A Comprehensive Life Cycle Analysis of Old- and Next-Generation Ships

Topic: Sustainable Production and Consumption Policies
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The International Maritime Organization (IMO) revised its Greenhouse Gas (GHG) Strategy to achieve net-zero GHG emissions from international shipping by 2050. Following this global trend, Japan is also taking actions to reach this goal by introducing Liquefied Natural Gas instead of heavy oil as marine fuel and investing in steel ships operated by hydrogen or ammonia, which do not emit any GHG on board.

It is important to note that ship components (e.g., engine, fuel tank, and fuel supply system) vary in size and require different materials for construction. Consequently, the intermediate inputs necessary for manufacturing ships significantly affect the amount of CO2 emissions directly and indirectly induced by the manufacturing process. A previous study also discusses the feasibility of reducing onboard fuels by weight (Kim and Choi, 2023).

Few previous studies have analyzed the amount of CO2 emissions in the manufacturing process of ships with hydrogen- or ammonia-combustion engines. In a relevant prior study, Shi et al. (2023) emphasized the importance of the green fuel pathway in shipping, as well as the manufacturing of ships. They analyzed the cost of introducing renewable energy throughout the ship life cycle. To the best of our knowledge, there have been no previous studies addressing a comprehensive life cycle analysis of next-generation ships with hydrogen- or ammonia-combustion engines. The novelty of this study is the following. This study represents the first attempt to clarify the effectiveness of introducing eco-friendly fuel alternatives to heavy oil to decrease the amount of life-cycle CO2 emissions for a specific ship type and weight.

To calculate the amount of CO2 emissions from manufacturing a specific type of ships in Japan in 2015, we utilized detailed ship inventory data from the Ministry of Land, Infrastructure, Transport and Tourism, 2015 Input-Output Tables for Japan from the Ministry of Internal Affairs and Communications, and the 3EID database (Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables) from the National Institute for Environmental Studies.

The results show that the final demand for steel ships manufactured in Japan contributed to emitting 10 million t-CO2e of CO2. Breaking down the emissions based on ship materials, pig iron and electricity had the highest CO2 emissions, in that order, accounting for about 35% and 17% of the total CO2 emissions from ship manufacturing, respectively. This suggests that the amount of CO2 emissions could be affected if ship materials and components are changed due to fuel substitution.

Subsequently, based on the Statistical Survey Data on Coastwise Vessel Transport from the Ministry of Land, Infrastructure, Transport and Tourism, we calculated the amount of CO2 emissions from operating large and small ships, including cargo ships and oil tankers, in Japan in 2015. The results show that the amount of CO2 emissions was about 6.6 million t-CO2e to operate the ships in 2015. Based on these results, we found that the annual CO2 emissions per ship at the manufacture and operation stages were 320 t-CO2e and 49,000 t-CO2e for small ships, respectively. For large ships, the annual CO2 emissions per ship at the manufacture and operation stages were 13,000 t-CO2e and 103,000 t-CO2e, respectively. When comparing CO2 emissions between ship manufacture and operation, large ships emit 152 times more CO2 during operation than during manufacture, while small ships emit 8 times more.

Importantly, we further found that next-generation ships with hydrogen- or ammonia-combustion engines have significant CO_2 reduction potential throughout their life cycle. Thus, this study suggests promoting fuel substitution during operation while considering changes in CO_2 emissions during ship production.