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Energy Planning for Gas Consumption Reduction in a Hot Dip Galvanizing Plant

Guillermo Valencia[a], Erni Ramos[a], Lourdes Meriño[b]

[a] Mechanical Engineering Department, Universidad del Atlántico, km 7 antigua vía Puerto Colombia, Atlámtico - Colombia
[b]Agroindustrial Engineering Department, Universidad del Atlántico, km 7 antigua vía Puerto Colombia, Atlántico - Colombia
guillermoevalenca@mail.uniatlantico.edu.co

The application of a method for energy planning in order to reduce the gas consumption for a hot dip galvanizing process in a metallurgy company based on ISO 50001 standards was conducted in this research. The gas consumption for the company represents around the 75% of the total energy consumption for the company, indicating that the energy saving potentials are in the gas consumption. Three variables were taken from real data, gas consumption, level of production, and time; so, that to obtain energy performance indicators such as base line and goal line, consumption ratio with respect to the levels of production, base 100 efficiency indicators, and accumulated tendency of consumption or CUSUM. With an average production rate of 20000 m^2 per day, these indicators allowed setting objectives and goals to reduce the levels of gas consumption through the implementation of good manufacturing practices and production planning. For this case of study of a hot dip galvanizing process, were calculated saving potentials until 10% of gas consumption. The implementation of this method allows determining energy saving potentials in order to reduce greenhouse gases emissions and operational costs for the plant.

1. Introduction

The global economy has recently emphasized in primary energy sources, global supply chains, and energy consumption in the end consumer; In this sense, the world trade volume of energy use is 90% of the global primary energy generated (Reviews 2017), where approximately 37% of consumption corresponds to the industrial sector (Abdelaziz et al., 2011).
Energy management systems in industry are articulated to environmental management systems and jointly analyze economic, environmental and energy indicators. Therefore, energy management has become an aspect of great importance for all economic sectors and this is one of the most promising tools to reduce energy consumption and thus energy costs (Bernal-Conesa et al., 2016) (Schulze et al., 2016), also supporting sustainability and industrial eco-efficiency (May et al., 2016).
In order to promove the continuous improvement, many countries had developed a pwerfull plan to implement energy management systems to improve the savings and efficiency of the plants. The European Community has developed the Framework for Action on Climate and Energy to the year 2030, fuerthermore the International Organization for Standardization approved the ISO 50001, the Energy management systems standart, while in Colombia the activities related to ISO 50001 are regulated by the National Bureau of Normalization that has been adopted for use in the country as NTC ISO 50001 since 2011; but only three companies have been certified (Campos, Lora, Quispe, et al., 2011) (Campos, Lora, Prias, et al., 2011b).
All of the above highlights the strategic value of energy management for industry (Rudberg, Walderrrr, 2013). Therefore, the objective of this work is to analyze, evaluate and reduce the consumption of electrical energy in industry by the application of a case study to the process of hot dip galvanizing of metal sheets, in a company of the metal-mechanic sector whose process and products serve the industrial sector in Colombia, supported for this in a procedure for planning in the framework of ISO 50001 standard.

2. Materials and Methods

2.1 Energy Management System

The efficient energy management tools used in this study are based on the steps and procedures of quality management, supporting on the continuous improvement of the energy performance for industrial processes (Campos & Lora 2009). Since the approval of ISO 50001, a new stage of implementation of comprehensive management systems has been started at the global level, allowing, for different companies, the establishment of an energy policy aimed at improving the energy efficiency of processes, thus determining equipment and sub-processes that consume energy significantly, foreseeing projections and quantifying potential savings associated with production, and their respective action plans to achieve these potentials (Campos & Prias 2013).
The standard proposes a four-stage model: energy policy, energy planning, implementation and verification all inserted in the cycle of continuous improvement, where it is emphasized that energy planning with its main constituent elements are the foundation of strategies to improve energy performance (Campos, Lora, Prias, et al., 2011).

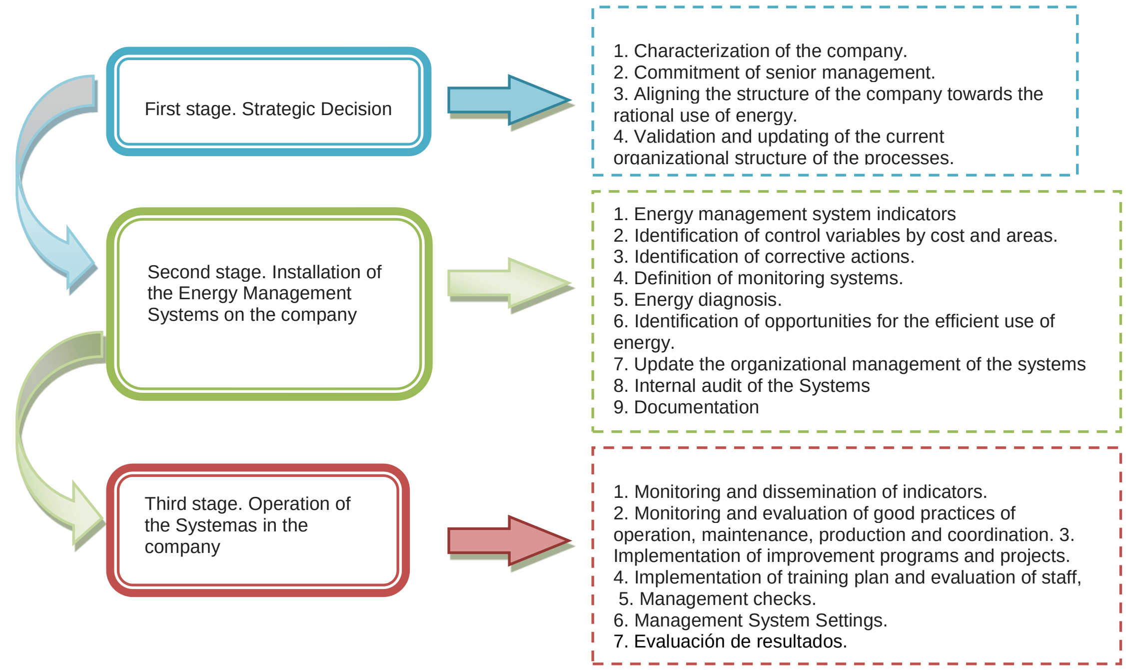

Figure 1. Components in energy management system

2.2 Energy performance indicators

In order to quiantify and calculate the energetic performance indicators, it is necessary to follow a methodology, starting at the statistic treatment of energy consumption, process and production information, then, estimating baselines and goals for each process, calculating later the results for: Consumption index, base 100 efficiency, and trend graphs, looking forward to a permanent improvement of the process (Campos & Prias 2013).
For the filtering of information, which is a pre-treatment of statistical data relevant to the study of the process, it is necessary to take an interval of one standard deviation as shown in equations 1 and 2.

$$Upper\ limit = E_t + 1 * Standar\ Deviation \quad (1)$$

$$Lower\ limit = E_t - 1 * Standar\ Deviation \quad (2)$$

where, E = Electric consumption in time t.
After the filtering, where it is necessary to comply with $Upper\ limit > E_{actual} > Lower\ limit$, the following is to proceed with the establishment of a goal-line, using real consumption data below the baseline of electric consumption, according to:

$$E_{Theoretical} - E_{actual} > 0 \quad (3)$$

Later, the real consumption index (IC) is built with energy consumption (E_{actual}) and production (p) as shown in Eq(4a).

$$IC_{Acual} = \frac{E_{Actual}}{P} \tag{4a}$$

While, theoretical consumption index is shown in Eq (4b),

$$IC_{Theoretical} = \frac{E_{theoretical}}{P} \tag{4b}$$

Another key indicator is the graph of cumulative trend, which is a tool that allows to monitor the company's electric energy consumption with respect to a baseline period. Finally, efficiency Base 100 index, is a tool for energy management that helps to evaluate the behavior of energy consumption measured during a period of production time in plant comparing with theoretical values calculated using the baseline. This index is calculated using Equation 5.

$$Base\ 100 = \frac{E_{theoretical}}{E_{Actual}} \times\ 100\% \tag{5}$$

This indicator generates warnings regarding positive or negative variations in the energy efficiency of the process, thus facilitating the analysis and proposal of action plans in function of energy improvements, allowing the analytical interaction between production and energy consumption, aiming at a Better process energy performance.

2.3 Application case: INDUSTRIAL LAMINATE PLANT

The company where the present work was carried out is a company from the Colombian metalworking sector that produces and markets cold rolled steel, galvanized steel, corrugated zinc tile and metallic architecture products. The plant exports about 5% of its production to Central America and the Caribbean, as well as to the countries of the Andean Community, in addition to Chile and EEU and belongs to an economic group with plants located in Puerto Rico, Dominican Republic, Costa Rica, Panama and Ecuador.
The plant has more than 30 years with a hot dip galvanizing line with a capacity of 70,000 tons/year, the process is shown in figure 2, In addition to incorporating the online annealing process

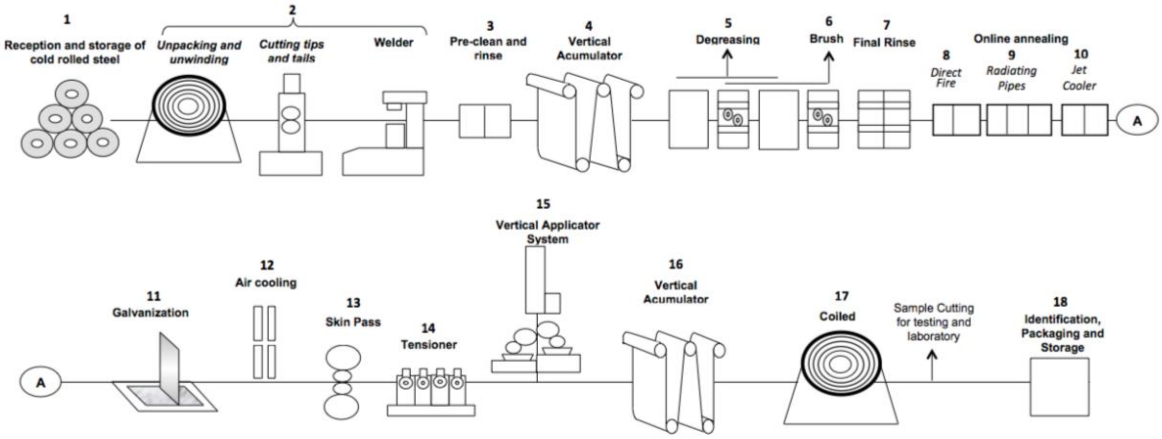

Figure 2. Flow diagram of process studied

3. Results and discussion

The results of the application of the energy characterization tools and analysis of energy performance indicators for the hot dip galvanizing line are presented below. As for the control limit plots, which set an upper limit and lower limit separated three times the standard deviation of the average of the data supplied from electric consumption as shown in figure 3a, for days 02 And 13 January, 19 April, 30 June, 01 and 07 July and 27 September consumption is below the lower consumption limit, therefore, these data will be considered atypical and not considered for the analysis of performance indicators.

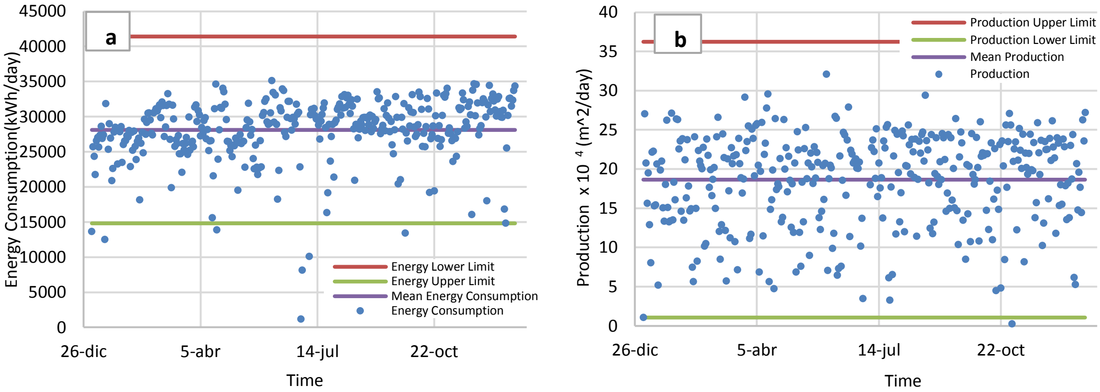

Figure 3. Control Charts for the hot-dip galvanizing process. a) Energy consumption, b) Production.

On the other hand, Figure 3b shows the control limit graph for the production data, resulting in that the production data for October 31 is an atypical data, which will not be considered for the energy product analysis. figure 4a shows the behavior of energy consumption and production over time, presenting similar behaviors in variation, however it is possible to observe atypical behaviors that can be explained by maintenance days or drawbacks in the production line, so it is necessary also to analyze in detail which events may have induced these behaviours.

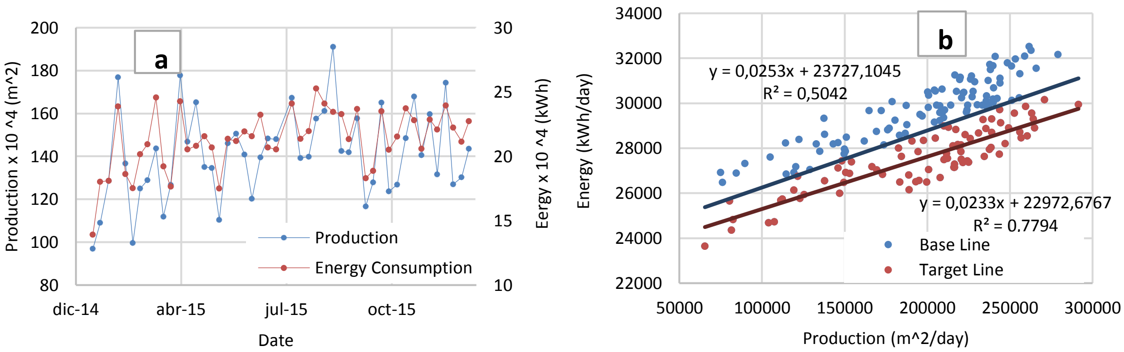

Figure 4. Energy management charts. a) Energy consumption and production, b) Base and Target line for the production plant

By drawing a graph of energy and production, from the data supplied from the hot galvanizing plant, the baseline was initially obtained with a linear correlation of $R^2 = 0.1824$, requiring data filtering in order to achieve an acceptable correlation for the analysis of energy performance indicators, without losing functionality between production and energy, obtaining the baseline and target line shown in figure 4b, where the target line was constructed from the production data and energy consumption below the baseline.

With respect to the theoretical consumption index and real consumption index, shown in figure 5a, it can be seen that the actual consumption index varies by 0.362 and 0.102 kWh/m^2, the process has production levels below the Critical production related to plant technology, which is calculated as 500,000 m^2/day according to the theoretical consumption index, however the company has production levels lower than the critical production, of which it is estimated that the average production rate for the company is approximately 200,000 m^2/day, which indicates that the hot galvanizing line can present better levels of energy performance, reaching lower consumption rates, through a better planning of the plant and production line.

Considering the trend for the year 2015 shown in figure 5b, it is observed that from the beginning of the year until mid-February, a stable behavior with a tendency towards good energy performance was maintained, this behavior is clearly observed in the second half of March, with also other short and notable periods with a tendency towards good energy performance (Trend line going down).

On the other hand, in the period from the second half of February to the first half of March a behavior is maintained that tends towards the poor performance of the hot galvanizing line, repetitive in the period from the end of May to the end of June. For the second half of the year there are behaviors with a tendency towards poor energy performance, with greater visibility from mid-November to the end of December.

For the application of the Base 100 efficiency index for the galvanizing line shown in figure 6, the points above the black boundary line are considered good energy performance and data is in the zone of good energy efficiency of the plant, while those located below the black line belong to a zone of energy inefficiency of the plant. However, it is important to notice that high-efficiency peaks are associated with random process behavior and are not the result of improvements in the company's energy management system.

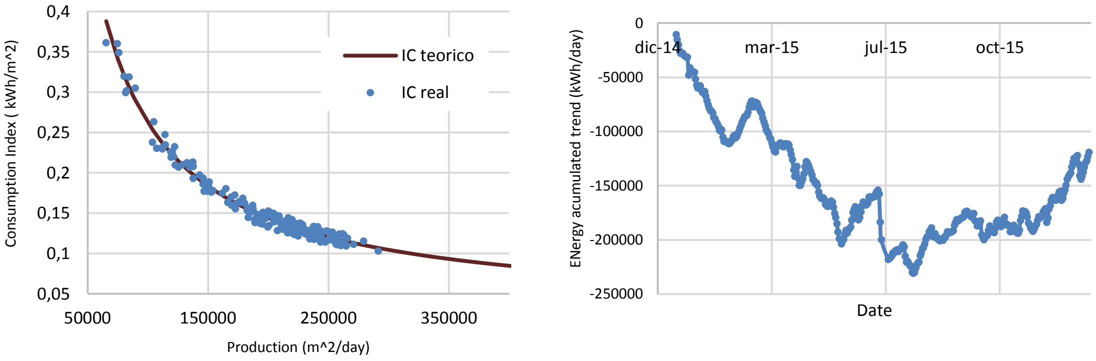

Figure 5. a) Theoretical consumption index versus real consumption index, b) Energy accumulated trend.

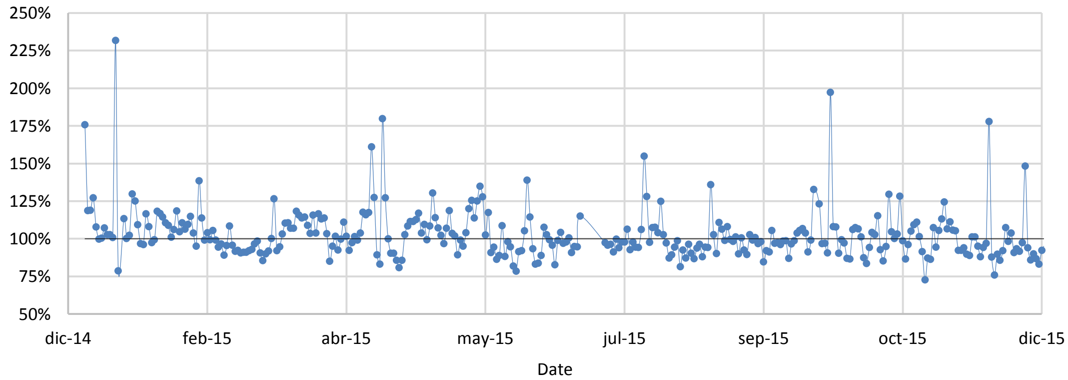

Figure 6. Efficiency Index Base 100.

Finally, the analysis of potential energy savings not associated with production, it can be reduced by 3.2 %, which translates into 754.4 kWh, while the potential for savings associated with production is 16,860 kWh, considering that the line has a critical production (PCRIT) of 500,000 m^2/day and an average production (PPROM) of 200,000 m^2/day.

4. Conclusions

The application of a procedure for energy planning for a hot-dip galvanizing plant made it possible to identify the causes of the deterioration of the electric energy consumption indicator, as well as to identify the different sources of inefficiencies in the process due mainly to the oversizing of the equipment and the operations and process planning scheme of the mills.

In addition, an operational strategy was proposed by the mills to process more than 500,000 m^2/day of product, which provides a saving of 16,860 kWh, and independent of planned production it was possible to find in the plant an extra potential of savings of 3.2% with the implementation of Operational and Maintenance good practices.

Finally, the 2015 baseline was obtained, proposing a target line for the years 2016 and 2017, allowing the projection of global savings of electric energy of 17,614kW.

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