ORIGINAL ARTICLE

Energy management in the Base Business Unit Agricultural Worshops in Granma Province

La gestión energética en la Unidad Empresarial de Base Talleres Agropecuarios Granma

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ABSTRACT: The present work was developed in the Base Business Unit (UEB) Granma Agricultural Workshops of Bayamo Municipality. It aims to evaluate the energy management in that plant, with the purpose of achieving greater efficiency and competitiveness. For this, the use of the methodology proposed by the Center for Study and Environment (CEEMA) of Cienfuegos University is used for the application of Total Efficient Energy Management Technology (TGTEE). On that purpose, the consumption of electricity, diesel, fuel oil, gasoline, lubricants and liquefied gas, as well as the costs for one kWh of electricity and one L of fuel, respectively, were registered for the years 2020 and 2021, according to the data in the Departments of Economy and Energy of the entity, with which a database was created applying the analytical-mathematical method of the (TGTEE), based on the Microsoft Office package (Excel). The results show that the energy carriers with the greatest weight in the production of the UEB are electricity and diesel. It is ruled out that the energy management is deficient since the determination coefficients (R^2) for both carriers are less than 75%.

***Keywords*:** Energy, Energetic Efficiency, Power Carriers, Correlation.

RESUMEN: El presente trabajo se desarrolló en la Unidad Empresarial de Base (UEB) Talleres Agropecuarios Granma del municipio Bayamo. El mismo tiene como objetivo evaluar la gestión energética en dicha planta, con el propósito de lograr una mayor eficiencia y competitividad. Para ello se recurre al empleo de la metodología propuesta por el Centro de Estudio y Medio Ambiente (CEEMA) de la Universidad de Cienfuegos para la aplicación de la Tecnología de Gestión Total Eficiente de la Energía (TGTEE). Para lograr dicho objetivo se parte de una base, que, , comprendió la toma de los consumos de electricidad, diésel, fuel oil, gasolina, lubricantes y gas licuado, así como los costos para un kW h de electricidad y un L de combustible, respectivamente para los años 2020 y 2021, registrados en los departamentos de economía y energía de la entidad, con la cual se confeccionó una base de datos aplicando el método analítico-matemático de la (TGTEE), apoyándose en el paquete de Microsoft Office (Excel). Los resultados evidencian que los portadores energéticos de mayor peso en la producción de la UEB son la energía eléctrica y el diésel. Descartándose de que la gestión energética es deficiente pues los coeficientes de *determinación (R^2) para ambos portadores son inferiores al 75%.*

***Palabras clave*:** energía, eficiencia energética, portadores energéticos, correlación.

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INTRODUCTION

The growth of energy consumption in the world, mainly in developing countries, has intensified concern about the large number of problems associated with its production, distribution and use. Both fossil fuels (oil, coal, natural gas) and nuclear energy have a formation cycle of millions of years, which implies that if the consumption rate is similar to the current one, they will end up running out in a fairly close period (Romero, 2011).

In the face of the worsening of global warming, the need is evident, not only to reduce energy consumption patterns, but also to diversify energy sources towards other "sustainable" ones, which take to rethink the management and usufruct of fossil resource available, since any change in the energy paradigm will necessarily be based, at least in principle, on this last type of energy (Ramos, 2011).

The saving of any form of energy and its rational use inevitably presupposes the application and control of a planned program for that purpose, but that program is not drawn up empirically, but supported by technically based methods or procedures, that is, it must be supported by energy diagnoses that allow identifying the efficiency and responsibility with which energy of any kind is used in each place that is applied (Almachi *et al.*, 2010).

The analysis carried out in numerous companies revealed the insufficient level of energy management existing in many of them, as well as the possibilities of reducing energy consumption and costs by creating technical-organizational capacities in companies to manage energy efficiently (Raña *et al.*, 2004; Borroto *et al.*, 2005; Ramos *et al.*, 2010; González *et al.*, 2011; de la Rosa *et al.*, 2014; Macías *et al.*, 2015; Gutierrez *et al.*, 2019).

In recent years, the UEB Granma Agricultural Workshops has carried out a series of actions in addition to systematic control with a perspective of guaranteeing its productions with a rational consumption of its energy carriers. However, the desired efficiency in the use and control has not been achieved. Taking into account that fact, it is feasible to carry out this research work, which aims to evaluate energy management based on Total Efficient Energy Management Technology to achieve greater efficiency in the use and control of carriers in the Granma Agricultural Workshops Base Unit.

MATERIALS AND METHODS

This research was developed in the UEB Granma Agricultural Workshops which is located on the central highway km $3^{1/2}$, via Santiago de Cuba, belonging to Bayamo Municipality, Granma Province. This UEB is a base business unit that is integrated into the Business Logistics, Group of the Ministry of Agriculture (GELMA).

Energy Characterization of the Factory

The energy characterization of the factory was carried out based on the analytical-mathematical method, as it appears in the Technology of Total Management of Energy Efficiency in Business Management (TGTEE) proposed by the Center for Energy and Environment Studies of Cienfuegos University (CEEMA, 2002). It consists of a package of procedures, technical-organizational tools and specialized software, which applied continuously and with the philosophy of total quality management, allows establishing new habits of management, control, diagnosis and use of energy, aimed at taking advantage of all the opportunities for saving, conservation and reduction of energy costs in a company. Its objective is not only to diagnose and leave a plan of measures, but essentially to raise the technical-organizational capacities of the company, in such a way that it is capable of developing a process of continuous improvement of energy efficiency.

The methodology used in this investigation reached the diagnostic test, and in this direction it was necessary to start from a base, which in the case of this investigation corresponded to the period from January, 2020 to December 2021. Taking the records of energy consumption of the energy carriers (electricity, diesel, fuel oil, gasoline, lubricant and liquefied gas) of Granma Agricultural Workshops, the authors carried out statistical studies to perform the energy evaluation of this entity.

RESULTS AND DISCUSSION

Evaluation of Energy Management Indicators

After processing the consumption records of the energy carriers applying the Total and Efficient Energy Management Technology, the structure of the company's energy consumption in the years a) 2020 and b) 2021 was drawn (Figure 1). The energy carriers that carry the greatest weight within the total consumption of the UEB in both years are electricity and diesel, respectively, since the sum of both represents 85,18% for the year 2020 and 83,46% for the year 2021. Following the Pareto Law, which states that, for energy, the efforts should be focused on 20% of carriers that represent 80% of the consumption of energy carriers, the authors will only carry out the analysis for these two.

After determine the energy carriers where the attention should be focused, the stratification was implemented, with the aim of looking for the particular cause of the effect. Figure 2 shows how diesel consumption behaved for the analyzed period, noting that within the activities that consume 80% of this energy carrier are the production derived from the steel industry and construction for investments, since these two activities represent 20% that generate 80% of the total consumption of diesel in the UEB.

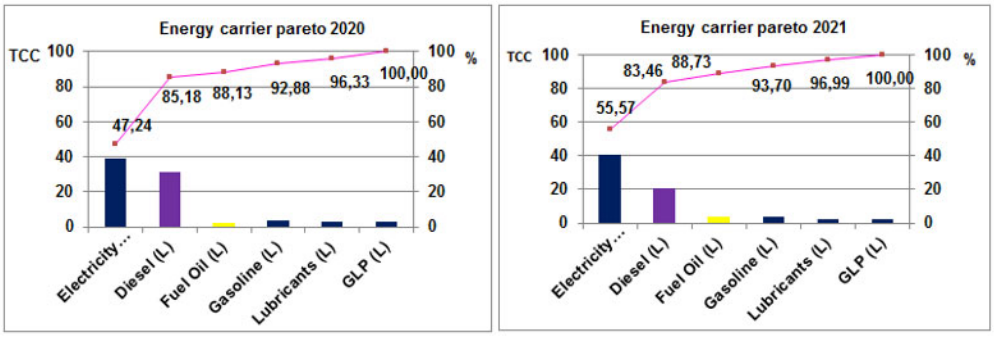
The same should be done with electricity. However, for this energy carrier, it was impossible to see what the particular cause was, to know what are the activities that represent 20% and generate 80% of the consumption of this carrier. The main cause is that there are no meters for key results areas and consequently, to know the electricity consumption by activity.

Subsequently, the electrical and diesel energy records for the year 2020 were processed, observing through the energy and production graphs over time (Figure 3), that there were variations between energy carriers and production. Result that differs from what the theory proposes, that the adjustment of this type of variables must be linear.

Despite this result, in the case of electrical energy (Figure 3a), a linear trend could be observed in the months from May to September. Similarly, when analyzing diesel over time (Figure 3b), it showed that the best behavior of this carrier over time was in the same period.

Likewise, Figure 4 shows the consumption of electricity and diesel over time for the year 2021. It could also be appreciated that in this period there were variations that did not lead to a linear adjustment.

However, in the case of Figure 4a (S.E. and production over time) it revealed that in the months of January and February, July and August, as well as in October, November and December, the adjustment is linear. In the case of Figure 4b (diesel and production over time) a tendency to the existence of fewer variations is shown. Only in March and April, the trend was not linear.



a) b)

FIGURE 1. Pareto diagram. a) Energetic carrier 2020 b) Energetic carrier 2021.

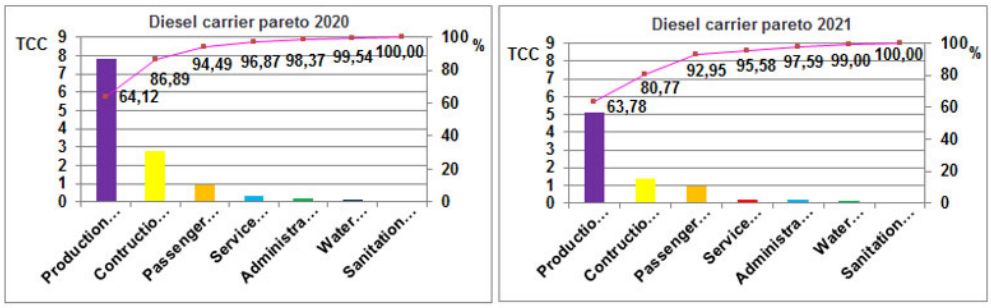


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FIGURE 2. Diesel consumption by activities in the UEB in the years a) 2020 y b) 2021.

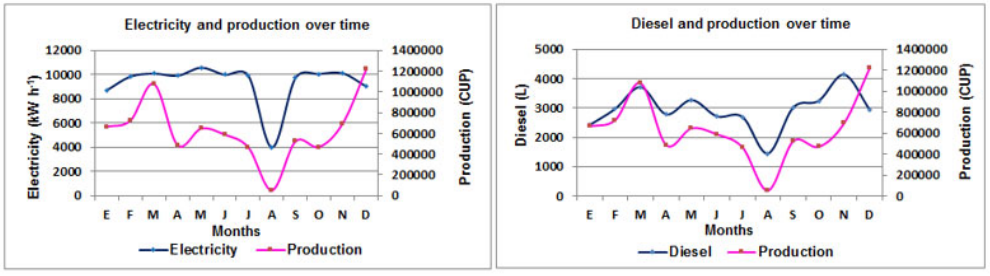

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FIGURE 3. Energy and production graphics a) Energy and production 2020 b) Diesel and production 2020.

When observing the correlation graphs for the year 2020 (Figure 5), it is evident that the indices used for this activity are not adequate.

This is supported by the values found when determining the coefficient of determination (R^2) in both carriers (0,26 for the case of electric power and 0,34 for diesel). These magnitudes are below those reported by Borroto *et al.* (2002). These researchers report that for the indices used in the activity to be adequate, the value must be greater than 0,75.

When carrying out this same analysis for the year 2021, it can also be seen that the indices used for this activity are not adequate (Figure 6) because the results of the determination coefficients for the consumption of Electric and Diesel Energy yielded values equal to R^2=0,50 and R^2=0,42; respectively. These magnitudes, although higher than those obtained in 2020, do not equal or exceed what was reported by Borroto *et al.* (2002).

On the other hand, Figure 7 shows the results of the behavior of the fuel consumption control, where it is observed that for the analyzed period, it is within the upper (LCS) and lower (LCI) control limits, evidencing that there is sequence and bias, since there are more than 7 points below the average consumption, data that correspond to the months from April to December, 2021.

When analyzing the behavior of energy management in the two years introduced, it is evident that the energy efficiency indicators in the UEB Granma Agricultural Workshops are not satisfactory. This result is derived from a series of measures to be

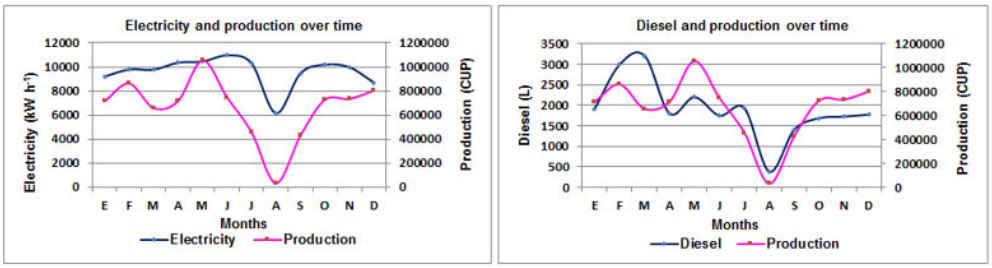

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FIGURE 4. Energy and production graphics a) Energy and production 2021 b) Diesel and production 2021.

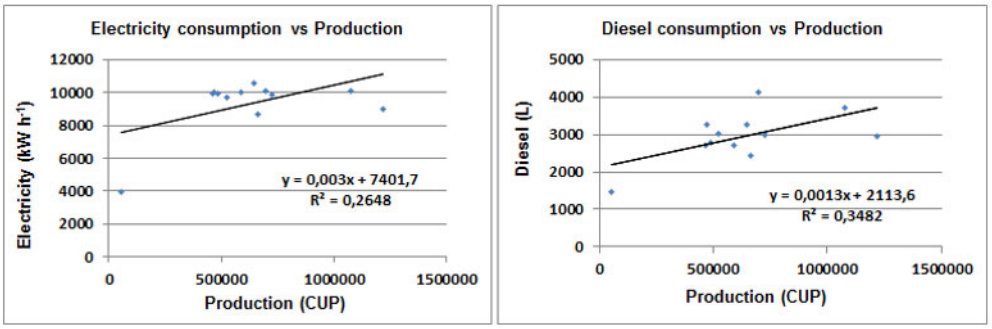

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FIGURE 5. Consumption graphics. a) Electric energy vs Production 2020 b) Diesel vs Production 2020.

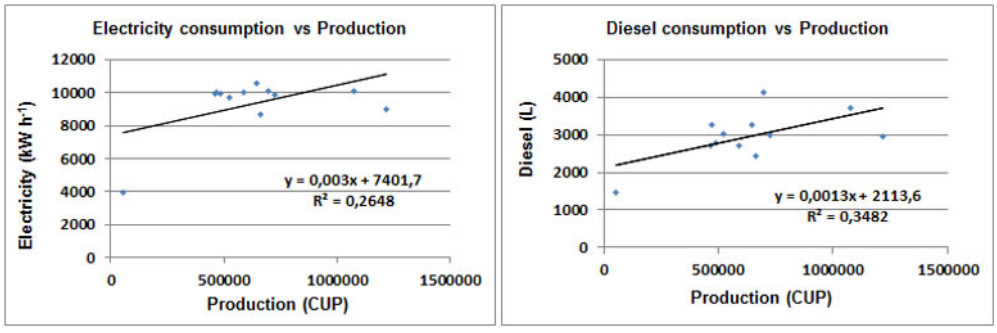

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FIGURA 6. Consumption graphics. a) Electric energy vs Production 2021 b) Diesel vs Production 2021.

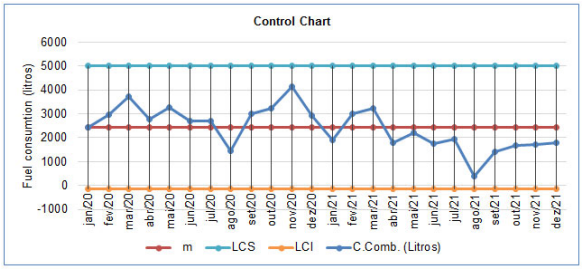

FIGURE 7. Diesel consumption control graphic for years 2020 and 2021.

taken both in the medium and short term (without economic investment and with economic investment) in the entity with the aim of improving its energy efficiency.

The results found in this research agree with those obtained by Martínez (2007), López (2011), Machado *et al.* (2013), de la Rosa *et al.* (2014) and Mohamed *et al.* (2016) where, when carrying out an energy characterization and evaluation in other companies, they found that there were variations between the energy carriers analyzed and the generated production, yielding values of the determination coefficients below 0,75. However, it differs from those presented by Verdecia *et al.* (2017) where, when carrying out an evaluation of the energy efficiency in Granma construction transport company, they found results that led to a linear adjustment with determination coefficients greater than 75% (97 and 99%). This result indicates that in the province, there are companies where energy management resources do not receive the appropriate attention in order to be more efficient and competitive.

In order to analyze the cost generated in the analyzed period, in terms of the use of the electric power carrier, the price per kW for this type of consumer will be considered and the variable charge ratio will be found.

Table 1 shows the results of energy costs, taking into account the consumption of electrical energy not associated with the production process in the two years under study. It is appreciated that the expenses were somewhat higher in the year 2020, with a difference of 19 CUP compared to 2021. This shows that the consumption of this carrier did not vary much. A total of 3 977,96 pesos in CUP were saved for this concept.

TABLE 1. Expenditure incurred in the consumption of electrical energy not associated with the production process

Year	kW*h	Price	Amount (CUP)
2020	7 401,7	0,27	1 998,46
2021	7 331,5	0,27	1 979,50
Total	-	-	3 977,96

In the same way, it is proceeded with diesel, the price of one liter will be taken for this type of carrier and the relationship of the variable charge will be found.

Table 2 shows the results of energy costs, taking into account the consumption of diesel not associated with the production process, in the period analyzed.

TABLE 2. Expenditure incurred in the consumption of diesel not associated with the production process

Year	L (l)	Expensive	Amount (CUP)
2020	2 113,6	2,00	4 227,20
2021	693,46	2,00	1 386,92
Total	-	-	5 614,12

It is observed that in the year 2020 the expenses referred to this carrier are higher than in 2021, with a difference of 2 840,28 CUP. And although it is evident that in 2021 the behavior of this carrier was better, adequate indices have not yet been reached regarding the fundamental activity. In general, an expense of 5 614,12 CUP was done, which can be reduced.

CONCLUSIONS

- The consumption structure of the energy carriers of the UEB was determined, where electricity and diesel fuel were the carriers with the greatest energy influence, since they represent 80% of the entity's consumption.
- The particular cause of an effect on deeper strata was analyzed and it was found that the production derived from the steel industry and the construction for investments are the activities that consume 80% of diesel.
- The linear correlation between electrical energy consumption versus production in the observed period is weak, with values of the coefficient of determination R^2 lower than 0,75 with magnitudes of 0,26 and 0,50, respectively.
- The linear correlation between diesel consumption versus production in the observed period is weak, with values of the coefficient of determination R^2 lower than 0,75 with magnitudes of 0,34 and 0,42, respectively.

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