proceedings

Proceedings

Energy Refurbishment Assessment of an Existing Educational Building. A Case Study †

María José Suárez López [1,*], Silvia Soutullo Castro [2], María Rosario Heras Celemín [2] and Eduardo Blanco Marigorta [1]

[1] Energy Department, University of Oviedo, EDZE 33203 Gijón, Spain; eblanco@uniovi.es
[2] Energy Efficiency in Buildings Unit, CIEMAT, Avda. Complutense, 28040 Madrid, Spain; silvia.soutullo@ciemat.es (S.S.C.); mrosario.heras@ciemat.es (M.R.H.C.)
* Correspondence: suarezlmaria@uniovi.es; Tel.: +34-985-182-114

† Presented at the 2nd International Research Conference on Sustainable Energy, Engineering, Materials and Environment (IRCSEEME), Mieres, Spain, 25–27 September 2018.

Published: 2 November 2018

Abstract: The building sector is the highest energy consumer (38.1%) in the European Union. This consumption has to be reduced in both new and existing buildings. Respect to the existing ones, they need an effective energy renovation as the current European Directives reflect. Specifically, all countries have to refurbish 3% of their public buildings per year since 2014. In this paper, several refurbishment measures have been applied to the Energy Department Building of the University of Oviedo, using simulation tools. The measures proposed modify the thermal envelope according to the climatic variables and normative restrictions. Also, a parametric analysis has been made studying the influence of these measures in the heating and cooling demand and quantifying their cost.

Keywords: energy efficiency in buildings; dynamic simulation; DOE2; energy refurbishment

1. Introduction

In the European Union (EU-28), the building sector (including residential and service ones) is the highest energy consumer (38.1%) according to the last data published by Eurostat (2016) [1], above transport (33.3%) and industry (25.9%). Therefore, in order to achieve a 20% reduction in greenhouse gas emissions, objective set by the European Union, this consumption has to be reduced in both new and existing buildings. Especially, existing buildings need to be renovated due to their higher energy consumption [2]. According to the Directive 2010/31/UE [3], all European countries have to refurbish 3% of their public buildings per year from 2014, fulfilling at least, the established minimal energy performance requirements.

There are several possibilities to reduce the energy consumption of existing buildings. One of them is to decrease the energy loads, modifying the thermal enclosure (or envelope) according to the climatic variables and normative restrictions. This manuscript presents the energy assessments proposed to refurbish the Energy Department Building of Oviedo University (Figure 1) placed in Gijon (Asturias). It is a rectangular building with two constructive bodies separated by two external patios and connected by three towers. The orientation of both bodies is north-south. In this building there are classrooms, offices and laboratories. On the back, five north-south rectangular modules, perpendicular to the main bodies, have been built for large industrial laboratories.

About the construction features of this building, the external envelope is made of concrete walls with big windows at the façades, ceramic slab with insulation and cement mortar. The ground is composed of heavy concrete slabs and gravel without insulation. And the roof is made of waterproof clays, gypsum plaster, insulation, reinforced concrete and cement mortar. The windows are composed of double glazing and frame with thermal break. This constructive configuration has been set as nominal one to obtain the thermal loads for the base case.

Figure 1. Energy Department Building at the Oviedo University Campus in Gijón.

2. Materials and Methods

A dynamic simulation model has been developed to analyze the energy performance of the Energy Department Building of the University of Oviedo. This model has been done by using the dynamic simulation tool Visual Doe 4.1 [4]. This software predicts the energy use of the building, performing unsteady-state calculations, solving the coupled and time-dependent equations considering 1 hour as time step [5]. The final results are the annual thermal loads of the building, including cooling and heating needs.

Taking into account the climatic conditions in Gijón and the available constructive and operational data of the existing building, several refurbishment measures have been proposed: the addition of thermal insulation in the façades, roof and floor, the windows renovation and the inclusion of shading devices.

The use of simulation tools allows the energy quantification of the selected refurbishment actions, calculating the influence of each measure on the thermal loads of the building. With this objective, an array of simulations has been executed, considering the building requirements and the normative restrictions [6]. In each simulation, only one refurbishment measure has been modified from the initial values while the rest has been kept constant. The upper and lower bounds of each battery of tests have been selected from the data of the retrofit products available on the market [7]. The outputs of these parametric runs are the annual thermal loads and the total cost.

Based on the annual thermal loads reached by each refurbishment measure, a local sensitivity analysis has been done [8]. This study highlights the most influential measures in comparison with the annual loads of the base case.

3. Results

The initial situation of the building has been modelled giving as result an annual thermal load of 55.5 kWh/m^2, with much higher heating than cooling load (88% heating and 12% cooling). Once the refurbishment measures have been selected, several series of simulations have been executed to analyze the energy performance of the building and quantify the influence of these upgrading actions on the annual thermal needs. Normative requirements for new buildings placed in Gijón since 2013 have been highlighted in yellow for each measure, as it can be seen in Figure 2. In all cases, commercial values have been used.

One of the upgrading measures of the building envelope is the addition of thermal insulation at the existing external façade. Two options have been studied: at the inner layer (varying the thickness from 5 to 10 cm) and at the outer layer (whose thickness varies from 6 to 14 cm). The results obtained with this measure are shown in Figure 2. This figure presents the energy savings (left axis) and commercial prices (right axis) in function of the thickness when adding external (upper graph squares) and internal (lower graph triangles) insulation at the façade.

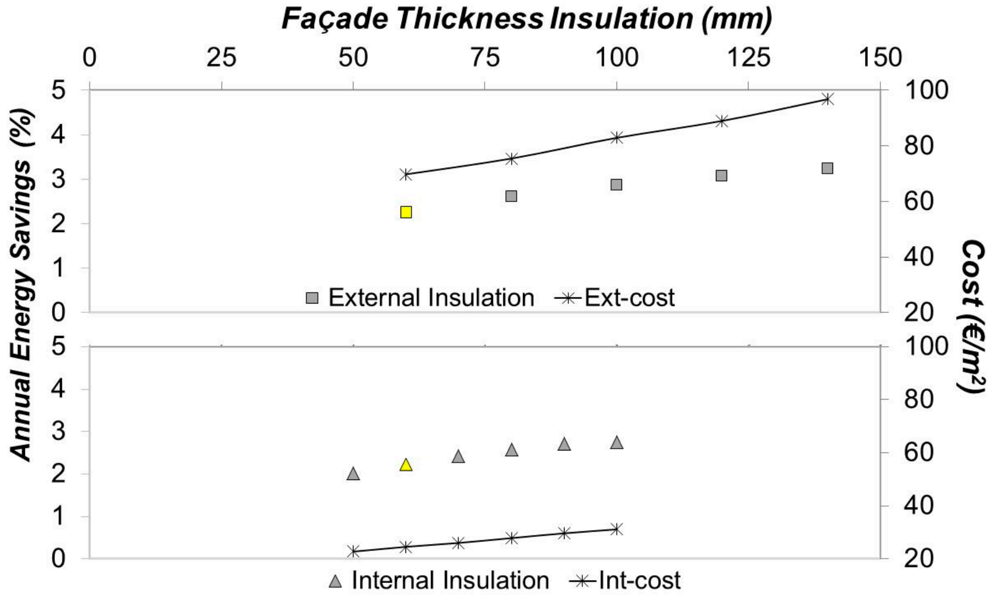

Figure 2. Energy savings and economical prices for added external or internal insulation to the facade.

In both cases the modification of the external façade follows a logarithmic correlation between the energy savings and the thickness of insulation, with R^2 higher than 0.99 in all cases. Similar energy savings have been obtained for both cases but the commercial prices for the external addition of insulation are higher because the installation is more complex (scaffoldings…).

Regarding the other refurbishment measures, in all of them the energy savings follow a logarithmic tendency in function of the thickness of the insulation (roof and ground) or the glass characteristics (windows renovation). In the case of the roof, the annual energy savings are higher than 6% and its cost is lower than the external façade one. But, when the insulation is added to the ground, the annual energy savings are very high, overcoming 38%, and its cost is intermediate between the external façade and roof. About the windows renovation, the energy savings vary from 3% to 10%, but its cost is very high. Finally, the inclusion of shading devices has been analyzed and the annual savings are higher than 4%. In this case, higher energy benefits can be obtained for the whole building if the annual shading devices installed over the roofs are solar collectors.

4. Conclusions

European directives related to the energy performance of buildings require effective energy renovation of existing buildings to reduce the energy requirements and minimize the pollutant emissions to the atmosphere at the city scale. The implementation of efficient refurbishment strategies should be adapted to the climatic conditions in the city and should be regulated by legal and constructive restrictions of the building. With this aim the dynamic simulation tool Visual Doe has been used to quantify the energy savings obtained in the renovation of the Energy Department Building of Oviedo University.

Several upgrading measures have been studied: addition of insulation on the envelope, windows renovation and shading devices. The highest annual energy savings are reached with the addition of insulation at the internal layer of the ground, around 40% by using the minimum thickness fixed by the Spanish normative. The modification of the façade achieves maximum energy savings about 3%, with a relatively low cost when it is applied at the inner layer. The roof improvement reaches maximum energy savings around 7% with a reasonable cost, and the renovation of windows achieves higher energy savings, about 10%, but this measure is expensive. Finally, the inclusion of shading devices has achieved maximum annual savings of 5% but the wide variety of available options (green elements, cloth canvas, solar collectors…) represents great price variability.

Author Contributions: S.S. and M.J.S. conceived and designed the models; S.S. performed the dynamic simulations; E.B. and M.R.H. analyzed the data; S.S., M.J.S. and E.B. wrote the paper.

Acknowledgments: The REHABILITAGEOSOL Project, Reference RTC-2016-5004-3, is a Project funded by the National Program for Research, Development and Innovation in Society Challenges, within the framework of the National Plan for Scientific and Technical Research and Innovation 2013-2016 from the State Research Agency (Ministry of Economy, Industry and Competitiveness), co-financed with FEDER Funds.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Eurostat, Energy Efficiency in Buildings. 2016. Available online: https://epthinktank.eu/2016/07/08/energy-efficiency-in-buildings/energy-consuption-by-sector/ (accessed on 15 February 2018).
2. Ma, Z.; Cooper, P.; Daly, D.; Ledo, L. Existing building retrofits: Methodology and state-of-the-art. *Energy Build.* **2012**, *55*, 889–902.
3. Energy Performance of Buildings Directive. *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings*; Official Journal of the European Union: Alicante, Spain, 2010; pp. 13–35.
4. DOE-2 Building Simulation Tool. Available online: http://doe2.com/ (accessed on 15 February 2018).
5. Lawrence Berkeley Laboratory. *DOE-2 Engineers Manual*; United States Department of Energy: Washington, DC, USA, 1982.
6. Soutullo, S.; Giancola, E.; Heras, M.R. Dynamic energy assessment to analyze different refurbishment strategies of existing dwellings placed in Madrid. *Energy* **2018**, *152*, 1011–1023.
7. Cype Ingenieros, Refurbishment Market Prices Tool. Available online: http://www.generadordeprecios.info/rehabilitacion/ (accessed on 15 February 2018).
8. Delgarm, N.; Sajadi, B.; Azarbad, K.; Delgarm, S. Sensitivity analysis of building energy performance: A simulation-based approach using OFAT and variance-based sensitivity analysis methods. *J. Build. Eng.* **2018**, *15*, 181–193.

© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).