STRATEGIES TO ACHIEVE THE NZEB GOAL IN THE ENERGETIC REFURBISHMENT OF EXISTING BUILT HERITAGE: A CASE STUDY

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ABSTRACT HEADING

We report a case study on the conversion into a Nearly Zero Energy Building (NZEB) of an existing building, “The Visitors Centre for Nature Interpretation” located in the Pyrenees mountains of Catalonia, Spain. The original building was constructed in the last decade using strategies of passive and low energy buildings. At that time, there were no regulations about energetic certification in our country, and we have no reliable information about the energetic performance of many modern buildings theoretically considered as “low energy”. The research was carried out by collecting data on real consumption and CO2 emissions values and analysing both the energy systems and the passive conception of the building. Afterwards, our conclusions furnished information on which to choose the strategies aiming at the energetic refurbishment and the conversion into nearly NZEB of this public centre. The main finding is that, by applying a combination of refurbishment options and improving the energy systems, a saving of approximately 50% is achievable in energy use and carbon emissions. Due the optimal levels of solar radiation in this place, the rest of the energy needed to afford the NZEB goal can be supplied by a photovoltaic installation placed on the roof. This approach can be applied to inspire and inform future reconversions of the existing modern buildings in Catalonia into NZEBs.

INTRODUCTION

The building sector is one of the productive sectors that needs to be acted upon if what is sought is a drastic reduction in CO2 emissions. As such, adapting existing buildings to future energy requirements, as provided for in the EU’s Energy Performance of Buildings Directive (2010/31/EU), is a challenge that must be addressed if we hope to deal with pressing issues of global warming and climate change. To achieve these objectives, the EU Directive urges Member States to ensure that as of 31 December 2020 all new buildings in the European Union (or 2018 in the case of public administration buildings) should satisfy nearly zero energy standards. Nearly zero energy buildings (NZEBs) can be defined briefly as buildings with a very high level of energy efficiency, whose very low energy requirements should be met by energy from renewable sources, so that the balance between energy consumption and energy production is zero. However the EU Directive says nothing about existing buildings, which constitute the majority of the built heritage in use, and it seems likely that in the EU, because of the economic crisis, very few new buildings will actually be built in the coming years. Therefore, the real challenge is how to address the energy performance of the existing built heritage.

This paper summarises the applied research carried out by our research unit in which the use of specific software tools is of great importance for verifying the performance of solutions developed, in the first instance, intuitively.

INTENT AND OBJECTIVES OF THE APPLIED RESEARCH

The building analyzed in this case study is the Visitors Centre for Nature Interpretation located in Son, a small village in the Pyrenees mountains in Catalonia (Spain). It lies at latitude 42° 37' N, longitude 1° 05' E and at an altitude of 1540 m. Based on the Köppen climate classification, Son occupies climate zone Dfb, characterized by mild summers and severe winters receiving snow in winter and constant rainfall throughout the rest of the year, exceeding 750 mm per annum. Average annual temperatures range between minus 10 and 25 ºC, and relative humidity between 65 and 100% in the summer and between 80 and 100% the rest of the year. The solar insolation index is high at around 4211 Wh/m2day, average, with a predominance of light winds from the west and south-west all the year.

The building was constructed during the last decade using passive design strategies in a highly valued environmental site located on the edge of the Aigüestortes National Park (Fig. 1). Based on data accumulated over the period of more than ten years in which the building has been in use, we performed a diagnosis of the existing building collating data on its energy consumption and emissions. Our study proposes a series of actions aimed at achieving the standards of low-energy buildings, maximizing the active use of renewable energy and enhancing comfort conditions. All in all, the actions seek to minimize the building’s environmental impact and so contribute, in some small way, to the global reduction in greenhouse gas emissions. In short, we seek to transform the Visitors Center into a nearly zero energy building.

The measures we took can be categorized in three types, implemented as follows:
1. Minimizing energy demand by enhancing the building’s energy performance: Increasing insulation, improving solar radiation control and natural lighting and exploiting enhanced ventilation for cooling in the summer.
2. Increasing energy efficiency and improving the building management systems.
3. Substituting conventional energy sources with renewable sources.

The subsequent economic evaluation enabled us to analyze the feasibility of these measures and their payback period.

EVALUATION OF THE PRESENT BUILDING

The main conclusions to be drawn from the bioclimatic and energetic analyses of the building can be summed up as follows:
• The building is poorly insulated, and have thermal bridges. The openings are simple with many air leakage.
• The openings in the building’s eaves block solar radiation in the summer and boost solar uptake in winter, but do not avoid penetration during warmer spring and autumn days.
• The building’s orientation and design protects it from the prevailing westerly winds and impede natural ventilation.
• The levels of natural lighting are poor in communal areas during the day (bathrooms and corridors) and the levels and distribution of natural lighting in spaces with large openings to the exterior are not homogenous.
• Poor natural lighting necessitates the use of artificial lighting in many areas and is responsible for high electricity consumption.
• The building requires some cooling loads which currently remain unsatisfied with either passive or active systems.
• The building uses propane gas as its primary energy source, which is responsible for its high CO2 emissions.

The total energy consumption of the building has been summarised in Table 1.
For assessing the CO2 emissions, we have taken into account the annual energy consumption from different sources and emission coefficients per unit (Table 2).

**ENERGY CERTIFICATION OF THE CURRENT BUILDING**

A simulation was conducted with Leader and Calener software (Table 3) providing the following results: the building has a significant heating load (G) that can be attributed to the area’s climatic conditions and a significant cooling load (C). Its CO2 emissions are average, being awarded a D, which is some way off the optimum level (A).

According to Spanish regulations the building’s energy certification is graded as a B and the environmental conditions achieved inside the building must be: 23°C - 25°C temperature / 45% - 60% relative humidity range in summer and 21°C - 23°C temperature / 40% - 50% relative humidity range in winter.

**ACTION CHECK LIST**

This section describes the actions planned to reduce the building energy consumption and achieve Nearly Zero Energy Building while improving indoor environmental quality. Will also detail the software tools that have been used for energy modeling.

**Table 3. Energy certification**

<table>
<thead>
<tr>
<th>Primary source</th>
<th>Annual energy consumption</th>
<th>Conversion in kWh</th>
<th>Annual emissions CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>136,829 kWh</td>
<td>136,829 kWh</td>
<td>0,25 kgCO2eq/kWh*</td>
</tr>
<tr>
<td>Electricit y - Photovoltaic</td>
<td>2,629 kWh</td>
<td>2,629 kWh</td>
<td>0</td>
</tr>
<tr>
<td>Propane gas</td>
<td>23,314 kg</td>
<td>324,512 kWh</td>
<td>2,94 kgCO2eq/kg</td>
</tr>
<tr>
<td>Diesel</td>
<td>10,577 kWh</td>
<td>26,300 kWh</td>
<td>2,72 kgCO2eq²</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>15,194 kWh</td>
<td>15,194 kWh</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>505,664 kWh</strong></td>
<td><strong>TOTAL</strong></td>
<td><strong>131,5 Tn</strong></td>
</tr>
</tbody>
</table>

Ratio (kWh/m²/year) 202
Ratio (kg/m²/year) 53

While it is evident that to increase energy efficiency of the building, the first action should be to improve the insulation, in some well-designed buildings of our modern built heritage like this one, specific constructive solutions to improve thermal performance of the building envelope are very difficult to implement, due to its high cost and the modification of its image. Therefore in this particular case study it was decided to use other strategies that do not damage the outward appearance and the interior finishes.

**ENERGY BALANCE**

Among the different actions proposed we have included a new primary energy source, namely, biomass. Propane gas and diesel consumption has been virtually eliminated, limited now solely to the kitchen. We have not taken into consideration the fuel used in the electric generator as consumption is restricted to exceptional occasions (when there is a power outage) and so this does not form part of the building’s normal operating conditions. The building’s electricity consumption has undergone a significant reduction (in the order of 37%), which has considerably improved the ratio of energy consumed per square meter/year.

**CO2 EMISSIONS**

Taking into account the reductions in consumption outlined in the previous section (and ignoring fuel consumption for the reasons presented above), the CO2 emissions can now be assessed. The electrical energy harvested from the photovoltaic system makes a negative contribution to CO2 emissions because it is clean energy fed into the grid, which helps improve the energy mix. This output also improves the ratio of energy consumed per square meter, as it offsets a significant proportion of the total, reducing the ratio from 202 kWh/m² to 131 kWh/m² in the initial year of the proposed scenario.

Without taking the photovoltaic system into consideration, CO2 emissions are significantly reduced from an initial 302 tons/year to 131.5 tons/year, thanks to the marked reduction in the total amount of electricity consumption and virtual elimination of propane gas consumption. If we consider the total energy harvested from the photovoltaic system, we see this generates all the electricity consumed, thus enabling us to certify our building as a net zero energy building.

Energy consumption and CO2 emissions are summarized in Table 4.
The building in our case study today generates 100% of its energy. This is a clear example of energy efficient architecture employing the tools of the bioclimatic design process. Active energy efficiency and the use of renewable energy sources are the way to shrink a building’s carbon footprint. Finally, we conclude that the most useful contributions of our applied research lie, first, in its ability to inspire and lead architects and engineers in the future energetic refurbishment of built heritage as they convert them into NZEBs. This proposal is a practical demonstration that sustainability is not an obstacle to design but rather a challenge to creativity. And, second, our proposal has the ability to revive those productive sectors suffering the effects of the current economic crisis. The example reported here should reduce resistance within the construction sector to adopt these principles, thereby allowing a successful theoretical concept to become a reality that can be accepted by the market and so generate renewed economic activity.

In a not too distant future, the progressive implementation of the Energy Performance of Buildings Directive in the building sector will lead a transition to the design of new buildings in which the energy concept constitutes a fundamental premise. This clearly represents a major challenge for architects, radically changing the way we design buildings.

This paper has made various contributions to this debate. In terms of methodology, it has stressed the importance of using specific software tools to verify the behavior of the solutions proposed. As shown with the corresponding architectural modifications, any existing building can achieve the nearly zero energy standards and produce its energy requirements from renewable sources in the building or in its surrounding environment. The building in our case study today generates 100% of its energy. This is a clear example of energy efficient architecture employing the tools of the bioclimatic design process. Active energy efficiency and the use of renewable energy sources are the way to shrink a building’s carbon footprint.

Finally, we conclude that the most useful contributions of our applied research lie, first, in its ability to inspire and lead architects and engineers in the future energetic refurbishment of built heritage as they convert them into NZEBs. This proposal is a practical demonstration that sustainability is not an obstacle to design but rather a challenge to creativity. And, second, our proposal has the ability to revive those productive sectors suffering the effects of the current economic crisis. The example reported here should reduce resistance within the construction sector to adopt these principles, thereby allowing a successful theoretical concept to become a reality that can be accepted by the market and so generate renewed economic activity.

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