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EVALUATION OF THE APPLICATION OF ENERGY REGULATIONS FOR BUILDINGS IN COLOMBIA: A CASE STUDY

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Abstract. All over the world, regulatory frameworks promote energy efficiency in the building sector. In 2015, the Colombian government issued Energy Regulations 0549. This regulation establishes the minimum percentages of energy savings that new buildings must meet. Almost ten years after the issuance of this standard, there is no evidence of a technical study that uses a case study to evaluate the degree of compliance with the regulations of a typical residential building. This study analyzes the construction characteristics and obtains the energy model of a middle-income multifamily building built after the issuance of the standard to evaluate the degree of compliance with the standard and the effectiveness of its mechanisms. The results show a partial integration of the recommended energy-saving measures and the absence of precise instruments to guide the builder in the evaluation tasks.
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Key words. Energy saving policy, Building energy simulation.

1. Introduction

Buildings consume a lot of energy [1], [2]. To improve their performance, governments and organizations worldwide have established various regulatory frameworks that promote the integration of energy-saving strategies. Almost ten years ago, the Colombian government issued Resolution 0549, a regulation setting the minimum percentages of energy savings for new buildings according to typology and climate.

Some studies contracted by government entities reveal difficulties in applying the standard due to the lack of adequate verification and control instruments that facilitate compliance. Other studies, for their part, identify the lack of capabilities in construction companies as the cause of the difficulties. However, there needs to be evidence of the existence of technical studies that evaluate the implementation of local regulations on the energy behaviour of a conventional building.

For this reason, this study aims to evaluate the application of local energy regulations in a representative building of middle-income residential buildings in the Metropolitan Area of Bucaramanga. The building was built after the standard was issued. It is located in a tropical climate and almost entirely devoid of artificial air conditioning systems, as is the case with most buildings in the country.

The evaluation of compliance with regulations took into account an energy analysis based on simulations with DesignBuilder. This study is structured around four sections. Section 1 presents the context of Colombian rules and the existing alternatives for compliance. In section 2, the building under study and the creation of its respective energy model are described. Section 3 presents the energy analysis results, and finally, section 5 presents the study's conclusions.

2. Energy regulations for buildings in Colombia

In 2015, Colombia's national government issued regulations on energy efficiency in buildings (RES 0549) [3]. This regulation regulates the percentages of energy savings that new buildings must satisfy according to their typology and climate. The energy savings percentages established by the rules are shown in Table I.

Table I. Minimum percentage of energy savings

	Minimum savings percentage			
Typology	Cold	Tempered	Hot-dry	Hot-wet
Hotels	20	35	25	45
Hospitals	35	25	35	30
Offices	30	30	40	30
Malls	25	40	35	30
Educational	45	40	40	35
Non-VIS housing	25	25	25	45
VIS Housing	20	15	20	20
VIP Housing	15	15	20	15

The standard requires a minimum energy saving of 25% for the building under the studio.

To comply with the standard, builders have two alternatives: the prescriptive and performance methods.

To comply with the prescriptive method, builders must issue a self-declaration of compliance stating the integration of a group of energy-saving measures recommended by the standard according to the type and climate. The measures suggested by the standard for middle-income residential buildings in hot, dry climates are improvement of the window-to-wall ratio, solar protection and natural ventilation.

On the contrary, compliance through the performance method requires quantifying the energy intensity indicator associated with the building through energy simulation tools. The savings percentage is calculated by comparing this indicator with the baseline indicator provided by the resolution. Table II relates the baseline indicators proposed by the regulations according to the typology and climate.

Table II. Energy consumption baseline

Indicator [kWh/m²/year]	Cold	Tempered	Hot-dry	Hot-wet
Hotels	96.1	151.3	132.5	217.8
Hospitals	249.6	108.3	344.1	344.1
Offices	81.2	132.3	318.2	221.3
Malls	403.8	187.8	187.8	231.5
Educational	40	44	72	29.8
Non-VIS housing	46.5	48.3	36.9	50.2
VIS Housing	44.6	44.0	34.6	49.3
VIP Housing	48.1	53.3	44.9	50.6

3. Building under study

The building chosen to diagnose the application of the energy efficiency standard is located in the city of Bucaramanga, in Colombia, in a tropical region with temperatures ranging between 24 °C and 31 °C and a solar radiation average of 4.8 kWh/m^2·day [4].

This building was selected due to a representativeness analysis in which 14 other multifamily residential buildings were considered. This analysis included the participation of expert builders and design professionals [5]. It is a 12-story multi-family residential building in a middle-income neighbourhood. On each floor, there are six homes of approximately 62 m2 in area. Most homes have three bedrooms, a kitchen and a generous area generally used as a dining room. The building has an elevator service, a circulation area along the entire length of the building, and a central staircase.

The construction system obeys an industrialized system of walls mostly made of concrete. The glazing area represents approximately 20% of the envelope. The roof of the building is constructed of solid concrete, mortar, and reflective paint on the top.

Some homes had an air conditioning system installed in the main room. In all these cases, it was a 9000 Btu split-type system. Each home's energy consumption is close to 130 kWh/month.

4. Energy modelling of the building

The virtual model of the building under study was obtained using the energy simulation tool Designbuilder V6 through a process that involved two stages: geometric modelling and data assignment. The geometric modelling stage gave us a three-dimensional graphic representation of the building under study. Therefore, information from the architectural design of the building was required. The data allocation stage considers information on materials and electrical charges. It also involved a significant component of data related to the use of each home, such as occupancy density and types and use of loads. For this purpose, information was collected on-site from a representative sample of households for one week. From this information, the annual occupancy of the building was approximated.

Climate data were other inputs to the energy model. In this case, the authors had a historical climate archive of Bucaramanga.

After completing the modelling, the authors performed a model adjustment based on comparing the monthly simulated energy consumption with the monthly energy consumption provided by the energy company. After a couple of iterations adjusting some usage data, an error of less than 5% was achieved. The figure shows the energy model of the Building [4].

Figure I. Energy model of the building.

Based on the adjusted model, the authors defined several simulation scenarios. The first was the actual scenario, which included the building's current configuration and allowed the evaluation of its energy savings.

Following a thorough evaluation process, the authors configured the real model to generate four (4) energy models. These models were designed to assess the impact of various measures on energy consumption, including natural ventilation, horizontal shading, efficient glass, and efficient walls. Additionally, an energy model was created that incorporated all of these measures, providing a comprehensive evaluation of the building's energy efficiency when fully compliant with regulations.

5. Analysis of the implementation of the standard

As mentioned previously, there are two different alternatives to comply with energy regulations: the prescriptive and performance methods. This section analyzes the compliance with the standard of the building under study through these two approaches.

A. *Compliance through the prescriptive method*

As noted before, the prescriptive method verifies the implementation of the recommended measures in the building's design.
To validate compliance with the standard through the prescriptive method, it was necessary to inspect the design information. This demonstrates the degree of implementation of the measures recommended by the standard.

Table III relates the degree of implementation of the recommended measures in the building under study.

Table III. Degree of implementation of the measures recommended by the standard.

Recommended measurement	**Degree of implementation**
Window wall relationship	Implemented
Solar radiation	Not implemented
Natural ventilation	Partially implemented

According to the previous table, only one of the two measures recommended by the standard is adequately implemented within the building design. Despite the substantial incidence of solar radiation, the design did not integrate solar protection elements. In some living spaces, the premises' maximum height and depth ratio, do not satisfy natural ventilation parameters.

In addition to the above, the building has an adequate orientation (facades with more excellent glazing towards the south), which partially mitigates the impact of solar radiation. The roof's finish also stands out, providing a significant degree of albedo.

This method of evaluating compliance with the standard does not establish a degree of efficiency by which the building's performance can be compared with that of other buildings of its class. There is also no straightforward procedure for verifying compliance.

B. *Compliance through the performance method*

The performance method quantifies the energy savings associated with the building by comparing the evaluated building's annual energy consumption per square meter and the base value established by the regulations. The applicable base indicator for middle-income residential buildings in a hot-dry climate is 36.9 kWh/m^2.

The indicator associated with the evaluated building was quantified based on energy simulation. The results of the comparison between the building indicator and the base indicator are shown in Table IV.

Table IV. Comparison of the evaluated building indicator with the base indicator.

Case	Annual consumption [kWh/m^2]	Energy savings [%]
Real	30.5	17.3
Base line	36.9	

According to the previous Table's results, the energy savings associated with the building under study do not satisfy the minimum savings percentage required by the standard (25% savings). This may be due to the mismatch of the baseline indicators or the need for more clarity in the indicator calculation process.

Voluntary certification systems such as LEED recommend quantifying the indicator associated with the building in the certification process by comparing the building's performance with that of a reference building, which, among other things, integrates a fictitious artificial air conditioning system responsible for guaranteeing the conditions of comfort inside the building.

In this study, the authors adapt this recommendation to evaluate the energy impact associated with each measure based on calculating the virtual energy for comfort. For this purpose, a standard air conditioning system defined according to the recommendations of Appendix G of ASHRAE 90.1 was available for the living spaces of the building [6]. The comfort temperature to be guaranteed by the air conditioning system was set at 24°C. This analysis also considered measures such as efficient glass and walls.

After the simulation of each measure, the authors calculated the percentage of savings compared to a reference building built conventionally without considering energy-saving measures. The results of this analysis are presented in Table V.

Table V. Percentage of savings of each savings measure taking into account the calculation of virtual energy for comfort.

Case	**Indicator [kWh/m^2]**	**Savings compared to the real case [%]**
Real	93.96	0.0
Natural ventilation	78.98	15.9
Horizontal shading	88.50	5.8
Efficient glasses	89.39	4.9
Efficient walls	91.49	2.6
All measurements	70.2	25.6

The results show that adequate use of natural ventilation can generate a savings percentage close to 16% compared to the real one. Installing solar protection elements can also generate approximate energy savings of up to 6%. However, other measures with higher technical specifications and implementation costs, such as installing efficient glass and walls with insulation systems, do not offer significant energy savings.

On the other hand, implementing all the measures studied guarantees compliance with the standard. However, optimizing measures with low implementation costs and more significant savings is how to comply with the regulation without affecting the design budget.

6. Conclusions

The results of this study show that the building under study integrates some energy-saving measures but still needs to satisfy the minimum savings requirements posed by local regulations evaluated based on the prescriptive method and the performance method.

The evaluation of the building through this last approach reveals the need for instruments supporting the builder in energy modelling tasks and quantifying the savings percentage. Clear rules in this regard can ensure compliance with the regulations.

The energy savings potential of integrating passive measures in middle-income multifamily residential buildings can only be determined from considerations like virtual energy for comfort.

The results of the evaluation of the different scenarios of integrating measures show that optimizing natural ventilation and solar shading could lead to compliance with the regulation.

The authors recommend that the relevant entity implement a process to adjust the energy consumption baseline since the existing baseline may omit some aspects of the current dynamics of the multifamily residential building stock.

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