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Shore power system and its environmental impact *in the Port of Santos*

Sistema shore power e seu impacto ambiental no Porto de Santos

El sistema eléctrico terrestre y su impacto ambiental en el Puerto de Santos

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Abstract :

This work presents an analytical approach regarding the Shore Power system's viability and effectiveness in the Port of Santos. Seeking to identify its objectives for reducing pollutant emissions by environmental regulations, the service capacity of this system and its Infrastructure, including energy supply, capacity and compatibility with the needs of ships. Comparing its environmental and economic benefits in addition to the cost of your investment. Analysis of this system is an important component of efforts to make maritime transport more sustainable. This academic research is justified in providing important information for decision-makers, the maritime industry, and researchers interested in finding sustainable solutions for maritime transport in the Port of Santos. Based on available scientific evidence, this study is expected to contribute to developing policies and practices that promote the reduction of emissions at the Port, reducing environmental impacts and improving global air quality.

Keywords: *energy; Port; shore power; sustainability; technology.*

Resumo:

Este trabalho apresenta uma abordagem analítica a respeito do sistema Shore Power quanto à sua viabilidade e eficácia no porto de Santos. Buscando identificar os seus objetivos para a redução das emissões dos poluentes, conforme a regulamentação ambiental, a capacidade do atendimento desse sistema e sua infraestrutura, incluindo a capacidade de fornecimento de energia e a compatibilidade com as necessidades dos navios. Comparando seus benefícios ambientais e econômicos, além do custo de seu investimento. A análise desse sistema é um componente importante dos esforços para tornar o transporte marítimo mais sustentável. A justificativa para essa pesquisa acadêmica é fornecer informações importantes para tomadores de decisão, indústria marítima e pesquisadores interessados em encontrar soluções sustentáveis para o transporte marítimo no porto de Santos. Com base nas evidências científicas disponíveis, espera-se que este estudo contribua para o desenvolvimento de políticas e práticas que promovam a redução das emissões

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no porto, minimizando assim os impactos ambientais e com melhoria da qualidade do ar global.

Palavras-chave: energia; porto; shore power; sustentabilidade; tecnologia.

Resumen:

En este trabajo se presenta una aproximación analítica al sistema de energía costera en cuanto a su factibilidad y efectividad en el puerto de Santos. Buscando identificar sus objetivos para la reducción de emisiones contaminantes, de acuerdo a la normatividad ambiental, la capacidad de servicio de este sistema y su infraestructura, incluyendo la capacidad de suministro de energía y la compatibilidad con las necesidades de los buques. Comparando sus beneficios ambientales y económicos, así como el costo de su inversión. El análisis de este sistema es un componente importante de los esfuerzos para hacer que el transporte marítimo sea más sostenible. La razón de ser de esta investigación académica es proporcionar información importante para los tomadores de decisiones, la industria marítima y los investigadores interesados en encontrar soluciones sostenibles para el transporte marítimo en el puerto de Santos. Con base en la evidencia científica disponible, se espera que este estudio contribuya al desarrollo de políticas y prácticas que promuevan la reducción de emisiones en el puerto, minimizando así los impactos ambientales y mejorando la calidad del aire global.

Palabras clave: *energía; puerto; energía costera; sostenibilidad; Tecnología.*

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1. Introduction

Shipping is vital in global trade, accounting for a significant portion of global cargo transportation. However, emissions from this sector have contributed to air pollution, climate change and human health impacts. To address these issues, the International Maritime Organization (IMO) implemented regulations in 2020 to limit the content of sulfur and other pollutant gases in fuels used by ships.

These regulations aim to reduce sulfur oxide (SOx) emissions and fine particles that harm the environment and human health. Studies show that SOx emissions from shipping account for a significant proportion of global emissions, contributing to acid rain and respiratory problems.

Shore Power, also known as "shore power supply," is a system used at docks to provide electricity to ships while they are at berths; instead of ships using their own diesel generators to produce electricity while in Port, this system allows them to connect to a clean, onshore power source while they are docked. This avoids burning tons of fuel that emits high CO2, NOx, SOx, and other particles into the atmosphere.

To investigate the impacts of these regulations and find sustainable solutions, methodologies based on the review of specialized scientific literature, including academic articles, government reports and data from international organizations such as the IMO and the International Energy Agency (IEA), were used. This approach made it possible to analyze the effects of regulations already implemented in different regions and identify the best practices to reduce emissions in maritime transport.

In this context, it is important to highlight the role of the Port of Santos. As one of the largest ports in Latin America and an important entry and exit point for goods, the Port of Santos plays a crucial role in maritime trade and cargo transportation. Implementing IMO regulations in the Port of Santos is essential to reducing pollutant emissions and promoting more sustainable practices in the sector, contributing to the preservation of the environment and improving the quality of life in the region.

2. Theoretical Basis

The Shore Power system is an important technology for improving port operations and reducing pollution, including in the Port of Santos. Studies carried out by Vidal (2022), the Transportation Research Part E article (2022), SEBRAE (2023), US Environmental Protection Agency (2017) and the project led by UNIVALI (2020) highlight how Shore Power can be an innovative solution to make maritime transport more sustainable and reduce its impact on the environment. In the context of the Port of Santos, its implementation can contribute to protecting the coastal ecosystem and encourage companies' use of carbon credits, promoting significant environmental and economic benefits (SPA, c2023).

2.1 Shore Power System

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The term "Shore Power" or "shore power supply" used in this article refers to a system that uses electrical energy from port facilities to supply ships. This process allows emergency equipment, refrigeration, cooling, heating and lighting to continuously receive power while the main and auxiliary engines remain switched off.

It is considered a sustainable alternative as it replaces diesel in energy generation, reducing the emission of toxic gases, polluting particles and noise caused by vessels.

2.2 Port of Santos

The Port of Santos originated in the 16th century when it operated with simple and rudimentary structures. At the end of the 19th century, it was granted to private investors, and the *Companhia Docas de Santos* (CDS) was established in 1890 to manage it. In 1892, the CDS built the first 260 meters of quay, inaugurating the first Organized Port of Brazil (SPA, c2023).

The strategic location of the Port of Santos was a crucial factor in its development. Initially situated on the coast, the founder of Santos, Brás Cubas, realized that moving the port inland from the estuary would offer more excellent protection against storms and pirate attacks. Thus, the Port was established at the site known as Valongo, where the old berths had been located (SPA, c2023).

With the expansion of sugar production in the interior of the State of São Paulo, Calçada do Lorena, a paved road that facilitated access to the Port, was built at the end of the 18th century. From 1795 onwards, this route also began to be used for coffee exports (SPA, c2023).

In the 19th century, the Baron of Mauá and other businessmen convinced the imperial government of the importance of building a railway connecting São Paulo to the Port of Santos. In 1867, the São Paulo Railway was inaugurated, allowing production flow in just four hours of travel. (SPA, c2023)

Over the years, the Port of Santos has become an important center for maritime trade. It is now the largest Port in Latin America, playing a fundamental role in the country's economy (SPA, c2023).

2.2.1 Infrastructure

The Port is located along the Santos estuary on the coast of the state of São Paulo, between the boundaries of the Santos, Guarujá and Cubatão municipalities. Its territorial extension is 16 km and has a total functional area of 7.8 million m². Its navigation channel is 30 km long and 15 m deep. Approximately 13 km of berths and more than 60 berths are composed of public and private terminals (TUPs) focused on storing and moving cargo and passengers (SPA, c2023).

SANTOS PORT AUTHORITY (SPA) is the entity responsible for managing, controlling and inspecting this infrastructure and port facilities. This privately held public company is linked to the *Ministério da Infraestrutura* (MINFRA),

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formerly the *Companhia Docas do Estado de São Paulo* (CODESP) and *the Agência Nacional de Transportes Aquaviários* (ANTAQ).

As a multipurpose port connected to a broad production and transportation infrastructure network, the Port of Santos enables the movement of millions of tons of goods and merchandise. It is the largest port complex in Latin America (SPA, c2023).

2.2.2 Implementation and Installation

The Port of Santos's Infrastructure for implementing Shore Power involves installing electrical connection equipment, such as transformers and power distribution panels, at the berths. In addition, it is necessary to adapt the vessels to receive electrical energy supplied from the shore by installing compatible connection systems. It is also important to provide a stable electrical grid with sufficient capacity to meet the energy demand of the vessels. These measures will allow vessels docked at the Port of Santos to use Shore Power as an energy source, thus reducing the use of diesel generators and the associated environmental impacts (Vidal, 2022).

3. Method

3.1 Carbon Emissions

Greenhouse gas inventory is an essential tool for assessing and monitoring greenhouse gas emissions in a given region. In the situational diagnosis of greenhouse gases in the Port of Santos, Santos Port Authority (SPA) plays a key role in collecting and analyzing this data.

Table 1 shows some of the leading greenhouse gases' global warming potential (GWP). Carbon dioxide (CO2), the main greenhouse gas, has a GWP of 1. This means it is used as a reference for comparing the global warming potential of other gases.

Table 1: Carbon Emissions.

GAS	POTENCIAL DE AQUECIMENTO GLOBAL
Dióxido de Carbono (CO_2)	1
Metano (CH_4)	28
Óxido de Nitrogênio (N_2O)	265

Source: GHG Protocol (2022).

According to Table 1, methane (CH4) has a GWP of 28 times higher than carbon dioxide. This is due to its ability to retain heat in the atmosphere for a shorter period. Nitrous oxide (N2O), in turn, has an even higher GWP, with a value of 265. This means that it has a much more significant impact on global warming compared to carbon dioxide.

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Based on this information, it is possible to carry out a more precise analysis of greenhouse gas emissions at the Port of Santos and how much it can be reduced. SPA can use this situational diagnosis to implement measures for new energy sources aimed at reducing these emissions, contributing to mitigating the impacts of climate change.

3.2 Environmental Problems

The substances mentioned in Table 1, such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), contribute to environmental problems such as global warming and air pollution. These problems are widely studied and documented by scientific and environmental organizations such as the IPCC—the Intergovernmental Panel on Climate Change. The Panel on Climate Change is the United Nations body that assesses the science related to climate change.

In the context of Port of Santos, it is important to consider the emissions of these greenhouse gases in its port activities. The situational diagnosis carried out by Santos Port the Port Authority (SPA) can help identify the primary sources of emissions and implement measures to reduce them. Based on the findings of the IPCC report, it is crucial to act urgently to limit global warming to 1.5°C and mitigate the catastrophic impacts of climate change on the Port of Santos and around the world.

3.3 The Importance of Shore Power for the Environment

According to the study by Santos et al. (2017), implementing Shore Power in the Port of Santos can significantly reduce greenhouse gas emissions. This technology allows ships to connect to the power grid instead of using diesel generators, thus reducing fuel burning and atmospheric emissions. This is corroborated by Sotello (2012), who highlights that Shore Power can reduce air pollution and improve port environmental quality. The implementation of Shore Power in the Port of Santos can result in an approximate reduction of about 1% in carbon dioxide (CO2) emissions, 28% in methane (CH4) emissions, and 100% in nitrous oxide (N2O) emissions, which are substances expelled when ships burn fuel. These results can be increased with the help of other sustainable energy sources (SPA, c2023).

3.4 Types of Sustainable Energy

Different types of sustainable energy sources exist, such as Shore Power, wind and hydropower. As Abad (2018) mentioned, these energy sources can be used to improve the construction of commercial buildings. In addition, ANTAQ's (2019) research highlights the growth in container movement in Brazilian port facilities. The use of containers in logistics, as mentioned by *Brasilmaxi Logística* (2018), has significant benefits. It is worth mentioning that the reinvention of maritime transport through containers was an important milestone, as mentioned by Keedi (2015).

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4. Results and Discussion

Analyzing Table 2 below, it is possible to observe the estimated average consumption in each Brazilian Port studied, considering the implementation of the Shore Power system. In addition, the table also shows the estimated energy cost using the utility's energy over the period from 2010 to 2020. This data provides an overview of the impact of the Shore Power system on energy consumption and associated costs in Brazilian ports. For a more in-depth analysis, comparing the values between Ports and identifying possible trends or significant variations over time would be interesting. This can provide valuable insights to improve energy efficiency and reduce port operational costs.

Table 2: Energy consumption and estimated cost using Shore Power from utility power.

Porto ou Terminal	Consumo médio entre 2010 e 2020 (MWh)	Custo estimado com energia entre 2010 e 2020 utilizando a energia da concessionária
Itaguaí	16531,70	R$ 6.943.314,00
Itaqui	33293,79	R$ 11.319.888,60
Paranaguá	53374,56	R$ 27.754.771,20
Rio Grande	55918,71	R$ 21.249.109,80
Santos	163282,56	R$ 71.844.326,40
Suape	53000,28	R$ 19.610.103,60
Terminal Aquaviário de Angra dos Reis	19817,21	R$ 7.530,539,80
Terminal Aquaviário de São Sebastião	35399,51	R$ 14.867.794,20
Terminal da Ilha Guaíba	4802,73	R$ 1.82.037,40
Terminal de Tubarão	13672,46	R$ 6.015.882,40
Terminal Marítimo de Ponta da Madeira	9129,18	R$ 3.103.921,20
Terminal Portuário do Pecém	15801,86	R$ 5.372.632,40

Source: ANDRADE et al. (2023)

The Port of Santos, with the approval of the Ministry of Ports and Airports, will reduce the tariffs charged to so-called "green ships" with lower pollutant emissions (SPA, 2023). The proposal encourages both port facilities and vessels to reduce emissions of pollutant gases such as NOx and SOx beyond the regulated limits.

Table 3: Shore Power energy discount spreadsheet.

Pontuação ESI (*score*)	Desconto
De 0 a 30	0%
De 31 a 50	5%
De 51 a 70	10%
De 71 a 100	15%

Source: SPA (2022)

The Environmental Ship Index (ESI) scoring spreadsheet determines the energy discount for ships that use Shore Power or any other system and technology. Thus, generating an incentive for its use, the score varies from 0 to 100, and the

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discount is applied according to pre-defined ranges. The higher the score, the greater the energy discount.

5. Conclusion (or Final Considerations)

Countries are increasingly concerned about the environmental impact generated by cultural and economic exchange in global maritime transport. To reduce damage to air quality in port cities, this study analyzed the implementation of a system known as Shore Power, which provides clean electrical energy to ships, minimizing potential negative impacts on the Port of Santos.

The implementation of the Shore Power system in the Port of Santos has proven viable due to the significant reduction in pollutant gas emissions. Furthermore, the results of this study indicate that the use of Shore Power not only contributes to the reduction of emissions but also to the reduction of noise, which facilitates its adoption in the port sector. Taken together, these results suggest that the viability of Shore Power is related to the price of electricity compared to fuel oil and the use of renewable energy sources.

Therefore, this study can contribute to the economic analysis and cost comparison between Onshore Energy and fuel oil used in the port sector. Additionally, it is recommended that further research be carried out to investigate the possibility of implementing Onshore Energy in other ports and to analyze its potential to reduce emissions in the sector further.

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