Analysis of the Potential for Energy Savings in a Company in the Hotel Sector

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Abstract

This article presents the development of an energy characterization of a company in the hotel sector in Barranquilla, Colombia, as well as the establishment of energy baselines, consume index and kg of CO\textsubscript{2} not emitted into the atmosphere. To obtain the baselines, linear adjustments were made to the corresponding data, accompanied by statistical filtering and the development of a theoretical consumption function. Based on the foregoing, a total electricity (EE) saving potential of 18\% and 11\% for natural gas (NG) was calculated, both for improvements in maintenance, operational culture actions and for occupancy management. It was concluded that, through the application of an energy review, establishment of energy performance indicators, it is possible to know the business capabilities for the reduction of energy consumption of the organization and a starting point for the development of an energy management system according to the NTC ISO 50001: 2011 standard.

Keywords: Hotel sector, Energy management, Indicators of performance, Baselines, Pollution

1. Introduction

As companies in the service sector, hotels do not manufacture products; its basic purpose is accommodation, space rental and meal service. Around this, the need
arises to permanently maintain and guarantee the best conditions of cleaning, lighting, air conditioning and ventilation, among others, which requires an investment of thermal and electrical energy through different sources such as natural gas, electricity, diesel [1] [2] [3]. In hotel organizations, energy expenditure ranges from 3% to 6% of total expenses, so their savings and management represent a significant contribution to the company's finances [4].

Energy management in hotel sector companies and buildings has been a source of studies for around 40 years as shown by Lee et al. [5] who have registered favorable results as evidenced by Onüt et al. [3] by highlighting the achievements obtained in hotels in China and Greece with estimated savings of up to 273kWh/m² of construction. The development of monitoring programs for consumption variables such as BEMS (Building Energy Management Systems) that, together with an optimal analysis of operating conditions, represent an effective strategy for energy saving in buildings as assessed by Rocha et al. [6] in hotels in Austria and Spain. On the other hand, as part of the study in this area, models have been developed that have allowed to predict and control certain parameters among which the white box parameters can be mentioned, that is, those that are completely theoretical as those used by the EnergyPlus software or the reactive energy developed by Mahendra et al. [7]; the so-called black box parameters, which arise from experimental correlations that allow us to estimate the thermal load, comfort temperature and energy consumption as developed by Ma et al. [8] and mixed models or gray boxes as mentioned by Li & Wen [9].

In the continuous search to generate actions in the industrial and commercial sector aimed at energy saving, the NTC ISO 50001: 2011 standard was developed in 2011 [10]. This is aimed at reducing greenhouse gas emissions and other related environmental impacts, as well as reducing energy costs through systematic energy management [11]. For this implementation, it is necessary to carry out a diagnosis and characterization of the company at the energy level in order to evaluate the areas and equipment of significant energy use and direct the necessary improvement actions. This type of studies has been carried out in companies from different sectors of the economy, such as in the metal-mechanical sector reported by Cárdenas et al. [12] and Valencia et al. [13] who developed models of equivalent production to perform an energy diagnosis in an agro-industry, thus granting a correct design of different products in the same line of processing. In the same way, Valencia et al. [14] conducted a correlation energy vs. production and they established indicators of operational performance, which allowed an energy planning and, based on this, projected savings of up to 17.7MWh / year in a metal-mechanic industry. The objective of this work was to make an energy characterization to a hotel company in the city of Barranquilla, Colombia in order to identify the potential savings of the different energy sources, generate awareness and organizational culture about energy efficiency in the sector, implement performance indicators pursuit of the development of an energy management system in accordance with the guidelines of NTC ISO 50001: 2011 standard.
2. Methods

To carry out the energy characterization in a company of the hotel sector in Barranquilla was collected natural gas and electricity monthly consumption data from 2 years and the occupation in the same frequency.

2.1 Energy baseline

The baseline consists of a linear model that describes the energy consumption of the organization as a function of a variable with a significant impact in a specific temporal space. For this company in the hotel sector, the significant variable is the occupancy of the bedrooms, that is, the recurrence in the use of them on a monthly basis. Because the hotel provides additional services such as restaurant and lounge rental, an equivalence variable was established based on the thermal load of such spaces, which is called equivalent occupation (EO) and is calculated using equation (1). In relation to this variable, a general linear function is obtained, as shown in equation (2).

\[ EO = \frac{\text{Tons of cooling of the lounge}}{\text{Tons of cooling of one bedroom}} \]  

\[ E_{BL} = m \times OE + b \]

\( E_{BL} \) = Energy that theoretically should have been consumed according to the baseline. Where the tons of a standard hotel bedroom are 1.5TR (average thermal load of hotel bedrooms).

In order to obtain the resulting baseline, an initial correlation \( E_{BL0} \) is necessary and from this a filtering of data is performed to get the highest correlation between the dependent and independent variable. It should be noted that the exclusion of the data is made up to a minimum number such that the final function does not lose significance. The upper \( (L_{CS}) \) and lower \( (L_{CI}) \) limits of the range in which the valid data of the sample are contained are given by equations (3) and (4), where \( S_{x,y} \) represents the standard deviation of the original data. If one of these is above or below this limit, it is excluded from the total data set.

\[ L_{CS} = E_{BL0} + 1.5S_{(x,y)} \]  

\[ L_{CI} = E_{BL0} - 1.5S_{(x,y)} \]

Regarding the target line, this results from the linear correlation of the data that are below the baseline meaning that corresponds to the best consumptions reached. It follows a general form equivalent to that illustrated by equation (2) and allows estimating the desired energy behavior and knows potential savings by improving the operation and maintenance without variation of technology.

In the case of natural gas, it was not possible to obtain the mathematical model through linear regression. Therefore, the baseline is a control chart in which the
energy-production trend is analyzed over time and the values are recorded outside the statistical control limits, that is, values that are far from the behavior, mean ± 3 times the standard deviation of the data [15].

2.2 Consumption index [IC]

Consumption index [IC] represents the energy consumption per production unit and its value is an inverse function of the occupancy rate handled. This index follows a general equation as shown in (5) and it allows to know the productive rate or desired occupation that the hotel must manage, so that its energy expenditure is minimal per unit of production. Additionally, when compared with real indexes, it is possible to estimate savings associated with production management.

\[ I_C = \frac{E_{\text{Real}}}{OE_{\text{Real}}} \text{[kWh / OE]} \quad (5) \]

\( E_{\text{Real}} \) = Actual value of measured consumption.

3. Decrease in emissions [Ton CO\(_2\)]

The energetic saving of any source brings associated an environmental improvement product of the so-called indirect emissions, which depend on the source of generation or the fuel used. The emission factor FE represents the amount of CO\(_2\) that is released from the production of each unit of electricity, or in fuels case, the amount of CO\(_2\) that is released per unit consumed of this energy. In Colombia, this factor is defined by the Unidad de Planeación Minero-Energética (Energy Mining Planning Unit, UPME). In this case 0.401 kg of CO\(_2\)/kWh was taken as the factor for electric power according to resolution 0843 of 2016 [16] and 1.942 kg of CO\(_2\)/m\(^3\) from the Guide for the organizational inventories of greenhouse gases GHG by use of fossil fuels in commercial and industrial activities of the Natura foundation [17].

4. Results

The results obtained for each statistical test are described below.

4.1 Control Charts

Figures 1.A and 1.B show the control charts for electric power and natural gas, respectively. The average line of each graph represents the average consumption over the time interval, with consumption of 152,112 kWh/month for electricity and 6,093 m\(^3\)/month of natural gas. Of these, there is a high variability in the consumption of natural gas over time and more marked trends in electricity, with periods of homogeneous consumption between June and December 2015. No data is observed outside of the statistical limits for which the behavior has been managed under a valid range and not associated with atypical events.
In general, it is emphasized that for equal months of different years completely different results are obtained, which shows that although they are in an equivalent commercial space (season of the year), consumption is significantly affected by factors other than occupation.

![Figure 1. Control chart. A. Electric energy, B. Natural gas](image)

Source: Author's elaboration

### 4.2 Baseline and Target line

As a result of correlating the productive energy information of the hotel and performing the respective data filtering, for electrical energy, a sample of 19 data was used, corresponding to 2 years of monthly information, and 79.17% reliability. A baseline subject to the function $E_{BL} = 31.508EO + 90,122$ [kWh/month] was obtained, reaching $R^2 = 0.67$, denoting a strong dependence on the electric power consumption with respect to the equivalent occupation shown as the black line in figure 2.A. The slope of the function is called the technological consumption index and represents the energy consumption per unit of equivalent occupation, which indicates that each room occupied monthly records an electricity consumption equivalent to 31.508 kWh/month. As for the intercept, it represents the energy not associated with the occupation, that is, if the company did not handle any productive rate, it would still be consuming 90,122 kWh/month associated with maintenance work, consumption of administrative areas, lighting and cooling in areas common, and all those services that hotel must guarantee and that do not generate a direct profit for this one.

The green line represents the target behavior ($E_{LM}$), which is obtained by correlating all those consumptions below the baseline, that is, the best productive energy results achieved by the company. The function that describes the target behavior is given by $E_{LM} = 31.508P + 79,830$ [kWh / month], and when compared to the baseline adjustment, a reduction in the independent parameter and a permanence of the slope are noted. This is due to the fact that the data with which the target line is made handle the same technology, unlike the independent term that is associated with operational behavior, which does vary over time. Based on the
above, a 7% average savings is calculated, equivalent to 10,292kWh/month, as a result of the difference between the independent terms of the base and goal functions, what is operationally reflected as the range of improvement of operational and maintenance actions, not associated with production.

Regarding natural gas, the use of variable EO/month is not significant, therefore it is necessary to record the number of people who use the hotel services as a variable, information that was not available. Therefore, the savings were estimated from a base consumption given by the average managed by the hotel, and a goal determined by the data that are below the average consumption. Based on this, an average saving of 11% is calculated, equivalent to 643m$^3$/month.

### 4.3 Consumption index

Figure 2.B. shows the behavior of the consumption index for the different levels of occupation, both theoretical and real. Theoretically, this index is described according to the function $IC = 31.508 + 90.122 / P$ [kWh /EO]. From this it is concluded that the occupation that generates a minimum consumption index or also called maximum efficiency production (PME), is 2.627 EO/month with an IC of 76 kWh/month. The consumption index reached under the average occupation is 78.68 kWh/month and subject to the maximum occupations of 70.19kWh / month. From the above it is observed that when managing occupations in the hotel it is possible to achieve a saving of 11% equivalent to 17,000 kWh / month.

### 4.1 Decrease in emissions [Ton CO$_2$]

Table 1 compiles the results associated with the reduction of CO$_2$ emissions associated with energy savings. There is a total decrease in emissions of 12,247 Ton CO$_2$/month. From the environmental point of view, it is more significant to implement improvement strategies focused on electric power for this case, associated with the fact that consumption is greater and therefore a percentage unit saved has a greater impact on the saving of CO$_2$ emissions. All these results set the basis for the development of an energy management system within the hotel.

![Figure 2. A. E.E. Baseline, B. E.E. Consumption index](source: Author's elaboration)
Analysis of the potential for energy savings

The identification of the significant energy uses and the potential for improvement represent the starting point for closing the gap between the current behavior of the hotel and what the NTC ISO 50001: 2011 standard dictates, in parallel of a direct saving in the expenses in services within the hotel, improving aspects of profitability, and the improvement in the operational culture impacts on the reliability and availability of equipment and services (steam, hot water and refrigeration), providing guarantees to hotel guests and clients.

Table 1: Compiled of savings in energy and CO2 emissions

<table>
<thead>
<tr>
<th>Electric Energy</th>
<th>Potential savings</th>
<th>Monthly</th>
<th>Tons of CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>kWh</td>
<td></td>
</tr>
<tr>
<td>By improvements in operational practices and maintenance management</td>
<td>7</td>
<td>10,292</td>
<td>4,128</td>
</tr>
<tr>
<td>By production planning</td>
<td>11</td>
<td>17,000</td>
<td>6,8170</td>
</tr>
<tr>
<td>TOTAL</td>
<td>18</td>
<td>27,292</td>
<td>10,998</td>
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</table>

<table>
<thead>
<tr>
<th>Natural Gas</th>
<th>Average saving</th>
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<th>Tons of CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>643</td>
<td>1,249</td>
</tr>
</tbody>
</table>

Source: Author's elaboration

5. Conclusions

Based on the study of the energy-production information of a hotel located in Barranquilla, the following conclusions were obtained:

- The equivalent occupation (EO) was established as a variable that describes the production in the hotel and correlates better with the consumption of electrical energy. However, this variable does not align with the consumption of natural gas, so it is necessary to collect and monitor the number of people who occupy both the restaurant and the rooms, as a tentative variable for future studies regarding this energy.
- A base model for EE subject to the function $E_{LB}=31.508P + 90.122$ [kWh/month] was obtained, reaching $R^2=0.67$, denoting a strong dependence on the consumption of electrical energy with respect to the equivalent occupation.
- A target model was obtained for EE subject to the $E_{LB}$ function $=31.508P + 79.830$ [kWh/month], thus identifying a savings potential associated with improvement in operational practices, without cost associated with technological renovation.
- The minimum consumption index or also called maximum efficiency production (PME) was calculated, is 2.627 EO/ month with an IC of 65.81 kWh / month, the consumption index reached with the average occupation is 78.7kWh / month and with maximum occupancy is 70.19kWh / month.
- At an environmental level, reductions of 12,247 Ton of CO2/month emitted were estimated.
References


Analysis of the potential for energy savings


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