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A Guide for Evaluation of the Architectural Design Requirements of Energy Efficiency in City Hotels

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Abstract: Tourism is a very important sector in the economic sphere, but it is also one of the services of most traditional energy consumers, so it is necessary to develop strategies aimed at promoting the use of renewable energy sources. This research is aimed at providing a guide for the evaluation of architectural design requirements for energy efficiency in city hotels, allowing the creation of a database with the main architectural design problems that affect the energy efficiency of this category of hotels. In the conformation of the guide, international methods of evaluation and certification of the sustainable energy efficiency of buildings are considered, which allow to complement the current Cuban norms in relation to the design requirements for energy efficiency in buildings.

Key words: energy efficiency; evaluation; architectural design

1. Introduction

Hotels are the main energy consumers in the modern world, because they provide users with a variety of services to obtain the required comfort. Meeting customer needs is a challenge for energy consumption and effective management. Correct application and compliance with the basic design requirements of buildings to improve energy efficiency can minimize the increase of solar energy heat and reduce the energy costs required to adjust the indoor space without affecting the indoor comfort conditions.

The hotel industry in Santiago, Cuba is growing steadily. According to the data of Tourism Real Estate Company in Santiago of Cuba, the city has 14 hotels, accounting for 56% of the total.

Energy efficiency in the tourism sector aims to reduce costs and improve facility efficiency. To optimize the relationship between the energy consumption of buildings and the services developed, it is necessary to observe similar systems: the building system, defined by its design and construction; the climate system, defined by the climatic variables of the place where the building is located; the facilities system, defined by the characteristics of the energy-consuming equipment; and the user system, determined by the practices of use and expectations of thermal comfort and environmental quality.

Energy efficiency means meeting customer requirements with the lowest energy expenditure and the lowest environmental pollution. This concept involves carrying out production activities or providing services to maximize the useful results of society, reducing the possible technical expenditures of energy carriers, and reducing environmental pollution through the use of energy.

High-efficiency and energy-saving buildings are based on the use of natural energy to design the surrounding shape and space, and the appropriate selection of building materials and components, so as to minimize the use of traditional energy.

According to the high energy consumption required by buildings, there are different sustainability assessment methods. These methods meet the need to measure the performance of buildings not only in the field of energy, but also in other aspects related to indoor environmental quality: innovation and design, sustainable sites, materials and resources, etc., which influence the different stages of the life cycle of a building and, in particular, the use and operation of a hotel.

These methods of assessing energy use cannot be applied directly to different nations or countries without the necessary adjustments to geographical, cultural, economic and social parameters, as they can lead to results that do not reflect the reality of a region (Guillén et al. 2015).

The above method is also used to certify and classify various buildings according to their energy efficiency. In our country, without such a process, we must find a way to achieve classification, which is a response to interdisciplinary work. However, there is a set of NC 220, which considers that energy efficiency is based on cost-benefit analysis, complying with all other current standards without affecting the performance of the building.

According to some architects, NC 220-1:2002 (National Bureau of Standardization, 2002) omits the very important aspects that affect the environmental comfort and energy efficiency of buildings. Only the thermal requirements of the building envelope are evaluated, excluding other requirements required to achieve comfort, such as the positive or negative impact of the site, direction, building shape, internal design, luminous enclosure, indoor environmental quality and others (Serray Coch, 1995). For all these reasons, the country needs a more comprehensive procedure to evaluate the energy efficiency of buildings and their surrounding design, which can also be applied to other building themes.

The main purpose of this study is to propose and partially implement the evaluation guidelines for the design requirements of energy-saving buildings in urban hotels. The theoretical basis of the study is the development of building energy efficiency, the analysis of international methods for evaluation and certification of hotel building energy, and the study of NC 220-1 (National Bureau of Standardization, 2002).

2. Materials and Methods

This work is divided into three important moments:

(1) Status diagnosis.

(2) Suggestions on evaluation guidelines for energy efficiency requirements of urban hotel building design.

(3) Apply the guide to the case study.

The observation of the current situation of energy consumption of hotel facilities shows that it is necessary to establish a database of hotel energy evaluation results. This makes it possible to distinguish the level of energy consumption between hotels of the same type and category, determine the reasons for the maximum consumption, and understand the potential of hosting new systems based on renewable energy. The database also avoids the same defects and deficiencies in the energy consumption of the new design and renovation of the hotel as the existing facilities.

As a conceptual starting point, we proceeded to the analysis and synthesis of a series of evaluation methods of sustainable energy efficiency certification categories of buildings (Guillén et al. 2015), granted by organizations from

different countries, such as LEED (Leadership in Energy and Environmental Design), from the United States; BREEAM (Building Research Establishment's Environmental Assessment Method), from the United Kingdom; Verde, from Spain; Casbee, from Japan; and HQE (Haute Qualité Environnementale), from France. These methods arise in response to the need to measure the performance of buildings, not only in the energy field, but also in other aspects linked to the quality of the indoor environment: innovation and design, sustainable sites, materials and resources (U.S. Green Building Council, 2009; Guillénet al., 2015, pp. 67-70).

At the same time, according to the standards of some experts, the NC 220-1:2002 application program (National Bureau of Standardization, 2002) was analyzed. In this analysis, the following limitations were found:

- Limited knowledge of the properties of components and materials of the enclosure.
- It only evaluates the thermal energy behavior of the shell, not the luminous energy behavior.
- It does not affect other basic aspects of building energy performance: site, building form, enclosure and design of indoor environment, and the potential of building to use renewable energy (Serray Coch, 1995).

Finally, a survey of experts or specialists is included as a research method to define the level of importance of the evaluation parameters and requirements.

3. Results

Based on the analysis of the sustainable assessment methods of international energy categories and the Cuban Standard 220-1:2009 in the above assessment guidelines, the architectural design requirements and parameters for the energy efficiency assessment of urban hotels are determined (Figure 1).

Figure 1. Architectural design parameters for energy efficiency in city hotels.

The evaluation guide for energy efficiency requirements of urban hotel building design is defined from the following stages or steps:

(1) Selection and characterization of research cases.

(2) Evaluation of design parameters and requirements of energy-saving buildings in the case study.

(3) Determine the energy efficiency level of the hotel.

(4) Accuracy of architectural design recommendations to minimize solar thermal gain, use natural light and reduce energy consumption of the hotel.

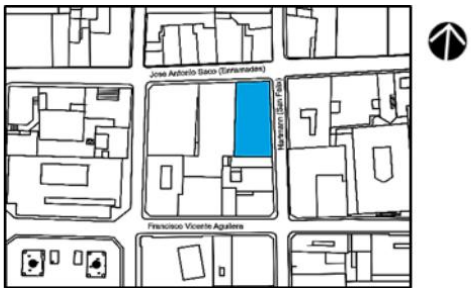
4. Selection and Characterization of the Case Study

The application of the guide begins with a general characterization of the hotel, with emphasis on aspects related to housing components, interior design and renewable energy use systems. The results are presented in sheets that summarize the requirements and parameters of the hotel's architectural design, based on energy exchange criteria, in accordance with NC 220-1:2002 (National Bureau of Standardization, 2002), and qualitative and quantitative criteria of other authors.

5. Evaluation of Energy Efficiency Design Requirements of Hotel Buildings

Based on the above premise, this chapter aims to reveal a guide as the basis for evaluating the energy efficiency of urban hotels based on architectural design factors. The application results of the guide in Iberostar San Félix City Hotel, Santiago, Cuba (Figure 2 and Figure 3) are also shown in summary form. The analyzed aspects are integrated in the table, making the interpretation of these aspects more simple.

Figures 2. Iberostar San Félix City Hotel, 4-star hotel (construct area 666 m^2).



Figures 3. Location.

The evaluation of this work focuses on the architectural design of the hotel, and its purpose is to evaluate the energy behavior related to the architectural design solutions in the use or operation of urban hotels. However, it does not include the assessment of the technology included in its operation, which is the responsibility of experts in other disciplines.

5.1 SL I - Site location

This parameter is evaluated based on the urban climate data and the characteristics of the field physicists, such as the site height of the city boundary, the direction of the hotel building, the building density of the surrounding buildings, whether there is an outdoor paved area and green space.

5.2 BF II - Building form

This parameter is the decisive factor of climate utilization and its relationship with the environment. The compact hotel minimizes the area of the enclosure, thus reducing the heat loss and income, and optimizing the energy consumption of the HVAC system. The form of articulated buildings is more suitable for the climate of our country, because the articulated buildings are small and can use ventilation and natural lighting.

The shape of the building is defined by a set of geometric and volumetric characteristics. These characteristics are the compactness, porosity and slenderness of the building and have repercussions from the climatic and lighting point of view, and the equations proposed by Serray Coch (1995) are accepted for the definition of the characteristics.

5.3 BE III - Building envelope

According to the envelope design requirements specified in NC 220-1:2002 (National Bureau of Standardization, 2002), this parameter is evaluated as follows:

- Compliance with design requirements for opaque roofs and horizontal span closures (skylights). The roof is generally the element with the highest heat gain from solar radiation. It is evaluated according to section 5.1 and 5.3 on the basis of the roof heat gain factor (HGF) and the shading coefficient (SC) for the non-opaque parts of the roof.

- Compliance with design requirements for vertical and horizontal span enclosures. It is evaluated on the basis of the relative solar gain coefficient (RSGC). It depends on the characteristics of the glass or window type, the interior or exterior shading screens and the orientation and dimensions of the screens or exterior solar obstruction elements.
- Compliance of opaque wall design requirements. The evaluation is based on the total heat transfer coefficient (U) according to section 5.4. It can be improved according to the wall features such as the part of the wall completely protected from direct sunlight, the part of the building itself, the sunshade, the adjacent building or the hill or or bluffs. If this wall is covered all year round. On the exterior wall, we must consider taking constructive solutions to minimize the increase of heat, and put more emphasis on air-conditioned places to reduce power consumption.

5.4 IEQ IV - Indoor environment quality

This parameter links the interior components with those of the envelope, aiming to improve natural ventilation and lighting, as a complement to artificial lighting; make the use of air conditioning more efficient, control air pollutants and improve occupant comfort.

According to NC 220-1 (National Bureau of Standardization, 2002) and other regulations, when evaluating the design and indoor environmental quality of buildings, the compliance or compliance degree of the design requirements related to the building envelope category must be considered.

These requirements are as follows:

- According to Article 4.2 of NC 220-1 (National Bureau of Standardization, 2002), the air conditioning places are evaluated, including the following aspects: the tightness of the places on the walls, windows, doors, skylights, pipes and floors of each functional unit. Considering that the air conditioning system is the largest energy consumer of urban hotels, this requirement is very important.
- Evaluate natural or artificial ventilation according to the basic ventilation requirements in Section 4.1. NC 220-1 natural comfortable ventilation (National Bureau of Standardization, 2002). Ventilation and natural lighting are limited to a small number of hotel services. However, it has brought great advantages in cost efficiency by promoting services with less energy consumption.
- According to the method of calculating natural light developed by De la Peña (2008), natural light can be evaluated according to the global light reduction coefficient (τ_0).

5.5 URE V - Use of renewable energy

This parameter mainly evaluates the current use of renewable energy in the hotel and/or the potential of using renewable energy. Reducing demand and improving efficiency often make most or all of the energy needs of renewable resources buildings cost-effective.

Determination of the energy efficiency level of the hotel. As a way to facilitate the level of energy efficiency of the parameters and requirements of architectural design of a city hotel, levels of importance are defined, based on the application of a survey to experts or specialists on the subject. The survey applies to a sample of 15 experts or specialists on the subject, including ten hotel designers and five researchers on the subject of comfort and energy efficiency, accounting for 67% and 33% respectively.

The importance level of the parameter is defined according to the average value assigned by the respondents; If required, ballots are allocated according to the level of importance of each one (see Table 1).

In order to determine the overall energy efficiency level of urban hotels according to the architectural design parameters and energy efficiency requirements, the levels and standards shown in table 2 are proposed. The design requirements of buildings and the score level assigned to them may vary depending on the building theme.

Table 1. Possible scores of design parameters and requirements for energy-saving buildings of urban hotels

Parameter	Highest score	Requirements	Possible score
Site location	7	Hotel building direction	4
		Green space/outdoor pavement area ratio	3
Building form	3	Building compactness	1
		Indoor courtyard use	1
		Slenderness or height	1
Building envelope	9	Thermal gain of opaque cover	3
		Obtain heat through windows, doors and horizontal blades	4
		Get heat through the wall	2
Indoor environment quality	6	Airtightness of air-conditioned places	3
		Natural ventilation	1
		Natural lighting through windows, skylights, monitors, ducts, etc.	2
Use of renewable energy	5	Use of renewable energy systems in the hotel	4
		Potential for the use of renewable energy renewable energies in the hotel	1
The highest score that can be assigned to a city hotel			30

Table 2. Overall energy efficiency level of urban hotels

Energy efficiency level	Score	Parameter evaluation criteria (must be complied with)
High	25-30	These five parameters are evaluated from B (high score)
Average value	21-24	The surrounding parameters of the building are evaluated as B, and the indoor environmental quality is evaluated as at least R.
Low	17-20	Only depends on the score obtained
Inefficiency	0-16	Only depends on the score obtained

The evaluation of the architectural design parameters and requirements involved in the energy efficiency of Iberostar San Felix four-star hotel shows that the energy efficiency level of the hotel is low (Table 3, Graph 1).

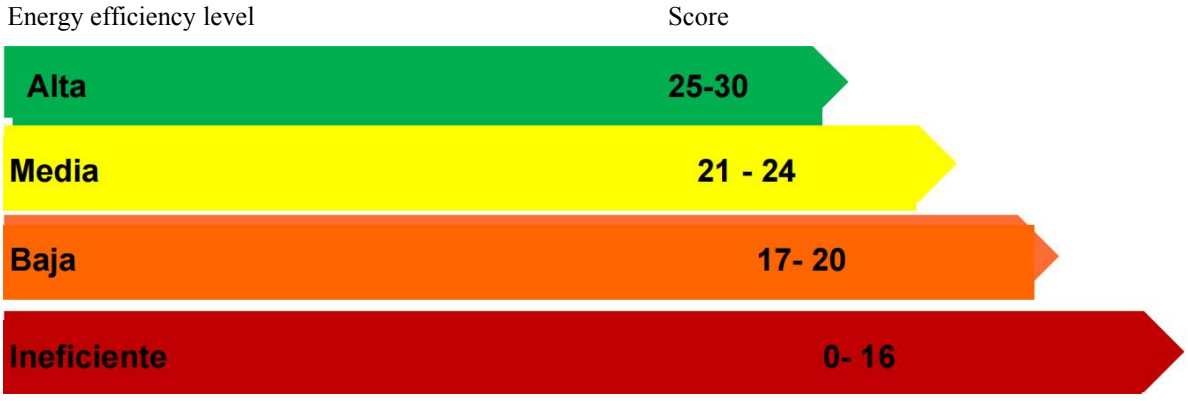
The distribution of scores must be carried out by a working group to reduce the subjectivity involved in these procedures.

Table 3. Iberostar San Felix Hotel performance synthesis

Evaluation parameters and requirements		Iberostar San Felix Hotel			
		Conform to CN 220-1 and other standards	Performance evaluation	Score	
SL I. Site location	Orientation	Favorable direction	Orientation of housing facades to the N and E is favorable to sunlight control	3	3
	Green space/paved area ratio	Non-conformance	There is no green space around the hotel	0	
BF II. Building form	Compactness	0.75	Minimize surface and reduce loss and energy gain	1	1
	Porosity	0.025	The disadvantage of roofed yard	0	
	Slenderness	0.76	Medium slenderness	0	
BE III. Building envelope	Opaque cover	Non-conformance	The use of false ceiling is crucial, because it can minimize the increase of heat, rather than the color of the deck surface	3	9
	Vertical blade (door and window)	Non-conformance	The use of medium-color curtains and operable blinds or shutters is conducive to indoor sun protection	4	
	Horizontal blade (skylight)	N/A	Do not use horizontal blades	-	
	Opaque wall	Conformance	The walls favored by the shadows provided by surrounding buildings and hotel balconies	2	
IEQ IV. Indoor environment quality	Local air tightness	Non-conformance	The shutters in the room are not completely closed. The opening of the air-tight entrance door to the hall is between 10 and 15 mm	0	1
	Room natural lighting	Non-conformance	The ventilation area of the room does not meet the area required for natural lighting	0	
	Room natural ventilation	Conformance	The clearance area related to floor area in the room conforms to NC 220-1	1	
URE V. Use of renewable energy	Available Systems	Solar heater	Use of vacuum tube solar heater	3	3
	Potential for incorporation	Limited site space	Limited positioning possibilities for photovoltaic panels or other renewable energy systems	0	
Low efficiency 17-20 points					17

Not applicable in this case (N/A)

Graph 1. Energy efficiency level



In order to improve the environmental comfort and reduce the solar thermal gain and energy cost of the research hotel, the following suggestions are put forward:

- Encourage the use of insulating materials and radiant barriers as part of the roof components.
- Improve the tightness of doors and windows in the envelope and interior.
- Improve the transparency of windows to provide more natural light in the rooms.
- Use light colors on facades to reduce heat transfer.
- Extend the use of renewable energy photovoltaic systems in roof areas for artificial lighting in common areas.

6. Conclusion

The proposed guide is based on NC 220-1:2009 on the design requirements for the thermal envelope of the building, but incorporates requirements and parameters that complement the evaluation of the efficient use of energy in city hotels, such as site, building shape, building envelope, indoor environmental quality and use of renewable energy.

The implementation of the evaluation guide in Iberostar San Felix Hotel can determine the incidence rate level of the parameters and the requirements for energy efficiency, which points out that it is necessary to reduce the heat transfer through the roof and walls, and improve the sealing to reduce the power consumption of the house air-conditioning.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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