Journal of Building Engineering 3 (2015) 79–93

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Integrated approach for school buildings rehabilitation in a Portuguese city and analysis of suitable third party financing solutions in EU

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ARTICLE INFO

Article history:
Received 7 April 2015
Received in revised form
22 May 2015
Accepted 24 May 2015
Available online 18 June 2015

Keywords:
Integrated approach for school building rehabilitation
Energy consumption for heating and cooling
Payback
Thermal rehabilitation
LCC
Available financial mechanisms to promote buildings energy efficiency measures

ABSTRACT

In this paper we present an integrated approach for building rehabilitation on a group of buildings of a primary school located in the southern suburbs of Lisbon – Moita, Portugal. The approach includes taking into account collected data concerning the actual energy consumption for: space heating; occupants' behavior, technical and architectural characteristics of the buildings. Detailed energy auditing was done to the buildings including interviews to pupils and teachers to understand occupants' behavior, construction materials used, energy consumption and lighting. Thermal images of the interior zones were generated to provide information about the temperature distribution and a notion about air or heat leak from or into the building. Based on the obtained data, 5 different energy retrofit scenarios were studied with different performance and cost-effectiveness targets, compatible with some European available financial mechanisms to promote energy retrofit of buildings. Life cycle cost analyses (LCC) should be taken into account to minimize environmental impact and some recommendations were suggested. Each scenario service life' presents an important effect in LCC. It is found that implementing those measures can cost-effectively reduce the annual energy use by 40% compared to the original building design.

1. Introduction

In Portugal, one of the main sources used in electricity energy are fossil fuels in thermal power plants (coal, oil, natural gas), which cause the emission of pollutants where CO2 is the main gas released. The Kyoto Protocol imposes an upper limit of CO2 emissions and other gases in the atmosphere, responsible for increasing greenhouse effect and contributing to global warming. Each state connected to the Protocol are obliged to create their own measures and policies, which enable the reduction of emissions of those gases harmful to the environment. In this area, the Portuguese environmental policy is presented in the resolution of Council of Ministers no. 20/2013, of 10 April, approving the National Action Plan for Energy Efficiency (Strategy for Energy Efficiency – PNAEE 2016 [1]) and the National Action Plan for Renewable Energy (Renewable Energy Strategy – PNAER 2020 [2]). According to this document, PNAEE and PNAER are energy planning measures that establish how to achieve the goals and define international commitments made by Portugal concerning energy efficiency and use of energy from renewable sources.

In Europe, the energy consumption in buildings rises up to 40% of the total energy consumption in the EU. Reducing energy consumption is a priority under the "20-20-20". Regarding the new buildings, Europe has declared that in a near future, they shall be nearly zero-energy consumption buildings. However, the natural slow renewal rate of the buildings makes vital their rehabilitation.

The building retrofit optimization problem is to determine, implement and apply the most cost effective retrofit technologies to achieve enhanced energy performance while maintaining satisfactory service levels and acceptable indoor thermal comfort, under a given set of operating constraints.

The overall process of a building retrofit can be divided into five phases (Fig. 1) [3].

The objective of an energy audit is to study the conditions of energy use in a building and subsequent identification of opportunities for improving energy performance, aiming the reduction of the energy bill and total costs at a local level (the consumer point of view) but also at a national level. The upfront capital required to install retrofit measures could be provided for example through private lenders in the form of a loan. This loan can be attached to the property, via the gas or electricity meter and the money is paid back to the lender by the occupants, via the energy suppliers [4]. Energy audit can be carried out by those private lenders with the supervision of the facility manager of the building (that represents property's occupant or owner).

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http://dx.doi.org/10.1016/j.jobe.2015.05.003

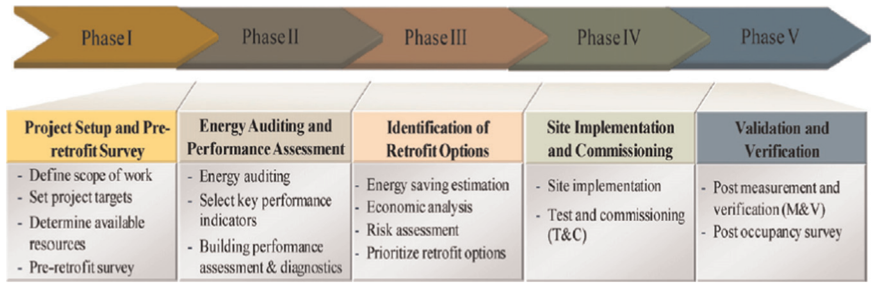

Fig. 1. Key phases in a sustainable building retrofit program (based in [3]).

By using appropriate energy models, economic analysis tools and risk assessment methods, the performance of a range of retrofit alternatives can be assessed quantitatively. The objective is to prioritize retrofit solutions based on relevant energy related and non-energy related factors.

Thus, energy audits enable the identification of real opportunities to save energy. Their objectives are:

- Determine the forms of energy used;
- examine how energy is used and their costs;
- establish the structure of energy consumption;
- determine consumption per division, category, or equipment;
- identify opportunities for improving energy performance;
- Analyze technical and economic solutions.

Alajmi [5] analyzed the results of an energy audit to an educational building in a hot summer climate (State of Kuwait). The purpose was to identify any energy conservation opportunities. A list including energy conservation opportunities (ECOs) was made taking into account non-retrofitting measures (no or minimal cost) and retrofitting (with cost) recommendations. Interestingly, the non-retrofitting ECOs saved 6.5% of the building's annual energy consumption, while the retrofitting ECOs can save up to 49.3%.

Desideri and Proietti [6] performed energy audit analysis for school buildings of a province in the center of Italy. They studied both thermal and electric energy consumption through energy auditing technique for 13 school buildings. Energy analysis of the school buildings showed that electric energy consumptions vary between 15% and 25% due to non-A/C sources, while thermal consumption contributed up to 80% of the total annual energy consumptions. By comparing the electric energy consumptions and thermal energy consumptions per unit volume, they shown that thermal energy saving could reach up to 38%. Electric energy consumption could be reduced by 46%, if the minimum optimal energy consumption is reached.

Santamouris et al. [7] carried out energy audits on 238 schools buildings in Greece for construction, heating, cooling, lighting, and mechanical and electrical systems, in order to verify the energy-consumption indicators and the energy-saving opportunities. The annual average total energy consumption is 93 kW h/m^2, of which approximately 72% is consumed for space heating. The implementation of various energy-conservation techniques shows a potential for 20% overall energy conservation.

Dimoudi and Kostarela [8] studied the potential of energy conservation measures in school buildings. They combined different energy saving measures in primary schools in Greece such as: insulation of the support frame, increased thickness of wall insulation, airtightness improvement and removal of shading devices. Results show energy savings of about 29%.

However, the success of a building retrofit program does not depend only on retrofit technologies. It also depends on: policies and regulations, client resources and expectations, building specific information, human factors and other uncertainty factors [3].

Being able to compare a building with the representative building stock performance and with regulations is a vital step for certification and to define specific retrofit measures. The development of reference building benchmarks requires some assumptions and data collection, which can prove a difficult task. However, they may be of significant advantage in seeking improvement of energy performance. A research work was developed in Irish primary schools [9] aiming the development of energy performance benchmarks for non-domestic buildings. According to them, while some factors such as activity, occupancy data, building area, number of pupils, age of building, etc. can be easy to obtain using questionnaires, other vital information for evaluation for energy performance of the building, such as construction details and type and efficiency of heating systems are often unknown. Combining questionnaires with a number of building surveys to collect detailed data for a smaller sample of buildings, as was done in the work presented in this article, could be the most practical solution for the development of reference building statistical benchmarks. Besides this, the measured rating has the benefit of representing the actual use of the building, and producing a rating according to this use. This is particularly appropriate to public buildings, as it assesses the actual performance, and generally this is a more important factor for public buildings.

Dowson et al. [10] studied the barriers, incentives and current performance of retrofit solutions in UK buildings. The UK faces a major challenge to improve the thermal performance of its existing housing stock and a range of fabric efficiency incentive schemes exist, but many do not target the full range of private and social housing. The Green Deal is the UK's key energy efficiency policy but the scheme is forecasted to have low consumer appeal and low incentives for investors. Besides this, calculated Green Deal loan repayments will be reliant upon estimated energy savings, yet it is claimed that retrofit measures may only be half as effective as anticipated due to a lack of monitoring, poor quality installation and the increased use of heating following refurbishment.

Another study from UK concerning buildings retrofit [11] show that in un-insulated older buildigs pre-1990 standards, cavity wall insulation can reduce heat loss through walls by up to 40%. Determining the actual savings requires knowledge of how much heat was originally being lost through the fabric. This enhance the importance of assessing the actual performance of buildings and doing buildings benchmarks may be of significant advantage in seeking improvement of energy performance.

The optimization of an energy efficient building needs a holistic integrated approach including the analysis of several processes: planning, building design, systems design, environmental system operation and management.

Concerning school buildings, large investments are required to improve their energy performance. Thus, for a good choice of the best business it is necessary to study a few characteristics which directly affect their adoption. Initial cost of the retrofit solution, payback return, energy savings, lifetime of the new solution and