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Energy efficiency labeling of buildings: An assessment of the Brazilian case

Norma do Nascimento Batista[a,b,*], Emilio Lèbre La Rovere[a], João Carlos Rodrigues Aguiar[b]

[a] Interdisciplinary Environment Laboratory, LIMA, Alberto Luís Coimbra Institute of Research and Graduate Studies in Engineering, COPPE, Rio de Janeiro Federal University, UFRJ, LIMA/COPPE/UFRJ, Rio de Janeiro, Brazil

[b] Department of Special Technologies, Electric Energy Research Center, Eletrobras Cepel, Rio de Janeiro, Brazil

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ABSTRACT

This paper addresses the application of Energy Efficiency Rating Technical Quality Regulations for Commercial, Service and Government Buildings – RTQ-C in order to ascertain whether the conventional construction system for buildings complies with these requirements. Additionally, it investigates the contribution of labeling to reducing electricity consumption by the building. To do so, the RTQ-C was applied to two buildings in order to calculate the efficiency levels of their envelopes and possible alterations are proposed for upgrading the envelope performance where pertinent. It is noted that conventional buildings adopting measures such as painting the walls and roof white, in addition to using smoked glass, are sufficient to bring the rating up to an A grade. As no specific concern was noted in the architectural designs for the buildings studied, making use of design strategies that minimize the use of electricity in these buildings, the findings of these case studies may well indicate that the RTQ-C has adopted technical requirements that are not particularly stringent. Consequently, it is believed that these requirements should be reviewed during a second stage, in order to make them more restrictive and attain further improvements in the constructed environment with better energy efficiency for buildings.

1. Introduction

The energy efficiency of buildings is a matter of interest worldwide, accounting for some 40% of annual global energy consumption [1]. In Brazil, the residential, commercial and government sectors accounted for 45% of total electricity consumption in 2008, with the commercial and government sectors consuming 22.7% [2].

Labeling is viewed as an effective tool for reducing energy consumption by buildings. According to the World Energy Council [3], labeling and minimum energy efficiency criteria are the top-performing options for obtaining fast improvements. Moreover, Brazil's National Institute of Metrology, Standardization and Industrial Quality – INMETRO [4] notes that when labeling is associated with performance goals, it constitutes an important tool for reducing energy consumption in Brazil, through encouraging technological upgrades in the fabrication of equipment earmarked for the domestic market, boosting the supply of good to consumers with better energy performances and thus bringing up their quality to international levels.

A major step forward towards greater energy efficiency in Brazil was the approval of its Energy Efficiency Act, introduced through Law N 10,295 [5] on October 17, 2001, which rules on Brazil's National Energy Conservation and Rational Use Policy.

This act strengthened Brazil's National Electricity Conservation Program (PROCEL) which launched its energy efficiency action plan for buildings (PROCEL Edifica) in 2003. One of the outcomes of this action plan, compliant with Law N 10,295 was the drafting of the Energy Efficiency Rating Technical Quality Regulations for Commercial, Service and Public Buildings – RTQ-C and supplementary documents [6–8]. These technical regulations were approved through Edict No 53 promulgated on February 27, 2009 by INMETRO and published in the Federal Government Gazette (DOU) on March 3, 2009. This was undoubtedly a watershed for the civil construction sector, as it ushered in a new set of dynamics guiding the quest for architectural solutions and supplementary lighting and air-conditioning projects that upgrade the thermal and energy performances of buildings designed. Alongside construction companies, architects, engineers and the manufacturers of construction materials and the consumer market will certainly be subject to changes in the ways that buildings are conceptualized, constructed and sold. More specifically, construction companies and building owners may well look ahead to the possibility of deploying the comparative advantages offered by a labeled building, particularly because of what the maximum efficiency level may represent in the sales process, stressing the reduction in energy consumption reflected in monthly electricity bills, heat-related comfort and

* Corresponding author at: Laboratório Interdisciplinar de Meio Ambiente, Rua Athos Silveira Ramos, Centro de Tecnologia, Bloco I, Sala 208, Ilha do Fundão 21945-970. C.P. 68565, Rio de Janeiro, Brazil. Tel.: +55 212 562 8759; fax: +55 212 562 8805.

E-mail addresses: normabaptista@ppe.ufrj.br, nnbaptista@hotmail.com (N.d.N. Batista), emilio@ppe.ufrj.br (E.L.L. Rovere), jocarlos@cepel.br (J.C.R. Aguiar).

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marketing activities highlighting green buildings, in order to add value to these products. This approach would result in financial benefits for the builder, the owner and user of the building.

Initially, although compliance is still voluntary, these technical regulations will become mandatory within a period that has not yet been defined, introduced in order to establish the conditions required for labeling the energy efficiency of commercial, service and government buildings through Brazil's National Electricity Conservation Label (ENCE) scheme [6–8]. Although Brazil is merely starting out along the road towards efficiency energy labeling for buildings, there is no doubt that labeling buildings will drive the development of architectural designs and the revitalization of existing buildings with higher quality, from the energy use standpoint, in addition to retrofitting existing buildings. According to Geller [9], the dissemination of information could well be more effective when combined with other policies such as: financing incentives, voluntary agreements or regulations. For example, the building education and training of constructors and legislators have been effective in the USA, conducted simultaneously with the adoption of more rigid energy efficiency standards for buildings [10].

However, at the current stage of building labeling in Brazil, there are no economic or tax incentives such as performance bonuses for construction standards or reductions in building taxes that would prompt interest in labeling among construction companies or owners. These incentives would be a way of stepping up the number of applications for labeling among owners and construction companies during the design phase as well as when revitalizing a building already in operation. On the other hand, Brazil's National Energy Efficiency Plan 2010–2030, which is currently being drawn up, makes provision for several actions under the aegis of building labeling, including capacity-building, disclosure and dissemination. It also addresses encouragement for including the energy efficiency concept in new and existing public buildings.

The energy performance of new buildings can be improved through labeling at the various project design stages, as the potential energy savings of a building are introduced at various design stages: architectural scheduling; draft design; project design development; construction system; construction management; post construction and maintenance. For example, during the draft design phase, potential savings vary between 40% and 50%; during the project design development stage, estimated potential savings vary from 30% to 40% [11]. In an existing building, improvements can be introduced through retrofitting systems that use electricity, together with interventions in the building envelope – although with some constraints in this case, as some project design strategies cannot be adopted, such as placement, shape and the use of materials that enhance heat and energy performances. However, according to Yilmaz [12], among the project design parameters affecting the thermal comfort of buildings and ensuring energy conservation during construction, the building envelope is the most relevant, as this is what separates the indoor environment from the outdoors.

According to INMETRO [13], five buildings were labeled in Brazil in 2009, in four bioclimatic zones BZ 1; BZ 2; BZ 3; and BZ 8. By July 2010, five buildings had been labeled in BZ 3. The prescriptive method was used to rate the efficiency levels of these buildings, which consists of an analytical proceeding that uses the equations presented in the RTQ-C (as shown in Section 2), with the entry date addressing the characteristics of the three systems covered by these regulations – envelope, lighting and air-conditioning. The envelopes of all these buildings were rated as A grade. For the buildings labeled in 2009, the justifications in general are: the use of shade elements, low percentage of openings and higher performance glass. The outcome of rating the building envelopes in terms of the characteristics of the labeled buildings draws attention to the criteria adopted in the RTQ-C, which may not be sufficiently stringent to encourage architectural designs adapted to climate conditions, ensuring heat related comfort in the building with significant reductions in electricity consumption, while helping mitigate the adverse impacts arising from its use. The relevant quantification of electricity consumption associated with each rating level for a building cannot be determined through the prescriptive method, meaning that it will be necessary to conduct another study using the simulation method through appropriate software. This method consists of comparing the thermo-energy performance of a real building with benchmark buildings (A–D), necessarily conducting simulations of the real and benchmark models. In Brazil, this practice is limited, as it is necessary to train practitioners in the use of the software.

Returning to the ratings of the labeled buildings, it is felt that, although the number of labeled buildings is not significant for a representative sample of the universe of buildings in various parts of Brazil, the following influences may be drawn: the minimum standard for building envelopes should encompass the criteria required for an A grade label; and the Regulations need to update the criteria adopted for energy efficiency ratings of envelopes. However, it is felt that the number of labeled buildings is not large enough to conduct any conclusive assessment of the criteria adopted for envelopes in the regulations, nor to define the minimum standard to be adopted for buildings.

As presented, the purpose of this paper is to ascertain whether the conventional construction system complies with the requirements in the regulations, while also striving to investigate the contributions of building labeling to reducing their energy consumption. To do so, the Energy Efficiency Rating Technical Quality Regulations for Commercial, Service and Government Buildings are applied, using the prescriptive method, in order to assess the envelope performance of two buildings used for educational purposes at a school in Rio de Janeiro, Brazil. The building envelope energy efficiency rating procedure is outlined: the energy efficiency ratings are calculated; and the outcomes are assessed in order to propose possible changes to the building envelopes that would improve their ratings. Finally, a brief evaluation is presented of the efficacy and effectiveness of these building envelope regulations, in addition to assessing the method, based on the findings of this study.

2. Energy Efficiency Rating Technical Quality Regulations for Commercial, Service and Government Buildings – RTQ-C – overview of the procedure [6,7]

These technical regulations encompass buildings with a total useful area of at least 500 m^2 and/or with electricity supplied at a voltage of at least 2.3 kV, with and without air conditioning or partially air conditioned. These buildings are designed for mixed use: residential and commercial; residential and services; or residential and government, although in this case the non-residential portion with a total minimum useful area of 500 m^2 is assessed separately.

Energy efficiency building labeling must comply with the criteria set forth in these regulations, which address the building envelope performance, the lighting system efficiency and capacity, and the air-conditioning system efficiency. In order to allocate energy efficiency ratings, two methods may be used: prescriptive and simulation.

These regulations specify the building efficiency ratings, which vary from A (most efficient) to and (least efficient), divided into three requisites: building envelope; lighting system; and air conditioning system. For the efficiency rating of each requirement, a number of points are assigned called the numerical equivalent – NumEq, which is used to calculate the general rating of the building.

They also assume that a building may be assessed and rated in parts, as set forth below: (a) for the building envelope rating, the energy efficiency rating must be defined for the entire building; (b) for the lighting system rating, the energy efficiency rating may be defined for a single floor or for a suite of rooms; (c) and for the air conditioning system rating, the energy efficiency rating may be defined for a single floor or a suite of rooms.

2.1. General building rating procedure [6,7]

The general rating procedure is outlined very briefly, as the main purpose of this paper is to present the building envelope efficiency rating, meaning the classification of just part of the building.

The general rating for the building and the ratings for the requisites – building envelope, lighting system and air conditioning system – must be assessed in order to produce the final rating. Consequently, weights are assigned to each requisite, which must be used in the equation that calculates the final score for the building.

Once the ratings have been established for each requisite, they are equivalent to a specific number of points, called the numerical equivalent, which is entered in the equation that calculates the final score for the building, which then defines its general rating.

In addition to the general prerequisites related to the three main requisites – building envelope, lighting system and air conditioning system – and the simulation, there are prerequisites specific to each main requisite. When no specific prerequisite is rated as adequate, the numerical equivalent will follow the efficiency rating as described below: building envelope – only E; lighting – D maximum; air-conditioning – B maximum.

2.2. Rating the building envelope through the prescriptive method – procedure [6,7]

The procedure for the building envelope rating through the prescriptive method is examined in greater detail, in order to ensure a better understanding of Section 3, which explains the efficiency rating system for envelopes of both the buildings examined in this paper.

Before moving on to calculating the building envelope efficiency, applying the consumption index (CI), the specific prerequisites must be rated as adequate, specific to the intended efficiency rating. These are related to the thermal transmittance ratings for the roof and the outer walls of the building; the surface colors and absorptance; and zenithal lighting. For a building envelope to achieve an A rating, all three prerequisites must be taken into consideration. For a B rating, two of these prerequisites are taken into consideration – thermal transmittance by the roof and the outer walls; as well as surface color and absorptance. For C and D ratings only one prerequisite is taken into account – thermal transmittance by the roof and the outer walls. The requirements for each of these prerequisites are presented below by rating level.

2.2.1. Rating levels

(A) A rating

(a) Prerequisite – thermal transmittance (U)

Roofs: thermal transmittance levels are determined according to the air conditioning of top floor areas or single-storey buildings as follows: 1.0 W/m$_2$ (m^2)K for the roofs of artificially air conditioned environments; 2.0 W/m$_2$(m^2)K for the roofs of environments without air conditioning.

Walls: thermal transmittance is determined for the bioclimatic zone in which the building is located. In bioclimatic zones 1–6, the maximum accepted thermal transmittance is 3.7 W/m^{2}K. In bioclimatic zones 7 and 8, the maximum accepted thermal transmittance is 2.5 W/m^{2}K for walls with a maximum thermal capacity of 80 kJ/m^{2}K and 3.7 W/m^{2}K for walls with thermal capacities of more than 80 kJ/m^{2}K.

(b) Prerequisite – surface colors and absorptance (α)

Walls: for bioclimatic zones 2–8, absorptance of less than 0.4 is required for materials used in the outer finishing of the walls.

Roofs: for non-apparent roofs, low solar absorptance colors must be used (pale shades), with absorptance of less than 0.4, except for rooftop gardens or unglazed ceramic roof tiles.

(c) Zenithal lighting

This paper does not consider zenithal lighting, as this option is not used in the buildings studied in Section 3.

(B) B rating

(a) Prerequisite – thermal transmittance (U)

Roofs: the thermal transmittance levels for the roofs of artificially air conditioned environments may not exceed 1.5 W/m^{2}K, limited to 2.0 W/m^{2}K for areas without air conditioning.

Walls: the B rating requirements are identical to those for the A rating.

(b) Prerequisite – surface colors and absorptance (α)

The B rating requirements are identical to those for the A rating.

(C) C and D ratings

(a) Prerequisite – thermal transmittance (U)

Roof: the maximum thermal transmittance level is 2.0 w/m^{2}k for the roofs of artificially air conditioned environments and areas without air conditioning.

Walls: the C and D rating requirements are the same as those for the A rating.

(b) Prerequisite – surface colors and absorptance (α)

No prerequisites.

Note: As the efficiency rating drops, the requirements listed in the prerequisites are less stringent.

Once these prerequisites have been met, a preliminary rating is obtained, then moving on to determine the building envelope efficiency through the building opening efficiency rating method based on a consumption indicator (CI_{env}) which is obtained through an equation.

There are two equations for each bioclimatic zone, one for building projection areas (A_{bp}) no larger than 500 m^2 and the other for buildings with projection areas larger than 500 m^2.

The equations for $A_{bp} > 500$ m^2 are valid for a minimum permitted shape factor (SF) constituting the ratio between the building envelope areas and the building volume (A_{env}/V_{tot}). Meanwhile, the equations for $A_{bp} \leq 500$ m^2 are validated for a maximum permitted shape factor. If the shape factor is above or below these values, the threshold and ceiling values must be used.

The consumption indicator (CI) must be calculated through the equation for the bioclimatic zone where the building is located.

In order to calculate the CI, some bioclimatic zones (BZ) were clustered together as follows: BZ2 + BZ3; BZ4 + BZ5; and BZ6 + BZ8.

This paper will examine in detail the calculation of the building envelope consumption index (CI_{env}) for the BZ6 + BZ8 /group, as the case studies presented in Section 3 are located in this region.

Consequently, the equations presented below are calculated for bioclimatic zones 6 and 8:

For $A_{bp} \leq 500$ m^2; limit: shape factor maximum (A_{env}/V_{tot}) = 0.48.

$$\mathrm{CI_{env}} = 454.47\mathrm{HF} - 1641.37\mathrm{SF} + 33.47\mathrm{POF_T} + 7.06\mathrm{SF} + 0.31\mathrm{VSA} - 0.29\mathrm{HSA} - 1.27\mathrm{POF_T}\cdot\mathrm{VSA} + 0.33\mathrm{POF_T}\cdot\mathrm{HSA} + 718 \quad (1)$$

Table 1
Efficiency rating interval ceilings and thresholds.

Efficiency rating interval ceilings and thresholds					
Efficiency rating	A	B	C	D	E
Threshold	–	$CI_{maxD} - 3i + 0.01$	$CI_{maxD} - 2i + 0.01$	$CI_{maxD} - i + 0.01$	$CI_{maxD} + 0.01$
Ceiling	$CI_{maxD} - 3i$	$CI_{maxD} - 2i$	$CI_{maxD} - i$	CI_{maxD}	–

For A_{bp} > 500 m^2; limit: shape factor minimum (A_{env}/V_{tot}) = 0.17.

$$CI_{env} = -160.36HF - 1277.29SF + 19.21POF_T + 2.95SF - .36VSA - 0.16HSA + 290.25SF \cdot POF_T + 0.01POF_T \cdot VSA \cdot HSA - 120.58 \quad (2)$$

where the variables for Eqs. (1) and (2) are:

CI – consumption indicator (adimensional); $\mathbf{A_{bp}}$ – building projection area (m^2); $\mathbf{A_{tot}}$ – total floor area (m^2); $\mathbf{A_{env}}$ – building envelope area (m^2); $\mathbf{A_{roof}}$ – roof area (m^2); $\mathbf{V_{tot}}$ – total building volume (m^3); **VSA** – vertical shadow angle between 0 and 45; **HSA** – horizontal shadow angle between 0 and 45; **SF** – shape factor (A_{env}/V_{tot}); **HF** – height factor (A_{roof}/A_{tot}); **SF** – solar factor; $\mathbf{POF_T}$ – total percent openings in façade (adimensional, for use in the equation).

The building envelope labeling rating procedure is presented below:

As the initial step, the CI_{env} is calculated from the building project design information using Eqs. (1) or (2), in compliance with the A_{bp}.

Then the maximum consumption index ceiling (CI_{maxD}) is calculated, using Eqs. (1) or (2), in compliance with the A_{bp} value and the Minimum SF, with the POF_T, SF, VSA and HSA values as presented below.

$$\mathbf{CI_{maxD}Parameters}: POF_T = 0.60;\ SF = 0.61;\ VSA = 0;\ \ HSA = 0$$

The CI_{maxD} represents the maximum rating that building must obtain in order to reach a D rating. If the CI_{env} exceed the CI_{maxD} value, the building envelope is classified with an E rating. If the CI_{maxD} value is less, the building envelope may be classified with an A, B or C ratings.

Then the minimum consumption index (CI_{min}) threshold is calculated using Eqs. (1) or (2), in compliance with the A_{bp} value and the minimum SF, with the values presented below.

$$\mathbf{CI_{minD}Parameters}: POF_T = 0.65;\ SF = 0.87;\ VSA = 0;\ \ HSA = 0$$

The CI_{min} represents the minimum consumption indicator for the building.

Next, the interval between the CI_{maxD} and CI_{min} value is divided into four parts, as shown in Eq. (3).

$$\text{Interval}\,(i) = \frac{CI_{maxD} - CI_{min}}{4} \quad (3)$$

Moving ahead, once the value of i is known, the ceilings and thresholds are calculated for each rating level as presented in Table 1 below.

Finally, the amount calculated for the CI_{env} is compared with the efficiency ceilings and thresholds presented above, thus reaching the building envelope efficiency rating. Each efficiency rating is assigned a score (numerical equivalent for each efficiency rating – NumEq), as presented below.

For efficiency rating A, the NumEq = 5; for efficiency rating B the NumEq = 4; for efficiency rating C the NumEq = 3; for efficiency rating D the NumEq = 2; for efficiency rating E the NumEq = 1.

However, as mentioned at the start of this sub-section, the prerequisites must also be rated: heat transmittance, absorptance and zenithal lighting. Should one of the prerequisites be rated as less efficient than the building envelope, the former will prevail over the latter.

3. Building envelope rating – case study

This section presents energy efficiency evaluations and ratings for two buildings, in compliance with the Energy Efficiency Rating Technical Quality Regulations for Commercial, Service and Government Buildings (RTQ-C).

Two buildings were selected from among the six that constitute the Corcovado German School (EAC), located in the Botafogo district, city of Rio de Janeiro, Brazil.

These buildings were selected in two phases, based on the following criteria:

(1) Building in use: located in the city of Rio de Janeiro; interest in the evaluation shown by the person in charge of the building; available documentation, including architectural plans; access to the site to conduct the field studies when necessary; (2) type of vertical closing materials; building envelope color; existence of shade-providing construction element.

The selection of a building in use is intended to demonstrate the limitations of retrofitting, thus stressing the use of bioclimatic and energy efficiency concepts in architecture during the project design stage. The influence of the construction elements, materials and colors on the building performance is underscored.

Based on the information in the project design documents and other data collected during the field survey of each building, a prior investigation of the building envelopes examined the building placement and the materials used, including the types of openings, finishes, glass and masonry, as well as the façade colors, in addition to identifying aspects offering potential electricity consumption reductions.

This investigation supports the assessment drawn up for the envelope rating of each building.

For rating and evaluating the building envelope, the physical characteristics of the building must be known, as presented below.

3.1. Case study

Initially, the following aspects are presented: building location; architectural designs; characteristics and dimensions, construction elements and building envelope materials. The prescriptive evaluation is then conducted, measuring compliance with the building envelope prerequisites as outlined in Section 2. The energy envelope efficiency rating is then determined for the building, using Eqs. (1) and (3) presented in Section 2. Additionally, alternatives are presented that upgrade building envelope ratings.

The information in the project designs was used to assess the buildings, supplemented or confirmed by data obtained through the field survey. However, whenever it proved difficult to obtain the necessary information during the field survey, the records in the project design documentation were used.

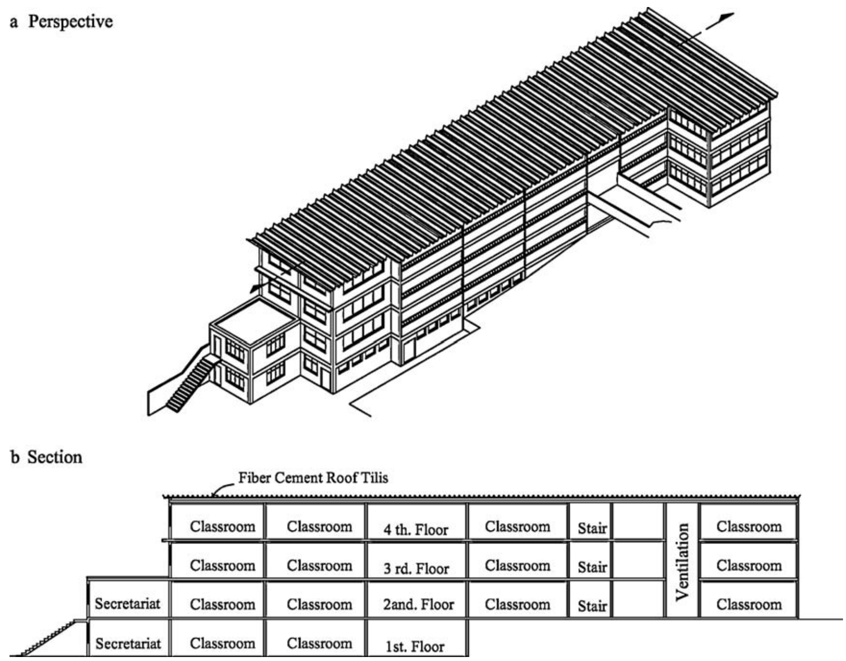

Fig. 1. Plans of the annex building or brick annex building: (a) perspective and (b) section.

3.1.1. Annex building or brick annex building

Data on the building:

Location – city of Rio de Janeiro;
Bioclimatic zone-8 (BZ 8);
No. of floors – 4.

As shown in Fig. 1, the architectural drawings are presented for the annex building or brick annex building used to calculate the envelope efficiency rating.

The information presented below addresses the dimensions of the building obtained from the architectural designs and supplemented by a field survey.

Data on the building:

Total area (A_{tot}) = 1694 m^2
Building projection area (A_{bp}) = 423.5 m^2
Building envelope area (A_{env}) = 1786 m^2
Total volume (V_{tot}) = 5215 m^3

Presented below are the variables used in Eq. (1) for calculating the building envelope consumption index – CI.

Eq. (1) variables:

Shape factor (SF) = A_{env}/V_{tot} = 0.34
Height factor (HF) = A_{bp}/A_{tot} = 0.25
Solar factor (SF) = 0.87%
Horizontal shadow angle (HSA) = 9.87°
Vertical shadow angle (VSA) = 0
Percentage openings in façade (POFt) = 26%

The construction elements are presented below. They were obtained from the design documents and/or the field survey.

3.1.2. Construction elements

3.1.2.1. Wall. Wall tiling: thickness (t) = 0.01 m; outdoor plastering: thickness (t) = 0.025 m; bricks and mortar: thickness (t) = 0.10 m; indoor plastering: thickness (t) = 0.025 m.

3.1.2.2. Slab (roof). Fiber-cement roof tiles: thickness (t) = 0.008 m; layer of air: thickness (t) = 0.10 m (this figure corresponds to the mean thickness of the layer of air between the roof tiles and the concrete slab); concrete: thickness (t) = 0.12 m; layer of air: thickness (t) = 0.16 m; plaster: thickness (t) = 0.02 m.

3.1.2.3. Transparent elements. Colorless glass: thickness (t) = 0.003 m; solar factor (SF) = 87%

3.1.3. Prescriptive evaluation of the building envelope

Building envelope prerequisites

(a) Thermal transmittance by opaque elements (U) – walls and roof – are presented below:
Wall: U_{roof} = 2.28 W/m^{2}K.
Roof: U_{roof} = 0.713 W/m^{2}K.
According to the RTQ-C:
Wall – for BZ8, walls with thermal capacity exceeding 80 kJ/m^{2}K at maximum thermal transmittance must be 3.7 W/m^{2}K, in order to obtain A and B ratings.
Roof – for artificially air conditioned environments the roof transmittance value may not exceed 1.0 W/m^{2}K in order to obtain an A rating.

(b) The total area absorptance (α) of the walls and roof is presented below:
Walls: $\alpha_{general}$ = 0.49.
Roof: $\alpha_{general}$ = 0.70.
According to the RTQ-C:
Walls and roof – for absorptance of less than 0.4, the rating is A or B.

Determining the building envelope efficiency

Using Eq. (1): building envelope consumption index (CI_{env}) = 282.37; maximum building envelope consumption index (CI_{maxD}) = 293.88; minimum building envelope consumption index (CI_{min}) = 277.31.

Using Eq. (3): interval (i) = 4.14.

The interval limits for the energy efficiency of the envelope set forth below in Table 2 below are used to assess the building envelope efficiency.

Table 2
Efficiency rating interval ceilings and thresholds.

Efficiency rating interval ceilings and thresholds					
Efficiency rating	A	B	C	D	E
Threshold	–	$CI_{maxD} - 3i + 0.01 = 281.46$	$CI_{maxD} - 2i + 0.01 = 285.60$	$CI_{maxD} - i + 0.01 = 289.75$	$CI_{maxD} + 0.01 = 293{,}89$
Ceiling	$CI_{maxD} - 3i = 281.45$	$CI_{maxD} - 2i = 285.59$	$CI_{maxD} - i = 289.74$	$CI_{maxD} = 293.88$	–

The CI_{env} (282.37) is higher than the A rating ceiling (281.45), but lies within the B rating ceiling (285.59) and threshold efficiency levels (281.46), so the efficiency rating is B. However, as the roof and walls absorptance prerequisites were not rated as A or B, the building envelope rating is C and the numerical equivalent (NumEq) is 3.

In order to upgrade this rating, three alternatives are proposed:

Alternative 1 – white painting on the roof.
Alternative 2 – white painting on the walls.
Alternative 3 – substituting transparent glass by smoked glass with a thickness of 3 mm and SF of 72%.

The alternatives 1 and 3 bringing the roof and walls absorptance level up to 0.23 and 0.20; and, in order to increase the CI rating, alternative 3 bringing the CI_{env} up to 281.31, as this is lower than the A rating ceiling of 281.45 presented in Table 2, the envelope efficiency rating rises to A grade. A summary is presented in Table 3 below of the outcomes of the alternatives for upgrading efficiency levels and ratings.

According to the RTQ-C:

Walls and **roof** – for absorptance of less than 0.4, the rating is A or B.

So, by bringing together alternatives 1 or 2 and keeping the smoked glass with a SF = 72%, the envelope rating would rise to B. Using all three alternatives, the envelope rating rises to A.

3.1.4. New building or sports court building

Data on the building:

Location – city of Rio de Janeiro;
Bioclimatic zone-8 (BZ 8);
No. of floors – 4.

Fig. 2 presents the architectural designs for the new building or sports court building used to calculate the envelope efficiency level.

The following information obtained from the architectural drawings is as presented below, supplemented by the field survey.

Data on the building:

Total area (A_{tot}) = 1550.75 m^2
Building projection area (A_{bp}) = 387.70 m^2
Building envelope area (A_{env}) = 2016 m^2
Total volume (V_{tot}) = 8316.60 m^3

The variables used in Eq. (1) are presented below, for calculating the consumption index – CI.

Eq. (1) variables:

Shape factor (SF) = A_{env}/V_{tot} = 0.24
Height factor (HF) = A_{bp}/A_{tot} = 0.25
Solar factor (SF) = 72%
Horizontal shadow angle (HSA) = 26°
Vertical shadow angle (VSA) = 8°
Percentage openings in façade (POFt) = 17%

The construction elements are presented below. The information in these tables was obtained from the design documents and/or the field survey.

3.1.5. Construction elements

3.1.5.1. Wall. Outdoor plastering: thickness (t) = 0.025 m; bricks and mortar: thickness (t) = 0.10 m; indoor plastering: thickness (t) = 0.025 m.

3.1.5.2. Slab (roof). Fiber-cement roof tiles: thickness (t) = 0.008 m; layer of air: thickness (t) = 0.85 m; concrete: thickness (t) = 0.25 m; layer of air: thickness (t) = 0.09 m.; plaster: thickness (t) = 0.02 m.

3.1.5.3. Transparent elements. Colorless glass: thickness (t) = 0.003 m; solar factor (SF) = 72%.

3.1.6. Prescriptive evaluation of the building envelope

3.1.6.1. Building envelope prerequisites.

(a) Thermal transmittance by opaque elements (U) – walls and roof – are presented below:
Wall: U_{roof} = 2.28 W/m^{2}K
Roof: U_{roof} = 0.17W/m^{2}K
According to the RTQ-C:
Wall – for BZ8, walls with thermal capacity exceeding 80 kJ/m^{2}K, the maximum thermal transmittance must be 3.7 W/m^{2}K, in order to obtain A and B ratings.
Roof – for artificially air conditioned environments the roof transmittance value may not exceed 1.0 W/m^{2}K in order to obtain an A rating.

(b) Total area absorptance (α) of the walls and roof are presented below:
Walls: $\alpha_{general}$ = 0.31

Table 3
Alternative for upgrading efficiency levels and ratings.

Alternative for upgrading efficiency levels and ratings					
Alternatives	Absortance (α) value and classification	Solar factor (SF) %	CI_{env} value and classification	Envelope classification	NumEq
1	0.23 (wall) A or B 0.70 (roof) different of A or B	87	CI_{env} = 282.37 B	C	3
2	0.49 (wall) different of A or B 0.20 (roof) A or B	87	CI_{env} = 282.37 B	C	3
3	0.49 (wall) different of A or B 0.70 (roof) diferent of A or B	72	CI_{env} = 281.31 B	C	3
1 + 2	0.23 (wall) A or B 0.20 (roof) A or B	87	CI_{env} = 282.37 B	B	4
1 + 2 + 3	0.23 (wall) A or B	72	CI_{env} = 281.31 A	A	5

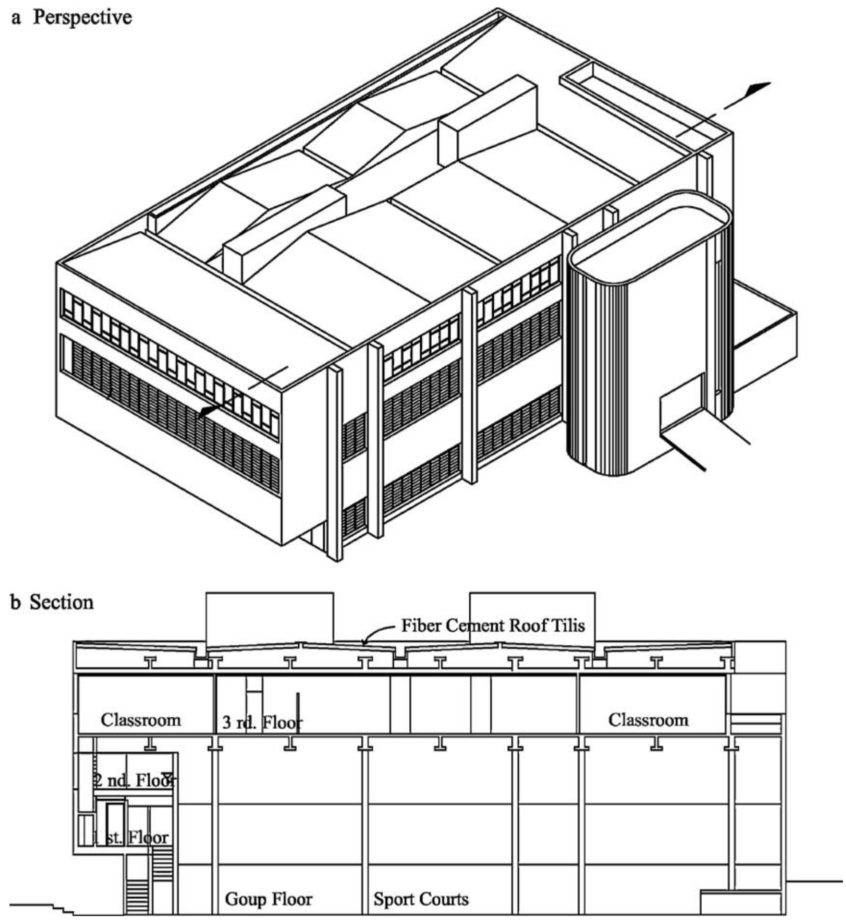

Fig. 2. New building or sports court building: (a) perspective and (b) section.

Roof: $\alpha_{general}$ = 0.70

According to the RTQ-C:

Wall and roof – for absorptance of less than 0.4 the rating is A or B.

Determination of the building envelope efficiency:

Using Eq. (1): building envelope consumption index (CI_{env}) = 439.24; maximum building envelope consumption index (CI_{maxD}) = 458.14; minimum building envelope consumption index (CI_{min}) = 441.56.

Using Eq. (3): interval (i) = 4.14.

The interval limits of the efficiency ratings used are presented in Table 4 in order to assess the building envelope efficiency.

Comparing the value for A rating ceiling (445.71), as shown in Table 4, and the CI_{env} = 439.24, as shown, it is noted that CI_{env} is lower than the ceiling for the A grade. Thus, the envelope efficiency rating according to the CI is A grade.

Nevertheless, considering the absorptance prerequisites (α) for the roof its respective acceptable rating level as presented, the envelope rating drops to a C grade and the numerical equivalent (NumEq) is 3.

In order to upgrade the envelope rating below, three alternatives are proposed as ways of upgrading the absorptance (α) of the roof and the respective rating of the envelope as presented below:

Alternative 1 – white painting on the roof, replacing the natural color of the fiber cement roof tiles.

Alternative 2 – slab with garden substituting apparent concrete slab and fiber cement roof tiles in their natural color.

Alternative 3 – slab with garden + roof tiles painted white replacing the apparent concrete slab and the roof tiles in their natural color.

The alternatives 1, 2 and 3 bringing the roof absorptance level up to 0.28, 0.68 and 0.26, respectively. A summary is presented in Table 5 of the outcomes of the alternatives for upgrading efficiency levels and ratings.

According to the RTQ-C:

Roof – for absorptance of less than 0.4 is rated as A or B.

So with alternatives 1 and 3, the building envelope rating is A with alternative 2, the building envelope rating remains C.

Table 4
Efficiency rating interval ceilings and thresholds.

Efficiency rating interval ceilings and thresholds					
Efficiency rating	A	B	C	D	E
Threshold	–	$CI_{maxD} - 3i + 0.01 = 445.72$	$CI_{maxD} - 2i + 0.01 = 449.86$	$CI_{maxD} - i + 0.01 = 454.00$	$CI_{maxD} + 0.01 = 458.15$
Ceiling	$CI_{maxD} - 3i = 445.71$	$CI_{maxD} - 2i = 449.85$	$CI_{maxD} - i = 453.99$	$CI_{maxD} = 458.14$	–

Table 5
Alternative for upgrading efficiency levels and ratings.

Alternative for upgrading efficiency levels and ratings				
Alternatives	Absortance (α) value and classification	CI_{env} value and classification	Envelope classification	NumEq
1	0.28 (roof) A or B	CI_{env} = 439.24 A	A	5
2	0.68 (roof) different of A or B	CI_{env} = 439.24 A	C	3
3	0.26 (roof) A or B	CI_{env} = 439.24 A	A	5

4. Analysis and discussion of the findings

Case study 1 – the annex building or brick annex building presents a conventional construction system with the following envelope characteristics: window frames with colorless glass; masonry wall in pierced ceramic bricks covered with brick-colored ceramic tiling; concrete roof slab with fiber cement roof tiles in their natural color, with no heat insulation and a thin layer of air and verandah. Rating this building by the RTQ-C criteria indicates that the absorptance values of it roof and walls are not allowed for the A or B rating. Moreover, through the CI calculation, the envelope is rated as B, so that the envelope is rated as C. Thus, in order to bring the envelope rating up to an A grade, three alternatives are proposed, two related to the absorptance values of its walls and roof; and one to type of glass with a lower SF (smoked glass) instead of the original (colorless glass). By bringing together Alternatives 1 and 2, the absorptance values for the walls and roof (painting the surfaces white), are reduced to an acceptable value for an A or B rating, meaning that the envelope rating rises to a B grade, as the classification of the CI_{env} is B. With Alternative 3, replacing colorless glass by smoked glass, the CI_{env} rating rises to a value within the A grade limits, but the absorptance of the walls and roof are not allowed for the A or B rating, meaning that the envelope is rated as C grade. Only by bringing together alternatives 1, 2 and 3 is the envelope rated as an A grade, as in this case the prerequisites are altered to a value acceptable for an A grade rating and the CI_{env} value falls within these limits. It is noted that measures such as low absorptance paintwork on the walls and roof and the use of glass with a lower solar factor than colorless glass, makes it possible to achieve the maximum rating levels for buildings with conventional construction system in BZ 8.

However, the replacing the type of glass used in the openings is not always feasible, as this is not a simple or low-cost project. One way of justifying the investments needed to obtain an A rating would be to measure the drop in energy consumption through energy consumption and analysis software, comparing the energy reduction gains for the A and B ratings. But to do so, the assessment must be undertaken through energy consumption analysis software, which differs from the method used in this paper. Another justification for these investments would be the fact that an A rating carries weight in the public relations field, in terms of benefits for the environment and environmentally commendable conduct by the building owners. In the specific case of a school, an A rating would also offer information to all students in the environmental, energy and climate change fields, in addition to disseminating a culture focused on efficient energy use extending beyond the walls of the school.

Case study 2 – the new building or sports court building features conventional architecture with the following envelope characteristics: window frames with smoked glass; wall in pierced ceramic brick masonry with white-painted stucco finish; roof in fiber-cement roof tiles in their natural color with no heat isolation and with a thin layer of air; concrete slab and apparent concrete pillars in their natural color. Assessing this building by the RTQ-C criteria for rating its envelope, it reaches a C grade as, according to the results for the absorptance prerequisite, the roof absorptance value is not accepted for an A or B rating. Thus, even with the B rating of the CI_{env} the envelope rating drops to a C. Faced with these results, three alternatives are proposed for increasing the envelope efficiency level in terms of the roof absorptance.

One alternative is to paint the fiber-cement roof tiles white, leaving the concrete roof slab bare and unpainted, which would bring the absorptance value down to an acceptable level for an A or B rating. Thus, the envelope rating continues as the CI_{env} rating, which in this case is A. The second alternative involves covering the bare roof slab with a garden, which would not usher in as much improvement as in the previous case study. This is because white has a low absorptance value that is well below that of a garden, while 84% of the roof area is protected by tiles. Thus, the absorptance value remains higher than the acceptable level for an A or a B rating. Thus, the envelope rating is C. It is important to recall that the lower prerequisite rating prevails over the higher envelope consumption rating. A third alternative blends these two options, lowering the absorptance value and raising the envelope rating to an A grade. However, it should be borne in mind that the drop in the roof absorptance value due to white-painted tiles and a garden is much less significant than the alternative that leaves the roof slab bare with the roof tiles painted white. Although the financial costs have not been calculated for preparing and planting the garden, followed by its ongoing upkeep, it is believed that the impact on energy consumption would not support this option. Consequently, in order to draw up a more detailed assessment, an energy consumption analysis of alternatives 1 and 3 is required, using appropriate simulation software, as the method used to calculate the efficiency rating for this paper is prescriptive, which does not quantify the building energy consumption.

An important aspect of applying the regulations is the difficulty of obtaining the information required to conduct the assessment in compliance with the criteria set forth in the RTQ-C, as it is not common to keep as-built records in Brazil during and after the construction stage. In general, the executive project designs are taken to constitute the as-built documentation, although it is well known that alterations may be introduced during construction. When undocumented, these changes make it difficult to obtain accurate information for assessing the building.

Another noteworthy point is that, in order to attain an A or B rating in the studies presented, based on the conditions of the buildings, all that was required was to paint the walls and roof with a low absorptance color – a strategy that should already be in place at the location of the buildings under examination: the city do Rio de Janeiro.

Bearing in mind that the buildings under assessment are conventional, meaning that they do not encompass appropriate project design strategies for energy efficient buildings, and do not make use of modern, efficient materials, the findings of these studies are noteworthy for the criteria adopted in the regulations, in terms of their stringency, for higher envelope efficiency levels, which proved insufficient to obtain the necessary level for heat-related comfortable buildings that are also energy efficient. Thus, in order to make this assessment conclusive and applicable to all cases, a larger sample is required representing buildings in the bioclimatic zones. However, taking these findings and assessments of the case studies presented into account, together with the inference that the criteria adopted by the regulations are somewhat lax, the A rating would be recommended as the standard for labeled buildings in order to meet the objectives of: reducing electricity consumption and CO_2 emissions, as well as heat-related comfort that an efficient building must provide. However, it must be acknowledged that there is still a long path to be pursued, as labeling began in 2009, and there are currently only ten buildings labeled by the prescriptive method in Brazil.

This method does not supply energy consumption that is an important indicator in the building labeling assessment process. Moreover, this is a complex method that is hard to understand, requiring training to apply it. In order to quantify electricity consumption, the most indicated method is simulation through appropriate software, as the prescriptive method merely pursues the objective of rating efficiency levels in compliance with the technical requirement set forth in the RTQ-C. There is no doubt that simulating energy consumption would be a value in the development of efficient project designs, but the existing software is hard to use, requiring special training for practitioners. Moreover, they do not provide any specific guidance on labeling, under the RTQ-C. In order to help architects, engineers, designers and other professionals, the building energy efficiency laboratory (LabEEE) is developing a building energy efficiency simulator [14].

Measurements of energy consumption would guide decisions on the steps required when designing or revitalizing a building in order to: save electricity with lower bills and assess the cost benefit ratios of steps taken at the design and revitalization stages in compliance with the ratings achieved. Additionally, quantifying energy savings would also allow: assessments of the impacts of the gains obtained, according to the efficiency ratings awarded; determining potential electricity savings due to labeling, while also assisting with the identification of the desirable efficiency level for buildings in Brazil.

Yet another aspect, it is believed that incentives will be necessary, together with information, training and capacity-building in order to ensure the success of the building labeling system in Brazil. It is believed that training and information on use, and the benefits of the regulations must reach out particularly to the architects and engineers; with capacity-building focused on technical, commercial and management areas. Above all, with regard to information, this must reach out mainly to the builders, owners and users of buildings.

In closing, what was assessed and discussed in this section indicates some relevant issues, which is certainly not intended to belittle building labeling, as this is a major step forward for energy efficiency in Brazil. Furthermore, it is felt that the regulation criteria are still in the initial stage, and will be reviewed over the next few years, becoming more restrictive, similar to other countries. It is expected that the implementation of the RTQ-C over the next few years will trigger positive impacts at the economic, technological, social and environmental levels. However, for these impacts to be known, it is necessary to monitor measure and assess them in qualitative and quantitative terms, based on economic, technological, social and environmental aspects, during a specific period. The outcomes may provide input for reviewing the initial efficiency criteria adopted in the regulations, with discussions leading to the establishment of new efficiency standards for buildings in Brazil, together with incentive policies.

5. Conclusion

This paper investigates whether the conventional construction system for buildings complies with the requirements established in the RTQ-C and measures the contribution of building labeling to reducing energy consumption. The focus of this analysis is one of the systems addressed by these Regulations: the building envelope.

The analysis of electricity consumption is qualitative, while the prescriptive method proposed by the regulations is used in this paper, which does not quantify electricity consumption when calculating energy efficiency ratings for the systems considered for building labeling.

In view of the findings of this case study, it seems that the gains and impacts of labeling have not reached their expected level as they are related to the stringency of the technical requirements established through the regulations for the envelope, which are not considered sufficient to result in any significant reductions in electricity consumption in labeled buildings, nor to result in any improvements in their constructed environment. This means that, in order to comply with higher rating requirements, only simple measures were required in the buildings under analysis, which should already be embodied in the buildings encompassed by the BZ 8 area.

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References

[1] A.M. Omer, Energy, environment and sustainable development, Renewable & Sustainable Energy Reviews 12 (2008) 2265–2300.
[2] National Energy Balance (BEN) 2009: Baseline Year 2008, 2010, available at: http://ben.epe.gov.br, accessed on: February 14.
[3] World Energy Council, Energy Efficiency: A Worldwide Review – Indicators, Policies, Evaluation, Agence de l'Environnement et de la Maîtrise de l'Energie, 2004, 221 pp., available at: http://www.worldenergy.org/documents/eepi04.pdf, accessed on: January 17, 2010.
[4] Normalização and Qualidade Industrial – Inmetro, Avaliação da Conformidade, 5 ed., Instituto de Metrologia, 2007, available at: http://www.inmetro.gov.br/infotec/publicacoes/acpq.pdf, accessed on: February 2, 2010.
[5] Law No 10,295 Promulgated on October 17, 2001: Rules on the National Energy Conservation and Use Policy, Federal Government Gazette (DOU), Brasília, DF, October 18, 2001, available at: http://legislacao.planalto.gov.br/legisla/legislacao.nsf/Viw_Identificacao/lei%2010.295.2001?OpenDocumento&AutoFramed, accessed on: January 13, 2010.
[6] Ministry of Mines and Energy (MME), Regulamento Técnico da Qualidade do Nível de Eficiência Energética de Edifícios Comerciais, de Serviços and Públicos, 2009, available at: http://www.labeee.ufrsc.br/eletrobras/etiquetagem/downloads.php, accessed on: December 8, 2009.
[7] Ministry of Mines and Energy (MME), Manual para Aplicação dos Regulamentos: RTQ-C and RAC-C, 2009, available at: http://www.labeee.ufrsc.br/eletrobras/etiquetagem/downloads.php, accessed on: December 8, 2009.
[8] Ministry of Mines and Energy (MME), Regulamento de Avaliação da Conformidade do Nível de Eficiência Energética de Edifícios Comerciais, de Serviços and Públicos, 2009, available at: http://www.labeee.ufrsc.br/eletrobras/etiquetagem/downloads.php, accessed on: December 8, 2009.
[9] H.S. Geller, Revolução Energética: Políticas para um Futuro Sustentável Relume Dumará, Rio de Janeiro, 2003.
[10] H. Geller, J. Thorne, U.S. department of energy's office of building technologies: successful initiatives of the 1990s, in: H.S. Geller (Ed.), Revolução Energética: Políticas para um Futuro Sustentável, Relume Dumará, American Council for an Energy-Efficient Economy, Rio de Janeiro, Washington, DC, 2003.

[11] E.et al. Hirst, Energy Efficiency in Buildings: Progress & Promise, ACEEE, Washington, DC, 1986.
[12] Z. Yilmaz, Evaluation of energy efficient design strategies for different climatic zones: comparison of thermal performance of buildings in temperate-humid and hot-dry climate, Energy and Buildings 39 (2007) 306–316.
[13] Instituto de Metrologia, Normalização and Qualidade Industrial. Available at: http://www.inmetro.gov.br/consumidor/produtosPBE/edificioscomercias.asp, accessed on: July 5, 2010.
[14] Simulador de Eficiência Energética de Edificações. Available at: http://www.labeee.ufrsc/eletrobras/etiquetagem/see/index.html, accessed on: July 5, 2010.