METRICS FOR ENERGY EFFICIENCY IN LOGISTICS OF FREIGHT DISTRIBUTION

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Abstract*: The paper is a study on the energy efficiency indicators that can be used for the activities in logistics of freight distribution, at the company level, as well as at macroeconomic level. There are highlighted also some solutions for increasing energy efficiency in distribution channels, starting from technical and logistics management actions, at the company level. There are revealed also the impacts of energy efficiency measures.*

1. INTRODUCTION

There are several motivations for the determination of the energy efficiency indicators. First is the economic aspect, any energy savings resulting in reduced costs and thus increase profits. A second aspect is the scarcity of energy resources, reducing consumption is a measure of energy security. And thirdly, but not necessarily the least, reducing energy consumption is one of the solutions that contribute substantially to reducing pollution and global warming.

Companies handle a large amount of data, but without their systematization there are useless and sometimes difficult to manage. For this reason, it needs to use some metrics, key performance indicators, useful in determine and analyse the performance of company. Identifying and determining the energy efficiency indicators is a first step in order to analyse energy efficiency, to make comparisons in time and space between activities, processes, equipment and facilities, as well as to enhance the energy efficiency.

The methodology of this study combines together different methods, mainly literature review, data analysis and problem identification.

2. ENERGY EFFICIENCY INDICATORS IN LOGISTICS OF DISTRIBUTION

Throughout time, in order to assess energy efficiency, there have been used a number of indicators. First, they were used to determine the energy efficiency of different activities of companies. For their determination, the initial collected data are those related to absolute the energy consumption and the energy costs at the level of economic entities. These energy consumptions can be decomposed and detailed on activities, on places of work, on equipments or taken into consideration other criteria. Energy consumptions are placed in relation to the results of the activities of the entities.

In general, the most commonly used are the indicators determined as a ratio between the results, respectively goods or services, and energy consumption for them. There are also calculated the so-called specific consumptions or relative consumptions, obtained as a ratio between energy consumption and values of the respective activities, expressed in physical units. For example, in the case of energy conversion processes, their analysis is most often based on energy return.

An analysis of total energy consumptions in distribution channels is quite complicated because logistics activities are diversified, the quantification of the results of these activities is done differently and supply chain could be quite extensive.

The most representative logistics activity, freight transport, is quantified in term of performance in various units: number of kilometres, number of vehicles required for the transportation existing quantities, carried quantity. But the specific units of performance quantification that best properly reflect the transportation performance are tonne-kilometre, vehicle-kilometre or any other standard loading unit-kilometre.

Starting from these there can be determined a series of energy efficiency indicators (table 1), such as specific consumptions, energy intensity, energy specific expenditures. For example, in what it concerns the distribution channels, for measuring energy efficiency it could be considered the following categories of such of indicators:

- Fuel consumption per tonne-kilometre;
- Fuel consumption per 100 kilometres;
- Fuel consumption per pallet-kilometre;
- Fuel consumption per package;
- Fuel consumption per tonne;
- Fuel consumption per client served.

Table 1. Energy efficiency indicators for transport

Energy metrics	Transportation metrics	Energy efficiency indicators
Energy consumption (oil, electricity, gas, others): - Rail - Road - Air - Water - Pipelines	Kilometres	Energy specific consumption = Energy consumption/ 100 kilometres
	Tonnes	Energy specific consumption = Energy consumption/ tonnes
	Tonne-kilometre	Energy specific consumption = Energy consumption/ tonne-kilometre
	Palette-kilometre	Energy specific consumption = Energy consumption/ palette-kilometre
	Vehicle-kilometre	Energy specific consumption = Energy consumption/ vehicle-kilometre
	Vehicles	Energy specific consumption = Energy consumption/ vehicle
	Value added	Energy efficiency = Value added / energy consumption
		Energy intensity = Energy consumption/ value added
Energy costs	Kilometres	Specific energy expenses = Energy cost/ 100 kilometres
	Tonnes	Specific energy expenses = Energy cost/tonne
	Tonne-kilometre	Specific energy expenses = Energy cost/ tonne-kilometre
	Vehicle-kilometre	Specific energy expenses = Energy cost/ vehicle-kilometre
	Palette-kilometre	Specific energy expenses = Energy cost/ palette-kilometre
	Vehicles	Specific energy expenses = Energy cost/vehicles
	Value added	Energy efficiency = Value added / Energy cost

Besides the physical energy efficiency indicators, it presents also relevance the value indicators. There can be used metrics such as:

- absolute energy expenses;
- specific energy expenses, measured as a ratio between energy expenses and the results of activity expressed in physical units;
- the weight of energy expenses in total expenses.

In what it concerns the warehousing, another logistics activity consuming important energy resources, energy efficiency indicators can be calculated by reporting to various activity data, such as of surface units, number of employees or added value of services rendered (figure 1).

There is also the possibility to report to the loading units, but this can be done rather

in the case of warehouses with a very limited range of products and with physical measurement units of the same type to ensure comparability.

For warehouses with a large assortment of products, with load units of different sizes, with different physical characteristics is recommended to replace these units with value units allowing comparability and calculation of calculation of synthetic indicators at the warehouse level or storage building.

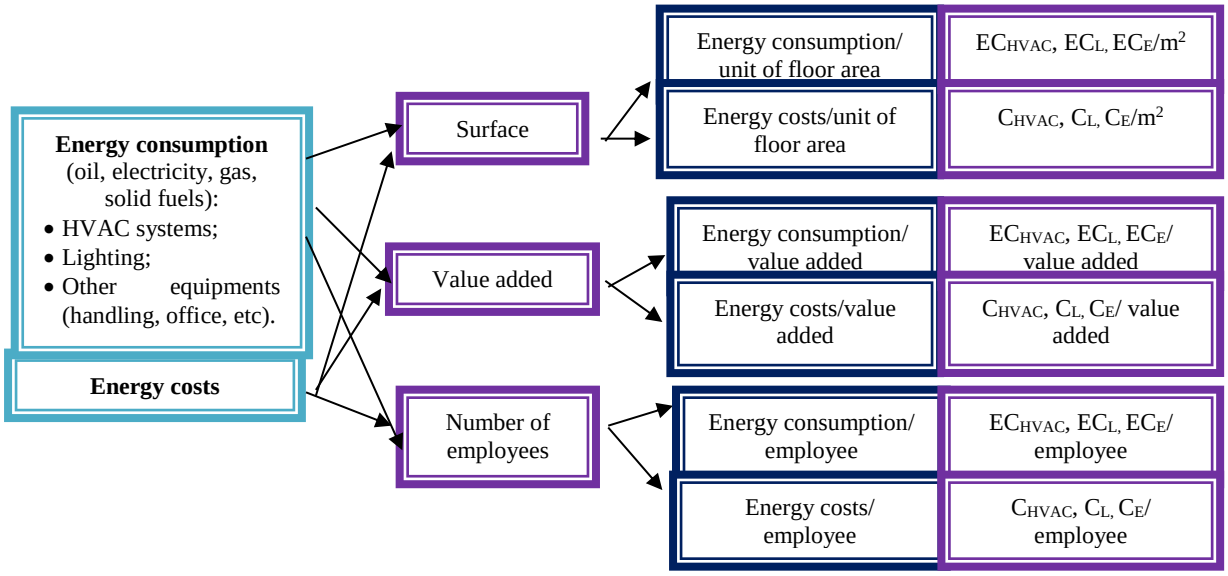

Fig.1. Energy efficiency indicators in warehousing

In order to do the analysis of energy efficiency in a warehouse, there can be made even more punctual determinations. For example, to determine the energy efficiency of lighting systems used in buildings serving logistics activities, it is reported their performance in lumens to energy consumption to obtain it. Moreover, determinations can be performed for each category of service, for each source of energy, for each heating, air conditioning or handling equipment and other technology.

In what it concerns the comparisons at international level of the energy efficiency, statistical data are most often global referring to the consumptions of energy in different sectors or to the energy intensity related to GDP or GVA (gross value added). Energy efficiency indicators can be converted into CO2 intensity indicators through unit 'gram CO2 emitted per tone-kilometer' (kg CO2 / t-km) [1].

In a classification of energy efficiency indicators realized by ICEMENERG [2], there have been identified three major categories of indicators:

1. Monitoring indicators of the trends in energy efficiency:
    a. Energy intensity;
    b. Specific energy consumption;
    c. Indicators of the evolution of energy efficiency calculated at the level of the economy as a whole or of the economic sectors;

2. Comparison indicators to compare the energy performance of different countries:
    a. Indicators adjusted according to the structures of national economies, price level, climatic conditions;
    b. Target indicators;
3. Diffusion indicators:
    a. Market penetration of the energy efficient;
    b. Diffusion of the most effective practices in terms of energy efficiency.

A study conducted by OECD [3] reveals that there are a number of issues related to data availability.

Given that the most important logistics activities are freight transport and warehousing, existing statistics are not relevant enough. Statistics relating to the transport sector allow identification of energy consumptions for freight transportation at the level of states, but in the case of activities related to storage of goods, existing statistics do not distinctly delimit this category of energy consumptions. Existent statistical data are global, related to service sector, such as energy consumptions of energy expenditures, without giving information on the specific consumptions of warehousing activities.

Aggregate indicators have the advantage of their availability, but their utility is limited and can lead to misinterpretations when they are incorrect handle [4].

3. POSSIBILITIES TO IMPROVE ENERGY EFFICIENCY IN DISTRIBUTION CHANNELS

In order to optimize logistic activities one of the objectives is reduction of energy consumption for a given level of service.

Among the logistics activities, transport stands out as the most important activity in the ensemble of these activities. For this reason, increasing energy efficiency is considered as an important goal of freight transports, especially in the case of road transports, large consumers of energy resources.

But, unfortunately transport is considered one of the most difficult sectors for improving energy efficiency [5]. Even though OECD countries are recording a reduction in energy intensity by improving the energy efficiency of new generations of vehicles, there are many problems at global level due to an increase of the use of road transport for goods in many of the countries in the world.

There can be taken into considerations some solutions for optimization energy consumption in transportation of goods, along the distribution chains, most of them based on new information and communication technologies. But it can take into account also fiscal measures to stimulate the reduction of energy consumption.

Implementing an automated fleet management solution enables improving energy efficiency [6]. In addition, it had an impact on driver safety, warning the driver about the vehicle over speed. There can be used, also, intelligent traffic management programs that optimize traffic flows in real time leading to increase energy efficiency. Route optimization using satellite navigation systems reduces fuel consumption per unit of freight transported [1].

Also for spaces used for logistics activities there have to consider a number of measures to improve energy efficiency. In order to increase energy efficiency in warehouses, it needs to take into considerations the key aspects of energy performance of the buildings, as well as handling, sorting, picking and transportation equipments.

In a study realized by Knowles [7], the author used the surface area to volume ratio as metric in order to determine the heat loss and gain direct influencing the energy performance, small values of this metric revealing minimum transfer of heat. As a result, these heat losses and gains depends on the form design, the best form identified being a cube. For day lighting and ventilation optimization the building form has to be one with building area closer to the perimeter area [8].

In order to get other energy savings for the buildings alongside the logistics channels there can be considered also:

- Orientations in relation to sun:
  - Rectangular buildings oriented on east – west direction maximize solar heat gain in winter and minimize it in summer [8];
- Orientations in relation to wind direction determine improvement in building ventilation and energy performance [9];
- Building insulation – determines reductions in heating needs, having as effect a better energy performance of the building [10].

Companies operating in logistics may use a range of optimization solutions which can cause significant reductions and energy costs. For the older buildings their isolation could be a first solution, while for new investments in storage facilities and categories of spaces for logistics, the measure would consist in construction of energy efficient buildings. In addition, their facilities such as handling, sorting, packing, labelling, picking equipments, as well as HVAC systems should be energy efficient.

By entering a building automation system (BAS) the company can control HVAC, electrical, and lighting systems [11]. The use of solutions of integration lighting and HVAC systems through daylight control and the advent of LEDs can also lead to increased energy efficiency [12]. Software-based solutions in the pump control in HVAC applications in distribution increase energy efficiency and eliminate external sensors and related procurement installation and maintenance cost.

Improvement of HVAC and control infrastructure, the introduction of centralized energy management control systems and replacing inefficient lighting systems cause

significant energy savings [13]. In a study conducted in 2014 [14], it had been revealed that in the selection of lighting products for office buildings, besides product quality, energy efficiency (97%) is decisive.

At the level of the member countries of the European Union introducing energy labeling and energy performance standards referring to technologies, equipment and buildings were some of the measures applied on a large scale. In Romania, at governmental level, there are, also, concerns regarding energy efficiency. In 2014 the requirements of the Directive on energy efficiency were transposed into national law.

Mandatory energy auditing of the companies and energy certification of buildings are among the measures taken by governments to make businesses to choose energy efficient solutions. In addition, the use of fiscal measures by the states can stimulate energy efficient investments.

A large part of these measures are also applicable to the companies operating in the logistics sector, in the distribution channels, such as those regarding the electric motors, electric traction, electric drive, air conditioning systems, equipment office, lighting products, which can contribute substantially to increasing the energy efficiency of logistics channels.

In order to inform all users there can be created information and energy consulting centres, but there can be used also a number of other means, such as guides, newsletters, dissemination best practice of energy efficiency solutions. Besides consumers' information measures, an important impact might have the programs for energy technology development and incentive programs for equipment manufacturers, as well as for producers of freight transport vehicles.

4. CONCLUSIONS

For monitoring energy efficiency and in order to be able to make comparisons in time and space, it is necessary to use energy efficiency indicators universally recognized and creation of databases adequate to these determinations. Different metrics regarding energy performance allow comparison of different kinds of systems and their relative efficiencies.

At the macroeconomic level it can be considered the relation between energy consumption and GDP, GVA, population and other macroeconomic variables.

To quantify the energy intensity of specific activities in distribution of goods it can be considered energy consumption reported to physical or monetary units resulting from these activities.

Increasing energy efficiency contributes not only to increase profitability of companies in logistic channel, but also to achieve social goals and sustainable development.

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