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FACILITATION OF TRANSPORT AND TRADE IN LATIN AMERICA AND THE CARIBBEAN

Energy consumption and container terminal efficiency

The ECLAC port and terminal energy consumption survey is the most comprehensive and relevant analysis of this issue both in Latin America and abroad. The data that it provides has made it possible to examine the trends and detailed structure of energy consumption and of efficiency measures in cooperation with the public and private sectors. It also contributes to formulating energy efficiency strategies and policies in the future.

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United Nations

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Introduction

The performance of container terminals needs to be improved in order to make them not only more competitive and productive, but also more sustainable. Consequently, measuring performance in ways that go beyond traditional efficiency and productivity measures is an emerging challenge. In the case of energy consumption, a clear link exists between the sustainability, efficiency, competitiveness and profitability of a terminal. This sustainability/efficiency link between energy consumption and performance is not yet well understood, nor has it yet been analysed in detail.

Today, the container terminal industry is under a great deal of pressure to meet economic and environmental standards. This industry's levels of energy consumption and the resulting emissions are significant but, despite increasing energy consumption rates and costs, few energy efficiency measures or strategies are in place in today's ports and terminals. Latin America's energy security is an issue that is high on the political agenda, and there is an emerging awareness of energy consumption, efficiency and the associated costs in maritime trade. Port authorities and terminal operators have started to become aware of the challenge of energy efficiency, and many of them are increasingly concerned with their emission profiles. The regulation of port areas has become more stringent, mostly in relation to sulphur and nitrogen oxides (Acciaro and Wilmsmeier, 2016; Acciaro, 2014), but in the future, regulations on particulate matter (PM) and other short-lived climate change gases are expected to become stricter as well. Energy consumption is an important factor in port operations and port-related economic activities and, with energy costs increasing for land-based industries as well, port authorities and terminal operators are looking for ways to reduce their fuel bills.

With the growth of global container trade and port infrastructure development, ports have come to be significant energy consumers. Latin America's container exports have undergone both a considerable increase in scale and structural changes as trade volumes have grown and reefer cargo (refrigerated perishable goods) has become more diversified (e.g., Vagle 2013a, 2013b). This type of trade not only requires different types of handling and logistics, but also consumes more energy throughout the transport chain.

Terminals around the world are working to shift from fossil fuel to electricity. These efforts are coupled with the development of renewable energy sources within the port perimeter (Acciaro et al., 2013). While some terminals have taken such steps voluntarily and have invested in energy-efficient technologies, many port authorities and terminal operators still lack an awareness of the importance of having energy-efficient infrastructure, and many times they lack sound strategies for measuring their energy consumption and for using energy-efficiency indicators (Wilmsmeier et al., 2014). Energy management strategies place ports in the middle of a complex web of energy flows and, in order for such strategies to be successfully implemented, terminal operators and port authorities have to be aware, as a minimum, of how energy is used in the port and where it is coming from (Acciaro, 2013). A coordinated approach can result in energy cost savings and can even provide a new source of business for the participating ports.

Within the shipping and port industry, which has experienced decades of sustained growth of throughput and overall expansion, energy management was not seen to be a particularly urgent issue until quite recently. However, in view of the current economic challenges, a changing geography and structure of trade, and a greater awareness and demand for sustainable logistics, the topic of energy efficiency has come to the forefront of academic and industry discussions.

This issue of the *Bulletin* analyses the state of the art of energy consumption in Latin American countries in an effort to shed light on current and future challenges and opportunities relating to the implementation of energy-efficiency strategies and to the further development of benchmarking tools to support sustainable terminal operations. This issue also seeks to build on the analyses presented in Issue No. 329 of the *Bulletin* and to explore new challenges in the geography of freight transport (Wilmsmeier, 2015).

I. ENERGY EFFICIENCY IN THE CONTEXT OF THE SUSTAINABLE DEVELOPMENT GOALS

The energy efficiency and consumption patterns of container terminals are related to 3 of the 17 Sustainable Development Goals.

The International Energy Agency (IEA) (2016) has reported that the transport sector's rate of energy consumption has been rising at an annual average rate of 1.4%. Most of this increase in total transport energy consumption is correlated with economic growth, higher standards of living and the consequent upswing in the demand for personal mobility.

Petroleum and other liquid fuels accounted for 96% of all fuel consumption in 2014. Motor petrol (or motor gasoline, as it is known in North America) remains the largest single transport fuel input, representing 39% of the total, with diesel coming in a close second at 36% as of 2012. Electricity still accounts for a much smaller percentage of the world's transportation fuel use, although its importance in passenger rail transportation is on the rise.

The proportion of the world's energy use that is covered by mandatory energy-efficiency regulations has almost doubled over the past decade, climbing from 14% in 2005 to 27% in 2014. Still, the current pace of progress in this respect is only about two thirds of what is needed in order to double the global growth rate in energy efficiency. Among end-use sectors, industry was the largest contributor to reduced energy intensity, followed closely by transportation. As crucial hubs in the global trading system, ports are an important link in the global logistics chain in which energy-efficiency potentials have yet to be taken advantage of. Thus, in the context of Sustainable Development Goal 7, ports can do their part to help double the global rate of increase in energy efficiency and can participate in international cooperation efforts to facilitate access to clean energy technology, including renewable energy and energy-efficient technologies.

Climate change poses the single biggest threat to development, and its widespread, unprecedented impacts place a disproportionately heavy burden on the poorest and most vulnerable. Urgent action to combat climate change and minimize its disruptions is integral to the successful implementation of the Sustainable Development Goals. (United Nations, 2016).

Sustainable Development Goal 9 encompasses three important aspects of sustainable development: infrastructure, industrialization and innovation. Infrastructure provides the basic physical systems and structures essential to the operation of a society or enterprise. Industrialization drives economic growth, creates job opportunities and thereby reduces income poverty. Innovation advances the technological capabilities of industrial sectors and prompts the development of new skills.

In the context of Sustainable Development Goal 13, the analysis and discussion of transport terminals' energy efficiency holds out the potential for leveraging opportunities for integrating climate change measures into national policies, strategies and planning, as these efforts help to raise awareness and build human and institutional capacity for climate change mitigation, adaptation, impact reduction and early warning. Furthermore, the development of baseline indicators opens the way for the creation of mechanisms for building capacity for effective climate-change-related planning and management in least developed countries and small island developing States.

Ports are an important component of physical infrastructure and facilitate over 80% of global freight flows. Port operations are highly energy-intensive activities and thus should play an integral part in the development of high-quality, reliable, sustainable and resilient infrastructure that can support future economic development. Upgrading and retrofitting port infrastructure to make it sustainable will increase resource-use efficiency and boost the adoption of clean and environmentally sound technologies and industrial processes.

In consequence, a discussion on energy consumption and efficiency and on monitoring and best-practice evaluation and implementation can make a meaningful contribution to efforts to attain at least three of the Sustainable Development Goals.

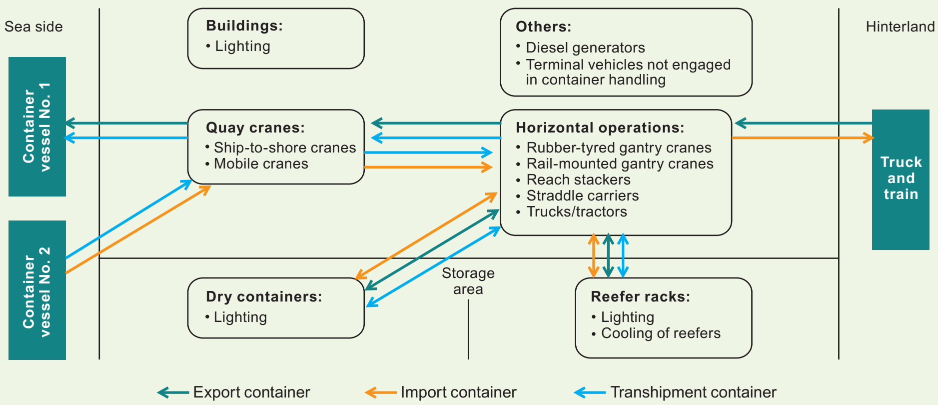
II. MEASURING ENERGY CONSUMPTION IN CONTAINER TERMINALS

A. Methodology

Only a small number of publications on energy consumption in container terminals exist (Wilmsmeier et al, 2014; He, 2016; Sha et al., 2016; He, et al., 2015a; He, et al. 2015b; Yang, et al, 2013; Yang and Chang, 2013; Geerlings and van Duin, 2011) and, in practice, very few terminals (e.g. Hamburg, Germany; Arica, Chile; and Valencia, Spain) analyse their energy consumption pattern in detail. Issue No. 329 of the *FAL Bulletin* benchmarked energy consumption in 13 container terminals in Latin America using an activity-based cost approach developed by Lin et al. (2001). This approach makes it possible to: (a) determine how much energy is being consumed in specific areas of operation; and (b) allocate a given level of energy consumption to a specific unit within a process or process cluster. In Issue No. 329, the following process clusters within a container terminal were identified: quay cranes, lighting, buildings, cooling (reefer containers), horizontal container handling and "other" (cf. Froese and Toeter, 2013). While it was possible to assign levels of energy consumption to different process clusters in the case of electricity, a certain share of energy consumption remained undefined, and the data were not detailed enough to permit the assignment of fossil fuel consumption levels to the corresponding process clusters. As of now, no integrated approach or recognized set of indicators has been developed for container terminals. A main limitation of existing research is the absence of reliable, detailed data. The existing literature generally relies on average and standard consumption figures to estimate overall energy consumption or to derive emission estimates (Geerlings and van Duin, 2011).

The issue of energy consumption in terminals can be addressed from two different perspectives: (a) an aggregate approach, in which containers are seen as consuming energy while being handled; and (b) one in which equipment is seen as consuming energy while handling containers. The latter comes closer to the idea of an activity-based approach (Lin et al., 2001; Wilmsmeier et al., 2013). The different types of equipment being operated in a terminal are a relevant factor if the activity-based approach is being used. Diagram 1 depicts the framework for the research on energy consumption in container terminals presented in this issue of the *FAL Bulletin*.

Diagram 1
ENERGY ACTIVITY CLUSTERS IN A CONTAINER TERMINAL



Source: Prepared by the authors.

The amount of energy consumed per container is then broken down into the amounts consumed by the different pieces of equipment that are used. Lighting and reefer cooling are exceptions, since energy in these process clusters is consumed during a given time and thus has an additional dimension. To identify the levels of energy consumption of the different pieces of terminal equipment, it is necessary to create an inventory of the existing equipment and the form of energy consumed by each type of equipment. Furthermore, the output of each type needs to be defined.

The type of cargo handling equipment used in a given terminal is determined by its container handling system. Brinkmann (2011) distinguishes between four different systems: a reach-stacker system with tractor-trailer units (TTUs), a straddle carrier system, a rubber-tyred gantry crane system with TTUs and a rail-mounted gantry crane system. Quay cranes are the only element common to all of these systems. Ship-to-shore (STS) cranes are widely used. It should be noted that some ports use regular trucks instead of TTUs. In some terminals, mobile cranes are used either instead of or in addition to STS cranes. (For more detailed information, see Spengler, 2015).

Table 1 lists the different equipment types and other energy consumers and the various possible energy sources.

Table 1
ENERGY CONSUMERS INSIDE A CONTAINER TERMINAL

	Diesel	Petrol	Natural gas	Electricity
Ship-to-shore cranes	●			●
Mobile cranes	●			●
Rail-mounted gantry cranes	●			●
Rubber-tyred gantry cranes	●			●
Reach stackers	●			●
Straddle carriers	●			●
Tractor-trailer units and lorries	●		●	●
Generators	●		●	
Buildings				●
Lighting				●
Reefer containers				●
Other port vehicles	●	●	●	●

Source: Prepared by the authors, on the basis of on Spengler, 2015.

B. Output indicators

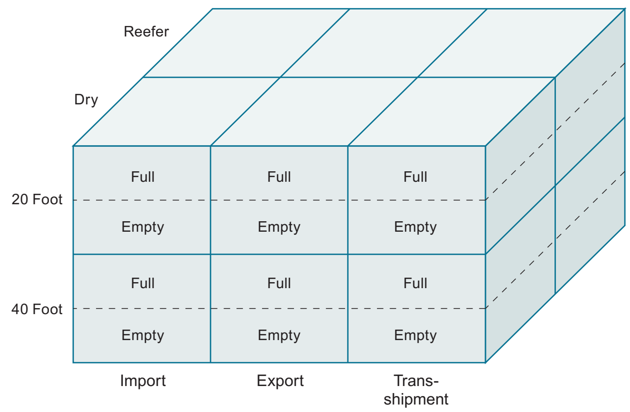
An analysis of energy consumption requires a detailed understanding of the portions of a terminal's energy bill represented by the different container types (Wilmsmeier et al., 2014). To be able to identify the energy consumption levels and profiles of different container types, an activity-based cost approach is recommended because this approach makes it possible to: (a) determine what area of operation is consuming what amount of energy; and (b) establish a set of detailed indicators.

The following energy activity clusters have been considered here: vertical operations (quay cranes), horizontal operations (e.g. reach-stacker (RS) cranes, rubber-tyred gantry (RTG) cranes, rail-mounted gangry (RMG) cranes, etc.), lighting, buildings and cooling (reefers). Time is another important factor when it comes to measuring energy consumption and setting indicators for energy efficiency because of: (a) the seasonality of certain types of traffic (e.g. reefers); (b) variations in the dwell time of different container types (e.g. import and export containers); and (c) ship calling patterns, all which can trigger significant variations and peaks in energy consumption.

Even though the literature on energy consumption in container terminals is quite limited, some work has been done on the energy consumption of specific types of cargo handling equipment from an operational perspective. This research indicates that busbar-powered RTGs equipped with online braking can reduce energy consumption by up to 60% (Yang, Chang and Wei-Min, 2013). In general, however, the researchers who have worked in this area do not share a systemic view of energy consumption beyond the effect of technical advancement. One example is the findings reported on the impact of electric rubber-tyred gantries on green port performance (Yang, Chang and Wei-Min, 2013).

Containers are most commonly referred to in a rather general way in the literature. When it comes to the consideration of containers as a variable, however, it has to be recognized that containers are multi-dimensional variables, since one container may have multiple properties. These properties include: full/empty, length, height, trade direction and type of container (Monios and Wilmsmeier, 2013). Given the different dimensions of the variable "container", the operational processes and related activities conducted in a terminal differ as well. Empty containers are less time-critical than full containers, which is reflected in their dwell times (Merckx, 2005). Likewise, reefer containers tend to have a significantly shorter dwell time than other containers. Container heights tend to have no more than a negligible influence on terminal operations, costs and energy consumption, but the differences between container types (i.e., reefer versus dry containers) do have a greater impact on operations and costs. Reefer containers need to be "plugged in" and monitored, and they thus consume additional energy. The four dimensions relevant to energy consumption in ports are displayed below. It is possible to argue that each feasible combination of these multiple dimensions contitutes a single product. In terms of the measurement of energy efficiency in container terminals, however, it may be more informative to determine which of those dimensions have the most significant impact on consumption patterns. As mentioned earlier, most activities conducted in a container terminal are performed on a container-by-container basis, regardless of its size. Assigning consumption, emissions or expenses to 20-foot equivalent units (TEUs) would inadvertently lead to a situation where too much consumption, emissions or expenses would be attributed to 20-foot containers. This analysis will therefore use containers (boxes) as a unit indicator. See diagram 2.

Diagram 2
THE MULTIDIMENSIONALITY OF CONTAINER VARIABLES



Source: Prepared by the authors.

C. An analysis of energy consumption in container terminals

This issue of the *FAL Bulletin* summarizes the most pertinent findings of a survey of over 35 container terminals in Latin America and the Caribbean which accounted for one third of the region's annual container throughput between 2012 and 2015. A total throughput of 205 million TEUs at the global level is shown in the database. These data were checked for normality and outliers.

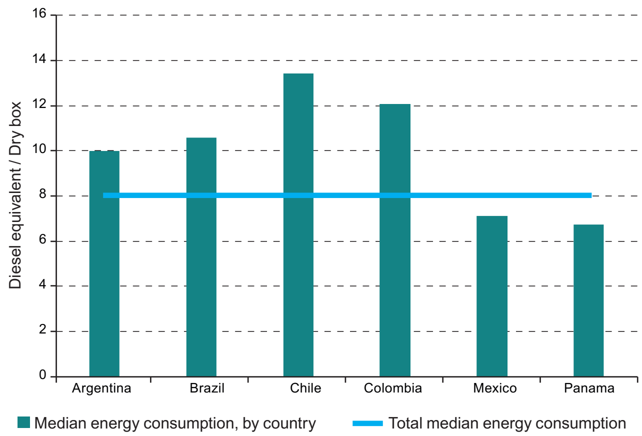
The results shown here are part of a global study on energy consumption in terminals and ports of all kinds. One of that study's recent outputs was the first inventory of energy consumption and efficiency in major Chilean container terminals ever to be published.[1] Follow-up publications for other countries, regional comparisons and reports on other terminal types, such as those that handle bulk and liquid cargo, are under way.

The following analysis provides some insights into the structure and evolution over time of this industry's energy use and efficiency in the region and is coupled with a discussion on other influential factors. For our purposes here, container terminals are defined as terminals at which bulk cargo makes up less than 5% of the total. When terminals are compared, data availability regarding consumption data is recognized as a crucial factor. By way of example, the per box consumption data for two different terminals are only comparable if both terminals provide data on their main energy sources.

D. Key findings

The median amount of diesel equivalent needed to handle a single dry container in the Latin American and Caribbean region was 8 litres in 2015. Previous calculations for 2013 showed an average consumption level of 8.6 litres of diesel equivalent.[2] Thus, a slight overall improvement was registered. A heterogeneous consumption pattern can be observed across the six countries shown in figure 1. Panama and Mexico exhibit the lowest energy consumption levels as expressed in diesel equivalent. The reasons for this may have to do with the different types of operations being conducted in these ports; Panamanian ports are primarily transshipment ports and thus have fewer horizontal movements and different energy mixes; a higher level of electrification will also reduce the level of energy consumption per container.

Figure 1
MEDIAN LITRES OF DIESEL EQUIVALENT CONSUMED IN THE HANDLING OF ONE DRY BOX (EXCLUDING REEFER CONSUMPTION), BY COUNTRY, 2012-2015

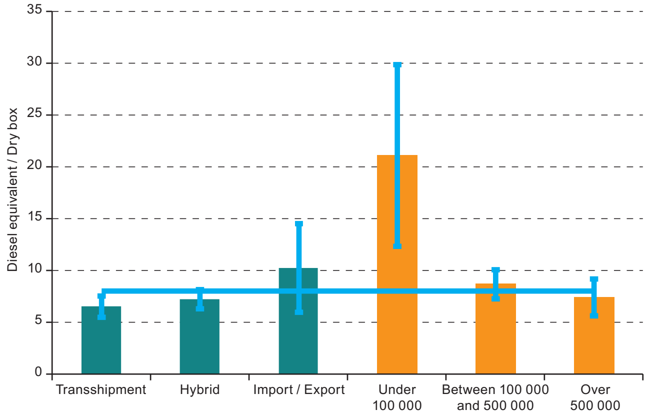


Source: Prepared by the authors, on the basis of data from the ECLAC Infrastructure Services Unit (various years).

[1] See [online] http://www.cepal.org/sites/default/files/events/files/boletin_ee-puertos-chile-cepal-mtt.pdf.
[2] Based on 41 terminals in 17 countries with a total throughput of over 37 million TEUs.

Further analysis of the observed variations between terminals and countries reveals a clear correlation between certain types of terminal operations and terminal size. Small terminals with fewer than 100,000 box movements per year tend to consume more than twice as much energy per box as terminals handling more than 500,000 box movements (see figure 2). Consequently, energy consumption patterns reflect economies of scale and point to the existence of a significant amount of untapped efficiency potential in smaller terminals. The data also indicate that specialized transshipment terminals have lower per box consumption levels than hybrid and import/export terminals do. These findings underline the importance of differentiating terminals by type and size when developing benchmarks.

Figure 2
MEDIAN LITRES OF DIESEL EQUIVALENT CONSUMED IN HANDLING ONE DRY BOX (EXCLUDING REEFER CONSUMPTION), BY TYPE AND SIZE OF TERMINAL, 2012-2015

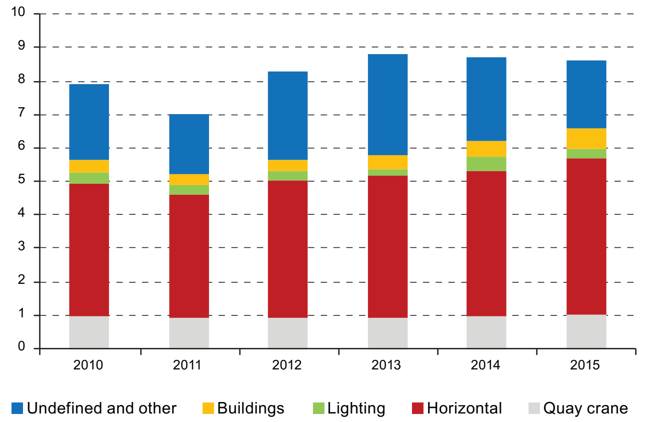


Source: Prepared by the authors, on the basis of data from the ECLAC Infrastructure Services Unit (various years).

Note: The calculations are based on data for 25 terminals in 8 countries.

An analysis of trends in energy consumption by activity cluster reveals that horizontal activities accounted for the greatest and fastest-growing share of energy consumption in the period 2012-2015. Horizontal activities are all those activities carried out by RTGs, reach stackers, RMGs, etc. and are principally based on diesel consumption; the substantial variations that are to be observed within this category are mostly due to differences in the operational layout of different terminals. In 2015, the median level of energy consumption per box for horizontal activities was 4.7 litres of diesel equivalent; in 2014 and 2013, the corresponding figures were 3.95 litres and 4.1 litres. It is also significant that the share of undefined and other energy consumption is decreasing over time, which points to the achievement of a better fit and higher quality of data over the years.

Figure 3
MEDIAN LITRES OF DIESEL EQUIVALENT CONSUMED PER ACTIVITY CLUSTER (EXCLUDING REEFER COOLING), 2012-2015



Source: Prepared by the authors, on the basis of data from the ECLAC Infrastructure Services Unit (various years).

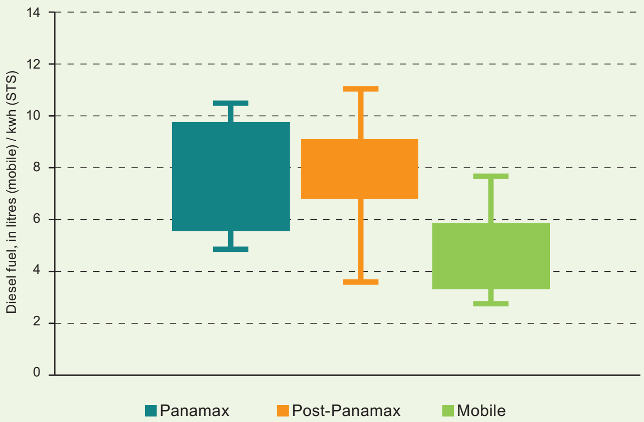
Note: The calculations are based on data for 31 terminals in 16 countries.

Vertical activities (STS and mobile cranes) consumed an average of around 10% of the total amount of energy used. Depending on the type of cranes deployed in the terminal, this value can vary significantly and is strongly influenced by the type of energy being used. Figure 4 depicts the differences in energy consumption by crane type, Panamax, post-Panamax and mobile cranes. Considering the consumption per move, STS cranes consume, on average, 7.9 kwh per move, with a significant spread in the observations. The average consumption of post-Panamax cranes is above that of Panamax cranes. It should be noted that the Panamax cranes in the sample are approximately 10 years older than the post-Panamax cranes. This indicates that the presumed technological advancements may not compensate for the apparent increases in consumption, which are most likely attributable to the increasing size of cranes and are mostly driven by external pressures, particularly increases in ship size. However, the sample size in terms of the differentiation between post-Panamax and Panamax cranes is relatively small.

Some of these modifications are chiefly aimed at increasing productivity, while others are mainly aimed at reducing energy costs and consumption. Their impact on consumption therefore varies significantly, and this is reflected in substantial variations in mobile cranes' consumption per box. It should, however, be noted that STS cranes are in almost all cases more energy-efficient and that a substitution of STS cranes for mobile cranes would be desirable not only to reduce energy consumption, but also to make energy consumption more predictable.

However, while equipping terminals with STS cranes would be a rather expensive undertaking, equipping the existing mobile cranes with twin spreaders would be less costly and could increase energy efficiency and productivity substantially in small terminals or in those where a large number of 20-foot containers are handled.

Figure 4
ENERGY CONSUMPTION IN VERTICAL CONTAINER HANDLING, BY CRANE TYPE
(In kwh and litres of diesel fuel)



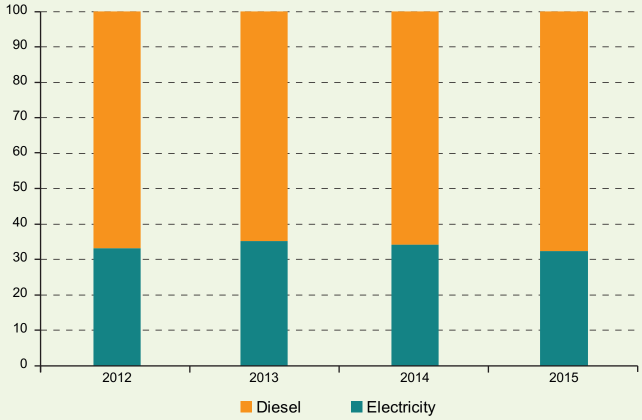
Source: Prepared by the authors, on the basis of data from the ECLAC Infrastructure Services Unit (various years).

Note: Based on 54 data points from 5 countries.

Diesel fuel is the main energy source for container terminals in Latin America and the Caribbean (see figure 5); the shares of diesel fuel and electric energy use have been almost constant over the last few years. On average, only 32% of the energy consumed in terminals in Latin America and the Caribbean was in the form of electricity in 2015. This underlines the observation that no major progress has been made in terms of electrification in the region. By way of comparison, the share of diesel fuel in the energy matrix of container terminals is 78% in Chile and 88% in Nigeria, while in Japan and Viet Nam, the corresponding shares in comparable terminals are between 50% and 60%.

However, the consumption patterns for diesel fuel differ across terminals and, to a significant extent, depend on the individual equipment configurations in each terminal. By way of example, diesel-powered mobile cranes account for between 30% and 38% of total diesel fuel consumption in Chilean container terminals if no STS cranes are in the terminal. In general, diesel-powered RTGs are the largest consumer of diesel fuel, followed by TTUs or RSs.

Figure 5
TRENDS IN THE SHARES OF ENERGY SOURCES IN LATIN AMERICAN AND CARIBBEAN CONTAINER TERMINALS, 2012-2015

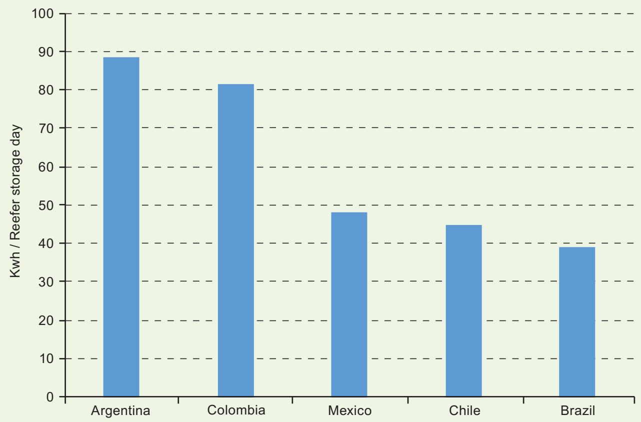


Source: Prepared by the authors, on the basis of data from the ECLAC Infrastructure Services Unit (various years).

Note: The calculations are based on data for 44 terminals in 20 countries. The country data cover the years from 2010 to 2015.

Reefer containers represent between 5% and 20% of total box movements in the Latin American and Caribbean region's terminals, and reefer cooling can represent up to 60% of a terminal's electricity consumption. On average, 17.6% of total energy consumption can be attributed to reefer cooling. This figure varies depending on how much reefer cargo is being handled. By way of example, in the case of Chile, reefer cooling represents almost one fourth of total energy consumption in the terminals under study. Median energy consumption per reefer storage day depends heavily on the country's infrastructure. The energy consumption for reefer cooling is time-dependent and thus directly correlated with the dwell time of full reefer containers in the terminal. Storage times vary significantly across countries and terminals and dependon the availability of cold supply chain infrastructure in the port and the port's hinterland. In some countries, reefer containers are used as terminal storage facilities owing to the absence of appropriate facilities outside the port. In these cases, energy consumption per box will be higher as a result of factors linked to the performance of the supply chain rather than the performance of the actual terminal. Figure 6 depicts the differences between selected countries per storage day associated with the corresponding cold supply chains. "Hot cargo" will consume additional energy because it needs to be cooled down upon arrival at the terminal. The type of reefer cargo involved also has a significant influence on energy consumption; for example, the cooling of refrigerated cargo is more energy-intensive than the cooling of frozen cargo.

Figure 6
AVERAGE ENERGY CONSUMPTION PER STORAGE DAY PER FULL REEFER CONTAINER, BY COUNTRY
(In kwh)



Source: Prepared by the authors, on the basis of data from the ECLAC Infrastructure Services Unit (various years).

Note: The calculations are based on data for 15 countries for the years 2010-2015.

The research presented here and the detailed analysis of energy consumption patterns that was conducted both point to a clear need to draw a distinction between the different products handled in container terminals, namely (full) reefers and standard containers. The approach used here makes it possible to calculate the emissions of these different products. Until now, these types of differentiated calculations have been absent from the literature. As one example, the levels of emissions per reefer box are relatively low in Chile's main terminals. Dwell times for reefer boxes are a crucial factor in determining consumption levels and thus emissions. In the case of Chile's Terminal Pacífico Sur, emissions (excluding Greenhouse Gas Protocol (GHG) scope 3 emissions) were calculated to be 27.57 kg of equivalent carbon dioxide (CO2e) per box[3] (TPS, 2013) in 2013. Applying the differentiation of container types arrived at using the activity-based approach, CO2 emissions per standard container are 19.32 kg and 66.18 kg of CO2 per reefer container, respectively. This reinforces the argument that reefer and dry containers should be treated as separate products. Based on this differentiation, the question arises as to whether the perception that container terminals account for no more than a marginal share of the emissions of the overall transport chain still holds true or not.

III. Conclusions

These findings concerning current levels of energy consumption of container terminals are highly relevant inputs for industry leaders and policymakers and point to the urgent need for action in order to address the issues of competitiveness, energy security and climate change and to analyse terminal performance on the basis of a more integrated, sustainable approach.

The research presented in this issue of the *FAL Bulletin* underscores the importance of using energy consumption as a basis for identifying energy-efficiency potentials and improving carbon footprint calculations. One of the challenges faced in previous research was how to go about assigning fossil fuel use to different process clusters. It was possible to fill this gap almost completely by employing the activity-based approach more consistently. The analysis of energy consumption patterns shows that a significant potential exists for reaping the benefits of technological change and electrification. By way of example, the number of litres of diesel fuel consumed per handled box in Chilean container terminals was equivalent to the number consumed by a fully laden truck travelling 17.6 km[4] in 2013 and, in total, more than 10.5 million litres of diesel fuel were consumed. This underlines the importance of taking energy consumption in container terminals into consideration when calculating emission levels.

A comparison of costs and emissions shows that some terminal operators are faced with opposing objectives, as they often must choose between cost reductions or emission reductions. This, in turn, points to the need for policy incentives. Policymakers and port authorities should support the efforts of ports and terminals to reduce energy consumption and emissions in various ways. These include helping terminals and other operators to introduce green technologies, developing differentiated port and terminal charges based on energy consumption, implementing energy management systems for ports that will pave the way for load shedding and smart grid (macro grid) applications, employing energy brokerages to allow for environmentally friendly and economical contracts with providers and developing an energy mix that includes own-energy production using wind farms, solar panel installations, tidal energy and other sources.

The findings discussed here have three main implications for terminal operators and policymakers. First, terminal operators can influence their energy consumption patterns by means of technological advancements, operational decisions or a combination of both. Second, expenses appear to be the driving factor in the decision-making process of terminal operators. A reduction in energy costs does not, however, necessarily go hand in hand with a reduction inemissions. Policy measures are needed to internalize the cost of emissions, at least to a certain extent. Third, the attribution of energy consumption, emissions or expenses

[3] 216.94 kg per TEU, multiplied by the correct TEU-factor –1.63– for this year and terminal.

[4] Trucks are estimated to consume 35 litres of diesel fuel per 100 km.

to a given unit should be done on a per-box basis, and a distinction should be made, at the least, between reefer and dry containers, since container terminals are multi-product facilities —a fact which is commonly overlooked when productivity assessments are being prepared.

The relevance of this last finding is not limited to terminal operators and policymakers, since it also makes a contribution to the work being done on the calculation of energy consumption and emissions in logistics chains. The consumption patterns of dry and reefer containers differ so immensely that a valid argument cannot be made for treating the methods of handling these two types of containers as if they were the same product. The usefulness of this finding is not confined to container terminals, as it is also applicable to any research on the consumption and emission patterns of container ships that transport a considerable volume of full reefer boxes.

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