UNIVERSIDAD TECNICA
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Tesis de Magister

Design and Sizing of an Energy Storage System for a Hybrid Tugboat

Tesis para optar al título de
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Agradecimientos

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Capítulo 1

Introduction

1.1. Motivation and Background

The growing global concern over climate change has significantly pressured industries to adopt sustainable practices. The maritime sector, responsible for approximately 30 % of global CO_2 emmisions, has continuosly increased int emissions, as shown in Fig. 1.

https://theroundup.org/co2-greenhouse-gas-emission-statistics/
https://www.container-xchange.com/blog/shipping-emissions/

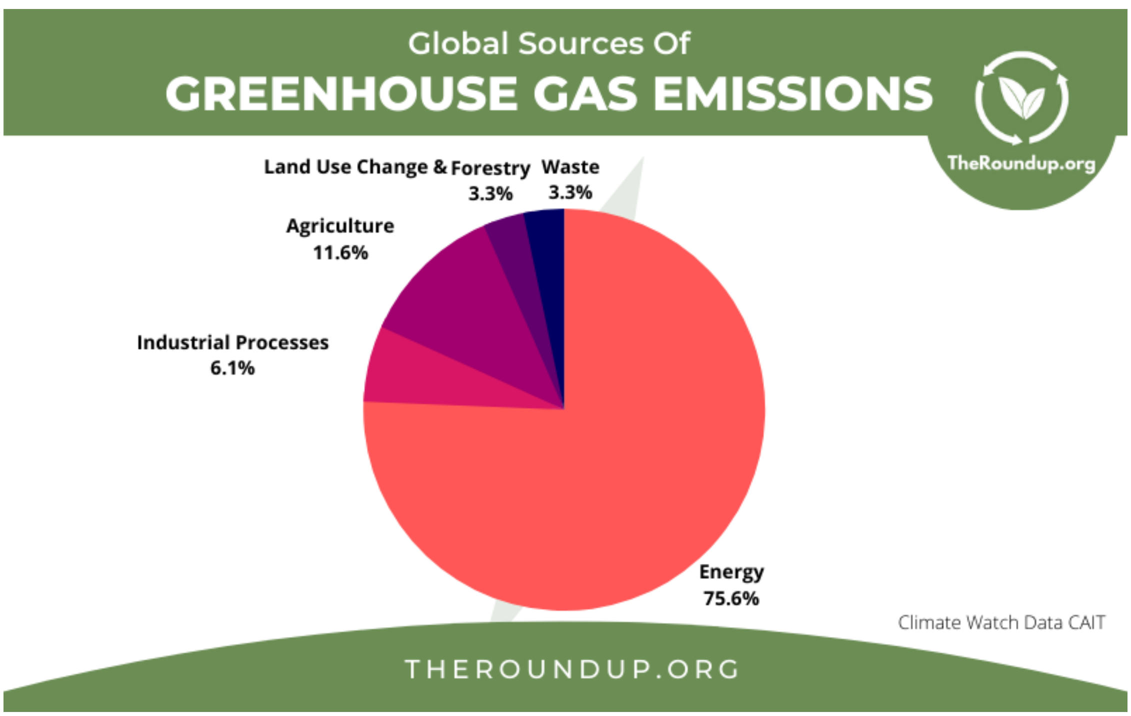
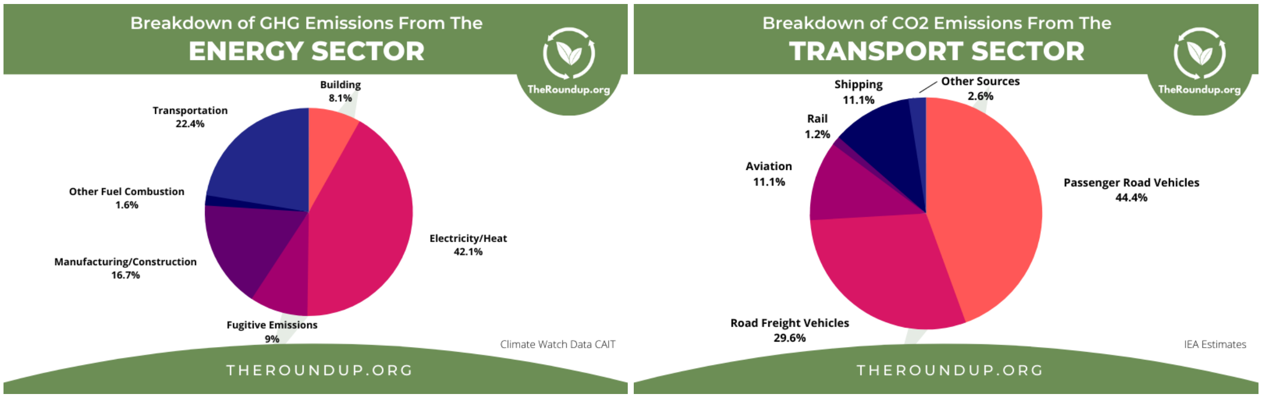


Figura 1.1: Global sources of greenhouse gas emissions. Source: theroundup.org

Addressing emission reduction is critical, as strict regulations on emissions and fuel efficiency aimed at mitigating the environmental impact of maritime activities are being implemented worldwide [2].

One promising approach is adopting electro-mobility technologies in maritime operations. In this context, electromobility can be implemented through various strategies [3], from hybrid



(a) CO_2 emissions from the energy sector. (b) CO_2 emissions from the transport subsector.

Figura 1.2: Breakdown of CO_2 emissions from the energy sector and the transport subsector. Source: theroundup.org

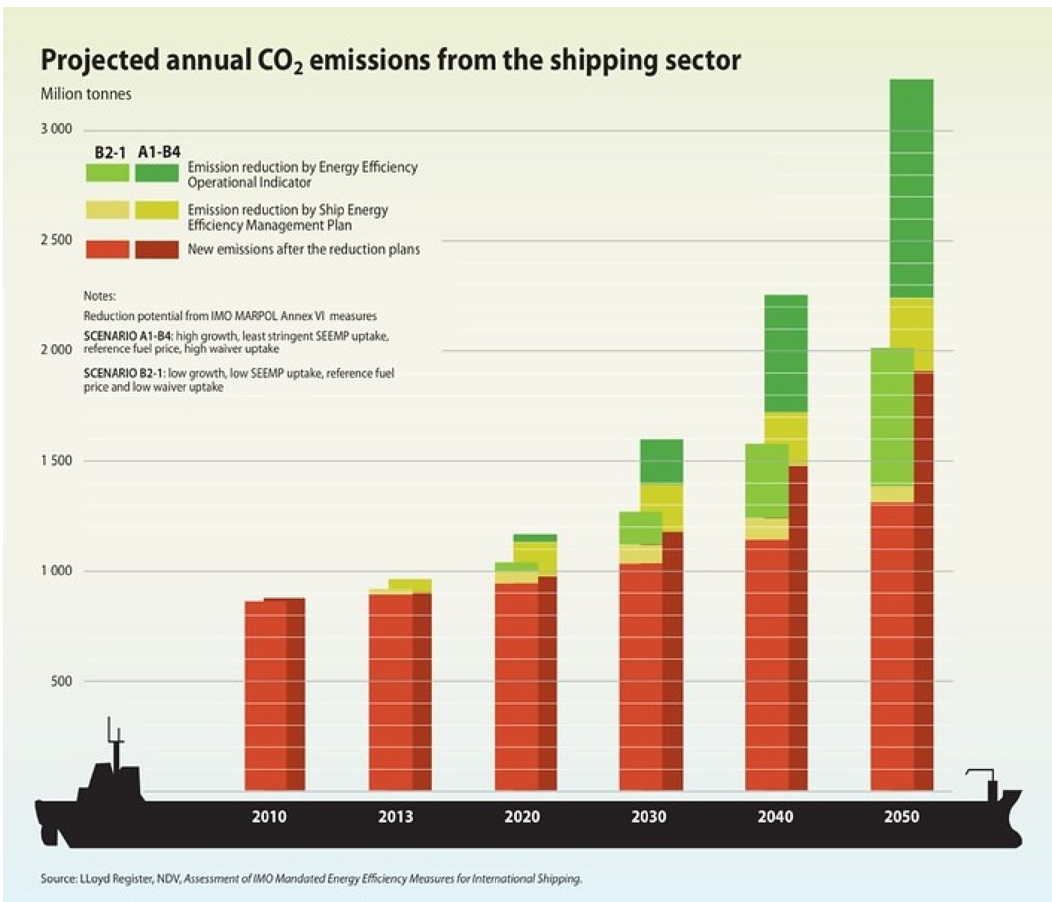


Figura 1.3: IMO greenhouse gas emissions strategy. Source: Lloyd Register, NOV, Assestment of IMO Mandated Energy Efficiency Measures for International Shipping

propulsion systems to fully electric vessels [4]. Hybrid propulsion, in particular, combines the advantages of diesel engines with electric power systems, offering a flexible and efficient solution for reducing emissions without compromising performance [5]. The hybridization of propulsion systems relies on the separate or simultaneous use of different energy sources [1].

Several studies have examined hybrid propulsion systems. A marine hybrid propulsion system, focusing on vector control of the electric motor during different modes and verifying the control feasibility [6]. The optimization of hybrid propulsion system design for a tugboat has been explored, presenting a methodology that streamlines powertrain component sizing and control, minimizing costs for a specific operating profile [7]. A coordinated control strategy for a variable-speed hybrid tugboat have been presented to improve fuel economy. The proposed strategy, validated through simulations and a smallscale experimental testbed, showed reduced costs and lower CO2 emissions [8].

Among vessel types, tugboats—used for towing and maneuvering large ships—are among the highest emitters per unit of energy due to their highly variable load profiles [3]. Tugboats and ferries are ideal candidates for hybridization due to their operational profiles, which involve prolonged idling, low-speed maneuvering, and frequent speed changes that lead to inefficient fuel consumption [9].

This paper focuses on designing and sizing an energy storage system for a hybrid tugboat as a specific electro-mobility solution. Despite advancements in marine hybrid technologies, a standardized methodology for tugboat hybridization remains undefined [10]. The study presents a design methodology addressing parameters such as load profiles, power and energy demands, battery technology selection, and propulsion system optimization. Theoretical analysis is presented and simulation shows a emissions reduction while maintaining the robustness needed for towing and transit activities.

1.2. Challenges and Research Opportunities

1.3. Thesis Objectives and Outline

[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23],

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