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The glazing area in residential buildings in temperate climate: The thermal-energetic performance of housing units in Lisbon

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ABSTRACT

This work aims to provide information related to issues of comfort and energy consumption, with emphasis on fractions of residential buildings with different transparent areas located in temperate climate, especially those that have more than 60% of the façade in glazing (window-to-wall ratio).

The study was developed in different phases, based on geometric models verified through experimental and numerical studies, which are capable of representing the main typologies found in the Portuguese building stock.

These models were used allowing the development of a solutions Matrix (current solutions mapping in performance verification process using the software *EnergyPlus*) and parametric studies, resulting on an information set (descriptive and visual) of interest available to the professional Architect; which allows to verify, identify and quantify the different effects and influences on the thermal behavior of units with such characteristics (large transparent areas), with overall results that may differ up to 75% only when changing a single parameter in units with large glazing areas.

Through the results is possible to observe an array of options and solutions (20%–80% of facade in glazing, including those of large proportion) under the reference conditions considered. Thus, the reader can easily obtain enough information to make required and desired decisions in the initial phases of the project.

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1. Introduction

Buildings are an important economic sector in Portugal, they represent close to 30% of the final energy consumption of the country and are responsible for almost 55% of the electricity consumption (17% residential and 36% services Fig. 1a); placing this sector in second place for greenhouse gases emissions. It is also important to consider that Portugal produces only a small fraction of the energy it consumes (about 20%, Fig. 1b) while the trends show an increase in the annual average consumption tied to an increase in the search for better comfort and building quality. More specifically in relation to the residential sector, it is worth highlighting that thermal comfort (heating and cooling) consumption represents almost one quarter (22%) of the total energy consumption of residential units [1].

Meanwhile, in the last decades Portugal was compelled to take action to limit the production of greenhouse gases; being emphasized the Decrees-Law 79–80/2006 [2,3] that established the residential buildings and services energy regulations (of 2006) that aimed to meet tighter building requirements for European Union countries and led, on average, to an increase of 25% in requirements in relation to previous levels, regulated by Directive n.° 2002/91/CE [4] (see Fig. 1c).

Both thermal regulations were revised in 2013, in line with Directive n.° 2010/31/EU [7], as can be observed in the new certification Decree-Law n.° 118/2013 [8] and in respective ordinances. These documents establish that the Portuguese building stock should progressively move towards almost zero energy needs, by applying a methodology where buildings are evaluated and subject to envelope thermal quality requisites, expressed in thermal transmission coefficient terms (U-values) and glazing solar factors. In

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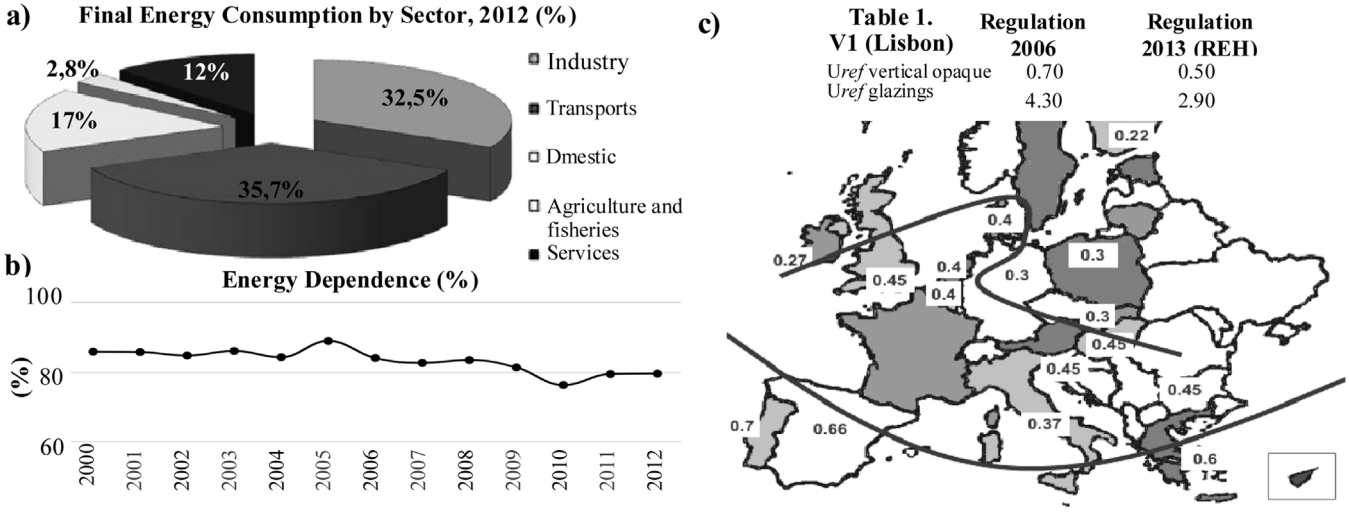

Fig. 1. (a) Chart Final Energy Consumption by Sector in Portugal [5]; (b) Chart of Energy Dependence in Portugal [5]; (c) Map with indicative U-values (W/m^2 ◦C) [6] of the vertical opaque envelope after Diretive n.◦ 2002/91/CE.

the residential buildings case, the established reference U value for vertical opaque envelopes is now between 0.30–0.5 and for glazing between 2.2–2.90. The corresponding values for Climate Zone V1, which includes Lisbon, can be seen in Table 1 of Fig. 1c.

The gradual tightening of building quality regulatory requirements (opaque and transparent elements) has been taking place at the same time as an increase in the interest in and application of glass in the Portuguese building stock, mainly in the big cities such Lisbon (Fig. 2). Over the past few years there have been advances in the development of glass material production, as well as the dematerialization of the façades and the dilution between the walls and windows of the building. Hence, this has become a constituent part of the envelope in residential buildings in Lisbon, especially those built in the last two decades (from 2000, see Fig. 2b), so as to present glazed façades or even the building itself almost glassy. Thus, it is possible to notice a change in the residential buildings on their façades and proportions of glazing areas.

In this context it is important to consider that: the major heat exchange in a building can occur through the transparent elements (due to the radiation directly transmitted into the interior); these corresponds to the building envelope element that has the greatest degree of flexibility and adaptation to climate changes as they provide increased control of the radiation, ventilation and natural lighting; and they are essential to successful application of the majority of the passive solar heating systems (when they have a correct solar orientation), with broad application in the Lisbon climate. In other words, this is the most dynamic, flexible, and interesting building envelope element that allows adjustments to obtain the desired interior conditions (more flexible and interesting element of the building envelope).

Thus, large glazing areas in residential buildings are architectural solutions and options that allow a more uniform exterior aesthetic reading, landscape contemplation, greater transparency and luminosity; but that in the meantime has a direct influence on the inner temperature conditions, and may provide a satisfactory thermal and energetic performance or not (depending on how they are designed). The larger the dimensions of a given glazing area belonging to a housing unit, the greater the potential for this gain or lose heat, due to the overall heat transfer coefficient (U-value) of the glazing being greater than the opaque envelope.

However, the thermal behavior of a building also depends on factors such as control systems and solar devices along the glazing, the thermal inertia, the thermal insulation level of the building, and the air exchange rates. So to evaluate interior conditions in residential buildings (even with large glazing areas) it is necessary to develop an assessment of different case studies in order to relate these variables, which also constitute the different elements of a Passive Solar System.

2. Objective

The main issue that arises in this study is: whether it is in fact possible to obtain, and which, solutions presenting internal conditions within certain indoor air temperature limits that simultaneously lead to lower energy expenditure; especially in residential buildings that have more than 60% of the main façade glazed.

It is also part of the objectives of this study:

- To observe a set of constructive solutions that represents a broad universe of solutions present in the building stock, with the non-opaque envelope as the main element. Thus, checking possible limits and constraints that may exist within the situations mapping, always respecting the architectural design freedom of the Architect.
- To investigate the influence of different parameters (type of glazing, solar shading devices, ventilation, thermal insulation, thermal mass) in solutions with special presence of glazing of large proportions.

Thus, concerned about the quality of buildings and the interior comfort conditions, the study aims to provide guidelines; which enable to consult, observe and compare different options/solutions under the conditions of Summer and Winter (and in an integrated manner on an annual basis) for a typically Mediterranean climate with well defined seasons as that present in Portuguese territory, resorting to Lisbon for application of the proposed methodology.

3. Methodology

This study presents a method based on a numerical component in view of experimental studies previously developed by *Tavares* [10], which focused on residential buildings in Lisbon with large areas of glazing built after the first thermal regulation in Portugal

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