor cover from concrete to wood.

The concept of mass timber construction (MTC) refers to a construction process which utilizes wood-based materials as the main product in its structural design and development. It is primarily applied in replacing more common building materials, including reinforced concrete and steel frames. As a substitute product, MTC is suitable for low- to mid-rise buildings, and has been used worldwide in public sector projects (e.g. libraries, community hubs) as well as standalone and multi-dwelling residential units [7]. Cross-laminated timber (CLT), known as one type of Engineered Wood Product (EWP), is a prime example of an MTC product, which is manufactured by using industrial adhesives to glue together the surfaces of timber boards laid length-wise and perpendicular to each other [8, 9].

As a sustainable alternative for traditional concrete and steel construction materials, the application of MTC has significant implications for the building industry. Compared to the manufacture of concrete and steel, the MTC process consumes less embodied energy [10]. Shifts and changes in policies towards taxing and pricing carbon mean that there is economic value in carbon sequestration through the use of timber products. A study by Buchanan et al. [11] postulates that increasing the use of timber in New Zealand's building sector by 17% would result in a 20% reduction in fossil fuel energy consumption and a corresponding 20% reduction in GHGE by the manufacturing industry. In a broader context, this represents a 1.5% reduction in New Zealand's national GHGE.

Currently, Europe comprises the most developed markets in terms of MTC adoption, with countries such as Austria, Germany, Switzerland, Sweden and Norway leading the way for the rest of the world [7]. In comparison, the application of MTC in Australia is still in its infancy stages, having seen less than five total projects completed to date [7]. However, as of May 2016, amendments to the National Construction Code (NCC) and the Building Code of Australia (BCA) have allowed for the construction of residential and non-residential buildings up to 25 meters in height (or approximately 8 stories tall) in accordance with Deemed-to-Satisfy (DTS) provisions, which include the use of both EWPs like CLT and traditional lightweight timber framing [12-14]. This change in policy is anticipated to create greater opportunity and incentive for a more extensive use of timber in the development of Australia's city and urban landscapes. It is also a step forward in addressing the issue of direct GHGE from the construction industry, which is experiencing tremendous growth driven by a population that is expected to increase to 32 million people by 2036 and require an incremental 4.2 to 4.3 million new houses to be built [15]. To help drive construction of mid-rise timber buildings in Queensland, The University of Queensland has established a new research center, The Center for Future Timber Structures, to innovate new timber building products, assess the barriers to timber use and increase timber use in the built environment [16].

The aim of this paper is to investigate the consequences for total carbon footprint and direct industry GHGE when building designs shift towards using low-carbon construction materials. Scenario analysis based on hybrid life-cycle assessment (LCA) was conducted to evaluate the carbon footprint of timber building stocks and potential carbon savings through its use in the construction industry compared to more common building materials such as concrete. The results were also compared to an alternative scenario whereby low-carbon (geopolymer) concrete is used instead of timber. Geopolymer concrete does not contain any Portland cement, which is energy and emission intensive to