

Development of a Framework for Sharing the Cost of Carbon Footprint Reduction in Products

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論文名： Development of a Framework for Sharing the Cost of Carbon Footprint Reduction in Products
(製品におけるカーボンフットプリント削減コストの分担に関する枠組みの構築)

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論 文 内 容 の 要 旨

Today, Global warming is currently a serious issue, and the IPCC (2022) emphasizes the urgent need for action. It is expected that CO₂ emissions from existing fossil fuel infrastructure, without additional mitigation measures, will exceed the remaining carbon budget for the 1.5°C target. Japan has declared its goal to achieve carbon neutrality by 2050. Among all sectors, the iron and steel sector accounts for approximately 14% of Japan's total CO₂ emissions in 2022. The iron and steel sector is closely linked to the construction sector through the supply chain. In housing construction, steel products are heavily used, and the decarbonization of the iron and steel sector has a significant impact on reducing the environmental burden of the construction sector. In addition, wooden houses account for about 90% of detached houses in Japan. While the spread of mid- and high-rise wooden buildings is expected, the increase in CO₂ emissions during construction is a concern. It has been shown that 94% of the CO₂ emissions associated with the final demand of the construction sector originate from the supply chain. In other words, most of these emissions are indirect, resulting from upstream activities related to construction. Therefore, coordinated mitigation efforts across multiple sectors are essential. Given the high costs of technology development and capital investment in the steel sector, combined with intense international competition, it is essential to allocate decarbonization costs across the entire supply chain. This study aims to identify CO₂ emission hotspots in the supply chain of wooden houses in Japan and to examine effective strategies for distributing the steel sector's decarbonization costs throughout the supply chain.

This study consists of five chapters. Chapter 1 outlines the current environmental situation of Japan's construction and steel sectors and clarifies the main research objectives of this study.

Chapter 2 reviews previous empirical studies that assessed environmental burdens in the construction and steel sectors using life cycle assessment (LCA) and environmentally extended input-output analysis (EEIOA), along with literature on emissions responsibility, to highlight the empirical contributions of this study.

Chapter 3 focuses on wooden houses, which account for 90% of Japan's housing stock, and analyzes CO₂ emission hotspots in the construction supply chain. First, the CO₂ emissions associated with the construction of a single average wooden house in 2015 were estimated using EEIOA. Then, a unit structure model was used to visualize the intermediate input structure, and a weighted adjacency matrix was created based on emission amounts. This was followed by an industrial cluster analysis. The main findings are as follows: (1)

The total direct and indirect CO₂ emissions per house are about 38 t- CO₂, with electricity, pig iron, cement, freight transport, and self-generated electricity sectors accounting for 65% of the total. Notably, pig iron and crude steel alone account for 12%. (2) Cluster analysis revealed that a cluster composed of steel and cement sectors is the largest source of emissions. Based on these results, this chapter proposes CO₂ mitigation strategies such as renovating vacant houses with reused foundations that contain large amounts of steel and cement, and supporting the introduction of low-carbon technologies in the steel sector. It also suggests that the government should mandate construction companies to report and disclose the carbon footprint of their new residential buildings.

Chapter 4 explores how to allocate emission responsibility and decarbonization costs related to the steel sector using EEIOA and structural path analysis. Specifically, CO₂ emissions are compared under the consumption-based and shared responsibility approaches and are analyzed at the supply chain path level. The main findings are as follows: (1) Under the production-based approach, the steel sector bears all the emission responsibility, whereas under the consumption-based approach, final goods sectors such as automobiles and non-wooden construction are the main drivers, and the steel sector's responsibility is significantly reduced. (2) Under the shared responsibility approach, the responsibility is fairly distributed between the steel sector and intermediate goods sectors. Even when the steel sector does not directly supply final goods sectors, it still bears indirect responsibility through the supply chain. (3) Using government-published cost estimates for technologies such as electric arc furnaces and hydrogen-based steelmaking, the thesis allocates decarbonization costs based on each sector's CO₂ contribution. As a result, the shared responsibility approach yields lower cost burdens for many sectors compared to the consumption-based approach. For example, the shipbuilding sector saw a difference of more than 20%. Based on these findings, this chapter proposes that designing flexible and effective support schemes that take into account both emission responsibility and payment capacity across sectors is essential for implementing realistic decarbonization policies.

Chapter 5 summarizes the analysis results obtained from Chapters 3 and 4, and presents the conclusions of this thesis.