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# Benchmarking the energy efficiency of office buildings in Belo Horizonte, Brazil

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## ABSTRACT

In countries in which energy efficiency regulations are already consolidated or in the process of being consolidated, an important parameter to be verified is the relative consumption of electric energy of existing buildings in accordance with established ranges of consumption for different types of buildings. In the present paper ISO 52003-1 methodology was applied to create a benchmarking for office buildings for the city of Belo Horizonte, Brazil and the work discusses the implications of using the standard's methodology for the Brazilian scenario. To fulfill this objective, it was necessary to gather electric energy consumption data for this type of buildings as well to survey for building constructive data. For the classification of buildings according to their consumption, a methodology was developed to isolate the annual consumption per area of the towers from EUI data for the whole building. Besides, information such as garages existence, lighting power density of the garages and the number of lifts was collected in loco as in many cases there was not access to the building projects. The results showed that due to the large variation in consumption data, the use of the average EUI instead of the median EUI value results in a better distribution for the towers energy consumption classification. This precaution can prevent excessive resistance in the market if a public benchmarking policy is stablished. Therefore, it´s concluded that the understanding of the consumption of electrical energy of the buildings plays a fundamental role in the establishment of goals for the new buildings.

## KEYWORDS

Energy use benchmark; energy consumption; office buildings; sensitivity analysis.

## INTRODUCTION

Energy is a major factor in global efforts to achieve sustainable development (Vera and Langlois, 2007) and buildings can be the key to achieving this goal (Rey et al., 2007), because they account for about 40% of the world's energy consumption (IEA, 2008). Thus, it is estimated that there is great potential to mitigate consumption in this sector. In Brazil, the energy matrix of buildings is closely linked to the use of electric energy, and buildings in the residential, commercial and public sectors account for 42.5% of this consumption (BRASIL, 2017).

Due to economic growth, developing countries have experienced a large increase in their energy consumption (Iwaro and Mwasha, 2010). According to the National Energy Plan 2030 (MME, 2007), the energy consumption of buildings in Brazil is projected to grow 3.7% per year by 2030. Lamberts et al. (2014) point out that every decision made during the design process can influence the buildings' thermal and luminous performance. Therefore, the understanding of the influential factors in the consumption of electrical energy of the buildings will have a fundamental role in the establishment of goals for the new buildings to be constructed.

According to Lamberts et al. (2014), a building is more energy efficient than another when it provides the same environmental conditions of comfort to its user, with lower power

consumption. In countries which energy efficiency regulations are already consolidated or under consolidation, an important parameter to consider is the relative consumption of electricity according to the building typologies. This type of survey is called benchmarking, which is a method used to compare the energy and/or efficiency of a building with a reference value (Perez-Lombard et al., 2009; Signor, 1999; U.S.D.E.C.B.I, 2009). From a collected database, it is possible to propose new criteria for the construction, as well as to evaluate existing criteria and improve the management of buildings of different performances (Chung et al., 2006). The information on the building performance and the indicators implemented in the regulations should be clear and detailed so that the user knows the level reached by the building (Nikolaou et al., 2015).

In July 2009, the Technical Regulation of Quality for Energy Efficiency Levels of Commercial, Services and Public Buildings (INMETRO Directive No. 163) was launched in Brazil. The purpose of this regulation is to "create conditions for the labeling of the energy efficiency level of commercial, service and public buildings" (BRASIL, 2010). In this regulation the classification of buildings varies according to five levels, with "A" being the most efficient and "E" being the least efficient. The first benchmarking initiative in Brazil was made for bank branchs in a study developed by the Brazilian Council for Sustainable Construction (CBCS). The benchmarking methodology for this typology was developed through linear regression analysis using data on electricity consumption, energy audits, and climate corrections (Borgstein and Lamberts, 2014).

ISO 52003-1- Indicators, requirements, ratings and certificates - Part 1: General aspects and application to the overall energy performance (ISO 52003-1:2017), launched in 2017, defines the ways of calculating the energy performance of buildings and procedures for setting reference values. Several European Union countries such as France, Germany, Italy, Portugal, United Kingdom are required to implement this standard.

Veloso et al (2017) article served as a basis for the present benchmarking study. The authors analyzed seven design features that influence the electricity consumption in office buildings for Belo Horizonte. According to the study, the air conditioning mode showed to be the most important feature with up to 58% impact in the electricity consumption prediction (the studied building modes were: unconditioned, mixed mode air conditioning and central air conditioning). For each air conditioning mode WWR, façade solar absorptance and SHGC also showed to be relevant design features in the consumption prediction of office buildings. The presence of glazed façade, the presence of solar shading devices and building age were also tested but with no significant results.

In view of the above, the objective of this article the application of ISO 52003-1 in the Brazilian scenario and the implications of proposed changes in the standard methodology in the establishment of a benchmarking for office buildings. It is important to emphasize that in Brazil the access to the data of electric energy consumption and characteristics of the buildings is restricted and for the most part stealthy and for that reason, it was necessary to develop a methodology for the buildings characterization.

## METHODS
### Experimental Design
For the present study a sample of buildings in the city of Belo Horizonte – Brazil was used. According to the climatic classification of Köppen, Belo Horizonte is classified as a Cwa climate, a hot and temperate climate with mild winter, 18 °C average temperatures in winter

and 22 °C in summer. The mild climate explains a high occurrence of mixed air conditioning in office buildings, that is, natural ventilation is used most of the time and only on hot days the air conditioning system is turned on. The number of office buildings in the city was accessed from a database provided by the City Hall. This database contains information from the IPTU (Urban Land and Territorial Tax) of all the existing buildings in the city approved until 2011. It was identified that until 2011, there were 568 buildings for commercial use and/or services from three to twenty-five floors and a gross floor area of more than 1,000 m².

**Consumption data**

For the analysis of the electric energy consumption, the consumption data of the 568 buildings were requested and the consumption data of 101 buildings were made available by the electric energy company of the city. Electricity consumption data available is from 2012 to 2014, divided monthly, and with no identification of this measuring unit in the building due to privacy State policies. In the received database, it was not possible then to discriminate the electricity consumption of the floor or room or the common use areas of the building, which led to the need for an on-site survey. Once EUI is quite different in office areas and garages of office buildings the aim of this survey was to separate the electricity consumption of the tower from the building garages. The decision to divide the building in these two parts (garage area and tower) was done because in the city the garage area varies greatly, from office buildings presenting no garage from buildings which present garages that represent up to 1/3 of the total constructed area.

It´s important to emphasize that it was not possible to access the internal loads of the studied buildings as access usually is granted only to the common areas of the buildings.

**Survey of building areas**

From the 101 buildings in which electricity consumption data was obtained, only 50 complete projects were made available by City Hall of Belo Horizonte. For the building sample to be larger, the other 51 buildings were visited to verify the existence or not of a garage. It was then possible to identify that 13.7% of the buildings visited did not have garages. For those buildings the building area provided by the IPTU or the by the architectural plans was considered as being the tower area. For the other buildings the tower areas were obtained by the architectural plans or by on-site visits.

**On-site survey of the garages electricity consumption**

To obtain the electricity consumption of the towers it was necessary to estimate the electricity consumption of the garages. This was done through a survey of the installed lighting system (number of lamps, lamp and ballast power and use hours) and the number of elevators of the sample buildings. The installed power multiplied by the number of hours of use was used to define the electricity consumption of lighting and elevators, considered to be the electricity consumption of the garages. To estimate the electricity consumption of the towers, the average electricity consumption data provided by the energy company was used and the electricity consumption of the garages was withdrawn.

**Building Classification**

For the building EUI estimation, only the electricity consumption of the building towers was used, divided by the corresponding area. The methodology of ISO 52003-1:2017 to determine the benchmark scales then was applied to the defined EUI. This standard presents a methodology for establishing a certificate of energy efficiency for buildings, including energy performance indicators. It allows the indication of the energy class of a certain building in comparison to the benchmark. ISO 52003-1:2017 establishes seven levels of efficiency - from

A to G. In Brazil, for commercial, service, public and residential buildings, this index varies from A to E. For the classification to be on the same scale used in buildings in Brazil, the highest limits established in ISO 52003-1:2017 were not used to determine the classification of buildings in the present work.

**RESULTS**

Figure 1 (a) shows the Energy Use Intensity - EUI (kWh/m²/ year) of the sample buildings. The graph (a) in the figure allows the verification of the significant differences between the EUI when the whole building is considered and when towers' and garages' EUI are considered separately. The upper and lower absolute variations are represented by the points, and the lower and upper part of the box represents the percentiles of 25 and 75% of EUI variations. The center line displays the data median and the upper asterisks the outlier values. The symbol inside the box shows the average value of the sample. It is observed in the Figure 1 (b) that in the tower there is a significant variation in the tower EUIs and that 75% of the buildings consume up to 100 kWh/m²/year. It´s also important to stress that if only centrally air-conditioned building towers were considered the mean EUI would be of 173 kWh/m²/year.
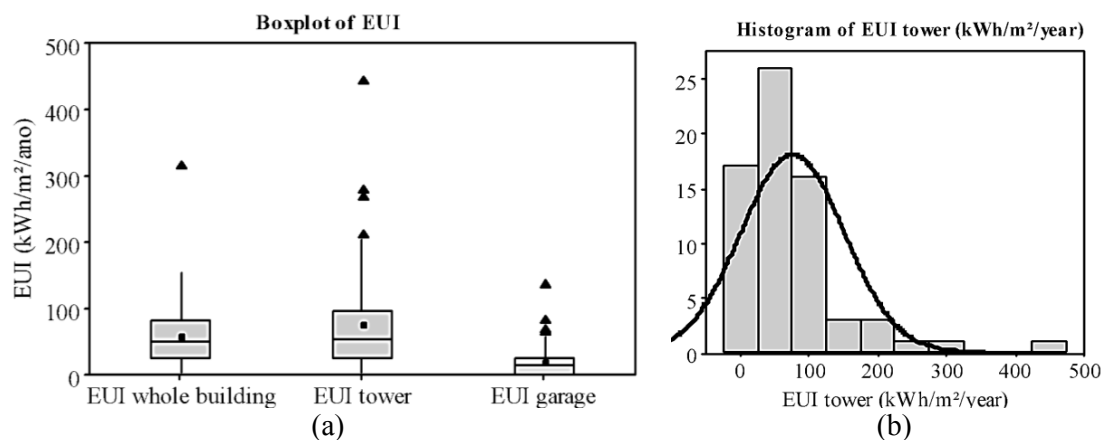


Figure 1. (a) Boxplot with the variation of total, tower and garage EUI; (b) Histogram of the towers EUI.

It is noticed that since the mean and median are not equal, the distribution is not normal, the mean value being greater than the median value. The standard deviations show that there is a great data variability. The average tower EUI is 30% higher than the whole building EUI and the highest electricity consumption found in the tower is an unusual value in the sample.

The EUI limit values using the EUIs with the median EUI value according to the ISO 52003-1: 2017 methodology, can be seen in Table 1. It can be observed that 50% of the towers were rated D and E. Based on these results, the mean value in place of the median was also tested and what can be verified is that there was a better distribution of the buildings among the classifications. The increase in the consumption limit for each classification was of 38.5%.

Table 1. Table of EUI electricity consumption limits of buildings and percentage per item.

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| Median Value | EUI [kWh/m²/year] | | 27.48 | 39.02 | 54.95 | 77.48 | |
| | Percentage of buildings | 27% | 6% | 18% | 13% | 36% |
| Average Value | EUI [kWh/m²/year] | | 38.05 | 54.03 | 76.10 | 107.30 | |
| | Percentage of buildings | 32% | 17% | 14% | 14% | 23% |

**DISCUSSIONS**

After the implementation of energy efficiency regulations in buildings it is necessary to understand how efficient buildings are in relation to their energy consumption. Therefore, the role of benchmarking is to create reference values. The discussion of the benchmarking of electricity consumption of buildings is recent in Brazil, and there are just a few studies on this subject in the country. A major obstacle is the lack of accessible data in Brazil, which led to the need of creating a methodology to extract data from both the building projects when accessible and from on-site visits when not.

It´s important to stress that the present study considered both mixed mode and centrally conditioned mode and divided the electricity consumption of garages and building towers. This decision along with the peculiarities of a continental tropical mild climate makes it difficult to compare EUI values with other studies in the literature.

It was found that there is a great variation in the electricity consumption among the sample buildings. The electricity consumption of the towers showed to be 418% higher than the garages consumption, which justified the separation of this electricity consumption. Still there was great variation of electricity consumption among the building towers due to the fact that there is diversity in the air conditioning mode. The building towers that use central air conditioning in their entirety being the largest consumers, should be studied separately for a better understanding of the specificities of their energy consumption, but once the sample available for the present study could be considered small, this was not done.

A higher number of samples might generate a better distribution using the median EUI value as proposed in ISO 52003-1: 2017 but what is perceived in Figure 1 and confirmed in Table 1 is that the mean EUI is always greater than the median EUI in the samples, showing that the EUI does not follow a normal distribution. Thus, due to the large variation in the EUI, as shown in Figure 1 (b), the use of the average in the value of the EUIs presented a better distribution in the classification of the towers. So as a suggestion for a possible public policy it is believed that the use of the average EUI would generate less resistance in the market given the available sample.

**CONCLUSIONS**

The construction, operation and use of buildings represent an important part of the country's energy consumption and therefore also present a great potential for energy conservation. The understanding of the buildings' consumption plays a fundamental role in the establishment of goals for the new buildings to be constructed and for retrofit policies for the existing buildings. The methodology of ISO 52003-1:2017 was important to create the ratings in this work and being slightly modified, presented a good distribution of the buildings in each level.

It is important to emphasize that this work is one of the first steps in the development of energy benchmarking for Brazil. As government, stakeholders, building owners and energy companies realize the importance of understanding the energy consumption of buildings for the country's economy, data might become more accessible and thus, it is expected that the analysis conducted in this work can be done for other types of buildings and even repeated for the same typology with a greater sample size.

The results presented in this work are a first picture of the situation of the energy consumption of office building towers with an area above 1,000 m² in the city of Belo Horizonte. It´s believed that this data can serve as a basis for future work in which major design features and occupancy

patterns can be analyzed to get a better understanding of the major influencing factors in electricity consumption of this typology.

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