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Energy Rehabilitation of Portuguese Residential Building Stock Through its Transformation into NZEB

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ABSTRACT: The first global oil crisis, led the European Union to start the necessary procedures in order to control and reduce the energy consumption of buildings. In Europe the energy consumption of residential buildings increased since 1990 until 2003 1.3% per year and it is expected that, by 2050, the energy consumption of buildings will have increased by 40%.

According to the EPBD-recast all member states should adopt the necessary measures so that buildings become highly efficient - nearly Zero Energy Buildings (nZEB's). Nevertheless, quantitative standards are not appointed, so each member state should establish the minimum requirements for energy performance in buildings attending to the local conditions. However before establishing these requirements it is necessary to evaluate the building stock and its energy efficiency.

As most of the Portuguese residential buildings are old and degraded an opportunity arises for the energy rehabilitation of the building stock, implementing EPBD-recast principles, making it more energy efficient and comfortable.

The aim of this study was to describe the current conditions of the building stock in order to identify whether there are suitable conditions for energy rehabilitation of buildings. The analysis performed showed that although there are a significant potential for building energy rehabilitation, there are also some constraints, namely the lack of credit and loans financing of banks.

1 INTRODUCTION

The first global oil crisis, in 1973, raised the first concerns over the excessive energy consumption in buildings.

The Directive 2002/91/CE (EPBD - Energy Performance of Buildings Directive) (EPBD 2002) was the first European regulation on the energy performance of buildings. The EPBD defined the procedures in order to establish the requirements for energy performance in buildings to be followed by the member states. In May 2010, came into force the EU Directive 2010/31/EU (EPBD-recast), which targets are to reduce the greenhouse gas emissions in 20% by 2020 and in 80% until 2050, in relation to the 1990 emissions levels, in order to achieve the goals outlined in the Kyoto Protocol (EPBD 2010).

The concept of nearly Zero Energy Building (nZEB) arises not only at European level but in a global context due to the significant impacts of the buildings on the energy consumption and on the environment worldwide. For example, in the United States of America (USA) commercial and residential buildings consume almost 40% of the primary energy and about 70% of all the electricity produced, and it is expected that the consumption of this sector increase by 2025 more than 50% (Tortellini 2006).

In Europe it is estimated that 40% of total energy consumption within the European Union is consumed in buildings. Therefore the buildings are responsible for a significant amount of

greenhouse gas (GHG) emissions. According to several forecasts the GHG emissions will continue to increase until the year 2050 (EPBD 2010).

To accomplish the EPBD recommendations, the Portuguese government defined as targets to increase in 40% the energy efficiency of buildings through the National Action Plan for Energy Efficiency (*Resolution of the Ministers Council of n.º 80/2006*), the review of the Thermal Regulations, for residential (RCCTE, *Decree-Law n.º 80/2006, 4 th April*) and office buildings (RSECE, *Decree-Law nº 79/2006, 4 th April*), and through the introduction of the National System for Energy and Indoor Air Quality Certification of Buildings (SCE, *Decree-Law nº 78/2006, 4th April*) (PORTUGAL & RCCTE & RSECE & SCE, 2006).

Nowadays all residential or small office buildings undergoing major refurbishments or changes in its envelope are required to accomplish the requirements defined in the RCCTE (RCCTE 2006). The implementation of these measures is intended to reduce the energy consumption levels through more accurate calculations. The 2006 version of RCCTE (RCCTE 2006) set greater requirements for the thermal quality of buildings which has resulted in the improvement of the thermal comfort of residential buildings.

2 OVERVIEW OF THE CURRENT SITUATION OF THE BUILDING STOCK

2.1 *Residential Buildings*

For decades there was an almost absence of interventions and investments in the rehabilitation of the Portuguese building stock, particularly when compared with similar European countries (IHRU 2004). This is the main reason for the current poor state of repair of a significant part of the Portuguese buildings that, in average, were, in 2001, 33.92 years old (INE 2001). In average the most recent buildings in Portugal were located in Autonomous Region of Madeira with an average of 32.33 years old, while the Autonomous Region of Azores had in average the older buildings with 34.26 years old. The buildings in Continental Portuguese territory had an average of 33.95 years old (INE 2001).

There were multiple factors that led to such situation. It is recognised by many actors in the construction sector that the rehabilitation of the residential building stock is needed (Corvacho 2010). The freezing of rents prior to 1990 has been the main reason for the lack of maintenance in the residential buildings. The absence of public policies contributing to stimulate the rental market and the low interest rates on loans for house acquisition were the other reasons for the lack of attractiveness of the rental market for families looking for a house.

Currently a new dynamic on the housing rental market is arising, with the increase in the number of families looking to rent a house rather than buying one, in a country which has a strong tradition of homeownership (IHRU 2007). In some areas, there are more people interested in renting houses than houses available. However, and according to provisional data from the 2011 Census, the number of houses available to rent increased 37.6%, while the rented housing stock grew only by 6.3% since 2001 (INE 2011).

This new trend is due to the current economic and financial crisis in the country, which led to a strong reduction in the loans granted by the banks for buying houses. Thus, this can be a unique opportunity to correct past mistakes. The energy rehabilitation appears as an opportunity to upgrade the existing building stock increasing their energy efficiency, comfort conditions and market value.

The energy rehabilitation of the Portuguese residential buildings would allow addressing residential buildings and social problems and also the energy dependency of the country. The rehabilitation would bring back to the market, unoccupied or energy inefficient buildings, increasing also its real-estate value.

In response to social needs, the investment on rehabilitation would contribute to increase the quality of life of the residents and to create new job opportunities. The reduction of the energy consumptions, that might be achieved, would be economically advantageous, both for the residents and for the country.

Furthermore, energy rehabilitation would also ensure the intergenerational sustainability of the building stock. It is necessary to make a good use of the existing energy resources and de-

velop new forms and concepts of building constructive technologies, so that there will be a solution for energy rehabilitation of any building built before 2006, taking into account the life cycle of each building in the decision making process.

Notwithstanding the positive effects for the society, the rehabilitation in general and the energy rehabilitation of buildings in particular, had not a significant role in the Portuguese construction market. The absence of a widespread awareness about the subject is perhaps one of the most important difficulties to its promotion. Other of the reason for the lack of investment in the rehabilitation is the lack of specialized workmanship in the sector. Frequently, technicians are not aware of the technical solutions available on the market and of the benefits of undertaking energy rehabilitation. About 40% of the anomalies in building are due to design defects and to wrong selection of technical solutions (Paiva 2002).

2.2 *Potential for Thermal Rehabilitation*

According to data from the 2001 Census, about 51% of the residential building stock that were built in Portugal in the 1960s, 1970s and 1980s needed some kind of reparation (Figure 1) (INE 2001).

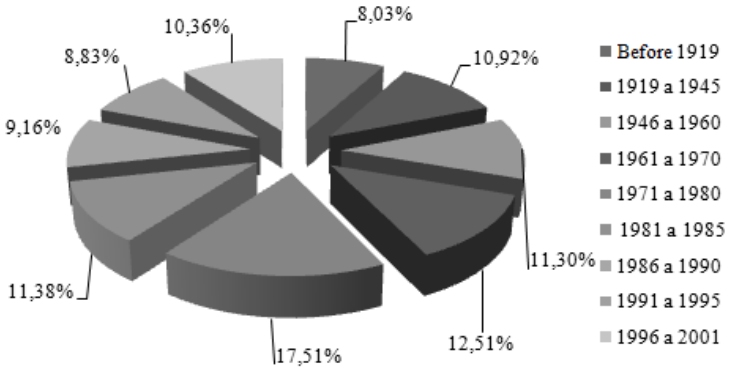

Figure 1. Rehabilitation needs in buildings (%) per decade (INE 2001).

Additionally, the first national thermal regulation only came into force in 1991. Before that the buildings were built without any specific concerns related to the thermal insulation of the envelope or to their thermal behavior. A significant number of these buildings have nowadays an inefficient thermal behavior and have energy rehabilitation needs.

Between 1990 and 2001 were built, 19% of existing residential buildings (INE 2001). Even that the Census statistics are not updated, the actual value should not be significantly higher, due to the slowdown of the construction of new buildings, after middle of 2008, due to the economic crisis.

The market of new residential buildings' has been forced to adapt itself to a new reality after a long period of growth in which more than the necessary buildings were built. Thus the number of licenses for the construction of new residential buildings has been decreasing. The forecast number of new residential building permits indicates a stagnation scenario that will be the near future reality of the Portuguese construction market. In 2006 were conceded 43,200 permits for apartments and 26,400 permits for housing (one and two dwellings), in a total of 69.600 permits. Since then the number of conceded permits has been reducing gradually. In 2007, were conceded 63,000 permits, about less 9.50% than the year before. In the year of 2008, 46.900 new permits were considered and in 2009 the numbers of permits continue to decrease to 34.700 new permits (EUROCONSTRUCT 2009).

Besides the studies indicated that this negative tendency will start to bounce back in 2011 and 2012, this reality was not confirmed and the decrease tendency continues due to a negative macroeconomic scenario (EUROCONSTRUCT 2009).

As, in Portugal the construction market has stagnated and the majority of the housing stock built before 2006 needs energy rehabilitation, this is an opportunity to enforce the goals of the EPBD-recast.

In Portugal the energy rehabilitation of buildings faces another challenge, as the large amount of private properties with several owners in the same building, not sensitized and informed, have different perspectives and some owners do not have capital available to perform the energy rehabilitation of their dwellings.

Although there is a market for energy rehabilitation of the existing buildings, it will be harder to apply the nZEB principles in buildings to retrofit than in new buildings, not only due to technical issues but also for economic reasons, among other reasons (ECEEE 2011).

2.3 *Energy Rehabilitation of Facades and Roofs*

In 2001, 38% of the building stock needed some kind of repair, and 3% of the buildings were extremely degraded (INE 2001). The majority of the rehabilitation interventions needed refers to the exterior envelope of the buildings, specially the window frames. About 47% of the residential buildings needed rehabilitation works in its facade. The second major retrofit interventions were needed in building roofs (representing in 2001 about 40%).

In 2010, 79% of the classic familiar residential buildings did not have any kind of thermal insulation in the exterior walls and about 89% did not had any kind of insulation in the roof (INE & DGGE 2011).

According to the Inquiry of Energy Consumption in the Domestic Sector (INE & DGGE 2011), in 2010, more than 75% of the south oriented windows were single glazed and only about 6% of the east and west orientated windows had double glazing with thermal cut (95% of single or double glazed windows didn't had any kind of thermal cut).

It is estimated that energy losses though the windows represent 35% to 40% of the total heat losses in a residential building during the heating season (Paiva 2000).

To improve the energy efficiency of the windows and reduce the thermal losses thought the windows it is necessary to improve the thermal insulation and air tightness. Some measures, like the increasing of the thermal quality of the frame and/or the glazing and also the study and the installation of shading systems (fins and overhangs and venetian blinds, shutters, etc.), can be adopted.

The increasing efficiency of the exterior envelope of the buildings would allow reducing the energy bill of the buildings and would also allow correcting some pathologic situations due to humidity and condensations.

The numbers presented reflect the necessity and the urgency for energy rehabilitation in Portugal. But, in general, the energy rehabilitation performed in roofs and facades is mainly related to the application or reinforcement of thermal insulation. In facades the replacement of single by double glazed windows is also a common used energy rehabilitation measure.

There are many solutions to increase the thermal insulation levels of the facades. The most common systems used in this kind of intervention are the ETICS system and the ventilated facades system (Corvacho 2010). Nowadays besides the conventional systems like the ETICS system there are also some unconventional energy rehabilitation solutions developed to be applied in facades like prefabricated panels with pipes and windows included (IEA ECBCS 2011). When it is impossible to apply the insulation in the outside of the buildings for example in multifamily buildings, there is always the possibility to apply the insulating in the inside.

However, the improvement of the thermal insulation of the envelope of the building might not be enough to guarantee that the building is energetically efficient. In the majority of the situations the referred measures must be analyzed and an integrated approach must be considered. It is then necessary to analyze each situation individually to better decide which are the best energy rehabilitation solutions for each building.

Other measures, like the installation of thermal solar panels to heat the domestic hot waters, the implementation of measures that take into account the shape and orientation of the building

site, the replacement of individual HVAC systems for centralized ones and the improvement of the indoor environmental quality should be also considered during the design. These factors would contribute to the global quality of the buildings and not only to their energy efficiency.

3 NZEB BUILDINGS – ENERGY REHABILITATION THROUGH BUILDINGS TRANSFORMATION

The recast of the European Directive about the energy efficiency in buildings, Directive 2010/31/EU (EPBD-recast), established that all the member states should adopt the necessary measures to improve the energy performance of the buildings. However the Directive did not established neither a definition nor a quantification of what considers being highly efficient. It refers that each member state has the responsibility to establish its own definition of highly efficient buildings based on a particular method to be established and adopted (EU 2010).

Although there is not a global definition of low energy consumption buildings in a generic and widely accepted way (EU 2009) there are buildings with an energy performance above the average performance of new buildings, built in accordance with the standards of local thermal regulations. It is estimated that energy savings in these buildings reaches 80% of operating costs compared with the conventional buildings.

In this framework, a new concept of buildings has emerged – the zero energy buildings (ZEB) and the nearly zero energy buildings (nZEB). In its essence the concept of nZEB building is based on the idea that these buildings can satisfy all their energy needs using local available resources, which should be sustainable and clean, including renewable energy sources.

A zero or nearly zero energy building (ZEB or nZEB) is a building with residential or commercial purposes with energy needs extremely reduced, due to its efficiency (thermal quality of the envelope and efficiency of the systems). The optimal concept of nZEB implies that the building produces enough energy to supply all the local needs, equaling or exceeding its annual energy consumption.

The nZEB buildings have energy consumption and emission of greenhouse gases associated, even that they are very low, mainly due to the use of renewable energy sources produced locally. Besides the energy consumption is almost zero they can interact with the network, consuming energy but also returning energy to the grid, when more than the needs that the building requires is produced.

The above referred motives show the urgent need to energetically refurbish the Portuguese residential building stock. However to achieve high levels of energy efficiency in the rehabilitation of the buildings it is necessary to develop new techniques and new concepts of rehabilitation to avoid that it only will tackle the maintenance and aesthetic aspects.

The rehabilitation of a building assumes not only that the initial building should be restored but also that its quality should be improved so that the final quality can be compatible with the current requirements and quality standards.

Nowadays there is a growing awareness of the need to reduce the energy consumption in the building stock and to reduce the planet global warming. These concerns lead to the need to find new and better ways to reduce the energy needs of the buildings and to produce the consumed energy locally.

Portugal, presents favorable conditions for using the energy rehabilitation of buildings to convert the building stock into ZEB or nZEB buildings. Due to its favorable geographic situation, with a high number of hours of solar exposition and high irradiation levels (Figure 2), Portuguese buildings can use solar thermal and photovoltaic panels to heat the domestic hot waters (DHW) and locally produce electricity.

The installation of solar thermal panels is mandatory (RCCTE 2006). The implementation of photovoltaic panels is not significant due to the high initial investment necessary and the time required to amortize the investment made. The installed area of solar thermal panels it is small, despite the existing potential of some Portuguese regions, especially in the South. However, in a general way the whole country presents favorable conditions, to produce energy, through the sun.

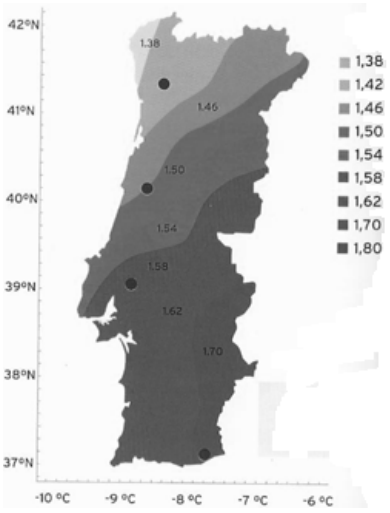

Figure 2. Index of the Average Solar Radiation received in Portugal (NOGUEIRA 2010).

The adoption of specific measures in buildings retrofit would allow, not only, real energy savings to the building owners, but also boosting the economy (ITIC 2009). For example the replacement of the existing single glass windows by windows with double gazing and thermal cut in every residential building would involve an economic activity about 2.358,50 million Euros. The application of thermal insulation on the façade will represent investments of 6.486,5 to 9.508,1 Million Euros and the investment in the roof thermal insulation would represent about 2.488,7 Million Euros (ITIC 2009).

4 CONCLUSION

A large part of the Portuguese building stock is outdated and it is very energy inefficient. This leads to negative consequences, high energy consumption and lack of comfort conditions of the populations, reduction of their quality of life, high levels of greenhouse gases emissions and the associated risk of failing the emission levels agreed by the country under the Kyoto Protocol.

The main measures of energy efficiency that could be adopted to transform existing buildings into nZEB buildings through energy rehabilitation would be:

- Replacing the single glass windows by double gazing with thermal cut windows;
- Placement of adequate shading devices;
- Increasing of the thermal insulation levels of the facade walls;
- Increasing the roof thermal insulation levels;
- Installation of thermal solar panels for DHW heating;
- Replacement of individual air conditioning systems by centralized HVAC systems, with high efficiency;
- Integration of passive solar design and natural ventilation techniques in buildings;
- Installation of photovoltaic panels and micro wind turbines, which could produce energy through microgeneration.

The introduction of renewable energy production in buildings, such as photovoltaic panels to produce electricity, is also one of the possible measures to take in account in the energy rehabilitation of buildings. However, some of these technologies have a significant initial cost that discourages and restricts its implementation.

In addition to the upgrade of the building stock, the energy rehabilitation is an opportunity to create jobs and boosting the economy. In reality there are several advantages to make energy rehabilitation, however the constraints that faces are still significant. Given the current

economic crisis, the lack of capital to invest is one of these obstacles but the greatest one still is the lack of awareness of the society to this problem.

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