Chapter 7
CO2 Emission Calculations in Shipping for Sustainable Ship Design, Construction, and Operation:
Assessing Strategies and Regulatory Tools for Low-Carbon Maritime Innovation

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ABSTRACT

Global trade considerably depends on maritime transportation, yet these activities generate substantial greenhouse gas (GHG) emissions, raising critical concerns

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among policymakers about climate change. In response, the International Maritime Organization (IMO) has implemented stringent regulatory measures towards the construction of energy-efficient ships and operations to reduce carbon emissions from both new and existing vessels. This chapter explores key IMO approaches, including the Energy Efficiency Design Index (EEDI), the Energy Efficiency Existing Ship Index (EEXI), the Ship Energy Efficiency Management Plan (SEEMP), the Energy Efficiency Operational Index (EEOI), and the Carbon Intensity Indicator (CII). The study performs a quantitative analysis of GHG emissions for real ships to validate IMO's emission targets. This chapter highlights the importance of integrating sustainable design principles and operational strategies to mitigate unsustainable practices in shipbuilding and maritime operations, paving the way for environmentally responsible shipping.

INTRODUCTION

The maritime industry plays a critical role in global trade and commerce, with over 80% of goods being transported via ships (Roy & Chakraborty, 2025). However, despite its economic significance, the maritime sector is a major contributor to global greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2). Studies demonstrate that international maritime transport produces approximately 3% of global CO_2 emissions and predict this share will rise substantially because of a lack of effective reduction strategies (EEA, 2022). Ship engines burning fossil fuels produce emissions threatening climate systems and human health. The rising importance of environmental sustainability and decarbonization objectives makes shipping CO_2 emission reduction significant for stakeholders. Thus, the International Maritime Organization (IMO), the regulatory body of shipping, established stringent regulations to lower shipping GHG emissions by enhancing vessel design and operational efficiency measures for existing and new ships. IMO regulatory instruments such as the Energy Efficiency Design Index (EEDI), the Energy Efficiency Existing Ship Index (EEXI), the Ship Energy Efficiency Management Plan (SEEMP), the Energy Efficiency Operational Index (EEOI) and the Carbon Intensity Indicator (CII) serve as an essential mechanism to ensure compliance with global decarbonization targets (Alhasnawi et al., 2024).

The EEDI, introduced in 2013, mandates minimum energy efficiency construction standards for new ships. The EEDI requires ships to achieve specific energy performance levels based on their capacity and function, encouraging the adoption of fuel-efficient designs and technologies (Barreiro et al., 2022). IMO's short-term emission reduction strategy, the EEXI, serves as a requirement for existing vessel compliance. The EEXI system differs from EEDI because it assesses existing ships

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