Capability and deficiency of the simplified model for energy calculation of commercial buildings in the Brazilian regulation

CAPABILITY AND DEFICIENCY OF THE SIMPLIFIED MODEL FOR ENERGY CALCULATION OF COMMERCIAL BUILDINGS IN THE BRAZILIAN REGULATION

Ana Paula Melo[1], Roberto Lamberts[1], Daniel Cóstola[2], Jan L.M. Hensen[2]
[1]Energy Efficiency in Buildings Laboratory, Federal University of Santa Catarina, Florianópolis, Brazil
[2]Building Physics and Systems, Eindhoven University of Technology, Eindhoven, The Netherlands

ABSTRACT

This paper provides a preliminary assessment on the accuracy of the Brazilian regulation simplified model for commercial buildings. The first step was to compare its results with BESTEST. The study presents a straightforward approach to apply the BESTEST in other climates than the original one (Denver, Colorado, USA). The second step consisted on applying the simplified model for common buildings, and compare the results with those obtained using a state of the art building energy simulation (BES) program. Significant errors were found when comparing the simplified model with BESTEST and the common buildings analyzed.

INTRODUCTION

Countries all over the world are discussing strategies to improve buildings energy efficiency and implementing energy regulations to reduce buildings energy consumption. Most of the regulations are based on the thermal performance of the buildings, informing through an energy label about its energy performance.

Investiments on energy efficiency provide financial rewards and enviromental benefits. However, Sardianou (2008) shows that policy makers should be aware that enviromental and energy education should also be consider as a conservation strategies. Pérez-Lombard et al. (2009) presents that the success of building energy certification will rely on three decisive concern: to achieve a label which produces expected results for the amount of resources invested; the accuracy of real energy savings; and the engagement to reduce the green house gases in order to prevent impacts on global warning.

Some of energy regulations make extensive use of state of the art building energy simulation (BES) programs, such as EnergyPlus and ESP-r in their energy assessment. Many governments, such as Portugal, Netherlands and Brazil, have been developing their own methods, which are primarily based on simplified models for energy assessment.

In Portugal the new thermal regulation was implemented and the regulation is divided into: Residencial Buildings (RCCTE, 2006) and Office Buildings (RSECE, 2006). The type and level of requirements depend on the category of the building. The accuracy of Portuguese thermal regulation simplified methodology for existing buildings was evaluated by Silva et al. (2009). Based on “in-situ” measurements to calibrate the input data, the results show that the simplified methodology results are usually 11% higher than the detailed methodology.

In Netherlands new buildings have to comply with the Dutch Code (NEN 2916) to settle on the energy performance of non-residential buildings. This code is applied to estimate the total primary energy consumption for lighting, cooling and heating, fans, pumping, humidification and hot water. Also, it brings a new process to establish the heating and cooling energy requirements of different air conditioning systems. The relation between energy performance standard and the actual energy use in buildings was investigated (CDC, 2004; Santil et al., 2009) and showed that there is a significant range between the EPC (Energy Performance Calculations) and the actual energy consumption.

In Brazil, the goverment has been taken initiatives to improve buildings energy efficiency. In 2001, the first energy efficiency law (Law n^{o} 10.295) in Brazil was signed (Brazil, 2001a) and published under a Code - Decree 4.059 (Brasil, 2001b). As a result, after years of studies and investments, the Regulation for Energy Efficiency Labelling of Commercial Buildings in Brazil (RTQ-C) was released in February 2009 (Brasil, 2009).

The implementation of RTQ-C sets for a great improvement on the energy efficiency of the Brazilian buildings. This regulation aims to classify buildings according to five levels: from "A" (most efficient) to "E" (least efficient). This classification can be based on: the results of hourly building energy simulation (BES) programs or by using a prescriptive method with is based on a simplified model.

Building energy simulation programs evaluate the building thermal performance integrating different input data applications. Different energy simulation programs have been developed (Crawley et al., 2008), increasing the possibility of analyzing those interactions. Building energy simulation programs demand considerable amounts of time and resources. Also, it requires much larger knowledge when compared to simplified methods. These simplified methods usually demand few input data and are built using several assumption regarding climate, patterns of use and construction tradition. They are a quick tool for energy assessment but they may also have a considerable uncertainty in their results, which may compromise the building energy labeling process.

During the development of the RTQ-C simplified model some characteristics related to building geometry were kept fixed and some parameters related to the building envelope were excluded from the simplified model to improve its coefficient of determination (Carlo, 2008).

Hence, the primary intent of this study is to provide a preliminary evaluation on the accuracy of the Brazilian regulation simplified model, determining whether the simplified model guarantee the building energy efficient.

METHODOLOGY

Regulation for Energy Efficiency Labeling of Commercial Buildings in Brazil

The Regulation for Energy Efficiency Labeling of Commercial Buildings in Brazil was released in 2009. The label evaluates the lighting system; envelope and air conditioning system, classifying the buildings according to five levels: from "A" (most efficient) to "E" (least efficient). The classification can be based on the simulation method or based on the prescriptive method.

The simulation method consists of comparing two models: proposed and reference building. The reference building should be detailed according to the prescriptive method and the proposed building should apply its own characteristics. However, both cases must enclose common characteristics such as same orientation, same patterns of use and building operations, same air conditioning system and set point temperature. In addition, it is mandatory that the simulation program and the weather file fulfill all the requirements listed in the RTQ-C. To achieve a label, the proposed building should consume the same or less energy than the reference building.

The energy efficiency classification for buildings envelope using the prescriptive method is based on a simplified model. This model was generated using a multi-linear regression analysis. This analysis is based on the energy consumption from different typologies of commercial buildings, calculated using a state of the art building energy simulation (BES) program, EnergyPlus.

During the development of the simplified model, all the different typologies of commercial buildings have the largest facade to north and south orientation. Also, all cases have a window air conditioning system with efficiency A. Those parameters were considered as fixed because the air conditioning energy consumption is proportional to its efficiency; and the building orientation has few influences on the building envelope (Carlo, 2008).

All the parameters that were not considered as main part of the building envelope were considered with predetermined value, such as ILD (Internal Load Density) and PU (Patterns of use), applying values of 25 W/m^2 and 11 hours, respectively. Those values were fixed after finding a satisfactory correlation throughout the statistic method application (R^2 = 0,9978 for buildings with projection area equal or less than 500m^2; e R^2 = 0,9989 for buildings with projection area higher than 500 m^2). Moreover, the wall and roof thermal transmittance were exclude from the simplified model as they do not present a satisfactory correlation in the equation.

The influence of wall thermal transmittance on the energy consumption depends on other parameters (Melo and Lamberts, 2008). As a result, the simplified model just takes into account the building geometry and some parameters related to the openings, such as WWR (window-to-wall ratio), FS (solar factor), AVS (horizontal shadings), AHS (vertical shading). The acronyms of WWR, FS, AVS and AHS are the same as used in the RTQ-C.

Carlo and Lamberts (2010) describe the RTQ-C simplified model and discuss about its limitations. One limitation presented is about the building geometry. The multi-linear regression could not describe all the building geometry variations on the same equation. As a result, two equations were developed based on the building projection area: higher than 500 m^2 and equal or less than 500 m^2. Therefore, before using the simplified model, it is essential to determine two factors: the FA (height factor) and FF (shape factor). The acronyms of FA and FF are the same as used in the RTQ-C. The first one is the ratio of roof area and total building area. The later is the ratio of envelope area and total building volume. Those factors inform if the building geometry is among of those geometries considered to develop the simplified model. Consequently, depending on the building projection area there are a minimum and a maximum values for FF that should be applied in the simplified model calculation. Each Brazilian bioclimatic zone has two equations presenting different maximum and minimum values of FF.

Based on that, the result from the simplified model is represented by a Consumption Indicator (IC). The acronym of IC is the same as used in the RTQ-C. First, IC should be calculated for the proposed building using the building own characteristics. Second, IC_{max} and IC_{min} should be calculated to get the maximum and minimum values to reach label D and A, consequently. The parameters and its values used in those calculations must be in accordance to RTQ-C. Then, the subtraction of IC_{max} and IC_{min} should be divided by 4 resulting in an interval (i). Finally it is possible to fill the Table 1 and analyze which label was achieved by the proposed building.

Table 1 Calculation to determine the building label

Label	A	B	C	D	E
Min	-	IC_{max}-3i + 0.01	IC_{max}-2i + 0.01	IC_{max}-i + 0.01	IC_{max} + 0.01
Max	IC_{max}-3i	IC_{max}-2i	IC_{max}-i	IC_{max}	-

BESTEST: comparison with simplified model

The use of state of the art building energy simulation analysis programs are becoming more common all over the world to determine the energy performance (Augenbroe and Hensen, 2004) and the energy consumption of proposed buildings. However, BES programs should be validated to present trustful results.

The BESTEST (Building Energy Simulation Test) is a method for testing and diagnosing of building energy simulation programs, developed in the Annex 43 “Testing and Validation of Building Energy Simulation Tools” of the Energy Conservation in Buildings and Community Systems (ECBCS) Programme of the International Energy Agency (IEA, 1995). The BESTEST was later used in the development of the ASHRAE Standard 140 (2004). This method includes several test cases, evaluating the influence of different physical process in the simulation results.

This study consists of running some BESTEST cases to compared its results with the RTQ-C simplified model results. The selection of the cases was based on the relevant parameters that are also considered in the RTQ-C simplified model. The cases selected were Cases 600, 610, 620, 900, 910, 920, 220, 240, 270, 290, 320, 400 (Table 2). All of those cases explore different combinations of parameters and settings, applying a weather characterized as cold clear winter/hot dry summers (Denver, USA). The simulations were carried out using the EnergyPlus program, which is validated by BESTEST and encloses all the requirements established by RTQ-C.

Initially, all the BESTEST cases were run taking into consideration the weather file of Denver - USA to be confident that the energy demand results are between the minimum and maximum values established by ASHRAE Standard 140. Then, the same cases were run for the weather file of Porto Alegre - Brazil to compare its results with the simplified model for Porto Alegre results.

The degree-days of cooling and heating, with base temperatures of 10 ^{o}C and 18 ^{o}C, respectively, were determined for both weathers of Denver and Porto Alegre. The base temperatures values are based on ASHRAE Standard 90.1 (2004) to characterize the climate of a city. The results show that Porto Alegre and Denver have 583 and 3343 degree days for heating and 3653 and 1907 for cooling, respectively. It is shown that both weathers present a significant difference in degree days. However, the weather of Porto Alegre is the one among the Brazilian weathers that presents the lowest temperature during the winter season in Brazil and an average summer temperature close to the weather file of Denver. Consequently, the weather file of Porto Alegre was applied to run the simulations, and the equation for the bioclimatic zone of Porto Alegre (number 3) will be used to perform this comparison.

Table 2 Characteristics of BESTEST cases applied to compare with the simplified model results

BESTEST	CHARACTERISTICS
Case 600	- 8m x 6m x 2.7m - 2 south windows (6 m^2 each) - Materials (low mass) - Infiltration: * 0.5 ACH - Internal gains: * 200 W continually - Setpoint: * heating < 20 ^{o}C * cooling > 27 ^{o}C
Case 610	- Same as case 600 - Overhang de 1 m
Case 620	- Same as case 600 - Windows orientation: * west and east
Case 900	- Same as case 600 - Materials (high mass)
Case 910	- Same as case 900 - Windows orientation: * west and east
Case 920	- Same as case 600 - Overhang de 1 m
Case 220	- Same as Case 600 - No infiltration - No internal gains - Setpoint: * heating < 20 ^{o}C * cooling > 20 ^{o}C - No windows: * high conductance wall
Case 240	- Same as Case 220 - Internal gains: * 200 W continually
Case 270	- Same as Case 220 - Windows as Case 600 - Interior shortwave absorptance: 0.9
Case 290	-Same as case 270 -Overhang de 1m
Case 320	- Same as Case 270 - Setpoint: * heating < 20 ^{o}C * cooling > 27 ^{o}C
Case 400	- Same as Case 600 - No infiltration - No internal gains - External solar absorptance: 0.1 - No windows: * high conductance wall

All the BESTEST cases selected are considered as low mass, except the case 900, 910 and 920 which are considered as high mass. The differences among the cases are: infiltration; setpoint, shading, internal load, window orientation and solar absorptance.

Case studies: comparison with simplified model and BES

This methodology consists in applying the RTQ-C simplified model and the simulation method into common commercial buildings. It was also chosen to consider typologies with a building projection area higher than 500 m^2 to differ from the simplified model applied in the BESTEST cases (building projection area less than 500 m^2). Moreover, the buildings applied have different values of FA and FF and combinations of WWR and efficient FS.

Four commercial buildings were evaluated (Figure 1), taking into consideration different total floor area and number of floors. All the typologies are acclimatized, except the central part of Typology 02 and 04. The typologies have the same parameters and values as those that were considered as fixed in the development of the simplified model. The parameters WWR (window-to-wall ratio), FS (solar factor) and AVS (horizontal shadings) were assumed to have different values (Table 03).

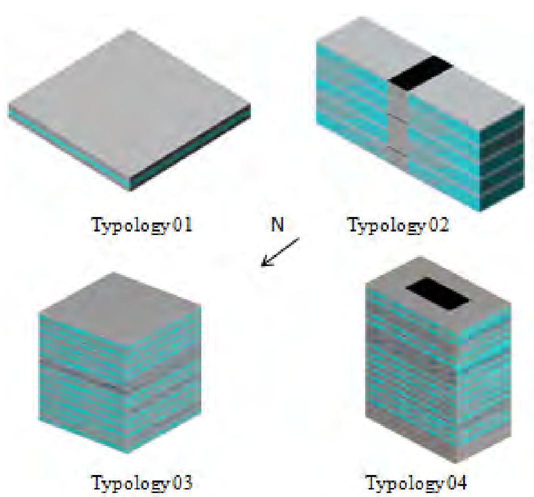

Figure 1 A 3D view of Typologies 01, 02, 03 and 04

The simplified model and simulation method were applied on those typologies and the final envelope label achieved by each method was compared to evaluate the differences between their results.

The analysis with those buildings was also carried out using EnergyPlus, selecting the weather file of Florianópolis which belongs to the same bioclimatic zone as Porto Alegre. The weather file applied is the same that was selected to run the cases to develop the simplified model for Florianópolis: TRY (*Test Reference Year*) from 1963, representing a typical year from a series of 10 years (Goulart, 1993).

All the cases studies have the wall and roof thermal transmittance of 3.7 W/m^2K and 1.0 W/m^2K, respectively. Those are the limits values established to achieve label A according to the prescriptive method.

Table 3 Characteristics of case studies

TYPOLOGIES	01	02	03	04
Length (m)	50	26.7	50	50
Width (m)	50	7.5	50	30
Height (m)	3.5	14.7	52.5	59.5
Total floor area (m^2)	2 500	1 001	37 500	25 500
Number of floors	1	5	15	17
WWR (%)	50	70	50	60
Solar factor	0.58	0.58	0.58	0.25
AVS (^{o})	0	12.5	0	0

RESULTS

Simplified Model and BESTEST

Before using the simplified model for bioclimatic zone 3 (Porto Alegre), the FF was calculated to be aware which value should be used during the simplified model calculation.

The total projection area for all BESTEST cases is 48 m^2, resulting in a FF value of 0.95. The maximum value of FF defined by RTQ-C for buildings with total projection area less or equal than 500 m^2 and intended for bioclimatic zone 3 is 0.70. Hence, the value of 0.70 was considered for the simplified model calculation.

The comparison between the RTQ-C simplified model and BESTEST results are presented in Figure 2 to 7. The first and the second columns are the maximum and minimum energy demand (MWh) values established by ASHRAE Standard 140. The third column is the energy demand result for Denver weather file using EnergyPlus. The next column is the energy demand result for Porto Alegre weather file using the EnergyPlus. And the last one is the simplified model result.

Analyzing the results for Case 600 (low mass) and Case 900 (high mass) in Figure 2 it can be noticed that the BESTEST building requires less energy for cooling and heating for both cases in the weather of Porto Alegre. Nevertheless, significant errors were found when comparing the cases for Porto Alegre weather data and RTQ-C simplified model. For Case 600, the simplified model presents a difference of +20 %; and for high mass construction (Case 900) the difference increases to +51 %. The results for simplified model is the same for both cases as it does not take into account the building thermal transmittance and thermal mass for its calculation. As a consequence, the result will not change when applying high mass on the building envelope.

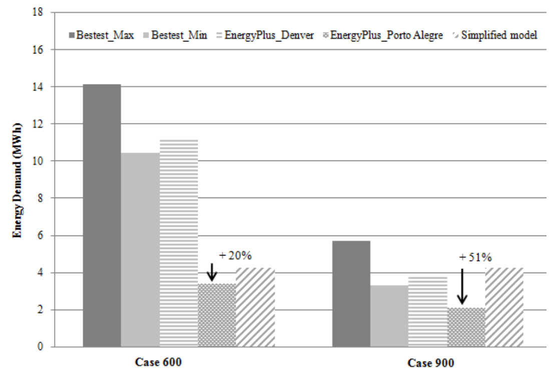

Figure 2 Cases 600 and 900 results

For Cases 610 and 910 (Figure 3) it can be observed that the simplified model present a difference of +24 % and +53 %, respectively, when comparing to Porto Alegre weather data results. Both cases have the same characteristics as the previous cases, except that they have a shading of 1 meter. Adding a shading device reduces the result for simplified model, but it still demonstrates difference when comparing with the cases for Porto Alegre weather file. However, changing the windows position for west and east orientation (Cases 620 and 920) the difference is -36 % and +4 %, respectively. These results are presented in Figure 4.

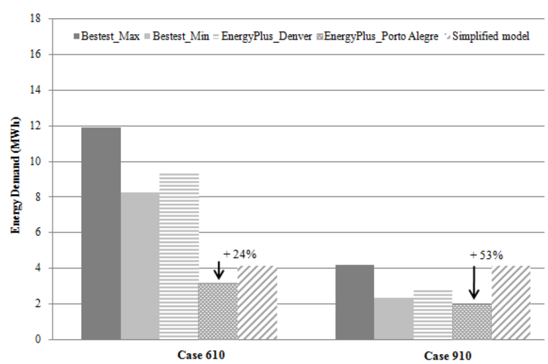

Figure 3 Cases 610 and 910 results

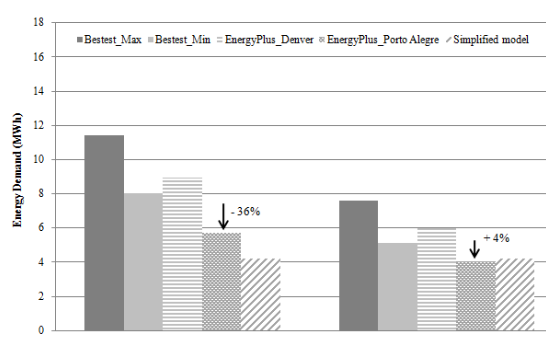

Figure 4 Cases 620 and 920 results

Analyzing the Case 220, where the windows were replaced by a high conductance wall, it is observed that the difference between the BES result for Porto Alegre and the simplified model result is +28 % (Figure 5). The Case 220 has a set point with no dead band (20 ^{o}C for heating and 20 ^{o}C for cooling) and also it does not include any internal gains. Adding a constant internal load of 200 Watts (Case 240), the difference between Case 220 and 240 increases in +5% due to a reduction in the heating load necessary to set the zone temperature according to the thermostat set point. The simplified model result is the same for Cases 220 and 240 as the internal gain is not considered for its calculation.

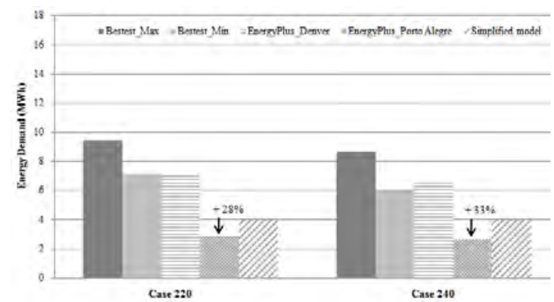

Figure 5 Cases 220 and 240 results

Adding windows into Case 220 (Case 270) it can be observed through Figure 6 that the difference is -5 % between the case for Porto Alegre weather file and simplified model results. For this case the windows reduce significantly the difference when comparing to the previous case (Case 220) without windows. The Case 290 has an overhang of 1 meter, reducing the difference. For those cases the simplified model results are different as Case 290 includes an overhang of 1 m.

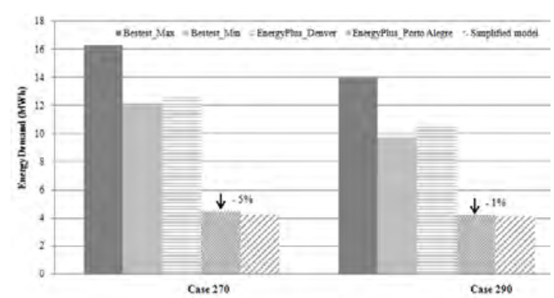

Figure 6 Cases 270 and 290 results

The Case 320 and 400 are presented in Figure 7. The Case 320 has the same characteristics as Case 270, except the setpoint range which is the same as Case 600 (20 ^{o}C for heating and 27 ^{o}C for cooling). The Case 400 is the same as Case 600, except that no windows and internal gains are considered. The difference between RTQ-C simplified model and

Porto Alegre weather data for both cases is approximately +50 %.

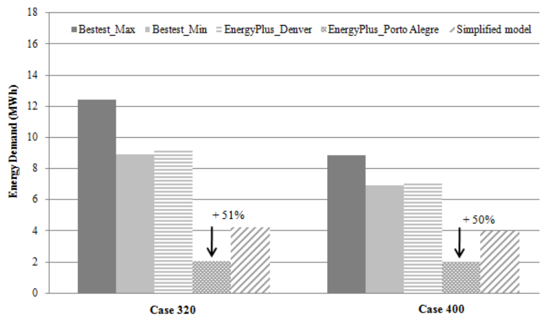

Figure 7 Cases 320 and 400 results

It is shown that for some cases the simplified model results are close to the BESTEST results for Porto Alegre weather data, but for others it presents difference. These differences can be explained as BESTEST geometry is not among the typologies considered during the simplified model development. Moreover, some of the BESTEST cases takes into account parameters that are not considered for the simplified model calculation, such as wall and roof thermal transmittance and thermal mass. Also, the BESTEST cases take into account different operations schedules and loads as those considered during the development of the simplified model.

Simplified model and BES

The FA and FF were calculated for the four buildings previously described in this paper. According to RTQ-C, buildings with a total projection area higher than 500 m^2 for bioclimatic zone number 3 should be consider a minimum FF value of 0.15 and for buildings with a total projection area equal or less than 500 m^2 for bioclimatic zone number 3 should be consider a maximum FF value of 0.70.

The Table 4 shows the value of FA and FF for each building.

Table 4 FA and FF factors

TYPOLOGIES	01	02	03	04
FA	1.00	0.20	0.07	0.06
FF	0.37	0.41	0.10	0.12
FFfinal	**0.37**	**0.41**	**0.15**	**0.15**

The Typology 01, Typology 03 and Typology 04 should have a minimum FF value of 0.15 and for Typology 02 a maximum FF value of 0.70. The Typology 01 and 02 presents a FF value of 0.37 and 0.41, respectively. Both values are acceptable by RTQ-C. However, the Typology 03 and Typology 04 achieved a FF value outside from the prescribed conditions. For those cases, the recommended minimum value of 0.15 was set during the simplified model calculation.

The minimum results for Typology 01 to achieve from label A to label E based on the simplified model and building simulations are presented in Table 5. The result for the simplified model is presented by IC and for the buildings simulations is presented by kWh/m^2.

Table 5 Label for Typology 01

Simplified Model - IC

Label	A	B	C	D	E
Min (IC)	-	137.87	144.54	**151.21**	157.88
Max (IC)	137.86	144.53	151.20	**157.87**	-

Simulation Method - kWh/m^2

Label	A	B	C	D
Min (kWh/m^2	94.8	97.5	**100.4**	108.3

The IC result for Typology 01 is 152.65. This value is between the maximum and minimum limits to achieve a label D. Applying the simulation method the energy consumption result is 98.08 kWh/m^2. This value is lower than the maximum limit of label D, but it has a higher value that label B. As a result, it achieves a label C.

The simplified model results for Typology 02 is 218.54, representing a label D (Table 6). Analyzing this typology through the simulation method the label achieved is C as its energy consumption is 78.2 kWh/m^2.

Table 6 Label for Typology 02

Simplified Model - IC

Eficiência	A	B	C	D	E
Min (IC)	-	211.18	213.82	**216.46**	219.11
Max (IC)	211.17	213.81	216.45	**219.10**	-

Simulation Method - kWh/m^2

Label	A	B	C	D
Min (kWh/m^2)	73.7	76.5	**78.7**	80.1

The results for Typology 03 in Table 7, shows an IC value of 49.84. This value is between the maximum and minimum limits for the label D. Considering the simulation method its energy consumption result is 26.9 kWh/m^2, achieving a label B.

The results for Typology 04 (Table 8) present the same performance as the previous typology. The IC is 53.43 representing a label D and the energy consumption for the simulation method is 122.4 kWh/m^2 representing a label B.

It can be noticed that the use of the simplified model led to a lower energy efficiency label when compared to the label obtained using BES.

Analyzing the label results of Typology 01and 02 for both methods, it can be noticed that BES provides a more efficient label than the label achieved by the simplified model. Analyzing Typology 03 and Typology 04 the simulation method presents two more efficient labels than the simplified model method. For those typologies the simplified model limitations should have an influence on the results.

Table 7 Label for Typology 03

Simplified Model - IC

Label	A	B	C	D	E
Min (IC)	-	35.06	41.74	**48.41**	55.08
Max (IC)	35.05	41.73	48.40	**55.07**	-

Simulation Method - kWh/m²

Label	A	B	C	D
Min (kWh/m²)	25.2	**27.10**	28.8	31.5

Table 8 Label for Typology 04

Simplified Model - IC

Eficiência	A	B	C	D	E
Min (IC)	-	35.17	41.85	**48.52**	55.19
Max (IC)	35.16	41.84	48.51	**55.18**	-

Simulation Method - kWh/m²

Label	A	B	C	D
Min (kWh/m²)	121.9	**123.5**	126.4	132.6

Considering that building energy simulation can better describe the physical phenomena involved in the calculation of energy consumption, it can be concluded that the RTQ-C simplified model may provide conservative results. The differences found in the case studies might indicate that the multi-linear regression adopted to develop the RTQ-C simplified model was unable to describe the relation between inputs parameter and energy consumption in the case of commercial buildings in Brazil.

Based on the simulation method, it can be observed that the minimum results to achieve each label are rather similar. However, to achieve a better label in the simulation method is more complex than in the simplified model as the user of the simulation program should have a great knowledge about all the building parameters and its systems performance to decrease the building energy consumption.

CONCLUSIONS

In this study the accuracy of the Regulation for Energy Efficiency Labeling of Commercial Buildings in Brazil (RTQ-C) simplified model for buildings envelope was evaluated. The methodology was based on a comparison between the simplified model and BESTEST results. In the next analysis, different commercial buildings typologies have been applied to understand the difference between the label achieved by the two methods presented in the Regulation for Energy Efficiency Labeling of Commercial Buildings in Brazil: simplified model and simulation method. Based on the results the following conclusions can be made:

- For some BESTEST cases the simplified model results present extensive difference when it has been compared with BESTEST cases results for Porto Alegre weather data, but for others it presents similarly results. Those differences can be explained as BESTEST geometry is not among the typologies considered during the simplified model development. Also, the BESTEST cases take into account different operations schedules and loads that were not considered during the simplified model development. However, the comparison between simplified model and BESTEST let to understand the influence of different physical process;
- The simplified model led to a lower energy efficiency label than the one obtained using simulation method for four commercial buildings that have been analyzed;
- The simplified model has resulted in two less efficient labels (Label D) for Typologies 03 and 04 result when compared to the simulation method (Label B);
- The results related to the RTQ-C simplified model may suggest that the simplified model is performing as a conservative method. Therefore, for those buildings which require a higher level of analysis the simulation method should be consider to label the building instead of the simplified model.

The development of the Regulation for Energy Efficiency Labeling of Commercial Buildings in Brazil is an important instrument that determines attitudes against to global warming and guarantees the energy efficient of future buildings in Brazil. However, this study emphasizes the need for a more accurate and efficient simplified model to establish the label of commercial buildings. It is important to maintain and ensure that the regulation continue to respond appropriately in the future, responding to the changes in buildings construction techniques.

ACKNOWLEDGEMENT

The first author is currently a PhD student from Federal University of Santa Catarina and doing part of her PhD thesis at Eindhoven University of Technology in the Netherlands (sandwich program). The work in this paper is a preliminary result of her

PhD thesis project. The work reported in this paper was supported by The Brazilian Federal Agency for Support and Evaluation of Graduate Indication – CAPES, Proc. nº 2335/10-7.

REFERENCES

ASHRAE, 2004. ANSI/ASHRAE Standard 90.1-2004: Energy standard for building except low-rise residential buildings. Atlanta, 2004.

ASHRAE, 2004. ANSI/ASHRAE Standard 140-2004: Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs. Atlanta, 2004.

Augenbroe, G., Hensen, J. 2004. Simulation for better building design. Building and Environment, 39 (8), 875-877.

Brasil, 2001a. Decreto No. 4.059, de 19 de dezembro de, 2001. Regulamenta a Lei No. 10.295e dá outras providências. Diário Oficial da República Federativa do Brasil, Brasília, 15 Janeiro (in Portuguese).

Brasil, 2001b. Lei No. 10.295, de 17 de outubro de 2001. Dispõe sobre a Política Nacional de Conservação e Uso Racional de Energia e dá outras providências. Diário Oficial da República Federativa do Brasil, Brasília, 18 Fevereiro (in Portuguese).

Brasil, 2009. Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO). Portaria 185, de 22 de junho de 2009. Regulamento de Avaliação da Conformidade do Nível de Eficiência Energética de Edifícios Comerciais, de Serviços e Públicos, Rio de Janeiro, 04 Fevereiro (in Portuguese).

Carlo, J. 2008. Development of a methodology for evaluating the energy efficiency of non-residential buildings envelope (in Portuguese). Thesis (Doctorade). Federal University of Santa Catarina, Florianópolis.

Carlo, J., Lamberts, R. 2010. Parameters and methods applied in the energy efficiency labelling regulation for buildings – part 1: prescriptive method (in Portuguese). Revista Ambiente Construído, v.10, n. 2, 7-26.

CDC, 2004: Relation between EPC and actual energy use of office buildings, ir. E.R. van den Ham, Climatic Design Consult in order by SenterNovem, 9 July 2004.

Crawley, D., Hand, W. J., Kummert, M., Griffith, B. 2008. Contrasting the capabilities of building energy performance simulation programs. Building and Environment, 43 (4), 661-673.

Goulart, S.V.G. 1993. Climate files to evaluate the building performance in Florianopolis (in Portuguese). Thesis (Master). Federal University of Santa Catarina,Florianópolis.

Melo, A.P., Lamberts, R. 2008. Opaque envelope parameters versus energy consumption in commercial buildings in Brazil. Journal of Building Performance Simulation, v.1, n.4, p 237–244.

NEN 2916, Energy performance of non-residential buildings - Determination method (in Dutch), NNI, Delft (The Netherlands), October 1994.

Pérez-Lombard, L., Ortiz, J., González, R., Maestre, I. R. 2009. A review of benchmarking, rating and labelling concepts within the framework of building energy certification schemes. Energy and Buildings, 41 (3), 272-278.

RCCTE 2006. Regulamento das Características do Comportamento Térmico dos Edifícios (Regulation of the Buildings Thermal Behaviour Characteristics), Ministry of Public Works, Transportation and Communications, Decree-Law nº 80/2006 of April 4.

Judkoff, R., Neymark, J. 1995. International Energy Agency building energy simulation test (BESTEST) and diagnostic method. Report NREL/TP-472-6231, NREL, Golden.

RSECE 2006. Regulamento dos Sistemas Energéticos e de Climatização de Edifícios (Regulation of the Buildings Energetic Systems and Climatization), Ministry of Public Works, Transportation and Communications, Decree-Law nº 79/2006 of April 4.

Santín O. G., Itard, L., Visscher, H. 2009. The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock. Energy and Buildings, 41 (11), 1223-1232.

Sardinou E. 2008. Estimating space heating determinants: An analysis of Greek households. Energy and Buildings, 40 (10), 1084-1093.

Silva, P., Almeida, M., Bragança, L., Mesquita, V. 2009. Methodology to enhance the Portuguese thermal regulation accuracy for existing buildings. In: Proceedings of the Building Simulation 2009, Glasgow, 2106-2113.