Trip Generation Centers (TGC Cargo) Environmetal Performance Evaluation: Libra TECON Terminal Case Study – Rio de Janeiro - Brazil

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ABSTRACT

The main objective of this paper is the development of a methodology based upon D´Agosto and Ribeiro (2004) to evaluate the impact of exchanging equipments and its fuel sources from business (operational costs) and environmental point of view. We applied the proposed methodology to Libra Terminais Rio that has 136 thousand square meters fully bonded space, with 9,600 square meters covered warehouse space and a 545 meters mooring dock that allows two ships to be berthed at the same time. We proposed some scenarios that make use of different vehicles to work at the terminal with the objective to reduce the environmental impacts of the operation. For each proposed scenarios the methodology was applied in order to evaluate their environmental benefits and operational costs. The methodology showed to be robust and can be used as a benchmark to compare ports and other logistic facilities. Besides the robustness of the methodology, it is simple to install and keep the data up to date. Thus, it could be used by Brazilian government as the basis of a new regulation to induce freight terminals to introduce environmental standards.

1. INTRODUCTION

Freight Trip Generation (FTG CARGO) can be defined as a place where there is a huge possibility of a lot of road and rail trip generation and attraction. Thus, a FTG CARGO needs specific infrastructure with docks to load and unload vehicles, parking area and other facilities. The nature of the operations that occur in a FTG CARGO causes environmental, social and economic impact in its hinterland. (CET, 1983; DENATRAN, 2001; Portugal e Goldner, 2003; Tolfo e Portugal, 2006; Kneib et al., 2010; Souza et al. 2010; Rede FTGC, 2013). Distribution centers, railroad yards, airports and ports can be classified as FTG CARGO.

The main objective of this paper is the development of a methodology based upon D´Agosto and Ribeiro (2004) to evaluate the impact of exchanging equipments and its fuel sources from business (operational costs) and environmental point of view.

We applied the proposed methodology to Libra Terminais Rio that has 136 thousand square meters fully bonded space, with 9,600 square meters covered warehouse space and a 545 meters mooring dock that allows two ships to be berthed at the same time. The wharf can receive ships with 13 m of draft. The container yard has a static capacity of 11.2 thousand Twenty Equivalent Units (TEU). Nowadays, the terminal has a fleet of equipments as follow: 4 electrical portainers, 4 diesel-electrical rubber-tired gantry (RTG) and 13 diesel reach stacker. The terminal has an intermodal access, railroad and roadway connections. (LIBRA, 2014).

Libra Tecon has been pursuing very important green goals for its operations. It is struggling to reach international environmental standards. Although, all these efforts, it does not have a methodology to evaluate the impact of a set of environmental actions in their goals what makes this study an original contribution (LIBRA, 2012).

This work is justified by the fact that in Brazil next to 95% of all international cargo trading is transported by sea and consequently requires harbor operation. Thus, any initiative in the direction of improving environmental performance of port activity is welcome (ANTAQ, 2011).

This paper is structured as follows: This section states its introduction. Section 2 brings the theoretical framework to support the methodology. Section 3 presents the methodology, the case study and its results. Section 4 brings the discussion of the results obtained. Finally, the last section brings the conclusions, the limitations and suggestions for further improvements of the methodology proposed.

2. THEORETICAL FRAMEWORK

This section presents the theoretical framework to support the methodology.

2.1. Port Operations

Ports can be seen as connections among road, rail and maritime transport modes or inland waterways. Thus, they expand the range of land transport modes. Ports as any place that has minimum dimensions for receiving ships safely and is protected from harsh conditions, such as strong winds, strong currents, high waves, freezing, among others (UNCATD, 1983).

Ports should be provided with facilities to enable the quick loading and unloading of the ships in an efficient and safety way and also receive, dispose and storage the cargo. Additionally, port should have areas dedicated to ship maneuver from the open sea to the berths. These facilities are known as the wet areas of the port and they are divided in: 1) anchoring area, 2) access channel, 3) turning basin and 4) berths (AGERSCHOU et al., 2004).

Mooring or berthing is the process of tying the vessel in a berth that can be defined as the physical space occupied by a ship. Some ports have a wharf with a linear dimension that can be occupied for several vessels (AGERSCHOU et al., 2004). A terminal is a sector of the port specialized in dealing with particular cargo. A container terminal is specialized in receiving and moving containers. In few words, containers are received at one gate from where trucks transport them to a pre-established stack in the cargo storage area. At this point, specialized equipment, such as RTG and reach stackers unload the containers from the truck to the correct position in the stack (AGERSCHOU et al., 2004).

2.2. Ecoeficiency in port operations

According to D´Agosto e Ribeiro (2004) the World Business Council for Sustainable Development (2000) defines the concept of eco-efficiency as the skill in measuring the evolution of an economic activity in an environmentally sustainable manner to meet human needs and upgrade the quality of life, steadily reducing environmental impacts and the consumption rates of natural resources, based on the environmental capacities of the planet. The World Business Council for Sustainable Development report sets out a framework that can be used by any business to measure progress toward economic and environmental sustainability.

Key elements and principles for eco-efficiency improvement Key elements	
Key elements	(1) Reduced material intensity
	(2) Reduced energy intensity
	(3) Reduced dispersion of toxic substances
	(4) Enhanced capacity of recycling material
	(5) Maximized use of renewable resources
	(6) Extended product life cycles
	(7) Increased service intensity
Principles	(1) Be relevant and meaningful in terms of environmental protection, human health and/or improving the quality of life
	(2) Inform decision making to improve the performance of the organization
	(3) Recognize the inherent diversity of business
	(4) Support benchmarking and monitoring over time
	(5) Be clearly defined, measurable, transparent and verifiable
	(6) Be understandable and meaningful to identified stakeholders
	(7) Be based on an overall evaluation of a company’s operation, products and services, especially focusing on all those areas that are of direct management control
	(8) Recognize relevant and meaningful issues related to upstream (e.g. suppliers) and downstream (e.g. product use) aspects of a company’s activities.

Table 1 – Key elements and principles for eco-efficiency

The Council proposed a triple-tiered structure to determine eco-efficiency indicators.

They are: categories, aspects and indicators. The categories represent the broadest-ranging classification level for the indicators, and are associated with determining the results (products or services values) and resources involved in the activities (environmental influence). To build the eco-efficiency measures each aspect may have a many indicators.

According to D'Agosto and Ribeiro (2004) quantity produced and net sales are general applicable indicators to measure product and service and total energy consumption, materials (raw and ancillary materials) and water consumption, greenhouse gas emissions and ozone depleting substance emissions are the related product\service that produces environmental impact. All indicators of product/service use and environmental influence are considered business specific.

2.3. Ecoeficiency in port operations

The eco-efficiency measures (EM) are performance measures obtained through the ratio between product/service value indicators (V) and those for environmental influence caused by generation or use of the product/service (EI) (Equation 1).

$$EM = V/EI \tag{1}$$

Eco-efficiency measures enable inclusion of other performance measures on transport system performance-evaluation programs. These new measures should consider both the economic (financial costs) and environmental (natural resources use, pollutant emissions etc) aspects of those programs. In a broader sense, service value indicators are the expression of transport capacity, such as the volume of freight transported by a distance.

2.4. Eco-efficiency management program (EEMP)

As explained by D'Agosto and Ribeiro (2004) the Eco-Efficiency Management Program (EEMP) come as a propose to improve traditional energy-efficiency programs that are focused in reducing fuel consumption. The EEMP suggests a short-term cost\benefit analyses to improve the economic aspects of these programs and bring a perspective for the inclusion of supplementary environmental aspects in energy end use management. To implement EEMP, it is necessary to consider the functional concept of the program.

2.4.1. Functional concept of EEMP

According to D'Agosto and Ribeiro (2004) the EEMP can be divided in planning and operational phases. It is also suggested two types of participants: the manager and the operators.

Planning phase considers the selection of eco-efficiency indicators, operators identification, data acquisition routine, eco-efficiency measures (EM) determination and its respective targets and EEMP supplementary programs. The operational phase includes regular inspections by the program manager, vehicles inspection programs (VIP), divided into weekly inspections (WI) and monthly inspections (MI), vehicles maintenance programs (VMP), fuel control programs (FCP), and alternative energy program (AEP).

D'Agosto and Ribeiro (2004) expose that it is important that the operators act on an induced basis, keeping the program manager advised of all information required for the planning and operation of the EEMP. In response to this, they must implement, maintain and upgrade supplementary programs.

2.4.2. . EEMP supplementary programs

D'Agosto and Ribeiro (2004) point that is necessary in the operational phase of EEMP a set of supplementary programs. Those programs are: regular inspections by the program manager, vehicles inspection programs (VIP), divided into weekly inspections (WI) and monthly inspections (MI), vehicles maintenance programs (VMP), fuel control programs (FCP), and alternative energy programs (AEP).

The VIP, VMP and FCP are part of ordinary fleet management programs, already implemented by EEMP operators. They represent tools to maintain good operational condition of the fleet and costs control. It is frequently possible to adjust those existing programs with the EEMP demands, what makes its implementation simple, fast and cheap. The AEP looks at the opportunity to use cleaner and/or renewable fuels. According to D'Agosto and Ribeiro (2004) the AEP must answer some key questions, related to the type of alternative fuel, its use extension, and its costs and economic/ecological viability.

3. CASE STUDY, ANALYSIS AND DISCUSSION OF THE RESULTS

First of all we collected the primary data form Libra Terminal Rio de Janeiro, locate in the city of Rio de Janeiro, Brazil, for the year of 2013. The data collected were divided in the follow information: throughput of containers, working hour for each equipment to move one TEU, total number of equipments of each type, total fuel used by each vehicle, type of fuel used by each vehicle, total amount of kilometers that each vehicle has traveled along the container yard, a set of vehicles working in the port, total amount of electrical energy used by each electrical vehicle, total amount of diesel oil used by each vehicle.

We consider in this paper only the impacts caused by the cargo handling at the terminal. There is no consideration over the activities outside the terminal.

We proposed some scenarios that make use of different vehicles to work at the terminal with the objective to reduce the environmental impacts of the operation. For each proposed scenarios the methodology was applied in order to evaluate their environmental benefits and operational costs.

3.1 Eco-efficiency measures evaluation

The study of each specific transport activity will show which eco-efficiency Key Performance Indicators (KPI) is best adapted to represent service value. For the environmental influence of the terminal operations, it was adopted a set of four indicators: 1) Total energy consumption, 2) Total renewable energy consumption, 3) Carbon dioxide emission, and 4) Equivalent annual cost. The selection of these eco-efficiency indicators is aligned with the main purposes of EEMP and complies with the key-elements and principles outlined in Table 1. It is proposed in this paper a methodology to evaluate these four KPIs and it can be seen at Figure 1

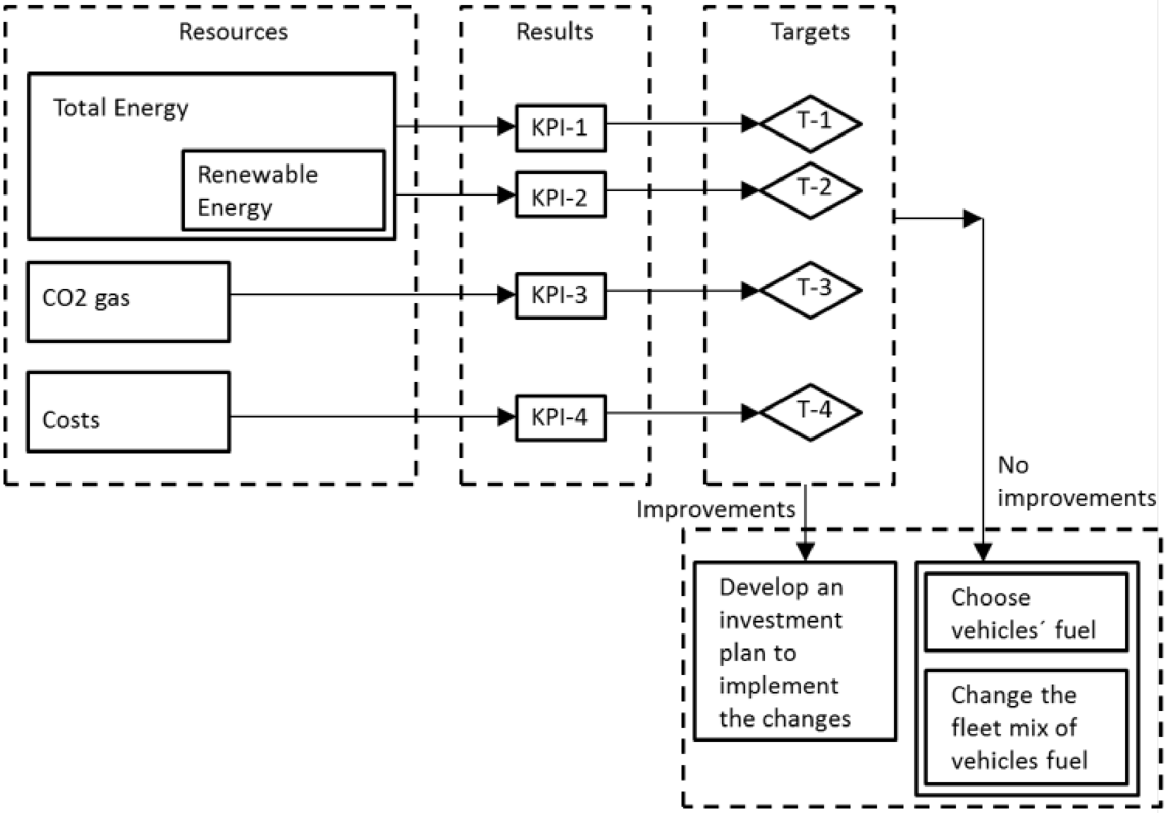

Fig. 1 - Eco-efficiency KPI evaluation process

The calculus of the Total energy consumption indicator (E) can be done by equation 2:

$$E = \sum_{j=1}^{m} \left(\sum_{i=1}^{n} NV_{ij} \; FE_{ij} \; WH_{ij} \right) CC_j \tag{2}$$

Where:
 - Total energy consumption indicator (MJ);

- Total number of different vehicles working at the port;
- Total number of different fuels used by the vehicles at the port;
- Total number of vehicles using fuel ;
- Consumption of fuel by vehicle (L / H);
- Working hour of vehicle using fuel (H);
- Calorie consumption of vehicle using fuel (MJ /L) ;

It can be extracted from de Total energy consumption another important indicator that is the Total renewable energy consumption (RE) This indicator is determined using the same equation, but considering only the vehicles that use renewable fuel, i.e., biodiesel, ethanol and electrical power

The Total carbon dioxide emission indicator (CO2) is evaluated using equation 3:

$$CO_2 = \sum_{j=1}^{m} \left(\sum_{i=1}^{n} NV_{ij}\ FE_{ij}\ WH_{ij} \right) EF_j \tag{3}$$

Where:
- Total carbon dioxide emission indicator (gCO2);
- CO2 emission factor of fuel (gCO2 / L);

To calculate the Equivalent annual cost indicator (EAC), it was considered the fuel consumption costs. This indicator depends on the fleet size, the transport operation and the costs of the alternative energy sources. The Total fuel consumption costs can be determined by equation 4:

$$FC = \sum_{j=1}^{m} \left(\sum_{i=1}^{n} NV_{ij}\ FE_{ij}\ WH_{ij} \right) C_j \tag{4}$$

Where:
- Total fuel consumption cost (US$);
- Cost of the fuel (US$ / L);

To establish a set of eco-efficiency KPI for the container terminal, we shall define a service value indicator (V). It was chosen the number of TEU that is an international, widespread, measure of work for this kind of terminal. Thus, the eco-efficiency measures can be seen in Table 2.

Eco-efficiency KPI	Expression	Performance target	Observation
Energy efficiency	*V / E*	*V / E'*	E' is the fuel economy obtained
Renewable energy efficiency	*V / RE*	*V / RE'*	RE' is the increase of renewable energy used
Emission of CO_2 efficiency	V / CO_2	V / CO_2'	CO_2' is the decreased CO_2 emission
Cost efficiency	*V / FC*	*V / EAC'*	EAC' is the necessary costs to implement the new vehicles

Table 2 – Eco-efficiency KPI

3.2 Scenarios for testing the environmental performance of the container terminal

Based upon the eco-efficiency KPI showed in the last section, 5 scenarios were tested to evaluate the investments and the environmental gains in the terminal´s performance. The proposed scenarios are shown in Table 3.

Scenario	Description
1	Actual vehicles and operations of the terminal
2	100% of all diesel tractor and trucks use 20% biodiesel + 80% diesel (B20)
3	Keep the Scenario 2 and exchange all diesel reach stacker for biodiesel (B20) reach stacker
4	Keep the Scenario 3 and exchange all diesel RTG for electrical RTG
5	Keep the Scenario 4 and exchange all diesel reach stacker for liquefied natural gas (LNV) reach stacker

Table 3 – Proposed Scenarios to Evaluate Terminal´s Performance

The Scenario 1 is considered the base line. Scenario 2 was chosen because it is simple to be implemented and is supposed to reach good results in short time. Scenario 3 is an incremental step in the way to improve environmental efficiency from Scenario 2. Scenario 4 is a step forward where huge investments must be done in exchanging the actual diesel RTG to electrical RTG. By the end, looking to a tendency in European Ports and considering the abundance of natural gas in Brazil it is proposed the Scenario 5 to analyze the exchange of B20 reach stacker for LNV reach stacker.

The hourly fuel consumption of each vehicle proposed in each scenario can be seen at Table 4.

	Diesel Reach Stacker	B20 Reach Stacker	LNV Reach Stacker	Diesel RTG	Eletrical RTG	Diesel Tractor	B20 Tractor	Diesel Trucks	B20 Trucks	Eletrical Porteniner
Scenario 1	13	-	-	4	-	15	-	18	-	4
Scenario 2	13	-	-	4	-	-	15	-	18	4
Scenario 3	-	13	-	4	-	-	15	-	18	4
Scenario 4	-	13	-	-	4	-	15	-	18	4
Scenario 5	-	-	13	-	4	-	15	-	18	4

Table 4 – Resume of equipaments for each scenario

These data represents the Libra Container Terminal practice. Some equipment as the electrical RTG the electrical consumption was taken from Multi Terminais that operates also in Rio de Janeiro Port, the LNV consumption by the reach stacker was taken from the experience of other ports operators.

Hourly Fuel Consumption (l/h or Kw/h)				
Vehicle	Fuel			
	Diesel	Electric	Biodiesel	LNV
Reach stacker	13,66	0,00	13,66	21,60
RTG	6,80	108,00	6,80	0,00
Tractor	3,16	0,00	3,16	0,00
Truck	3,24	0,00	3,24	0,00
Porteiner	0,00	579,42	0,00	0,00

Table 5 – Fuel consumption by hour by each type of vehicle

For each fuel the heat content, CO2 emission factor and the cost of each fuel in Brazil are presented.

	Fuel			
	Diesel	Electric	BioDiesel	LNV
Heat Content (MJ/l)	36,90	1,00	31,50	36,85
Emission Factor of CO_2 ($KgCO_2/l$)	2,71	0,00	2,43	2,06
Cost of the Fuel (US$/l or US$/Kw)	0,85	77,17	1,24	0,60

Table 6 – Heat content,CO2 emission factor and cost

For Scenario 1 the average worked hour per month for each equipment was taken from the historical operational files of Libra Tecon.

3.3 Results and discussion

Figure 2 shows the result for Energy Efficiency (EE) measure. For this measure it is desirable as bigger as possible value. It can be seen that Scenery 1 is worse than Scenery 2 because the energy consumption of B20 for trucks and tractor is smaller than for diesel use. Scenery 3 is better than Scenery 2 because all 13 diesel reach stacker use B20. Scenery 4 is the best because electrical RTG have the smallest energy consumption. Scenery 5 is the worst situation because the LNV reach stackers have the grater fuel consumption.

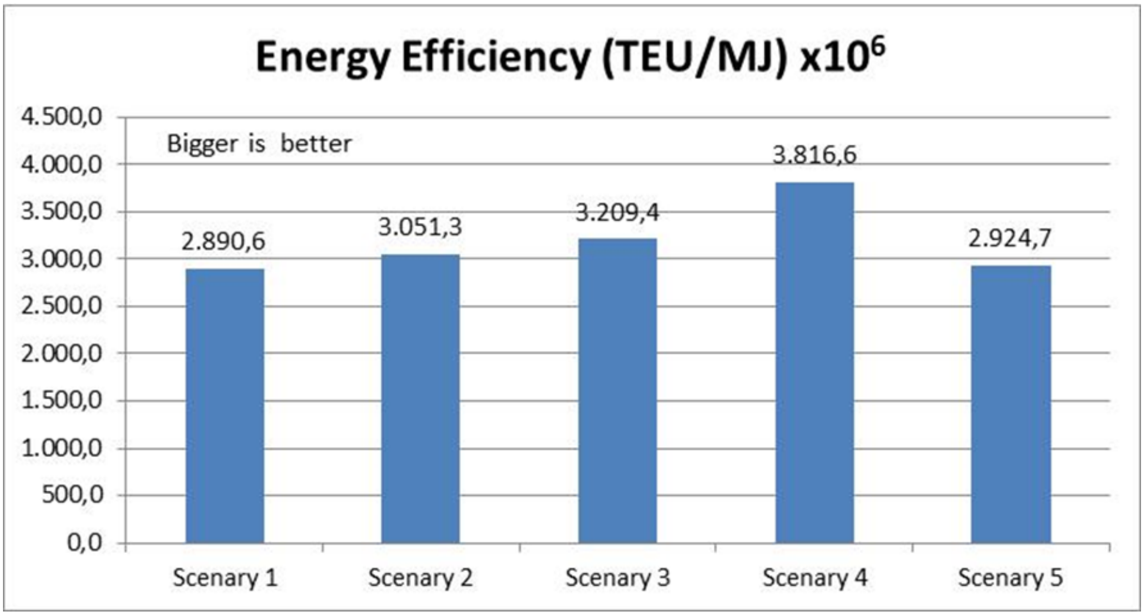

Fig. 2 - Energy Efficiency (EE)

Figure 3 shows the result for the Renewable Energy Efficiency (REE) measure. For this measure it is desirable as smaller as possible value. It is possible to see that the introduction of renewable energy leads to a better performance and Scenery 4, that mix the use of B20 and electrical energy, has the best output of all.

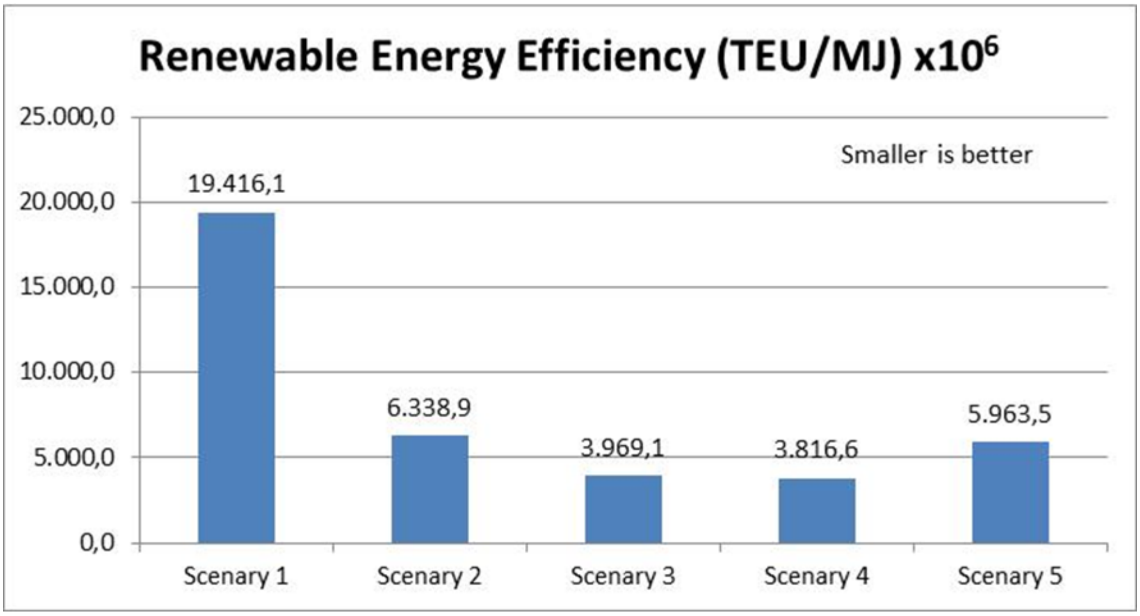

Fig. 3 - Renewable Energy Efficiency (REE)

Figure 4 shows the result for CO2 Emission Efficiency (ECE). For this measure it is also desirable as bigger as possible value. Following the results for EE and REE, Scenery 4 has the best result once B20 and electrical energy are used. Scenery 5 is the second best because LNV CO2 emissions are lower than diesel emissions.

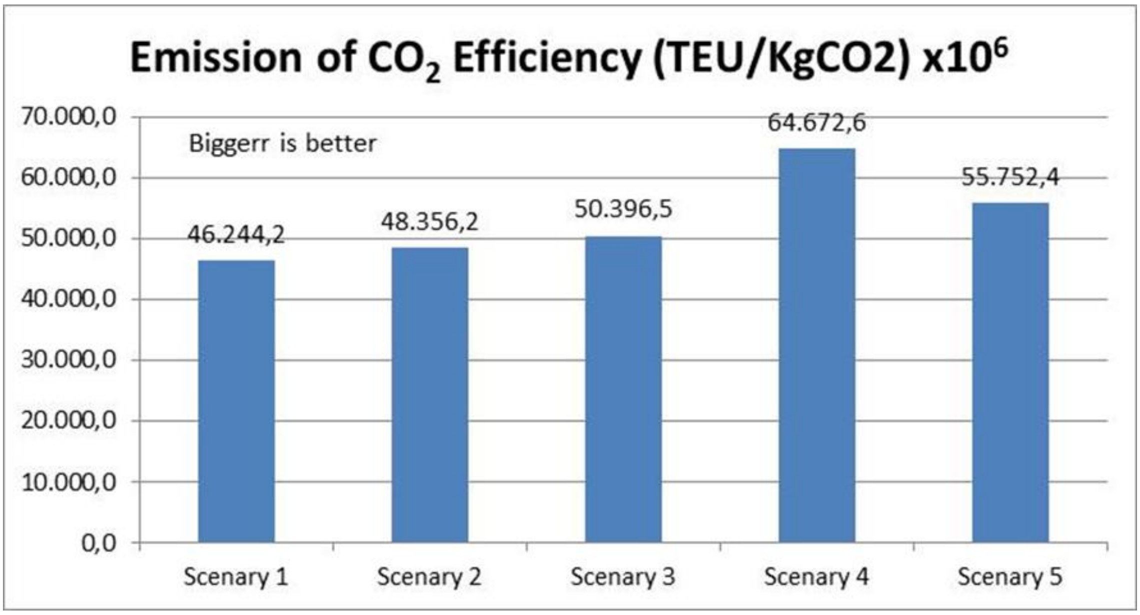

Fig. 4 - CO2 Emission Efficiency (ECE)

The results for Cost Efficiency (CE) are shown in figure 5. For this measure it is also desirable as bigger as possible value. The use of renewable energy (B20 or electric energy) turns the operation more expensive and in this case Scenery 1 is the best although Scenery 2 and 3 have similar results (0.03 % and 0.06% worst respectively). The introduction of electric energy makes Scenery 4 16.3% worse than the base line and the use of LNG in Scebery 5 makes 0,02 % of improvement over Scenery 4.

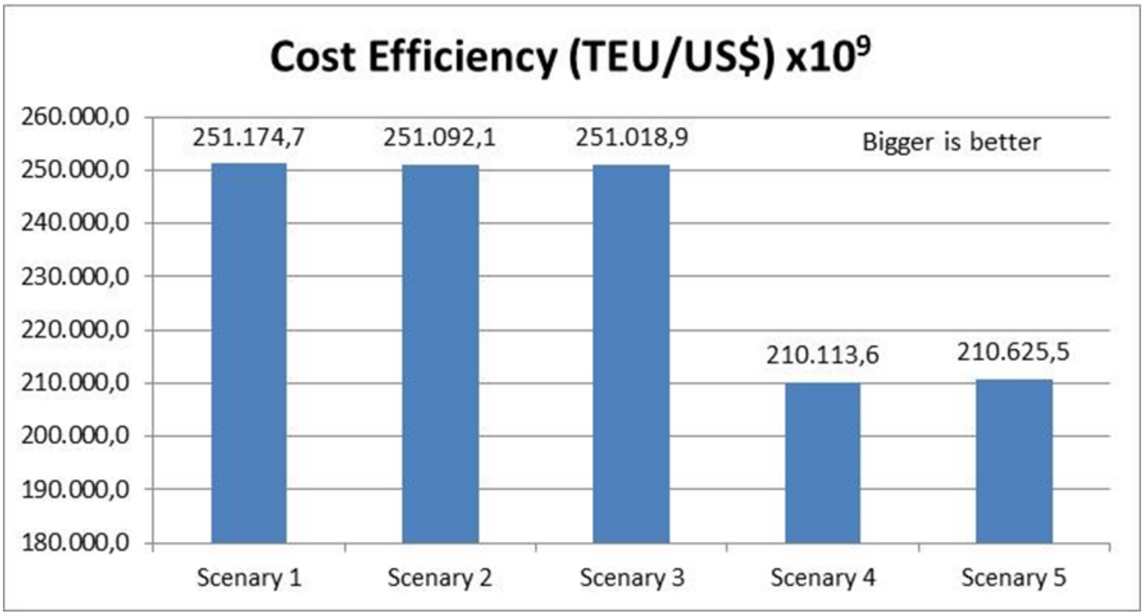

Fig. 5 - Cost Efficiency (CE)

After all the analyses of the 4 KPI it can be said that from the environmental point of view, considering EE, REE and ECE, Scenery 4 is the best. On the other hand, when we look at CE, Scenery 4 shows the worst result mainly impacted by the use of electrical energy. For cost efficiency point of view, Scenery 1, the actual one, is the best but its results are not environmental friendly.

4. CONCLUSIONS

Libra TECON Rio de Janeiro, an important container terminal in Rio de Janeiro, Brazil was evaluated from eco-efficiency point of view. The actual scenery shows poor environmental performance results. It can be improved by the use of renewable energy as shown in Scenery 4 where diesel is exchanged for B20 and electrical energy.

Considering the base line (Scenery 1) an improvement in energy efficiency of 32% and a reduction of CO2 emissions of 43% can be reached by the use of renewable energy increasing just 16% in operational costs. It shows that dimension of the trade-off among environmental measures and operational cost results is favorable.

The methodology showed to be robust and can be used as a benchmark to compare ports and other logistic facilities. Besides the robustness of the methodology, it is simple to install and keep the data up to date. Thus, it could be used by Brazilian government as the basis of a new regulation to induce freight terminals to introduce environmental standards.

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