Journal of
Marine Science and Engineering

MDPI

Article

Reducing Emissions in the Maritime Sector: Offshore Wind Energy as a Key Factor

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Abstract: The maritime environment is the setting for a variety of economic activities, such as offshore wind energy, aquaculture, salt extraction, and oil and gas platforms. While some of these activities have a long-term presence, others require decarbonization as they head towards their demise. In this context, the aim of this study is to develop a methodology to replace the electrical energy from offshore high-emission industrial processes with clean electricity generated by offshore wind energy. The proposal is structured in three phases: initiation, which involves the collection of quantitative, technical, and geospatial information of the study area; indicators, where the main indicators are calculated, and the best alternative is selected using multi-criteria evaluation methods; and finally, short-, medium-, and long-term scenarios are proposed. The methodology is evaluated in Spain, and the best alternative, which has a nominal power of 225 MW, is capable of avoiding up to 1.44 $MtCO_2$ by 2050.

Keywords: offshore wind energy; optimal selection; maritime sector; multi-criteria evaluation methods

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Citation: Gil-García, I.C.; Fernández-Guillamón, A. Reducing Emissions in the Maritime Sector: Offshore Wind Energy as a Key Factor. *J. Mar. Sci. Eng.* **2024**, *12*, 1985. https://doi.org/10.3390/jmse12111985

Academic Editor: Markel Penalba

Received: 8 October 2024
Revised: 1 November 2024
Accepted: 1 November 2024
Published: 3 November 2024

1. Introduction

In the current context of the climate emergency, transitioning the energy system towards a fossil-fuel-free model emerges as a crucial and urgent response to the global challenges posed by climate change [1]. This energy transformation is not only necessary but imperative to meet international commitments, such as the Paris Agreement. This commitment aims to limit the global temperature increase to 1.5 °C above pre-industrial levels [2] and is considered essential by the scientific community. In fact, exceeding this threshold could trigger irreversible and catastrophic climate impacts, affecting both ecosystems and human societies worldwide [3]. The shift towards clean, sustainable, and fossil-fuel-free energy is a complex challenge that requires a comprehensive rethinking of the current energy system. Renewable energy sources (such as solar, wind, geothermal, and hydroelectric power) play a central role in this transition, providing clean and accessible energy that, unlike fossil fuels, does not emit greenhouse gases [4].

However, the widespread adoption of these technologies requires significant investment in infrastructure and technology, as well as a structural transformation in how countries produce, distribute, and consume energy. A key component of this transformation is clean electrification. The acceleration of electrification through renewable energy sources not only reduces carbon emissions in sectors traditionally dependent on fossil fuels (such as transportation and industry), but also fosters the development of more efficient and resilient power grids. These grids need to include emerging technologies like energy storage systems and smart systems to ensure the stability of the electricity supply, mainly due to the intermittent nature of renewable sources like solar and wind [5]. Moreover, and despite the technological advances, the energy transition cannot rely solely on technology; a coordinated and collaborative global effort is necessary. Governments, industries, and other key stakeholders must work together