A Parallel between the Brazilian Energy Labelling System and the Passivhaus Standard for Housing

TUBELO, R. C. S.[1], RODRIGUES, L.[2], GILLOTT, M.[3]

[1, 2, 3] The University of Nottingham, Nottingham, United Kingdom

ABSTRACT: Energy consumption in the building sector has increased, and continues to increase, in both developed and developing countries. The housing sector alone is responsible for more than two thirds of the energy consumed by buildings. As a consequence, energy policies have largely been adopted to improve energy efficiency in new and existing dwellings.

By 2022, about 24 million new residential buildings will be built in Brazil through Brazilian social housing programs, which could greatly impact on the country's energy consumption. In an attempt to minimise the negative impact of this, the National Program of Energy Efficiency in Buildings (PROCEL Edifica) launched in 2010 the Brazilian Labelling Schemes for Residential Buildings (RTQ-R), which is a voluntary standard for evaluating energy efficiency in housing. The RTQ-R label is based on simplified calculations that produce an energy efficiency rating between A (more efficient) and E (less efficient). The Passivhaus standard, developed in Germany, is the fastest growing energy performance standard in the world with more than 30.000 buildings certified to date. It is based on a fabric first approach and established indoor comfort criteria with minimum energy consumption. Despite its success, the Passivhaus standard has not been implemented in Brazil.

In this paper, the authors use a correlation between the RTQ-R label and the Passivhaus standard as means to investigate the applicability of the German standard in the tropical country. Benefits and barriers of implementing the Passivhaus standard in Brazil are identified and discussed.

Keywords: Energy efficiency; Housing; Brazilian Labelling; Passivhaus standard.

INTRODUCTION

Growing importance is being given to the energy consumed by the housing sector due to its ever-increasing demand. It is estimated that the housing sector is responsible for more than two thirds of the energy consumed by buildings [10]. In Brazil, for example, the housing sector is responsible for 9.5% of national energy consumption [6] but, including energy consumed from the primary energy sector, this value reaches 22% of the energy consumed nationally [16].

In parallel, the current Brazilian social housing program entitled 'My life, my house' has increased and intends to raise offers of new housing for the next few years. It is predicted that, by 2022, up to 24 million new dwellings will have been built [7]. This target has dramatically altered the scenario of Brazilian housing and it may result in a significantly negative impact in Brazilian energy consumption.

In order to help mitigate the problem, the National Program of Energy Efficiency in Buildings (PROCEL Edifica) launched in 2010 the Brazilian Labelling Schemes for Commercial, Public and Services Buildings (RTQ-C) and the Brazilian Labelling Schemes for Residential Buildings (RTQ-R). The labels aim to implement energy conservation measures in new or existing buildings [18].

The RTQ-R label involves a method to evaluate the level of energy efficiency of housing units, multifamily residential buildings and common areas of multifamily buildings[1], which varies from A to E, for the building envelope and the hot water system [12]. The RTQ-R label uses a prescriptive method to evaluate the level of energy efficiency of naturally ventilated building envelopes and a simulation method to evaluate both naturally and conditionally ventilated building envelopes. The RTQ-R label determines the use of thermo-physical requirements such as the U-value, the thermal capacity, the solar absorptance and the envelope ventilation index. These values are based on the Brazilian bioclimatic zones[2] [2] and the Brazilian performance standard NBR 15575 [3, 4].

Although the RTQ-R label is meritorious for encouraging an improvement of the thermal performance of the building envelopes in Brazil, there is a worldwide tendency of aiming for higher levels of performance. The current energy efficiency agenda has focused its attention on designing and constructing housing that are more insulated and airtight [21]. In the United Kingdom, for example, there is a U-value maximum limit since 1965, and it has become more stringent over the years, reaching nowadays a value of $0.3W/m^2K$ for the walls and $0.2W/m^2K$ for the roofs and 0.25W/m2K for the floors [1, 20]. Revised values have been proposed by the consultation of Building

[1] Common areas of multifamily buildings also include a method to evaluate lighting system and pieces of equipment found in those areas.

[2] Brazilian bioclimatic zones range from ZB1 to ZB8, where ZB1 is the coldest zone and ZB8 is the hottest zone.

Regulation Part L 2012/13 [1]. The current maximum airtightness in the UK is $10m^3/hr/m^2$ at 50 Pa [8].

In Germany, the Passivhaus standard has become a successful strategy and it has been largely adopted in many other European countries. The Passivhaus standard applies robust criteria for the building envelope and the energy consumption. The Passivhaus standard suggests a highly insulated envelope with the adoption of U-value smaller than 0.15 W/m^2 and an envelope airtightness of no more than 0.6 air changes per hour (h^{-1}) at 50 Pa [8, 14].

The Passivhaus standard was originally designed for central Europe, but many studies have been developed to support the application of the Passivhaus standard in warmer climates. These studies have made advances by adjusting the Passivhaus standard for warmer climates and have identified the benefits of the Passivhaus Standard adoption for the building envelope thermal performance. The Passive-on [15], for example, investigated the Passivhaus standard adjustment for warmer climates in Europe. Another recent study carried out by Schnieders et al [19] provides an overview of the applicability of the Passivhaus standard for specific climates and also establishes preliminary criteria for the Passivhaus in different climates zones. In South America, initial studies have investigated the applicability of Passivhaus in Chile [11]. The remarkable difference between the original Passivhaus standard and the Passivhaus standard for warmer climates is the existence and the management of the summer season [15].

Despite these studies, there is little information of the applicability of the Passivhaus for the Brazilian climate. In this present study, the authors aim to provide an advance in this area and also correlate the current RTQ-R label with the Passivhaus standard.

COMPARING THE STANDARDS

Even though it is difficult to make comparisons amongst standards that do not measure the same parameters or do not have the same aim, it is feasible to extend the concepts from one standard to another one [8]. For instance, the RTQ-R label evaluates the housing energy efficiency level and it focuses on energy conservation measures [18] rather than on indoor thermal comfort. The Passivhaus standard, on the other hand, assesses energy consumption and its focus on comfort and energy used during the use phase of the building because the use phase is responsible for the major energy consumption impact.

Another important characteristic to take into account while evaluating national energy standards is the nature of the energy demand in those areas covered by the standard. For instance, the nature of Brazilian energy demand is different from that the Passivhaus Standard was originally designed. The Passivhaus was conceived to achieve ultra-low energy consumption for space conditioning through a high performance envelope (tight and insulated) and mechanical ventilation system with heat recovery. An effective ventilation system is essential for central Europe because the main demand in those countries is for heating. The Passivhaus ventilation system effectively minimizes the energy demand for space heating; and can reduce the heating demand so much that a conventional heating system may not be needed [8].

On the other hand, the RTQ-R label basically aims for improvements in the building envelope and in the water heating system. Improvements in the water heating systems are fundamental, since the Brazilian water heating for showers is mostly provided by electrical means. It is estimated that 73% of dwellings use electricity to heat water compared to only 5.9% of them that use gas and 18% of the dwellings do not present a water heating system [9]. This situation represents a huge impact on electricity demand, which impacts around 24% of total appliances electricity consumption.

The other aim of the RTQ-R label is improvements in building envelope, which expects to minimize the Brazilian heating and cooling demand. The national heating and cooling supply is basically provided by electrical means through the use of conditioning appliances, which results, on average, in 20% of overall appliances electricity consumption. In the north of Brazil, cooling appliances are responsible for 40% of the appliances total electricity consumption; in the south of Brazil, cooling and heating appliances combined are responsible for 32% of the appliances total electricity consumption [9].

A PARALLEL BETWEEN THE RTQ-R LABEL AND THE PASSIVHAUS STANDARD

A recent study developed by Schnieders et al [19], which analysed the Passivhaus standard for other climates, provided a set of indicators to use the Passivhaus across the world through the use of specific maps. These maps were elaborated from NASA data with average daily values of temperature, insolation and humidity over 23 years with a spatial grid resolution of one degree [19]. The findings do not exclude the simulation needs for each location, but they can orientate strategies to achieve the Passivhaus standard. These findings will be used here for establishing a parallel between the RTQ-R label and the Passivhaus standard.

Primary energy demand

The Passivhaus standard presents a mandatory requirement for the primary energy demand that must not exceed 120 kWh/m^2a. Efficient household appliances and water heating systems are required to achieve this target [8], otherwise it is difficult to fulfil this requirement.

The RTQ-R label does not establish a similar target or comparative parameters but strongly discourages the use of water heating system by electrical means. The use of this system for shower, for example, results in D or E system efficiency level. Furthermore, the RTQ-R label encourages the use of solar system and recommends that at least 70% of the total of water heating system comes from the solar source.

According to [19], the Passivhaus primary energy target demand can be achieved all over the world, although it might need a significant investment of money and time; and efficient household appliances may be required for hot climates as well. Moreover, analyzing the Brazilian map, as can be seen in Figure 1, it is feasible to fulfil the Passivhaus primary energy demand requirement, although in the Brazilian north region these target can only be achieved with some major efforts.

Space heating/cooling demand and heating/cooling load

The Passivhaus standard has a mandatory requirement for the space heating or cooling demand and for heating or cooling load. These mandatory requirements are that the space heating or cooling demand must not exceed 15 kWh/m²a or the heating/cooling load has to be less than 10W/m² over the day [14]. These suggested values have been continually investigated by the Passivhaus Institute to adapt the Passivhaus standard for other climates and higher values have been accepted for cooling demand when the cooling load is satisfied and vice versa; more precise relation can be found in [14].

Analysing the Brazilian energy demand, except for several regions in the south and southeast, which present a temperate climate with a defined winter and summer seasons and thus, the existence of heating and cooling demand, the vast majority of Brazilian regions have exclusively energy demand for cooling. The demand for cooling would seem to be easier to manage because the strategies are strictly related to cooling demand, but can be more complex in climates that present long periods of extreme high temperature and high levels of humidity as found in the north part of Brazil (Figure 2). In this climates, although can be possible to achieve low value of sensible cooling load, it becomes difficult to settle an acceptable level of sensible cooling demand due to the extensive and intensive hot period.

Figure 2 indicates the sensible cooling demand in Brazil. Some Brazilian regions, from the middle to the north, could face difficulties achieving an acceptable value of cooling demand that could justify a cost-effective implementation of the Passivhaus standard. According to Schnieders et al [19] a cooling demand above 45 kWh/m^{2}a makes impossible to achieve the Passivhaus standard in a cost-effective way.

Furthermore, in some locations there is also the existence of latent cooling demand, in other words, dehumidification can be required to provide thermal comfort. According to Figure 3**, t**he highest levels of dehumidification demand are located in the north region of Brazil, especially on the coast and in the amazon region. A high need for the useful cooling demand and the dehumidification demand, as pointed out by Schnieders et al [19] seems to restrain a cost-effective implementation of the Passivhaus standard in hot and humid regions, although more research needs to be developed in these areas.

The RTQ-R label does not use this methodology of cooling/heating demand or cooling/heating load. On the other hand, the standard uses the methodology of degrees-hour and the methodology of relative consume for heating and cooling to estimate the energy consumed by buildings. The values obtained from those methodologies are compared with reference values of energy efficiency according to each bioclimatic zone.

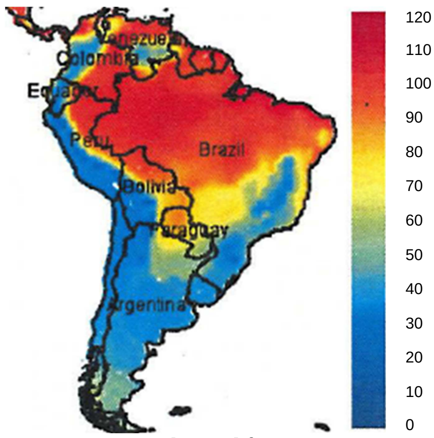

Figure 1: Primary energy demand for cost-optimized buildings in kWh/m^{2}a. Source: Schnieders et al, 2012.

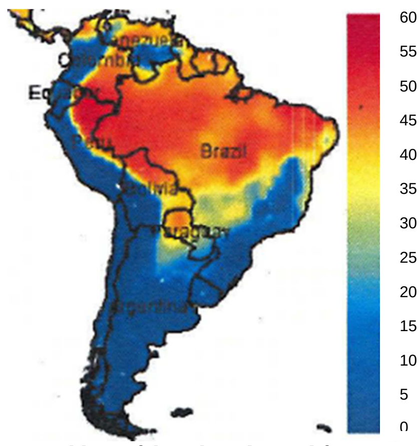

Figure 2: Sensible useful cooling demand for cost-optimized building kWh/m^{2}a. Source: Schnieders et al, 2012.

Insulation – glazing areas and opaque elements

The level of insulation to be adopted to achieve the Passivhaus standard comfort requirements strongly depends on the climate where the building is located. The Passivhaus standard for central Europe recommends a U-value ≤ 0.15 W/m^2 for the opaque elements and a U-value ≤ 0.80 W/m^2 for windows [14]. The opaque elements and the glazing surfaces should have a compatible level of resistance to avoid the solar radiation heat to enter the building during the cooling season and to allow the solar radiation heat to enter the building during the heating season.

For the Brazilian climate, the Passivhaus study [19] seems to suggest the use of two main types of glazing. For the green part on the map (Figure 4), it is suggested the use of a low-e double glazing with sun protection (U= 1.05 W/m^{2}K) whereas for the yellow part, it is recommended the use of a low-e triple glazing with sun protection as well (U= 0.6 W/m^{2}K). For both double and triple glazing, it is needed a solar protective glazing to reduce transmission and solar loads into the building [19]. In addition, it can be noticed that less strict requirements are adopted in the Brazilian middle-south part due to the mild nature of the climate.

Figure 5 shows the optimal U-value for the exterior opaque building components for the Brazilian regions. The north region presents the highest needed for low U-values (about 0.10-0.15 W/m^{2}K), in other words, requires a more insulated envelope due to the high temperatures that are found in those areas. The south and southeast regions, on the other hand, seem to be easier managed with higher U-values, between 0.3 W/m^{2}K and 0.4 W/m^{2}K.

Comparing these Passivhaus U-values requirements with those proposed by the RTQ-R label, it is possible to identify a significant difference (Table 1). The values adopted by the RTQ-R label are more permissive than those suggested by the Passivhaus study [19]. The RTQ-R label wall U-value requirement for the Brazilian bioclimatic zones ZB7 and ZB8, which correspond to those yellow areas found in Figure 4 (north region), is 2.5 W/m^{2}K for absorptances equal to or less than 0.6 and 3.7 W/m^{2}K for absorptances more than 0.6. For the roof, the values adopted by the RTQ-R label continues to be very permissive, with a U-value of 2.3 W/m^{2}K for absorptances equal to or less than 0.4 and a U-value of 1.5 W/m^{2}K for absorptances more than 0.4 (Table 1).

The use of reflective opaque elements (with low absorption coefficient) in hot regions is highly recommended by both the Passivhaus standards and the RTQ-R label since it reduces the absorption of radiant heat by the surfaces of the building envelope.

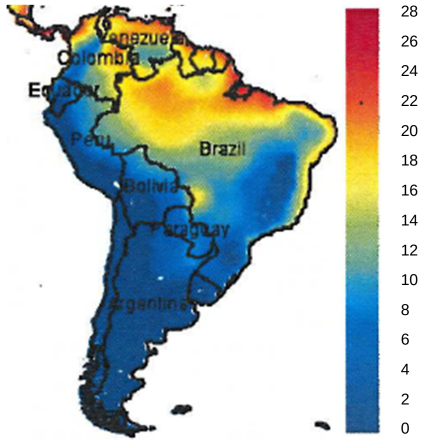

Figure 3: Dehumidification demand for cost-optimized building kWh/m^{2}a. Source: Schnieders et al, 2012.

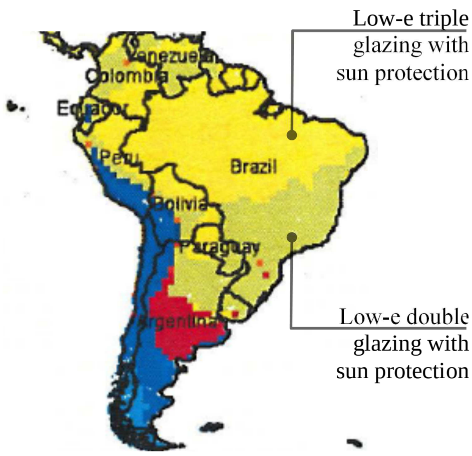

Figure 4: cost-optimal glazing with consideration of heating and cooling. Source: based on Schnieders et al, 2012.

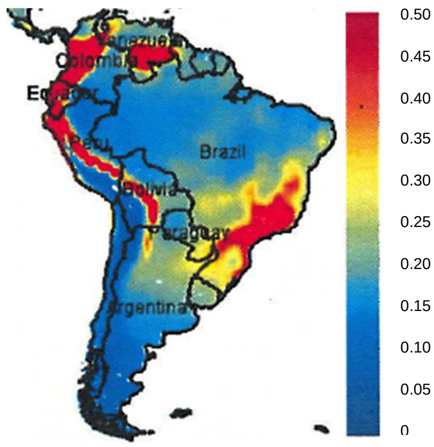

Figure 5: Optimal U-value in terms of cost for exterior building components for heating and cooling. Source: Schnieders et al, 2012.

Airtightness and ventilation

The Passivhaus standard adopts a mechanical ventilation system with heat recovery. In this system the incoming air is preheated by the extracted air through the heat exchanger without mixing both the incoming and the extracted air [8].

For an efficient operation of this system, a very airtight building envelope is required; better performance of the Passivhaus ventilation system occurs with airtightness between 0.3 and 0.4 h^{-1} at 50 Pa [8]. The Passivhaus airtightness envelope must not exceed 0.6 h^{-1} at 50 Pa. This requirement preserves the building envelope durability by avoiding the entry of humidity into the building; the lack of airtightness results in higher heat loss by the envelope [8].

In the Passivhaus standard, although the windows can be opened, they do not need to be opened for ventilation (although natural ventilation may be used when adequate). The main purpose here is to achieve a better building energy balance through the glazing areas of the windows. For instance, the Passivhaus suggests the adoption of 20% of floor area for south-oriented glazing and 5% of floor area for north-oriented glazing (north hemisphere) [15]. This recommendation allows maximising solar heat gain through the south glazing and minimizing heat loss through the north glazing. This requirement has a strong effect of reducing heating load and heating demand during the winter period.

Whilst windows are not necessarily used for ventilation in the Passivhaus standard, the RTQ-R label recommends their use. The RTQ-R label recommends opening areas for ventilation which ranges from 5% to 10% of floor area, varying with the Brazilian bioclimatic zone where the building is located [12]. In Brazil, there is an extensive use of natural ventilation and the main purpose of the windows is for ventilation. The glazing areas are recommended predominantly by the municipalities' standards (building codes) for natural lighting purpose and the opening areas is regulated by the building codes and national standards for ventilation purpose. Furthermore, in Brazil, mechanical ventilation systems are not commonly used in dwellings and there are no airtightness requirements [13].

Simulation software and comfort criterion

The simulation software used by the Passivhaus standard differs from that adopted by the RTQ-R label. The Passivhaus standard requires the use of the Passive House Planning Package (PHPP), which is an excel-based planning tool, whereas the RTQ-R label does not stipulate any specific building simulation software. The RTQ-R label requires the software fulfils the requisites of the ASHARE Standard 140 [5] and a computational building simulation should be conducted for both naturally and conditionally ventilated building envelopes [12]. The Passivhaus standard operative temperature is assumed to be 20ºC for cold climates and, for warmer climates, 25ºC [14] and 26 ºC with 60% of humidity [19]. The RTQ-R label adopts similar comfort criteria with a maximum threshold of 26 ºC [12].

Table 1 provides a summary of the requirements proposed by the Passivhaus standard and the RTQ-R label.

Table 1: summary of the requirement proposed by the Passivhaus standard and the RTQ-R label

	Passivhaus Standard	RTQ-R label
Nature of standard	Indoor comfort with minimum energy input	Energy saving
Primary energy demand	≤ 120 kWh/m².a	there is no requirements
Heating or Cooling demand	≤ 15 kWh/m².a	there is no requirements
Heating or Cooling load	≤ 10W/m²	there is no requirements
Airtightness	≤ 0.6 h^{-1} at 50 Pa	there is no requirements
U-value wall	≤ 0.15 W/m^2K	≤ 2.5 W/m^2K for ZB1-ZB2; ≤ 3.7 W/m^2K when absorptance (α) ≤ 0.6 or ≤ 2.5 W/m^2K when α > 0.6 for ZB3-ZB8
U-value roof	≤ 0.15 W/m^2K	≤ 2.3 W/m^2K for ZB1-ZB2; ≤ 2.3 W/m^2K when α ≤ 0.6 or ≤ 1.5 W/m^2K when > 0.6 for ZB3-ZB6; and ≤ 2.3 W/m^2K when α ≤ 0.4 or ≤ 1.5 W/m^2K when > 0.4 for ZB7-ZB8
Ventilation system	Mechanical ventilation system with heat recovery	Natural ventilation
Windows	Glazing area: 20% of floor area south-oriented and 5% of floor north-oriented for energy balance	Opening area: ≥5% of floor area for ZB7, ≥ 8% of floor area for ZB1-ZB6 and ≥10% of floor area for ZB8
Method of analysis	Energy balance method	Simulation or prescriptive method
Software	Passivhaus Planning Package (PHPP);	It has to meet ASHARE Standard 140 (2007)
Comfort temperature	20°C for winter 25°C for summer 26°C + 60% RH for summer	26°C for summer

BARRIERS TO THE IMPLEMENTATION OF ENERGY EFFICIENCY MEASURES IN BRAZILIAN BUILDINGS

The major barriers to the implementation of energy efficiency measures in Brazilian buildings are related to the lack of skilled labour to design and to execute energy efficient buildings. This current situation seems to create a barrier for the adoption of a compulsory labelling because there are not enough professionals who can certify the buildings.

Additionally, energy efficient homes do not yet mean an added value. Rodrigues et al [17] suggests that people may not be willing to pay a higher rent to live in an energy efficient home or invest more money to build an energy efficient house. Energy efficient homes are usually associated with a higher initial economic investment that is necessary to implement all the energy saving measures.

DISCUSSION

A Parallel between the Brazilian Energy Labelling System for residential buildings (RTQ-R) and the Passivhaus Standard was established in this paper. The variation between the standards was explored, regarding their aims, criteria, evaluating method and simulation software. It was identified, for example, that the RTQ-R label focuses on energy saving whereas the Passivhaus standard targets at smaller energy consumption and higher indoor thermal comfort. Another important observation was the different use of ventilation and, consequently, the differences of airtightness requirements suggested by each standard.

Barriers to the implementation of energy efficiency measures in Brazilian buildings were pointed out, which are linked with lack of skilled labour, resulting in difficult to implement a compulsory labelling.

A reduction in building energy demand and consequent improvement in energy efficiency is essential in order to ensure a sustainable future. Given the Brazilian ambitious targets for housing construction in the next decade, this is of primary importance. The findings of this research suggest that the Brazilian RTQ-R label could be reviewed to move towards the adoption of more insulated and airtight envelopes, particularly if any forms of active or hybrid space conditioning systems are used. Further research is needed to evaluate in depth the applicability of the Passivhaus standard for the Brazilian context.

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