Analysis of Different Energy Efficiency Technologies Based on Cost and Return of Investment

Giorgio Mustafaraj[1] Irida Markja, Klodian Dhoska
[1]Politecnic University of Tirana, Tirana, Albania

Abstract: *Application of different retrofitting technologies can play a significant role in reducing energy consumption of existing buildings. This research work analyses a building in Cork (Ireland) where underfloor heating system, and natural ventilation are used to maintain comfort conditions. Underfloor heating system is the main electricity consumer of this building. Different energy efficient technologies were implemented and analyzed in terms of reducing electricity consumption through an energy software. These technologies include replacing illumination with high efficiency light; replacement of electric motos with high efficiency; introducing underfloor heating time scheduling turning on and off based on predicted weather condition; installation of presence sensors to switch ON/OFF lighting. Finally, it was decided to implement underfloor heating time scheduling as energy efficient technology to be analyzed because of limited budget available and high return on investments provided by applying this method. Result analysis shows that electricity saving on bills was about 20% on monthly basis compared to previous consumption.*

Keywords: *ENERGY EFFICIENCY, BUILDING RETROFITTING, UNDERFLOOR HEATING SYSTEM*

1. Introduction

To reduce the pollution, in recent years were developed advanced technologies to cut down energy consumption. In European Union (EU) building consume for around 38% of overall electricity. The EU built the Energy Efficiency Directive (EED) in year 2012 which then was further improved throughout the coming years. The aim of EED is to encourage the EU countries to reduce energy consumption of buildings by developing new advanced technologies [1].

The main objective of energy retrofit is to enhance energy efficiency of building by improving for example building properties such as envelope and/or heating ventilation and air conditioning (HVAC) systems. Retrofitting existing building is necessary because HVAC plants and other properties deteriorate with time, and an improvement of these properties reduces energy consumption.

Griffith et. al. [2] analysed different retrofitting technologies for energy savings opportunities. They consider both cost of investment of applying different retrofit technologies and the obtained energy savings. Results analysis showed around 40% energy savings. Chidiaca et al [3] used different retrofit methods on nine different office buildings. They analysed the result related to energy savings and return on investment for different weather condition. Mills et. al. [4], demonstrated that by retrofitting different buildings produced an reduction of energy consumption by 16%. Aste and Pero [5] performed a research analysis in developing a retrofit approach. The procedure is based on an iterative process that allows selecting the most suitable energy retrofit technology for a particular building. Result analysis, shown a reduction of energy consumption by 40%.

The aim of this research work is: firstly, analyzing different energy retrofit technologies through an energy software called Design Builder [7], and secondly selecting the most appropriate such as underfloor heating time scheduling in terms of limited available budget.

Finally, the outline of this research work includes: Section II presents an overview of the building architecture and heating ventilation and air conditioning (HVAC) plants, Section III describes results analysis on different energy retrofit technologies, and Section IV provides conclusions.

2. Overview of the Building Architecture and HVAC Plants

The building under examination is part of University College of Cork in Ireland. Is a three floor that contains offices and labs with a total area of 4500 m^2 . The floors are reinforced concrete structure which presents a high thermal mass. A general overview of the building is presented in Figure 1.

Fig. 1 *General overview of building model [6,7]*

Figure 2 gives the Heating Ventilation and Air Conditioning (HVAC) plant that is present in the building. The majorities of the areas in the building (around 80% of the entire building areas) are supplied by natural ventilation and underfloor heating. The remaining zones of the building that includes toilets, stores and clean rooms are supplied by five Air Handling Units (AHUs). Water to water heat pump system is used to heat up the water up to 35oC, while a further increment of the temperature up to 38oC is obtained by the heat exchanger that on the other side is flowing water coming from the boiler. The water is then passed through underfloor heating system. Finally, for more detail information about the architectural and system plants refer to Mustafaraj et. al. [6].

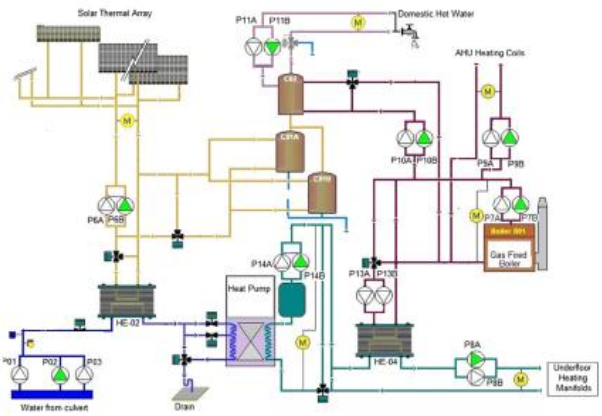

Fig. 2 *Overview of HVAC plant [6]*

3. Analysis of Results

Past researchers such as Mustafaraj et al. [6] completed model calibration. Present research work implemented a certain number of energy retrofit technologies. The energy retrofit technologies includes replacement with high efficiency lighting & occupancy sensors, substituting old motors with high efficiency motors, installation of variable speed drivers on water pump and high efficiency air conditioning systems. Three energy retrofit technologies were identified. The total cost savings were calculated based on the average cost electricity in Ireland that was fixed at 0.18 €/kWhr.

Table 1 summarizes the energy retrofit recommendation obtained. Replacement of lighting and motors with more efficient alternatives, could provide potential cost savings of €3881 but would include an implementation cost of €2736.

Table 4 *Energy Retrofit Technologies: Summary of Savings and Costs.*

Description of Energy Retrofit Technologies	Potential Savings (€/yr)	Implementation Cost (€)	Simple Payback Period (yrs)	Energy Savings (kWhr/yr)	Demand Reduction (kW)
Process Improvements					
1. Time schedule Heat Pump Modification	290	0	Immediate	5050	0
2. Replacement with High Efficiency Lighting	1858	1146	0.6	10327	0.241
3. Replacement with High Efficiency Motors	2023	1590	0.6	11240	1.757

Result analysis from Table 1 shows by applying ‘’Time schedule heat pump modification’’ the initial cost of investments is almost negligible, and the payback period is immediate. Because of limited budget available, this energy retrofit technology was chosen to be analyzed in more detail compared to the others through the present research. Before the heat pump was turned “ON” and “OFF” manually by a technician. Based on its experience and on weather forecast the time that the heat pump was kept “ON” varied between 6 and 12 hours. Present research work discovered that is required less time that varied between 4 to 8 hours to keep “ON” the heat pump. This was done automatically based on the real thermal behavior of the building. Figure 3 present a comparison between model simulation and manual real measurements for monthly electricity usage. Result analysis shows that electricity consumption was reduced between 20% and 27% monthly.

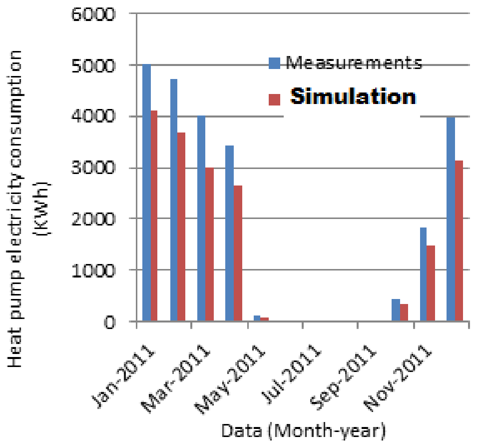

Fig. 3 *Monthly comparison of electricity consumption between manual (Measurement) and automatic control (Simulation by the software [7]) of the heat pump*

Finally, total electricity savings were calculated to be 5050 kWh/year (i.e. corresponding to a total savings of 290€/year). The payback period is immediate because there is no cost on investment for implementing this energy retrofit technology.

4. Conclusions

In this research work, three different types of energy retrofit technologies were investigated. Firstly, the time schedule of the heat pump was modified based on real thermal behavior of the building where the potential energy saving was calculated to be 5050 kWhr/yr with a potential cost savings of €290. Secondly, the proposed replacement of standard lighting with high efficiency lighting incorporating luminosity sensors would deliver a potential of €1858 which includes a simple payback period of 6 months. In this scenario, the cost of implementation was calculated to be €1146. Thirdly, the replace of standard motors with high efficiency motors was estimated to result in potential cost savings of €2023. In present work ‘’Time schedule heat pump modification’’ was chosen to be analyzed in more detail and implemented practically because limited badged and immediate payback. Finally, result analysis shows that electricity consumption by implementing ‘’Time scheduling heat pump’’ was reduced between 20% and 27% monthly.

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