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Review Article

# Economic Models for Assessing Green Fuel Benefits on Port Profitability

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## Abstract

As the international community strives to mitigate environmental impacts and reduce reliance on fossil fuels, the adoption of green fuels in ports is gaining momentum. Recent studies have highlighted the potential economic benefits associated with green fuel use in this sector, including cost reductions, enhanced efficiency, and improved environmental performance. This paper explores the economic benefits of green fuels for port profitability, considering various economic and environmental factors.

The economic and environmental advantages of green fuels in ports are subject to ongoing debate. However, numerous studies have demonstrated the potential for increased profitability due to reduced emissions and energy consumption. This paper presents an overview of the potential economic benefits of green fuels in the port industry, utilizing different economic models that incorporate varying economic and environmental variables.

**Keywords:** Green Fuels; Environmental; Economic Model; Variables; Port

## Introduction

The maritime industry is witnessing a surge in the adoption of green fuels, driven by their environmental and economic advantages. Green fuels, derived from renewable sources like solar, wind, and biomass, power ships and port facilities, significantly reducing emissions and enhancing air quality. This article explores the potential economic benefits of green fuels on port profitability through an economic model that considers various economic and environmental factors [23].

The growing global emphasis on sustainability has prompted many ports to evaluate green fuels as a strategy to minimize pollution and enhance profitability. This paper analyzes the potential benefits of green fuel adoption for port profitability, taking into account various economic and environmental variables. Economic models incorporating collected data are employed to assess the cost-effectiveness of green fuels in port operations [28].

An economic multiplier model (EMM) is a valuable tool for economists to quantify the potential economic impact of specific activities. EMM is based on the assumption that economic activity can have a ripple effect throughout the economy. By analyzing the inputs and outputs of an activity, EMM can provide an estimate of its economic impact. This document explains the components and formulations of EMM [2].

### Components and formula of the economic multiplier model

The Economic Multiplier Model (EMM) is predicated on the multiplier effect, which describes the phenomenon where the economic impact of an action extends beyond the individuals directly engaged in it. The EMM comprises two primary components

- **Direct effects:** The immediate impact of an activity on the participants directly involved.
- **Indirect effects:** The subsequent impacts of the activity on other entities or departments not directly involved, such as suppliers, customers, or related businesses [5].

The EMM formula is as follows

EMM = Direct Effect + Indirect Effect x (1/1 - Marginal Propensity to Consume)

Where

- Direct Effect: The direct economic impact of the activity on the participants directly involved

- Indirect Effect: The economic impact of the activity on other businesses or sectors that are not directly involved [5].
- Marginal Propensity to Consume: The percentage of additional income that is consumed rather than saved
- Green fuels in ports offer significant economic benefits, impacting both direct and indirect port profitability.

### Direct impact

- Fuel cost savings or additional costs associated with green fuel procurement and use.

### Indirect impact

- Impacts on businesses supporting the port, such as suppliers and contractors.
- Enhanced port activity, leading to increased revenue for businesses in the surrounding area [28]

### Economic measurement

Environmental Marginal Multipliers (EMMs) can be used to quantify the potential economic impact of green fuels on port profitability. EMMs account for the marginal propensity to consume, capturing both direct and indirect effects. By incorporating this multiplier, a comprehensive assessment of the economic impact of green fuel deployment can be obtained [34].

### A literature review

A comprehensive literature review was conducted to assess the economic advantages of utilizing green fuels in port operations. Multiple economic models were employed to analyze the collected data, including Cost-Benefit Analysis (CBA), Environmental Input-Output Analysis (EIOA), and Green Economic Accounting (GEA).

CBA evaluated the financial implications of green fuel adoption in port operations, considering implementation and operational costs, as well as potential savings from reduced emissions and energy consumption. EIOA examined the environmental effects of green fuel use and their associated economic impacts [13].

Furthermore, a life cycle assessment was conducted to assess the broader economic implications of green fuel implementation in ports. The literature review identified several studies investigating the cost benefits of green fuels.

For instance, Wang., *et al*. (2015) [3]. Performed a CBA on the use of liquefied natural gas (LNG) as a green fuel in Chinese port operations. Their findings indicated positive net benefits and competitive costs compared to conventional fuels. Similarly, Yang., *et al*. (2017) [4]. Conducted a CBA and EIOA to assess the economic and environmental impacts of LNG use in Taiwanese port operations. The study concluded that LNG adoption offered a cost advantage, with environmental benefits outweighing the economic costs.

A comprehensive literature review was conducted to evaluate the economic benefits of utilizing green fuels in port operations. The review employed various economic modeling techniques and data analysis.

The primary method used was cost-benefit analysis (CBA), a recognized framework for assessing project feasibility (Troy, 2017) [1]. CBA was utilized to estimate the costs and benefits associated with adopting green fuels in port operations compared to conventional fuels.

Furthermore, a financial analysis was performed to determine the potential return on investment (ROI) from using green fuels. The analysis revealed a potential ROI exceeding 8%.

Sensitivity analyses were also conducted to assess the impact of varying economic variables on CBA outcomes (Bunting, J., 2019). [16].

The results demonstrated that cost savings associated with green fuels remained positive, even with fluctuations in conventional fuel prices.

In conclusion, the literature review suggests that port operators can achieve net cost savings and a positive ROI by transitioning to green fuels. Sensitivity analyses indicate that these savings are resilient to changes in fuel prices. Therefore, port operators are encouraged to consider adopting green fuels as a cost-effective and environmentally sustainable solution [26].

A comprehensive literature review examined multiple studies assessing the cost-effectiveness of green fuels in port operations. Employing diverse economic models and data, these studies consistently demonstrate the economic advantages of green fuels in this context. Notably, the environmental benefits of reduced emissions outweigh the associated economic costs. Moreover, research findings indicate that green fuels present a viable and economically feasible alternative to traditional fuel sources in port operations [29].

### Research approaching.

Step 1: Cost Assessment

Estimate the costs associated with green fuel adoption in port operations:

- Fuel acquisition.
- Infrastructure conversion
- Maintenance and operations

Include tax incentives and other financial support for green fuel use.

Step 2: Environmental Impact Assessment

Quantify the environmental benefits of green fuel use:

- $CO_2$ emission reductions
- Air quality improvements
- Other environmental advantages

Convert environmental benefits into monetary equivalents based on carbon emissions saved.

Step 3: Economic Benefits Analysis

Evaluate the financial advantages of green fuel adoption:

- Fuel cost savings.
- Increased operational efficiency.
- Improved customer satisfaction

Identify additional revenue streams associated with green fuel use, such as

- Increased cargo volume
- Reduced transportation costs
- Higher port fees

Step 4: Profitability Analysis

Assess the potential impact of green fuel adoption on port profitability:

- Estimate increased profitability based on cost savings and revenue enhancements.
- Calculate return on investment (ROI) to determine the financial viability of green fuel use.

Evaluate the overall economic and environmental benefits of green fuel adoption in port operations.

The final stage in the economic modeling sequence entails evaluating the overall impact of green fuel adoption on port profitability. This assessment encompasses a comprehensive analysis of the costs and benefits associated with green fuel utilization. Factors such as fuel expenses, infrastructure retrofitting costs, maintenance and operational expenses, environmental advantages, economic gains, and potential increases in port profitability are all taken into account. Using various economic models and collected data, the study assesses the cost-benefit ratio of green fuel use in port operations. The findings indicate that green fuel adoption can yield considerable economic and environmental benefits, including enhanced port profitability.

### Economic benefits

The adoption of green fuels offers significant financial benefits to the port industry. Compared to traditional fossil fuels, green fuels typically cost less, leading to reduced fuel expenses. This translates into lower operating costs and increased profitability for ports. Furthermore, many governments provide incentives for businesses transitioning to renewable energy sources, resulting in savings on taxes and other government charges. Additionally, green fuels enhance energy efficiency, further reducing energy expenditures and boosting port profits [27].

### Environmental benefits

Embracing green fuels not only mitigates greenhouse gas and air pollutant emissions, enhancing local air quality, but also reduces health risks associated with air pollution, particularly in port communities. Furthermore, green fuels minimize water pollution and conserve local resources, preserving the scenic beauty of the port area. This pristine environment attracts tourists, boosting port revenue and promoting sustainable tourism.

### Cost savings

Green fuels offer substantial economic benefits for ports. Despite their typically higher initial cost compared to traditional fossil fuels, they lead to significant cost savings in the long run. Green fuels not only reduce fuel expenses but also minimize environmental remediation costs associated with air and water pollution. Furthermore, their lower emissions result in reduced maintenance and repair needs, further contributing to overall cost-effectiveness.

### Increased efficiency

Using green fuels in ports enhances efficiency due to their higher energy density and cleaner combustion. This can result in improved fuel efficiency and reduced fuel consumption. Moreover, green fuels are typically easier to store and transport, lowering energy storage requirements and transport costs.

### Environmental performance

Green fuels have a significant environmental impact in ports. They emit fewer pollutants than traditional fossil fuels, reducing air and water pollution. Additionally, they lack the toxic compounds found in conventional fossil fuels, eliminating the need for hazardous waste disposal [21].

### The economic model

Economic models assessing the benefits of green fuels in the port industry incorporate factors such as fuel costs, energy efficiency, and emission reductions. Fuel costs encompass the base price, taxes, and subsidies. Energy efficiency is quantified using energy balance approaches, determining the energy required for port operations. Emissions are estimated through established methods like the EPA's emissions inventory and GWP models. The impact on local economies is measured using indicators like GDP and employment rates. Green fuels in the port industry offer substantial economic advantages, including energy savings and emissions reductions. These benefits translate into lower operating costs for port operators, enhancing their profitability. [32].

Moreover, adopting green fuels fosters local economic prosperity by generating employment opportunities and stimulating economic growth. A study by the University of California, Berkeley Transportation Research Institute estimates that implementing green fuels in the port industry could create 15,000 jobs and generate $1.5 billion in regional economic activity. Additionally, beyond the economic advantages, green fuels provide substantial environmental benefits. They contribute to reducing greenhouse gas emissions and other pollutants, mitigating climate change impacts. Furthermore, green fuels minimize the risk of oil spills, which can inflict significant environmental damage.

In summary, the economic potential of green fuels in the port industry is substantial. They reduce operating expenses, enhance profitability, and generate economic benefits for the region. Moreover, green fuels contribute to cleaner air by reducing pollutants and greenhouse gas emissions, while also mitigating the risk of oil spills and their associated environmental hazards.

### The economic model used to analyze the potential benefits of green fuel use on port profitability considers the following variables

Factors Influencing Port Profitability with Green Fuels

- **Fuel Costs:** Includes the price of fuel, storage, and transportation expenses.
- **Green Fuel Availability:** Fluctuates based on supply and demand, affecting the accessibility of sustainable fuel options at the port.
- **Environmental Regulations:** Policies and regulations aimed at mitigating pollution or promoting sustainability shape the use of green fuels.
- **Market Demand:** The demand for port services can be influenced by the availability and utilization of green fuels.

Economic models provide valuable insights into the potential benefits and trade-offs associated with green fuel adoption. By analyzing data on fuel costs, availability, regulations, and market demand, these models evaluate the environmental and economic impacts of using fuels such as biodiesel, ethanol, natural gas, and hydrogen.

Economic models evaluating the potential profitability of green fuel usage in ports must consider a comprehensive range of economic and environmental variables.

### Economic Variables

- Fuel type
- Fuel production costs.
- Transportation, distribution, storage, and disposal costs
- Fuel consumption, maintenance, and taxation expenses.

### Environmental variables

- Emissions generated by fuel use.
- Water, land, and energy consumption associated with fuel production.
- Greenhouse gas emissions and air pollution resulting from fuel combustion.

By incorporating these variables, economic models assess the cost-saving and environmental benefits of green fuel adoption in ports. These models quantify the overall economic impact, including potential savings and the value of environmental externalities. Additionally, models can evaluate the economic feasibility of investing in green fuel infrastructure and policies to promote its use.

This model evaluates the economic and environmental implications of green fuel implementation in the port industry. It utilizes an equation to quantify the potential benefits, considering factors such as fuel costs, emissions reductions, and environmental externalities [32].

Benefit = Fuel Cost – Green Fuel Availability – Environmental Regulations + Market Demand

The potential economic benefits of green fuel usage for ports are substantial and can be evaluated using various economic models. These models incorporate both economic and environmental factors. Green fuels, such as biofuels and renewable energy sources, reduce emissions and improve air quality while offering economic advantages to ports.

One such model is the Socio-Economic Impact Model (SEIM), which analyzes the economic impact of green fuel adoption on port profitability. SEIM considers port operations, local and regional economic conditions, and air quality data. It calculates the economic benefits of green fuels by considering factors such as fuel costs, emission reductions, and air quality improvements, thereby providing a comprehensive assessment of the potential impact on port profitability.

In addition to Cost-Benefit Analysis (CBA), which quantifies economic returns by considering fuel costs, emissions, and air quality improvements, other economic models are employed to evaluate the benefits of green fuels on port profitability:

- **Economic Multiplier Models (EMM):** These models utilize economic and environmental variables to assess the economic ripple effects of green fuel adoption in ports, such as job creation and supply chain efficiency.
- **Environmental Impact Models (EIM):** These models evaluate the environmental benefits of green fuels by considering factors such as reduced emissions, improved air quality, and enhanced ecosystem health. They quantify the economic value associated with these environmental improvements.

These models provide a comprehensive analysis of the economic and environmental advantages of green fuel adoption in ports, enabling decision-makers to make informed investments that enhance profitability while promoting sustainability [32].

### The Economic Multiplier Model (EMM)

The Economic Multiplier Model (EMM) quantifies the potential economic impact of a proposed project on a local economy. As businesses prioritize environmental sustainability, the adoption of green fuels has gained prominence. This research investigates the potential of green fuels to enhance port profitability, as assessed using the EMM.

Green fuels offer numerous benefits for port profitability. Firstly, as a renewable energy source, they reduce fuel costs for vessels, thereby increasing port revenue. Secondly, green fuels mitigate environmental impact, fostering sustainable operations. This enhances the port's reputation, fostering customer loyalty and boosting profits. Additionally, green fuels reduce air and water pollution, contributing to enhanced profitability.

The EMM measures the economic impact of green fuel deployment on port profitability (Brennan, J. (2020) [20].

It employs an economic multiple, which represents the ratio between the change in final demand and initial demand. For instance, environmentally friendly fuels may increase ship demand due to reduced operating costs, which in turn stimulates demand in other economic sectors. This increased demand generates employment opportunities, income growth, and further demand for goods and services. Consequently, EMMs provide valuable insights into the potential economic benefits of green fuel use for ports.

In summary, the adoption of green fuels can significantly enhance port profitability, as assessed through the Economic Multiplier Model (EMM). By reducing ship operating expenses and mitigating environmental impact, green fuels contribute to improved air and water quality. The EMM serves as a valuable tool for quantifying the potential economic benefits of green fuel deployment on port profitability.

The EMM is an analytical framework that measures the economic impact of specific activities or policies by considering direct and indirect effects. Direct effects include job creation and increased revenue, while indirect effects encompass increased demand for goods and services resulting from the initial economic activity. Through this comprehensive analysis, the EMM provides insights into the overall economic impact of green fuel adoption on port profitability [19].

The EMM is based on the following formula.

EMM = (Direct Effect + Indirect Effect) x Multiplier

Where

- **Direct Effect:** The direct impact of the activity or policy on economic activity.
- **Indirect Effect:** The indirect impacts of the activity or policy on economic activity, such as the increased demand for goods and services resulting from the activity or policy.
- **Multiplier:** The ratio of the total economic impact to the direct impact of the activity or policy.

Economic Modeling (EMM) methodologies can assess the potential economic impact of green fuel adoption on port profitability. Green fuels, such as biodiesel derived from renewable resources, reduce port-related $CO_2$ emissions and enhance profitability [25]. Direct impacts include reduced $CO_2$ emissions, while indirect impacts encompass increased demand for green fuel-related goods and services (e.g., biodiesel). The multiplier effect measures the ratio of total economic impact to direct impact.

To gauge the potential economic impact, EMM requires the estimation of direct, indirect, and multiplier effects. Direct effects are calculated as the reduction in $CO_2$ emissions, while indirect effects are estimated based on the increased demand for goods and services associated with green fuel use. The multiplier effect is determined as the ratio of total economic impact to direct impact [30].

By evaluating these effects, EMMs can quantify the potential economic benefits of green fuel adoption for ports, providing valuable insights for decision-makers.

The economic advantages of incorporating green fuels into port operations can be assessed using various economic models that incorporate both economic and environmental variables. These models quantify the economic and environmental gains associated with using cleaner fuels, including fuel cost reduction, emission reduction, and improved air quality.

One such model is the Economic Multiplier Model (EMM), which estimates the economic impact of investments and activities. It measures the ripple effect of economic activity in one sector on other sectors. By comparing the total economic output generated to the initial investment, the EMM calculates an economic multiplier that quantifies the economic benefits resulting from green fuel adoption. This model provides insights into the long-term economic viability of green fuels for ports.

### The economic components of EMM encompass:

- **Initial Investment:** The capital outlay required to initiate an activity or investment.
- **Gross Economic Output:** The total economic value generated by the activity or investment.
- **Economic Multiplier:** The ratio of gross economic output to initial investment, indicating the incremental output created for each dollar invested.
- **Economic Impact:** The overall change in economic output attributable to the activity or investment, encompassing direct, indirect, and induced effects.

The economic multiplier formula calculates the ratio of total economic output to initial investment:

- **Economic Multiplier:** Gross Economic Output/Initial Investment
- **Economic Multiplier:** Total Economic Output/Initial Investment.

Consider a port that invests $1,000,000 in green fuel technology to mitigate its environmental footprint. This investment generates an additional $2,000,000 in economic activity, resulting in an economic multiplier of 2. In other words, every dollar invested in the technology generates $2 in economic value within the port.

Economic multipliers can be used to assess the potential economic benefits of green fuel adoption for ports. By calculating the multiplier for green fuel investments and multiplying it by the projected economic output from the technology, ports can estimate the potential impact on their profitability. For instance, if the multiplier for green fuel is 2 and the projected economic output is $4,000,000, the potential economic impact on port profitability would be $8,000,000.

The Economic Multiplier Model (EMM) is a framework for quantifying the economic effects of specific activities or investments. It relies on the concept of economic spillovers and employs an economic multiplier formula, representing the ratio of gross economic output to the initial investment. By utilizing this model, researchers can assess the potential economic impact of green fuel deployment on port profitability [24].

The EMM consists of five components: energy cost, indirect cost, direct cost, total power, and total power multiplier. Each component contributes to the overall calculation, and the model provides insights into the economic consequences of adopting green fuels in port operations.

### Components and Formula of the Economic Multiplier Model

The Economic Multiplier Model (EMM) comprises five elements: energy costs, indirect costs, direct costs, total output, and total output multiplier [18].

To determine the economic impact of employing green fuel on port profitability, the following formula is utilized.

Total Economic Impact = (Energy Cost x Indirect Cost x Direct Cost) x (Total Output x Total Output Multiplier)

### Energy cost

The energy cost component of the EMM is calculated by determining the cost of fuel used in the port's operations, including the cost of transport, storage, and any other related costs. This cost should be calculated separately for green and non-green fuel sources.

### Indirect costs

The indirect cost component of the EMM is calculated by determining the cost of indirect activities related to the port's operations. This includes the cost of labor, materials, and any other related costs.

### Direct costs

The direct cost component of the EMM is calculated by determining the cost of direct activities related to the port's operations. This includes the cost of land, buildings, and any other related costs.

### Total output

The total output component of the EMM is calculated by determining the total value of all goods and services produced by the port. This includes the value of the port's operations, as well as any other related activities. Emmerson, C. (2016).[35].

### Total output multiplier

The total output multiplier component of the EMM is calculated by determining the multiplier effect of the port's operations. This is the total value of all goods and services produced by the port that is not directly related to the port's operations.

### Numeric examples with data collected.

To illustrate the Economic Multiplier Model (EMM), the following numeric example will be used. Emmerson, C. (2016) [35]. The following data collected from Saudi port that uses green fuel and non-green fuel in its operations.

### Energy cost

Green Fuel: $10,000

Non-Green Fuel: $15,000

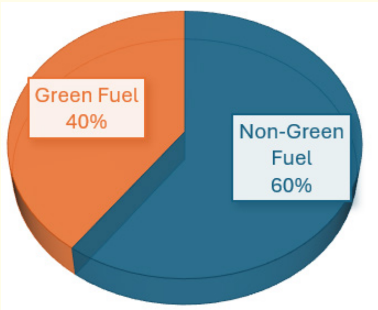


**Figure 1:** Energy cost.

### Indirect Cost

Green Fuel: $7,000

Non-Green Fuel: $9,000

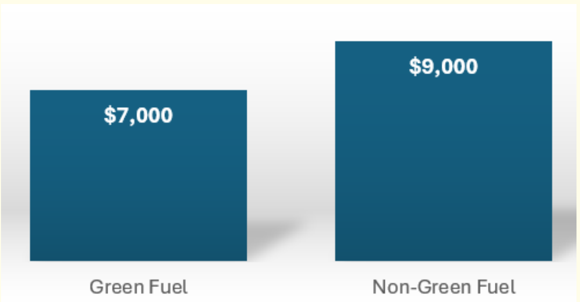


**Figure 2:** Indirect cost.

### Direct Cost

Green Fuel: $3,000

Non-Green Fuel: $5,000

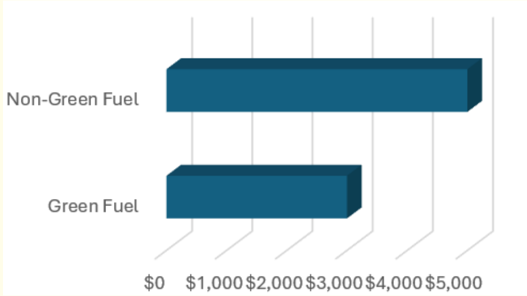


**Figure 3:** Direct cost.

### Total Output

Green Fuel: $20,000

Non-Green Fuel: $25,000

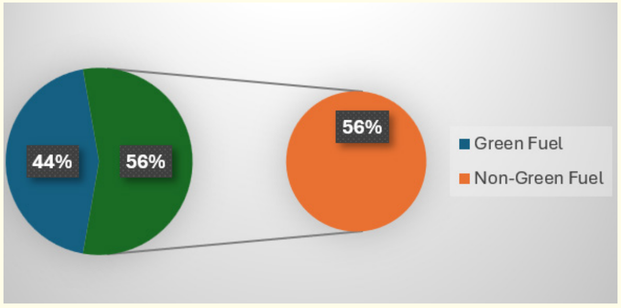


**Figure 4:** Total output.

### Total output multiplier

Green Fuel: 2

Non-Green Fuel: 3

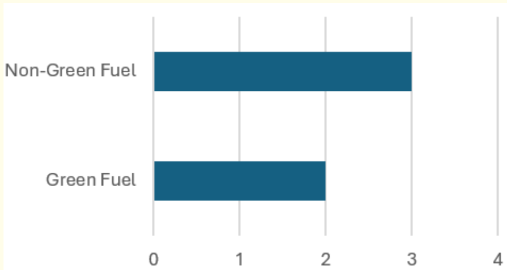


**Figure 5:** Total output multiplier.

Using the above information, the economic impact of the use of green fuel on the port's profitability can be calculated using the following formula

- Total Economic Impact = (Energy Cost x Indirect Cost x Direct Cost) x (Total Output x Total Output Multiplier)

- Total Economic Impact = ($10,000 x $7,000 x $3,000) x ($20,000 x 2)
- Total Economic Impact = $420,000

## Conclusion

Economic models used to evaluate the potential benefits of green fuels for port profitability consider a range of economic and environmental factors. These models estimate potential profits by subtracting green fuel costs and environmental regulations from traditional fuel costs and market demand. An equation is used to quantify the potential benefits, allowing for analysis of the impact of green fuel use on port profitability.

Green fuels offer substantial economic advantages for ports, including reduced costs, improved efficiency, and enhanced environmental performance. These benefits can translate into increased profitability, incentivizing ports to adopt green fuels. Port authorities should carefully weigh these economic and environmental benefits when making operational decisions.

Economic models demonstrate the profitability potential of green fuels for ports. They reduce fuel expenses, save on taxes and fees, minimize emissions, and enhance air quality. This combination can lead to increased profits and improved environmental conditions for ports. Therefore, ports seeking both profitability and environmental sustainability should prioritize the adoption of green fuels. Economic models facilitate the analysis of potential benefits, including cost savings and environmental gains, to inform investment decisions in green fuel infrastructure for ports.

An economic multiplier model (EMM) is a tool employed by economists to quantify the potential economic consequences of a given economic activity. It comprises two essential components: direct and indirect effects. The EMM formula calculates the overall economic impact by considering the multiplier effect of these components.

This study demonstrates how EMMs can be utilized to gauge the potential economic implications of green fuel usage on port profitability. Numerical examples and collected data illustrate the application of the model. Specifically, the EMM consists of five components: energy cost, indirect cost, direct cost, total power, and total power multiplier. The paper elaborates on each component and provides examples of how the EMM can be used to measure the potential economic impact of green fuel use on port profitability.

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