Portuguese EPBD Based Regulation put side by side with Energy Simulation Tools

Pedro P. Silva[1*], Sandra Silva[2], Manuela Almeida[2] and Luís Bragança[2]

[1] DST, S.A., Rua de Pitancinhos, apartado 208 – Palmeira, 4711-911 Braga, Portugal

[2] Department of Civil Engineering, University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal

[*] Corresponding Author, psilva@civil.uminho.pt

Abstract

In 2002 EU implemented the Energy Performance of Buildings Directive which led to the revision of the buildings thermal codes. The transposition of EBPD into the Portuguese legislation was made through three regulations: RCCTE for residential buildings, RSECE for office buildings and SCE that establishes the energy labelling system. The national code RCCTE sets two methodologies for assessing the energy performance of buildings: a simplified methodology and a more detailed one, depending if it is an existent or a new building. It has been observed that since the entrance into force of these codes, the project teams are using the RCCTE methodologies as tools to estimate the energy consumption of buildings. In this work it was tested the accuracy of this approach, performing two studies: one where the energy needs obtained with the RCCTE methodology were compared with the ones obtained with a dynamic simulation tool; and another where the same energy needs were compared with the ones obtained with a simplified RCCTE methodology foreseen for existing buildings. With the studies performed it was verified that the RCCTE methodology is accurate enough, except for the coldest regions, where another kind of tool should be applied. The simplified methodology showed inaccurate results and must be used with caution. However, with some corrections, important improvements can be achieved.

1. Introduction

In 1987 the Bruntland Report [1] was published which largely contributed to the worldwide recognition of the excessive energy consumption problematic. Even though, the building sector in the EU is responsible for 33% of raw materials consumption, 40% of final energy consumption, and 50% of electricity use [2, 3]. Only in 2002, an EU directive, EPBD – Energy Performance of Buildings Directive [4] addressing this problematic was effectively implemented, imposing new rules regarding both the EU buildings thermal performance and the harmonization of all thermal regulations in the EU. Portugal carried out the EBPD transposition into national legislation through the entrance into force of a set of three regulations: one for the residential buildings sector – RCCTE [5], another for the office buildings sector – RSECE [6] and a third one regulating the buildings energy certification system – SCE [7]. This set of regulations was issued in 2006, however the entrance into force was settled into three phases: in July 2007 only new large buildings (>1000m^2) had to comply with the regulation; in July 2008 the new requirements were extended to all new buildings; and in January 2009 to all buildings, new and existing ones. Therefore, some lessons might already be learned, like a general improvement in the building design, from a thermal point of view. On the other hand, although it was not an objective of these regulations, it is observed that the project teams currently use the prescribed methodologies to predict the energy consumption of buildings and also to test several design alternatives. Therefore, this paper intends to verify the accuracy of this approach and the need of using additional tools, like dynamic energy simulation tools, to reach reliable results.

2. Estimation Methods

To predict a building thermal behaviour there are two possible approaches: using a steady-state methodology or tool, as RCCTE methodologies (both the more detailed and the simplified one), that have better repeatability, but are not able to capture system complexities; or using dynamic simulation tools, that are more flexible, but more time and effort consuming.

The methodology described in the RCCTE code is a steady-state yearly based calculation methodology and its goal is to estimate the residential buildings heating and cooling needs, and the domestic hot water needs. The heating needs are obtained applying a degree-days method and the envelope heat balance for the heating season. The cooling needs are obtained applying the average difference between the indoor-outdoor temperature and the envelope heat balance during the cooling period.

The RCCTE simplified methodology, targeted to existing buildings, is similar to the more detailed one but has several simplifications in what concerns the achievement of the required input data. This way, it is possible to reduce the time needed to audit an existing building and thus make the certification process simpler, easier and more affordable for the users.

2.1. RCCTE methodology

This regulation defines reference values for the heating and cooling needs (Ni, Nv, respectively, in kWh/m^2.year) in order to limit the specific heating and cooling needs (Nic, Nvc, respectively). Therefore, the Nic and the Nvc calculated values cannot be higher than the Ni and the Nv reference values. The Nic and Nvc values are obtained using the following equations:

$$N_{ic} = \frac{Q_t + Q_v - Q_{gu}}{A_p} \quad (1) \qquad\qquad N_{vc} = \frac{(Q_1 + Q_2 + Q_3 + Q_4)(1 - \eta).}{A_p} \quad (2)$$

With: ***Q_t*** **-** total heat losses through the building envelope in Winter; ***Q_V*** **-** heat losses due to air changes; ***Q_{gu}*** **-** useful heat gains; ***A_p*** – heated floor area (m^2); ***η*** **-** heat gains utilization factor; ***Q_1*** **-** total heat gains through the building envelope in Summer; ***Q_2*** **-** heat gains by solar radiation; ***Q_3*** **-** heat gains by air changes; ***Q_4***- heat gains due to internal heat sources.

The heating specific needs result from a balance between the heat gains and heat losses taking into account the envelope characteristics and the local climate.

The cooling specific needs are a result of the sum of all the heat gains through the envelope, due to ventilation, due to solar radiation and internal heat sources. The conductive heat flow through the building envelope is calculated combining the effect of the temperature difference (indoor-outdoor) and the solar radiation.

In what concerns climate, Portugal is divided in three winter climatic zones (I1, I2, I3) and three summer climatic zones (V1, V2, V3), organized from the less severe (index 1) to the most severe (index 3) climate.

2.2. RCCTE simplified methodology

As previously mentioned, the only differences between the detailed and simplified methodologies are related to the following simplifications in the input data achievement:

- *Geometrical survey*: ignore floor areas associated to recesses and projections with less than 1m; measure the floor area by the external perimeter and then reduce the value in 10% corresponding to the partition walls; ignore exterior doors area if they have less than 25% of glazed surface.
- *Heat loss reduction coefficient (τ)*: in the calculation of heat losses to non heated spaces, consider a fixed value of 0.75 for the τ factor;
- *Thermal bridges and elements in contact with the ground*: if the building constructive solution creates surface thermal bridges, aggravate in 35% the exterior envelope "U-Value"; for linear thermal bridges use a conventional value of ψ = 0.75 W/m.ºC;
- *Mechanical Ventilation*: apply an airflow rate of 100 m^3/h per each WC, with a power consumption of 16W per WC;
- *Shading Facto*r: consider for the shading factors due to overhangs, fins and surroundings, in the heating season, a value of 0.57 if there is no shading, 0.28 for regular shading and 0.17 for intense shading; in the cooling season consider a value of 0.57 if there is no shading, 0.50 for regular shading and 0.45 for intense shading;
- *Thermal Inertia*: instead of a detailed calculation of the thermal mass there are a set of rules to estimate the building inertia (e.g. for strong thermal inertia it is required concrete floor and ceiling slabs, stucco or gypsum finishing, etc.);

With these simplifications, it is possible to obtain the energy needs in less time and with less complexity than with the detailed building audits methodology.

2.3. Dynamic simulation Tool

Computer-based simulation is accepted by many studies as a tool for evaluating the buildings energy consumption [8, 9, 10].

The software applied in this study was eQuest (The Quick Energy Simulation Tool), which is an easy to use building energy analysis tool that combines a building creation wizard, an energy efficiency measure wizard and a graphical results display module with an enhanced DOE-2.2-derived building energy use simulation program [11, 12]. Within eQuest, DOE-2.2 performs an hourly simulation of the building design for a one-year period. It calculates heating or cooling loads for each hour of the year, based on factors such as: walls, windows, glass, people, equipment loads, and ventilation.

This study was performed using the climatic data, the internal heat gains, the hourly airflow rate and the heating and cooling set points (20ºC and 25ºC respectively) as presented in the Portuguese thermal regulation.

To demonstrate the building compliance with the regulation, the national database of hourly annual typical climates for every municipality in Portugal must be used to eliminate any uncertainties derived from the use of different climatic data sets. So these database were also used in the dynamic simulation to be possible to compare the results (even thought this database does not have the wind velocity and direction that can be important in a dynamic simulation).

3. Methodology

Having in mind that RCCTE presents two calculation methodologies, one for new buildings and a simplified one for existing buildings, there were performed two types of studies:

- Study 1 – For new buildings - the RCCTE methodology was applied to a set of selected case studies to estimate the heating and cooling needs, calculated for the four more representative Portuguese climatic regions – Bragança (I3, V2), Faro (I1, V2), Lisboa (I1, V2) and Porto (I2, V1) and the results were compared with the ones obtained with the application of a dynamic simulation tool.
- Study 2 – For existing buildings – The simplified RCCTE methodology was applied to a set of selected case studies to estimate the heating and cooling needs. These case studies were located in Felgueiras (I2, V2); Braga (I2, V2) and Bragança (I3, V2) and the results were compared with the ones obtained with the application of the RCCTE methodology and with the application of a dynamic simulation tool.

The heating and cooling needs were calculated using RCCTE methodology and eQuest, with standard occupancy data, climate and internal gains provided at national level.

3.1. Case Studies

To perform Studies 1 and 2 there were selected three different buildings – a detached, an attached and a multifamily building, with different construction solutions.

Case Study 1 (CS1) is an attached single-family dwelling, which is located in an urban area in Felgueiras (I2, V2). The building, with 2 floors, is a single residential unit and has two bedrooms. The construction system is based on a steel reinforced concrete pillars and beams structure, single pane lightweight concrete masonry units (lightweight CMU) walls with external insulation and clear double glass with aluminium frame windows. The dwelling floor area is Ap = 137.69 m^2, with a floor to ceiling height- Pd = 2.7 m, located at an altitude of 100 m and 50 km away from the coastal line.

Case Study 2 (CS2) is a detached single-family house, located in a rural area in Braga (I2, V2). The building, with one floor, is a single residential unit and has two bedrooms. The construction system is a low cost construction system based on a steel reinforced concrete pillars and beams structure, single pane concrete block walls (CMU) and clear single glass with aluminium frame windows. The dwelling floor area is Ap = 54.42m^2, with a floor to ceiling height - Pd = 2.44 m, located at an altitude of 89 m and 60 km away from the coastal line.

Case Studies 3 and 4 (CS3, CS4) are on a multi-family building, which is located in an urban area of Bragança (I3, V2). The building has five floors, the Case Study 3 is on the first floor, and the Case Study 4 is on the second floor and both have two bedrooms. The construction system is based on a steel reinforced concrete pillars and beams structure, double pane brick masonry walls with insulation on the air gap and clear double glass with aluminium frame windows. The dwelling floor area is Ap = 90.03 and 89.80 m^2, for CS3 and CS4, respectively, with a floor to ceiling height- Pd = 2.5 m, located at an altitude of 650 m and 160 km away from the coastal line.

The case studies floor plans are presented in Figure1.

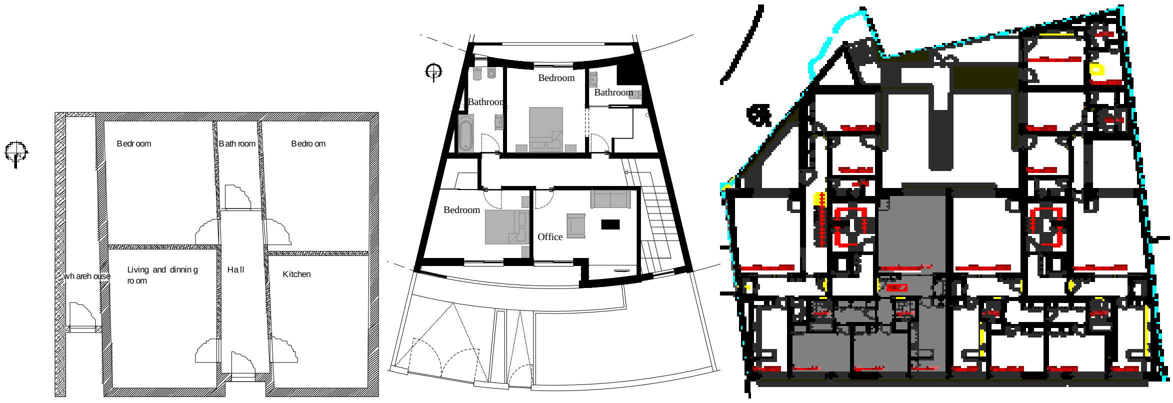

Fig. 1. Floor plans of Case Study 1, 2 and 3

4. Results

4.1. Study 1 - RCCTE methodology versus Dynamic Simulation Tool

The Specific Nominal Heating Needs (Nic) and the Specific Nominal Cooling Needs (Nvc), calculated following the RCCTE methodology, are presented in Figure 2 for the three studied buildings located in the four previously mentioned cities.

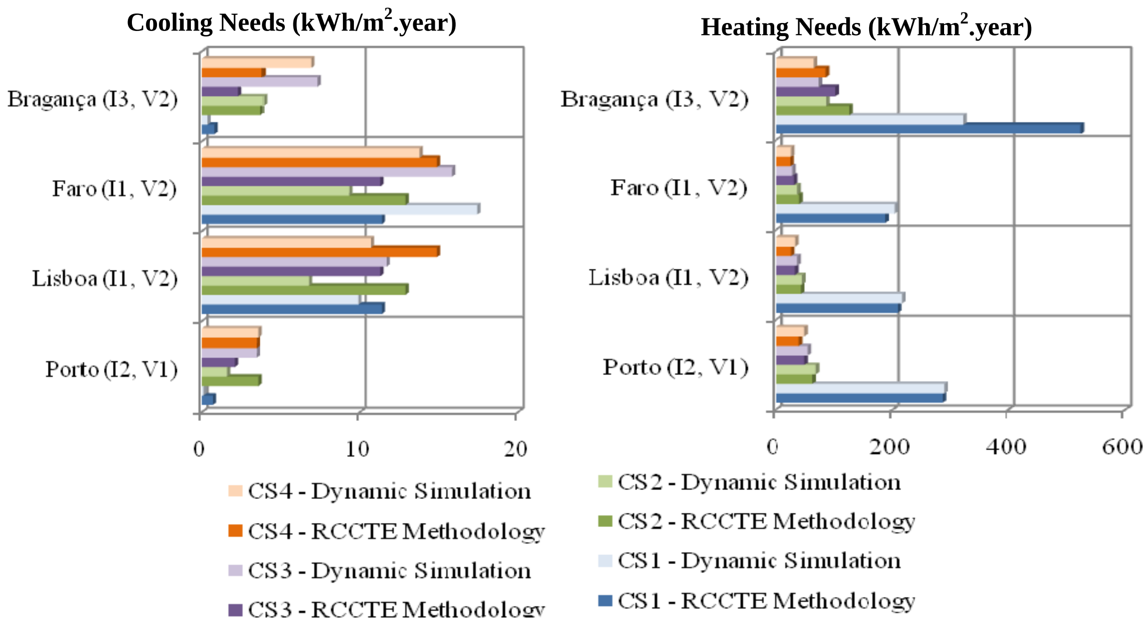

Fig. 2. Energy needs for four climatic zones using dynamic simulation tool,and RCCTE methodology.

The three selected buildings were also evaluated applying the dynamic simulation tool. For that, the building models were created (Figure 3) and calibrated using the RCCTE data:

- Weather data – a climatic file using the information presented in the RCCTE database (from the tool SOLTERM) was generated;

- Internal loads – the occupancy, lighting and equipment loads were obtained based on the RCCTE data.

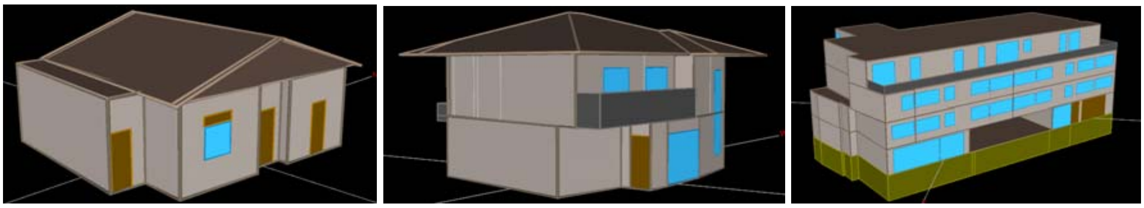

Fig. 3. Simulation model of Case Study 1, 2 and 3

Lisboa and Faro, that belong to the same winter and summer climatic zone, but have different heating periods and heating degree-days, have similar specific nominal heating needs (10% differences) and the same specific nominal cooling needs. The heating needs for the buildings in Bragança, that have more unfavourable winter climatic conditions and longer heating period, are more than 60% higher than the specific nominal heating needs of the same buildings located in Lisboa (Figure 2).

For Porto, Lisboa and Faro the differences in the heating needs obtained with both methods are less than 10%, but for Bragança the differences reach 38% for the detached building, that is non insulated, 31% for the attached building and about 26% and 29% for the multifamily dwellings.

The relative differences in the cooling needs are higher for the detached building in Porto, due to the higher heat exchanges, as this building is non-insulated, has a higher shape factor and is naturally ventilated.

The heating needs for Bragança using the RCCTE methodology are always significantly higher than the ones predicted using the dynamic simulation tool, even though the climatic file used in the dynamic simulation is based on the climatic data used in RCCTE.

4.2. Study 2 - Simplified and Detailed RCCTE methodologies versus Dynamic simulation tool

The heating, cooling and total needs calculated following the simplified and the more detailed RCCTE methodologies and the dynamic simulation tool are presented in Figure 4, for the following locations: CS1 – Felgueiras, CS2 – Braga, CS3 and CS4 – Bragança.

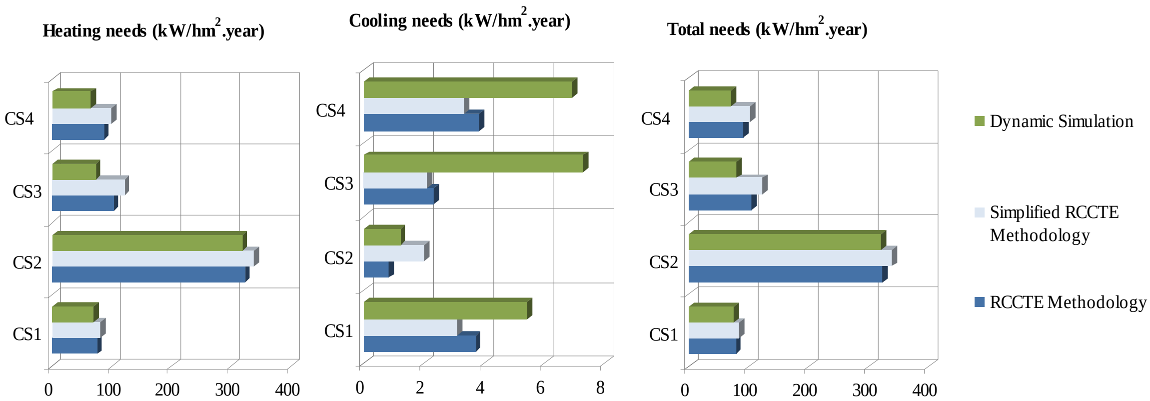

Fig. 4. Energy needs in four climatic zones using dynamic simulation tool, RCCTE more detailed and simplified methodologies.

The total energy needs of the simplified RCCTE methodology are, in average, 9% higher, than the detailed methodology and 20% higher than the dynamic simulation. Therefore, taking into account the differences found, a parametric study was performed in order to evaluate which parameter has the highest impact on the results obtained with the three methods. It was concluded that the heat losses reduction coefficient (τ) is the factor with higher impact. Therefore, the admitted simplification in the simplified methodology introduces a significant error that could be reduced if a more realistic value of τ is used. Figure 5 shows the results considering variable τ values in the simplified RCCTE methodology. It is possible to see that now, the results obtained with the two RCCTE methodologies are closer.

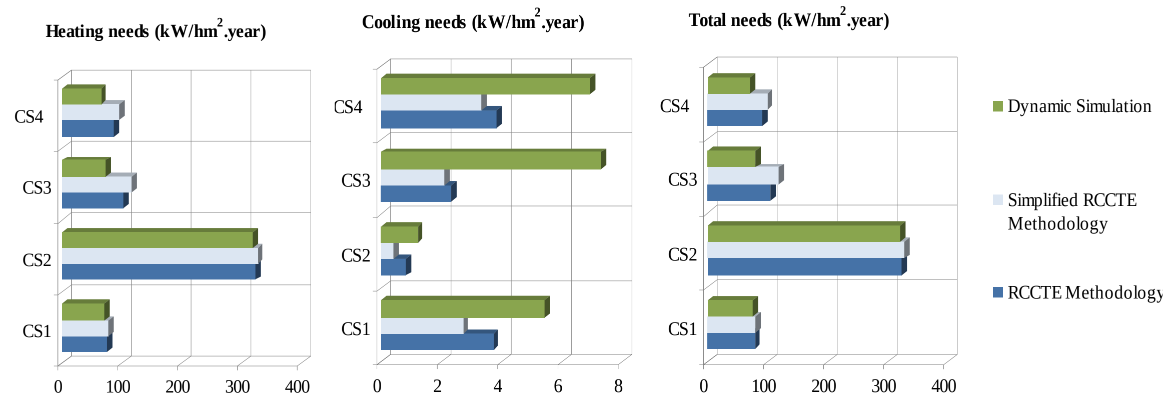

Fig. 5. Energy needs in four climatic zones using dynamic simulation tool, RCCTE more detailed and simplified methodologies.

The total energy needs of the simplified RCCTE methodology, without the simplification of the losses reduction coefficient, are, in average, 5% higher, than the detailed methodology and 17% higher than the dynamic simulation. However, since the simplified methodology always overestimates the energy needs, it should be used with caution.

5. Conclusion

As the RCCTE methodology is a steady-state method, it was expected to find differences between the results obtained with the RCCTE methodology and the dynamic simulation methodology.

The RCCTE calculation methodology presents good results for the I1 and I2 Portuguese climatic zones, since the differences in the heating and cooling needs obtained using the RCCTE methodology and the dynamic simulation are small. This method just appears to have a higher difficulty in estimating accurately the heating needs for buildings in the Portuguese I3 winter climatic zone (more severe), especially for buildings with less or no insulation.

The small differences detected between the RCCTE methodology and the dynamic simulation methodology, in terms of heating needs, for I1 and I2 climatic zones is a good indication, as these climatic zones cover most part of Portugal and the heating needs are the most important in Portugal.

This study shows that the RCCTE detailed methodology is an accurate tool to compare the thermal behaviour of buildings. Thus, the building certification will allow a realistic comparison between the certified building stocks in different climatic regions of the country.

This study also has shown that the simplified RCCTE methodology produces acceptable results, when compared with the more detailed RCCTE methodology, and it is possible to achieve even better results if more realistic values of the heat losses reduction coefficient (τ) are used.

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