Application of the nZEB methodology in the retrofitting of a typical Portuguese dwelling from the 50's.

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Abstract

Buildings and the whole built environment are in a key role when societies are mitigating climate change and adapting to its consequences. More than 50% of the existing residential buildings in EU-25 were built before 1970. Thus, these buildings are of significant importance in reducing energy consumption and CO2 emissions. The existence of more nearly zero energy buildings (nZEB) is a possible solution for this problem. This study aims to analyze the application of the nZEB methodology in the retrofitting of a typical Portuguese dwelling build in 1950. It was shown that the primary energy used can be reduced to a very low value (11,95 kWhep/m2.y) in comparison with the reference consumption (69,15 kWhep/m2.y), with the application of the best construction techniques together with the use of energy from on-site renewable sources.

Keywords - nZEB building; Renewable energy; Retrofitting

1. Introduction

Currently, in all European Union the building energy consumption is around 40% from the total energy consumed, and is predicted its increasing for the next decades. In order to invert this tendency, European Parliament launched in May 19 of 2010 the Energy Performance Building Directive (EPBD) recast (European Parliament Council, 2010). The main goal was to implement a new concept Nearly Zero Energy Building (nZEB) which means a building with a very high energy performance, where energy needs are almost zero and must be satisfied by energy from renewable sources produced locally or near [1]. Furthermore, as of December 31, 2020, all new buildings must meet this new concept, while occupied and owned by public authorities must fulfil the same requirements until the day December 31, 2018 [1].

More than 50% of the existing residential buildings in EU-25 were built before 1970 [2]. Thus, these buildings are of significant importance in reducing energy consumption and CO2 emissions. In Portugal 31,2% of the existing residential buildings were constructed between 1945-1970 [2]. Furthermore, on an average, new European dwellings are about 60% more energy efficient than the ones constructed before the first oil crisis in the 1970s, and consume 28% less than dwellings built in 1985 [3]. This shows the importance of these buildings for the goal of reducing the energy consumption of buildings in Europe.

According with EPBD 2010, each Member State (MSs) has to define the requirements necessary to a building to be considering nZEB taken account the cost-optimality principle. Progress report by [4], indicates that 11 MSs have detailed nZEB definition published in a legal document. In Portugal, we still have no clearly definition of the nZEB requirements. In the directive ‘nearly zero-energy building’ means a building that has a very high Energy performance (EP). The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources (RES) produced on-site or nearby [5]. According to [4] 10 MSs definition includes the EP indicator in kWh/m2.year and in 5 MSs there is a RES requirement.

2. Methodologies

This study tries to show that it is possible to make a retrofitting of a typical Portuguese dwelling, in order to transform in an nZEB building, using the actual constructions technologies. As we refer above there’s not an nZEB requirements definition in Portugal yet. Because of this absence, for this study we use the methodology presented in [6]. In order to achieve what is required by directive undergoes by conjugate different solutions at building envelope level, with passive systems and sealing measures, according to the climatic conditions of the location.

The methodology presented in [6] propose to combine the different requirements in a coherent assessment of nZEB. The proposed assessment methodology goes step by step “from the needs to the overall energy performance expressed in primary energy use”. Only if the requirement of each step is reached, then the building can be qualified at the end as nZEB [7]. The first requirement is reflecting the performance of the building fabric characterized by the energy needs. The second requirement is reflecting the performance of the technical building systems (HVAC installation, domestic hot water supply, built-in lighting installation) characterized by the energy use. The third requirement is reflecting the contribution of energies from renewable sources (e.g. active solar systems), characterized by the non-renewable primary energy consumption. The EPBD (2010) indicates that the very low amount of energy required has to be covered to a very significant extent by energy from renewable sources. The Primary energy indicator (*EPp*) can be calculated according with (1).

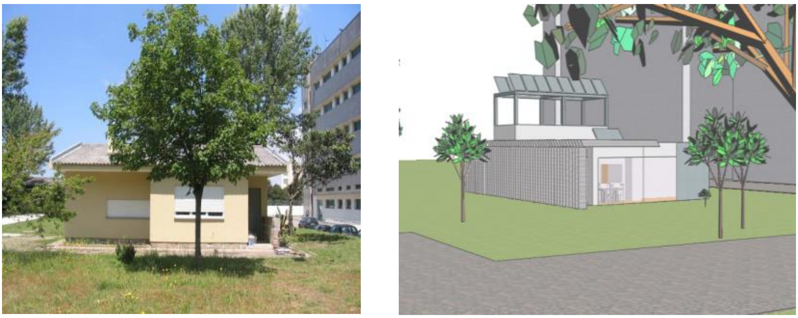
$$EP_P = E_P / A_{net} = (\Sigma_i (E_{del,i} f_{del,i}) - \Sigma_i (E_{exp,i} f_{exp,i})) / A_{net} \quad (1)$$

Where $E_{del,i}f_{del,i}$ is the annual weighted delivered energy for energy carrier *i*, and $E_{exp,i}f_{exp,i}$ is the annual weighted exported energy for energy carrier *i*, including re-delivered energy and energy exported to functions at the building site that are not included in the energy performance.

In [6] is presented the definition of the Renewable Energy Ratio (*RER*) as the ratio of the renewable primary energy, (calculated with renewable primary conversion factors), on the total primary energy (calculated with total primary conversion factors).

$$RER = REP_p / EP_p \quad (2)$$

The building in study was constructed in the 1950's with the intention of being the dwelling for the guard of the Instituto Superior de Engenharia do Porto (ISEP). The retrofitting of this building has the intention to create two internal lab units: Lab Unit 1 is for service training and conferences; and Lab Unit 2 is for residential housing. The total area of construction is approximately 150 m2. The thermal envelope of both units is characterized by having the requirements of high quality construction. In this study we only analyzed the residential unit.



a) b)

Fig. 1. a) Existing building. b) New building project model.

We can see in Table 1 the comparison of the quality of thermal envelope according with the actual Portuguese Legislation [8]. The U's values for the new building are half of the values of the Portuguese reference building and allow a huge improvement comparing with the existing building.

Table 1. Comparison between the average global heat transfer coefficient of the existing building ($U_{avg,E}$) the average global heat transfer coefficient of the new building ($U_{avg,N}$) and global heat transfer coefficient of the reference building (U_{ref}).

Envelope element	$U_{avg,E}$ (W/m²°C)	$U_{avg,N}$ (W/m²°C)	U_{ref} (W/m²°C)
Exterior Wall	3,59	0,24	0,50
Interior Wall	1,47	0,49	1,00
Roof	3,07	0,17	0,40
Windows	5,00	1,30	2,90

Although the quality of the envelope, it's necessary the installation of systems to provide proper heating, cooling and Domestic Hot Water (DHW). For this purpose, it was predicted the systems that can be seen in Table 2. The solar thermal panel and the photovoltaic panel have a useful area of 2,3 m^2 and 30 m^2 respectively, and both are facing south.

Table 2. Building systems.

Function	**Existing Building**	**New Building**
DHW	Electric water heater	Solar thermal panel
Production and exportation of Electricity	n. a.	Photovoltaic panel
Heating, Cooling and DHW	Electric heater	Heat Pump
Ventilation	n. a.	Mechanical Fans
Ventilation	Natural openings on windows	Natural openings on windows

With the objective to assess the predicted energy consumption of the new building it was performed an energy analysis using the methodology of the Portuguese legislation [8]. For the contribution of the renewable energy sources it was performed an annual dynamic simulation with the following assumptions. It was considering an appliances density of 4,5 W/m^2 and a lighting density of 3,7 W/m^2.

3. Results and discussion

The results of the simulation give us an estimation of the energy needs for the building. We can see in Fig. 2 the disaggregated energy needs (the lightning energy needs is not considered in the Portuguese calculation methodology for residential buildings).

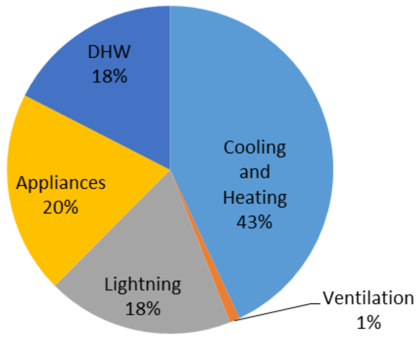


Fig. 2. Residential energy needs.

The value of the energy needs of the building was 11,95 kWhep/m2.y, whereas the energy needs of the reference building was 69,15 kWhep/m2.y. This means that the building has only 17% of energy needs of the reference building, making it an energy class A+, the highest level in Portugal, whereas the existing building has a value of energy needs of 501,29 kWhep/m2.y (energy class E). This high value reflects the actual poor quality of the thermal envelope and the use of equipment with low energy efficiency. The total primary energy use in the building was determined using the primary energy factors indicated in the Portuguese legislation [9]. The total annual value of renewable energy produced on-site is 3474 kWh, wherein, the solar thermal panel produces 1070 kWh and the PV panels produce 2404 kWh, which represents a *RER* of 84%. The Fig. 3 presents the monthly production of renewable energy in the building.

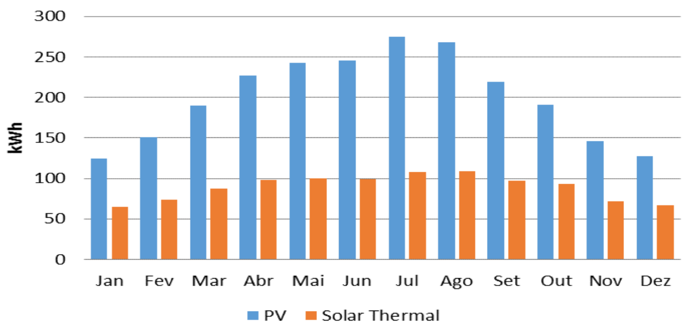


Fig. 3. Monthly production of renewable energy.

Regarding the CO2 emissions, the new building has an emission of 0,6 t/year whereas the existing building have an emission of 6,57 t/year. This represents a reduction of 91% and savings of 150t in 25 years. The Table 3 presents a benchmarked between the building in study and examples of nZEB definitions in some MSs [5].

Table 3. Benchmarked between nZEB definitions in different MSs for residential buildings.

	Building in study (Portugal)	Denmark	Belgium Flemish	Cyprus	France	Estonia
EP_p (kWh/m^2.y)	11,95	20	30	180	50	50
RER	84% (37,4 kWh/m^2.y)	51-56 %	> 10 kWh/m^2.y	25%	-	-

We can see that this building would be considering nZEB according with the different definitions of nZEB in all MSs analyzed.

4. Conclusions

The nZEB concept is a response of the European Union to reduce the energy consumption of the buildings. The retrofitting of older buildings it's an opportunity that should be used. With this study we prove that a retrofitting of a 1950's building, using the actual construction technology, can result in an nZEB building. Although the Portuguese definition of nZEB it's not publish yet, when we compare with definitions of different MSs the requirements are fulfilled. For obtain this result it was important to have a high quality thermal envelope for the building and use equipment's with high performance. The Portuguese climate is very favorable to use renewable energy sources, which reflects the high RER value obtained by this building. The timeline for the publication of nZEB definition in Portugal should take place as soon as possible, so that the new and refurbished buildings can meet the requirements referred in the EPBD.

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