Journal of Civil Engineering and Architecture 12 (2018) 355-361
doi: 10.17265/1934-7359/2018.05.004

Labelling of the Energetic Efficiency on a Case Study in Passo Fundo, RS, Brazil, in Accordance with the Mentioned Methods under the Respective Brazilian Regulation—RTQ-C

Letiane Beninca[1, 2, 3], Grace Tibério Cardoso[4] and Cristiana Rodrigues[5]

1. School of Civil Engineering of Meridional Faculty (IMED), Passo Fundo 99070-220, Brazil

2. Postgraduate Program in Civil Engineering (PPGCI) of Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Brazil

3. School of Architecture of Barcelona, Barcelona Tech, Universitat Politècnica de Catalunya (UPC), Spain

4. Postgraduate Program in Architecture and Urbanism (PPGARQ), Meridional Faculty (IMED), Passo Fundo 99070-220, Brazil

5. Postgraduate Program in Civil Engineering (PPGEC), Meridional Faculty (IMED), Passo Fundo 99070-220, Brazil

Abstract: Having as a starting point of the problematic energy consumption of buildings, it studied the panorama of energy efficiency, emphasizing the Brazilian program of the INMETRO (Instituto Nacional de Metrologia, Normalização e Qualidade Industrial), PROCEL "Edifica" (national program for energy efficiency in buildings), contained in the norm RTQ-C (technical requirements of the quality for the level of energetic efficiency of commercial, service, and public buildings). For a better understanding of the regulation, it elected a building, emblematic in the city of Passo Fundo, RS, Brazil, illustrating the perspective of the program. The building was classified in accordance with the two methodologies presented by the program: prescriptive and simulation, so it was possible to investigate the peculiarities of each methodology and the own regulation. After the application of the methodologies, we came to the conclusion that the prescriptive method is less accurate and requires more dedication by the evaluator to do all the calculations and surveys required, however, it is the fastest tool and accessible to the field professionals. The simulation on the other hand, is a more accurate methodology and reaches levels of analysis that the prescriptive method does not reach, but still is a tool that needs large initial financial contribution and prior knowledge.

Key words: Energy efficiency, labelling, Brazilian regulation.

1. Introduction

This paper seeks to investigate the subject of energy efficiency, seeking to explore the knowledge especially in the Brazilian Labeling Program of INMETRO (Instituto Nacional de Metrologia, Normalização e Qualidade Industrial). That is supported by the PROCEL EDIFICA (national program for energy efficiency in buildings), which obeys the RTQ-C (regulation of the technical requirements of quality for the level of efficiency energy of commercial, service and public buildings) [1].

Starting from a case study in the city of Passo Fundo, Rio Grande do Sul, Brazil, the two methodologies presented by the regulation: prescriptive and simulation were applied, verifying the contributions to the investigative process of each method, as well as its limitations. The results obtained by the regulation were analyzed, as well as the reliability of both methods and their application for the specific case of an educational building.

Corresponding author: Grace Cardoso, Ph.D. candidate; research field: climate dynamics applied to building. E-mail: gracetiberio@hotmail.com.

2. The Methodologies of the Regulation (RTQ–C)

RTQ-C, aims to create conditions to label the energy efficiency of commercial, service and public buildings. It includes, as a general description, to specify methods for the level classification of energy efficiency of those buildings [2].

It can be applied to buildings with a minimum useful area of 500 m^2 or within an electrical supply voltage of 2.3 KW or more, for buildings with air conditioning, partly conditioned and/or naturally ventilated. It is a requirement for analysis, that commercial buildings with air-conditioned must be verified by simulation, that the human permanence provides temperatures (within the comfort zone) for 80% of the hours of use per year [2].

Deeping the knowledge about the program, the regulation presents two methodologies for the classification of the energetic level of the buildings. These methods involve contemplating the general and specific data and prerequisites of each section of the regulation.

2.1 Prescriptive Method

Equations are applied receiving as input information concerning the characteristics of the external structure (architectural and constructive), lighting system and air conditioning in an analytical procedure. The obtained score determines the classification of the energy efficiency of the systems separately, resulting in numeric equivalents that will be used in the final classification equation. The method can be explained in Fig. 1 [3].

2.1.1 General Prerequisites

These prerequisites are related to elements of the building, such as elevators, water heating system, and determine the criteria for each parameter of the building. Once these parameters do not reach the value estipulate on the regulation, the classification of the building decreases to the prerequisite level [2].

2.1.2 Specific Prerequisites

In the prescriptive method, there are three specific systems that have to be analyzed, if the building are not in conformity with those items, the level of the final classification will decrease. The first system is the external structure, where it verified the zenithal opening (presence or absence) and the opaque components. The prerequisites are the thermal transmission (U) and solar absorption of the walls and roofs [2].

The lighting systems were adapted for the country based on the Norm 90.1 by ASHRAE [4], and the prerequisites are: division of circuits by independent devices in each closed room, contribution of natural light and automatic shutdown of the lighting for system in ambiences with more than 250 m^2 [5].

The third system, is the air conditioning, its prerequisite is only required for level A, where the conducts of the system need to have the minimum thickness established by the regulation for the thermal insulation for heating and cooling [2].

2.1.3 Final Classification for the Prescriptive Method

The final classification equation of the building (PT) is calculated using the numeric equivalent result of the three systems evaluated separately. In the total evaluation, the systems will have the following weight division: for the external structure will be 30%, for the lighting system in 30% and air conditioning, the highest weight with 40%. These results will be used in Eq. (1), however it must attend the general and specific prerequisites [5].

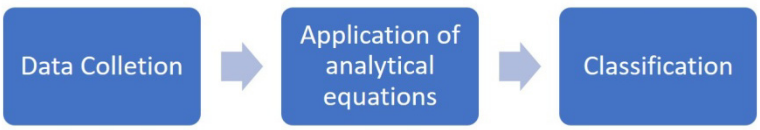

Fig. 1 Prescriptive method scheme.

$$PT = 0.30 \cdot \left\{ \left(EqNumEnv \cdot \frac{AC}{AU} \right) + \left(\frac{APT}{AU} \cdot 5 + \frac{ANC}{AU} \cdot EqNumV \right) \right\} + 0.30 \cdot (EqNumDPI) + 0.40 \cdot \left\{ \left(EqNumCA \cdot \frac{AC}{AU} \right) + \left(\frac{APT}{AU} \cdot 5 + \frac{ANC}{AU} \cdot EqNumV \right) \right\} + b_0^1 \quad (1)$$

where,

EqNumEnv: numeric equivalent of external structure;

EqNumDPI: numeric equivalent of lighting system, identify by DPI (illumination power density).

EqNumCA: numeric equivalent of air conditioning system;

EqNumV: numeric equivalent of no conditioned and/or naturally ventilated ambience (the value has to be verified by simulation; if this does not happen, its value is equal to 1);

APT: useful area of the temporary permanence ambience, since not conditioned (corridors, stairs and bathrooms);

ANC: useful area of the non-conditioned ambiences of prolonged permanence, with verification of POC (percentage of hours occupied in comfort) by natural ventilation, through simulation;

AC: useful area of the conditioned ambiences;

AU: useful area;

b: score obtained by bonuses ranging from 0 to 1.

2.2 Simulation Method

This method is a comparison of the final energy performance of the real building with these classificatory references. For this, it is necessary to perform the energy efficiency simulation of the models A, B, C and D, like specified on the RTQ-C and compare these results with the result of the real building. The simulations must be made through specialized software such as Energy Plus, DesignBuilder, Esp-r, among other software approved by BESTEST (building energy simulation test) method. The method is exemplified with Fig. 2 [5].

2.2.1 Final Classification for the Simulation Method

The total score (PT) of the fully simulated buildings will be calculated by the equation:

$$PT = EqNumS + b_0^1 \quad (2)$$

where:

EqNumS: equivalent numeric of the simulation (given by de comparison of the models);

b: score obtained by bonuses ranging from 0 to 1.

Bonuses: measures that prioritize the use of strategies that reduce the environmental impact and can be check for both methods. They can reach, at most, one (1) point added to the overall score. This point will be attributed if it is justified and proven with initiatives such as: the rational use of water, use of water heating by solar panels, use renewable energy sources, use cogeneration (heat and energy), reuse of heat in thermodynamic processes (can occur in the form of steam, hot and/or cold water) or any innovations that promote energy efficiency [3].

From the general score, determined by the used method (prescriptive or simulation), the building will be classified in Table 1, by the scale of value from A to E, where A is the more efficient and E the less efficient.

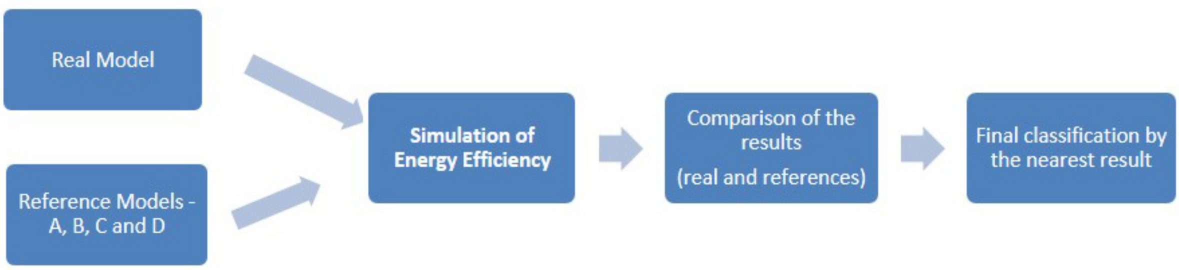

Fig. 2 Simulation method scheme.

Table 1 Final score and classification.

Score	Classification
≥ 4.5 to 5	A
≥ 3.5 to < 4, 5	B
≥ 2.5 to < 3.5	C
≥ 1.5 to < 2.5	D
< 1.5	E

3. Application of the Methodologies on an Educational Building

3.1 Location and Climatic Conditions

The case study to evaluate the two methods of the PROCEL EDIFICA (RTQ-C), is an educational building, with four floors, with a total area of 7,240.15 m², in a residential and commercial zone of the city, of Passo Fundo, Rio Grande do Sul, Brazil. The city is located on the coordinates of longitude of 28º15'46" and latitude 52º24'25" with medium altitude of 680 m above the sea level. According to the climatic classification of Köppen, the region has a humid subtropical (temperate) mesothermal climate (Cfa) [3].

The city has an average annual temperature of 17.5 ºC and has the warmest month in January and the coldest month in June. The region is characterized by moderately warm summers and mild winters. In the colder months it is common to form frost and, occasionally, the occurrence of snow. It Also, enjoys well distributed rains throughout the year, with September being the month with the highest volume (206.8 mm) and April the lowest (118.2 mm). The relative air humidity remains between 67% in the months of November and December and in 76% in the month of June. The predominant winds are from NE (north east) direction, with average velocities of 3.80 m/s and 4.70 m/s, with secondary winds coming from the SE (south east) [3]. The NBR 15220 classifies the city in the bioclimatic zone 2 [6].

3.2 Verification of the General Prerequisites of the Regulation (RTQ-C) for the Building

At the beginning the general prerequisites for the building, have to be verified. At this point some equipments that are not considered in other items of the regulation, were evaluated such as elevator efficiency, existence or absence of water heating, the possibility of individualized measurement of electrical circuits (or their absences). In the same way, the presence of sustainability strategies or initiatives that reduce the environmental impact, was analyzed. The score of the Building C of IMED is detailed in Table 2.

4. Classification of the Building by the Prescriptive Method

4.1 External Structure (Env)

4.1.1 Determination of the External Structure efficiency

To determinate the classification of the envelope, all the data (architectural and constructive characteristics) of the building must be collected to the procedure of the efficiency determination. The data values should be inserted into the equation of the index of consumption (ICenv), which is determined by the bioclimatic zone, the projection area and the form factor.

Fig. 3 shows the classification of the external structure, with an energetic consumption of 34.34 with classification B.

4.1.2 Verification of the Specific Prerequisites

It analyzed the constructive characteristics of the walls, roof, external colors and zenithal lighting to verify the prerequisites of the envelope, the results are specified in Table 3:

During the process of certification, in this case, the prerequisites do not attend the mayor level of the criteria, thus the evaluation of the building; according to these parameters, it will decrease to level E, although the calculation of the envelope was a better classification (C).

4.2 Lighting System (DPI)

The procedure of determining the efficiency of the lighting system has the main objective to establish the limit of power of the internal lighting (DPI). It used the method of the area of the building to classify the efficiency of the system.

First, it was verified the acceptable maximum limit of lighting power density for the main activity in the building, by the INMETRO classification [2]. Then multiplying the total of the illuminated area of the

Table 2 Classification of the general's prerequisites.

General's prerequisites		Classification
Electrical circuit with centralized measurement	Does not have	B
Water heating	Do not apply	X
Elevator	Does not have (the elevators do not have frequency inversions)	B
Bonuses	Does not have	X
Classification		B

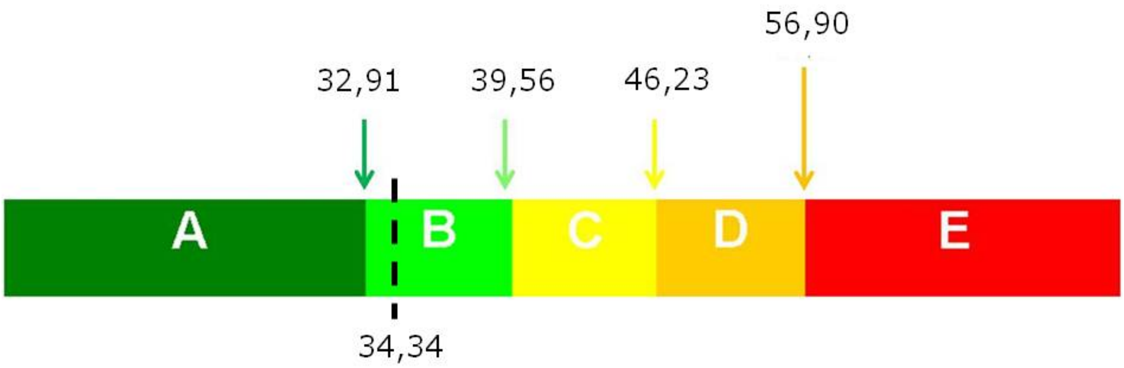

Fig. 3 Scale of the index of consumption (ICenv) of the building.

Table 3 Classification of the external structure prerequisites.

Specific prerequisites	Value	EqNum	Classification
Thermal transmission	Uwall: 2.24 W/(m²·K)	3	C
	Uroof: 2.06 W/(m²·K)	1	E
Absorption of the external surfaces coefficient	αwall: 0.40	5	A
	αroof: 0.85	1	E
Zenithal lighting	Zenithal < 5% (verified by simulation or the level will be C)	3	C
Classification		1	E

Table 4 Calculations of the DPIL for each level of efficiency.

Activity	DPIL level A	DPIL level B	DPIL level C	DPIL level D
Universities	10.7 W/m²	12.3 W/m²	13.9 W/m²	15.5 W/m²
Total	77,469.60 W/m²	89,053.84 W/m²	100,638.08 W/m²	112,222.32 W/m²

Table 5 Classification of the lighting system prerequisites.

Specific prerequisites		Classification
Circuit division	Yes	A
Contribution of natural light	Does not have	C
Automatic shutdown system	Does not have (It does not have ambiences larger than 250 m²)	C
Classification		C

building (7,240.15 m²) was multiplied by the DPI of each level.

Comparing the installed power of the building, 41,630.00 W, with the limits of the potential, it is verified that the classification of the lighting system is A, but the prerequisites have to be evaluated.

4.2.1 Verification of the Specific Prerequisites

It would be classified as level A, by the installed power of the building, but it does not attend the specific prerequisites, it has been decreased to level C classification.

4.3 Air Conditioning System (AC)

The air conditioners are all split type, with the efficiency evaluated by the PBE/INMETRO (2017) and are in accordance with the Brazilian and international standards. To find the system classification, all devices were weighted by their individual capacity and by the total building capacity, the results were multiplied by the efficiency of the equipment indicated by the INMETRO rate tables.

After verifying all the installed equipments of the building, the classification of the system was C. Checking the specific prerequisites for that item, it was observed that the system does not have insulation on the air conditioning conducts, but the prerequisite in this case is only for level A. Therefore, the classification remains C.

4.4 Final Classification of the Energy Efficiency of the Building by the Prescriptive Method

For the total classification of the building efficiency, all the variables found are put in the equation of the total classification.

$$PT = 0.30\left\{\left(1\cdot\frac{4,736.39}{7,240.15}\right)+\left(\frac{1,281.44}{7,240.15}\cdot 5+\frac{0}{7,240.15}\cdot 1\right)\right\}+0.30\cdot 3+0.40\cdot\left\{\left(2.5\cdot\frac{4,736.39}{7,240.15}\right)+\left(\frac{1,281.44}{7,240.15}\cdot 5+\frac{0}{7,240.15}\cdot 1\right)\right\}+0 \quad (3)$$

where, PT = 3.44.

After all calculations, the total score of C building of IMED, by the prescriptive method is 3.44, equivalent to level C.

5. Classification of the Building by the Simulation Method

For the building simulation, it used the software Design Builder version 2.0.4.001, which is a tool for simulating the thermal and energetic performance of buildings, and has the interface that uses the algorithms of Energy Plus.

The models of computational simulation (real and references) were created from the architectural plants with the intention of maintaining the reality, as possible in aspects of volume, materials and uses. All the building was modeled with the intention of evaluating the thermal changes between interior and exterior, following the speciation of the standard. The results of all simulations are shown in Table 7.

Table 6 Variables for the total score equation.

EqNum	Value
EqNumEnv	1 (E)
EqNumDPI	3 (C)
EqNumAC	2.5 (C)
AU (m²)	7,240.15
ANC (m²)	0
APT (m²)	1,281.44
AC (m²)	4,736.39
Bonuses	0

Table 7 Comparison of the result of the simulations.

Consumption	Real Building	Level A	Level B	Level C	Level D
Annual by m² [KWh/m²]	124.99	113.86	125.68	135.96	166.26

It is verified that the real model has the annual electricity consumption between level A and B, but it does not reach the total of B, so in this case, the efficiency level will be A, with 5 as an equivalent numeric 5. As the edification does not have any bonuses, the final classification is:

PT = EqNumS + B → 5 + 0 = 5 → Classification A

6. Comparison of the Results of the Methods

Analyzing the results provided by the methodologies, where the classification was: External Structure (ENV), level E; Lighting System (DPI), level C and Air Conditioning (AC), level C, reaching the total classification as level C and analyzing the results provided by the simulation method where the classification is level A, it is evident that the two methodologies do not correspond.

7. Conclusions

The difference between the two methods occurs because the prescriptive method can be considered as a simplification, trying to be more accessible to professional market. It considers important variables in their specific prerequisites, which surpasses a good classification. On the other hand, the simulation recreates the real building and the building reference comparing their energy performances, not evaluating each requirement separately, because they are contained in the models. However, it is a more difficult tool for the professional, because it needs the knowledge of the software and good computers to run the simulation.

References

[1] Brasil. Instituto Nacional de Metrologia Normalização e Qualidade Industrial (INMETRO). 2013. "Manual para Aplicação dos Regulamentos: RTQ-C e RAC-C." Brasília, DF, Brasil.

[2] Brasil. Instituto Nacional de Metrologia Normalização e Qualidade Industrial (INMETRO). 2013. "Regulamento Técnico da Qualidade do Nível de Eficiência Energética de Edifícios Comerciais, de Serviços e Públicos." Brasília, DF, Brasil.

[3] Beninca, L. 2012. "Prescripción y Simulación. Etiquetaje de la Eficiencia Energética del Edificio Comercial "Torre Plaza Shopping", Passo Fundo, RS, Brasil, en función de las dos metodologías de la Reglamentación Brasileña – RTQ-C." Master dissertation, Universitat Politècnica de Catalunya, Barcelona, España.

[4] American Society of Heating, Refrigerating and Air Conditioning Engineer (ASHRAE). 1989. "Energy Standard for Buildings except Low-Rise Residential Buildings." *ASHRAE Standard 90.1–1989*. Atlanta, EUA.

[5] Lamberts, R. 2010. "Eficiência energética da envoltória de edifícios de escritórios de Florianópolis: discussões sobre a aplicação do método prescritivo do RTQ-C." *Ambiente Construído* 10 (2): 59-69.

[6] Associação Brasileira De Normas Técnicas (ABNT). 2005. "NBR 15.220-3: Desempenho térmico de edificações: parte 3: zoneamento bioclimático brasileiro e diretrizes construtivas para habitações unifamiliares de interesse social." Rio de Janeiro, Brasil.