Efficient retrofit actions and advanced control strategies for a student hostel

S. Ferrari
Dept. Building Environment Science & Technology (BEST), Politecnico di Milano, Italy

ABSTRACT

In the 6th Framework Programme of the European Union, Politecnico di Milano is participating in an Integrated Project related to energy and environmental efficiency in buildings. This project (BRITA in PuBs) aims to increase the market penetration of innovative and effective retrofit solutions to improve energy efficiency and integrate renewables in buildings. The project includes exemplary retrofit of 9 demonstration public buildings in the four participating European regions (North, Central, South, and East). Among them, one is a student hostel, Daniel’s Palace, of Politecnico di Milano, in Milan, Italy.

The present study is addressed to the estimation of energy saving obtained using various retrofit actions in Daniels’s Palace building, with the implementation of advanced technological solutions and control strategies for energy supply, daylighting etc.

The building energy performances were assessed based on VisualDOE simulation software. The retrofit actions were evaluated as per their energy and environmental performances.

1. PROJECT DESCRIPTION

The Daniel’s Palace (Fig. 1) was built during 1950’s, it consist of four buildings (two 14-storeys towers, one 6-storeys block and one single-storey central block). The total floor surface is about 13.000 m^2 and the volume is 42.000 m^3. Like most buildings of those years, the complex was realised, without thermal insulation materials and with an old heating system. The building is served by a single central heating plant feeding all the radiators, without distinct thermal zones. Several electrical boilers are installed to provide hot water and conventional small systems e.g. split system etc. are used for cooling.

The Politecnico di Milano has rented this building for 35 years. To adapt it as a student hostel, recently it was decided to renovate the entire building. Under the conventional refurbishment design, the lower levels of the building will be used as offices, meeting rooms, library, coffee/internet-point, canteen, gym, etc. and will be served by air conditioning systems.

For energy point of view, the conventional refurbishment design is based on the windows replacement (new windows equipped with double panes glass instead of the existing single panes glass), a new heating system (new radiators for distinct thermal zones and one more efficient central plant) and adding VAV systems with electric chillers for the new services in the lower storeys.

In the framework of BRITA Project (2004), during the preliminary design phase of the

Figure 1: Photo of the building.

building, appropriate alternative technologies for lower energy consumption were assessed (Butera et al., 2004). For this, envelope measures are finalized to reduce the U-value of opaque surface (insulating layer in the air gap of the walls, roof insulation), even if not prescribed for building retrofitting, and windows (low-e glazing instead of the predicted standard double panes glass). Instead of the radiator heating system, the advanced energy rehabilitation based on a radiant ceiling heating system (low temperature operating) with forced primary air supply is implemented.

Each apartment of the hostel will be equipped with presence detectors coupled by daylighting sensors to control both the electricity (for illumination and for power outlets), and the thermal (hot water circulation on the radiant ceiling pipes and primary air cycle) energy supplying.

The energy production is provided by a trigeneration (CHP) system for heating, cooling with absorption chillers and electricity.

A BEMS (Building Energy Management System) will be integrated for providing energy only when actually needed and for ensuring the optimum management of the CHP system.

2. BUILDING CONTROL STRATEGIES

Several times people unintentionally over-use the energy supplies and the effects are often significant in terms of energy wastes. Some cases are listed below.

- Activated the artificial light when required during the day, it is common to forget to turn it off even if the natural daylighting level is become adequate.
- It happens to forget to turn off lights or to leave the electric appliances in a stand-by mode after their utilization.
- The windows periodically opened to renew indoor air (especially in absence of forced ventilation system for primary air supply) is left opened more than the needed time, especially when the thermal energy supply rises to ensure the temperature set point.
- It is more instinctive to open the window instead of reducing the thermostat set point when periodically indoor temperature becomes higher (i.e. because of the increasing internal heat gain).
- Many people usually don't care to turn off the local heating or cooling energy system while going out from the apartment.

The amount of energy wastes are related, on one hand, to the carelessness of the people behavior (in particular when any additional cost due to the higher energy consumption is not need to pay, i.e. in a hotel) and, on the other hand, to the absence of any equipment dedicated to perform specific controls.

In view of the above points, it was decided that each apartment of the hostel will be equipped with presence detectors coupled by daylighting sensors, for controlling both the electricity and the thermal energy supply.

It has to be mentioned that the new metal ceiling radiant system sounds more adequate to integrate the control strategies by managing hot water circulation on the radiant ceiling pipes and primary air cycle. In fact when the heating system is activated, in few minutes the aluminium ceiling temperature rises, providing a suitable value of mean radiant temperature to obtain comfort conditions.

3. ENERGY PERFORMANCES

VisualDOE (DOE-2.1.E-119 code) simulation tool was used to estimate the energy savings. The comparisons were made among the conventional refurbishment and the improved energy saving solutions, reaching the advanced rehabilitation results i.e. the synergetic effects of the several adopted measures.

Each building simulation model is divided into 68 thermal zone based on their orientations, levels in the building, uses, occupations and related HVAC systems. The simulation models were implemented for different cases as follows:

- *Case EX338*: base case, referred to the conventional refurbishment (cooling systems serve 15% of the building requirements).
- *Case 338ISOL*: base case (case EX338) improved with thermal insulation of opaque surfaces and low-emissivity glass instead of the conventional double panes.
- *Case 338RAD*: base case EX338 with low temperature heating system (radiant ceiling system) instead of conventional heating sys-

tem (the 85% of the entire building, except the zones for services in the lower levels).

- *Case 338CONT*: base case EX338 with control strategies scenario: the activation of electrical and thermal supply based on the presence detectors (the portions of the hotel effectively occupied by the people was allowed by an appropriate set of occupancies schedules, Fig. 2), as well as the activation of the artificial lights depending on the natural illumination level verified by the daylighting sensors.
- *Case BRITA*: the entire figures foreseen in the advanced rehabilitation strategy. In this simulation model all the previous solutions are contemporary present.

The simulation results in terms of building energy demand reduction in respect of base case EX338 are shown in Figure 3. It can be seen that a 22% reduction for thermal insulation strategies on building envelope (case 338ISOL), a 12% reduction of thermal energy demand for both the cases of lower water temperature supplying (radiant heating, case 338RAD) and energy supplied when people are present (case 338 CONT) could be obtained.

Moreover, variation of electricity and cooling demands are appreciable only in 338CONT case (as well as for BRITA case, obviously), however, if the artificial light control is also activated, consequently, the cooling needs decreases as well (because of the reduction of the heat generated by the electric lamps).

The comparison between the two extreme cases (EX338 and BRITA) for the electrical annual demand patterns are shown in the Figs. 4 and 5.

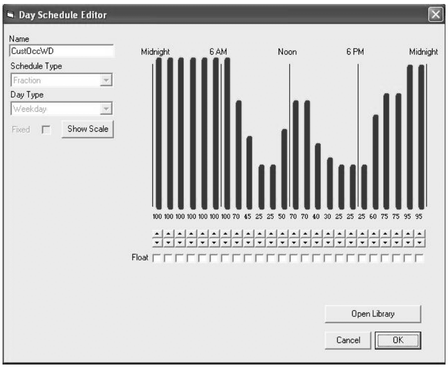

Figure 3: Example of occupancies schedule.

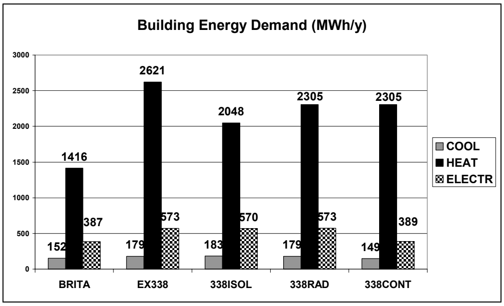

Figure 4: Comparison among annual energy demand.

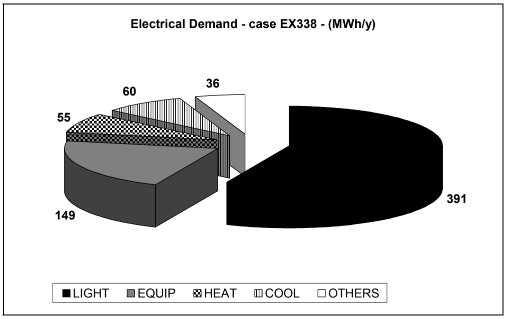

Figure 5: Electrical demand pattern (case EX338).

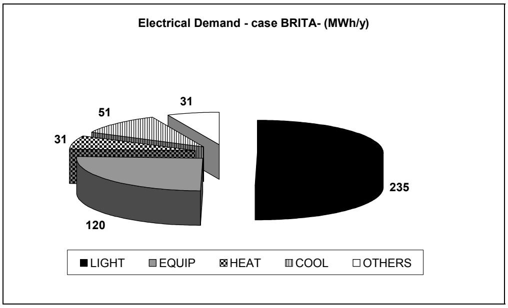

Figure 6: Electrical demand pattern (case BRITA).

In relation to the base case EX338, the cumulative energy savings for electricity obtained in BRITA case are as follows.

Because of the control systems, 40% reduction in the use of artificial light, 19% reduction electricity demand for equipments, and 15% reduction for electric loads related to the cooling systems are obtained. In addition to the control strategies, the improved envelope coupled with the lower temperature for radiant heating system results 44% reduction in electrical loads for heating systems. A reduction of 14% is obtained for the other appliances (i.e. pumps and fans).

In order to assess the energy consumptions the two extreme cases were simulated with con-

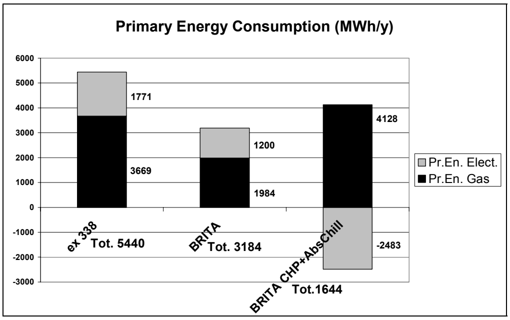

Figure 7: Primary energy consumptions.

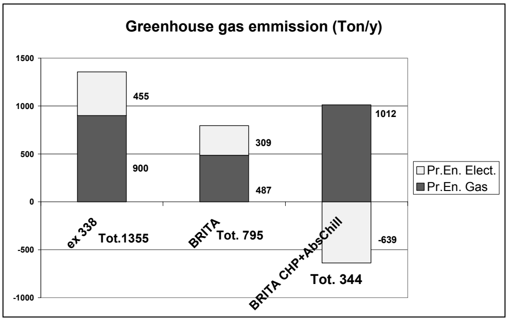

Figure 8: Greenhouse gas emissions.

ventional plants (natural gas hot water boilers and air condenser electric chillers) as provided by the conventional refurbishment. Moreover, a last simulation model was built for completing the advanced rehabilitation scenario: the BRITA-CHP+AbCh case that, based on BRITA case, includes combined heating and power generators (natural gas CHP otto cycle) coupled with single-stage absorption chillers. The comparison in terms of primary energy consumptions (national electric generation 39% of efficiency) is reported in Figure 6.

Obviously, the thermal driven (based on heating demand in winter and on cooling demand in summer) co-generator scenario implies an annual electrical energy production surplus feed to the national grid.

Referring to the conventional energy production system, improved primary energy savings with the BRITA solutions are about 40% in respect of base case (EX338). Moreover, about 30% of additional energy saving is obtained with tri-generation system (BRITA CHP+AbsChill) because of the electric surplus feed to the grid.

Figure 7 shows the estimated values of greenhouse gas emission (equivalent CO_2) corresponding to different cases analysed.

It can be seen that in the advanced case (BRITA-CHP+AbCh) more than 70% of GHG emission reduction can be achieve with respect to the conventional rehabilitation (case EX338).

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