Life Cycle CO2 Emission Analysis of Residential Buildings in Japan

Topic: Sustainable Production and Consumption
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Climate change is a major issue for human society, with many governments setting goals of achieving net-zero CO2 emissions The building sector accounts for approximately 30% of global energy consumption, and measures are urgently needed for this sector. In Japan, the turnover of housing stock is relatively high compared to other developed countries, partly due to the short legal lifespan of housing. This results in frequent demolitions and reconstructions, leading to significant CO2 emissions from construction activities.

Understanding the life cycle CO2 emissions of residential buildings is essential for sustainable urban development. To address this issue, efforts to reduce CO2 emissions at the construction stage are also crucial. One such effort is the promotion of wood use in buildings as a strategy to mitigate climate change. Japan has implemented policies to encourage the use of wood in construction, such as the Act on the Promotion of Wood Use in Public Buildings (enacted in 2010 and revised in 2021 as the Act on the Promotion of Wood Use in Buildings for Contributing to the Realization of a Carbon-Free Society), which extends the emphasis on wood utilization to all types of buildings. In response to these trends, several previous studies have analyzed the lifespan of Japanese houses (Kayo & Tonosaki, 2022) and CO2 emissions from wooden houses (Imada et al., 2024).

In Japan, residential buildings that have exceeded their statutory durability period are still traded in the real estate market after undergoing renovations or refurbishments, which extend their lifespan. Extending the lifespan of such older residential buildings through renovations or refurbishments may reduce environmental impact compared to constructing new ones. However, it remains unclear how extending the economic lifespan of residential buildings through renovations or other means affects CO2 emissions throughout their life cycle. Therefore, this study addresses a crucial research question: What role does extending the lifespan through renovation play in reducing the life cycle CO2 emissions of residential buildings?

The novelties of this study are as follows. First, this study is the first attempt to estimate the supply chain CO2 emissions during the construction phase of residential buildings for different construction method. To achieve this, we adopted an Environmentally-Extended Input-Output (EEIO) analysis and calculated direct and indirect CO2 emissions in the construction supply chain of residential buildings in Japan by construction method. This analysis was based on the Japanese Input-Output Tables in 2015 and the Embodied Energy and Emission Intensity Data (3EID) for Japan Using Input-Output Tables provided by the National Institute for Environmental Studies of Japan, and the statistical survey of building starts in 2015 conducted by the Ministry of Land, Infrastructure, Transport and Tourism.

Second, this study analyzed the CO2 emissions from both the construction and use phases of residential buildings in Japan and evaluated the impact of extending their economic lifespan through renovation on their overall life cycle CO2 emissions. Using data on real estate information actually traded in Japan and data on transaction land prices, we estimated the economic value of older residential buildings and the examined the difference in CO2 emissions during the use phase depending on whether or not the housing has been renovated.

As a result, we found that the COâ„ emissions during construction phase per unit of floor area were 195 kg-COâ„/mÂ² for wooden houses, 1,109 kg-COâ„/mÂ² for steel-reinforced concrete houses,

857 kg-COâ„/mÂ² for reinforced concrete houses, and 803 kg-COâ„/mÂ² for steel-framed houses. Furthermore, the results indicate that a shorter economic lifespan of residential buildings significantly contributes to higher CO2 emissions, whereas extending their lifespan gradually reduces CO2 emissions.

In conclusion, this study highlights the importance of integrating life cycle CO2 emission considerations into housing policies and urban planning. Renovation and retrofitting emerge as viable solutions to balancing economic and environmental sustainability while extending the functional lifespan of residential buildings. The findings provide valuable insights for policymakers, architects, and urban planners who aim to achieve low-carbon housing in Japan and beyond.