PASSIVE RETROFITTING OF OFFICE BUILDINGS: THE OFFICE PROJECT

M. Santamouris, E. Dascalaki and I. Koronakis

Group Building Environmental Studies, University of Athens, Department of Applied Physics, University Campus, Build. PHYS. -V, Athens, GR157 84
Email: edasc@dap.uoa.gr

ABSTRACT

OFFICE is a research project partly funded by the CEC dealing with the passive retrofitting of office buildings to improve their energy performance and indoor working conditions. The project is coordinated by the University of Athens with the participation of organizations and research institutes from eight European countries. The aim of the project is to develop global retrofitting strategies, tools and design guidelines in order to promote successful and cost effective implementation of passive solar and energy efficient retrofitting measures to office buildings. Within the frame of the project, ten office buildings located in different climatic zones around Europe are studied extensively. Case studies are carried out for the selected buildings including energy audits and monitoring activities, specific experiments as well as an assessment of the potential of proposed retrofitting scenarios for each building, with regards to the issues of energy conservation and cost effectiveness.

The final deliverables of the project are: a) Case studies presenting high quality examples of representative retrofitted office buildings in various parts of Europe b) a Rating Methodology classifying office buildings according to their energy consumption, CO_2 production and indoor thermal and visual comfort c) an Atlas describing the technical and economical potential for energy conservation of selected retrofitting scenarios for defined types of office buildings in different climatic zones of Europe and d) Design Guidelines, performance criteria and methodologies for best practice giving credit for renewable energy sources incorporated into office buildings, all presented in the form of a Handbook. Results from the assessment of the potential of various retrofitting scenarios proposed for each case study are included in the Handbook in the form of brochures.

This paper gives an analytical description of the activities carried out within the frame of the project and describes the resulting final deliverables.

1. INTRODUCTION

Energy consumption in office buildings is one of the highest compared to the consumption of other building types. The annual energy consumption in office buildings varies between 100 to 1000 kWh per square meter, depending on geographic location, use and type of office equipment, operational schedules, type of envelope, use of HVAC systems, type of lighting etc. Energy in office buildings is mainly consumed for heating, cooling and lighting purposes, while a significant portion is devoted to the consumption of office equipment.

Retrofitting of existing buildings presents by far the largest potential for the incorporation of renewable energy technologies and energy efficiency measures into buildings. Within many European countries there is considerably higher activity in retrofitting and reusing buildings than in constructing new ones. In the office sector, retrofitting of the post war stock is seen in the property market as the major area of activity for the next few years and thus the incorporation of renewable energy sources could be significant. However, existing energy related retrofitting actions tend to neglect almost completely aspects related to passive solar heating, daylighting and passive cooling of buildings.

OFFICE is a research project partly funded by the CEC dealing with the passive retrofitting of office buildings to improve their energy performance and indoor working conditions. The project is coordinated by the University of Athens with the participation of organizations and research institutes from eight European countries, namely: France, Italy, Germany, Switzerland, United Kingdom, Norway, Sweden and Denmark. The aim of the project is to combine knowledge and expertise acquired through recent research actions on the development of passive solar heating, passive cooling and daylight techniques, with best expertise on retrofitting of office buildings regarding architectural and engineering interventions.

Application of energy conservation techniques, as well as the use of solar and ambient alternative energy sources in offices, requires knowledge of the specific energy characteristics of the buildings. The later depends strongly on the conditions in the various climatic zones in Europe. In order to investigate the possibilities of successful application of retrofitting interventions on buildings located in various climatic zones, a total of ten buildings have been selected to be thoroughly investigated as case studies. The selection of the buildings was based on the requirement to derive a group of buildings presenting the maximum possible variety of features related to the building typology, client requirements, construction details, location, thermal quality of the envelope, type of utilized energy sources and energy consumption. The list of the selected case studies covers a wide range of climatic zones around Europe, namely: North European Coastal (3 buildings), Mid European Coastal (1 building), Continental (4 buildings) and Southern Mediterranean (2 buildings).

Monitoring activities in the selected buildings included thorough audits and recording of the indoor and outdoor environmental conditions as well as of the consumption per energy-end use. Retrofitting studies involved an assessment of the impact of proposed interventions on the energy performance of the buildings as well as an economic evaluation of each proposal. The results for each case study were presented in the form of brochures presenting high quality examples of representative retrofitted office buildings in various parts of Europe.

Data from energy audits in the above buildings, as well as from the energy simulations were used in order to develop a Rating Methodology classifying office buildings according to their energy consumption, CO_2 production and indoor thermal and visual comfort. Simulations were also run in order to derive the necessary information for an Atlas describing the technical and economical potential for energy conservation of selected retrofitting scenarios for defined types of office buildings in different climatic zones of Europe. Finally, the main research results of the project in the form of design guidelines, performance criteria and methodologies for best practice giving credit to renewable energy sources incorporated into office buildings, were all included in the Designer's Handbook.

2. MONITORING OF THE CASE STUDIES

The present state of each of the selected buildings was thoroughly investigated using standardized questionnaires for energy as well as indoor air quality auditing. In situ inspections were carried out by a group of experts in order to collect data regarding the architectural and engineering characteristics as well as past energy consumption data for the case studied buildings. Fu thermore, the actual thermal and energy performance of the buildings was monitored for an 11-month period. During this period the following data were recorded on an hourly basis:

- Climatic data from the nearest meteorological station: outdoor air temperature and humidity, global solar radiation, wind speed and direction
- Indoor air temperature at representative locations on the typical floor
- One supply and one central exhaust air temperature

Furthermore, the total energy consumption and its breakdown for heating, cooling, lighting and equipment was monitored either using special watt-meters or by reading the meters already installed in the buildings. In the later case the recorded values were monthly averages.

Short term monitoring activities involved extensive and detailed hourly recording of indoor and outdoor temperature and energy consumption for periods of one month during summer and winter. Specifically the following parameters were monitored:

Outdoor conditions (either at the location of the case study or at the nearest meteorological station): air temperature and humidity, wind speed and direction, direct and diffuse solar radiation.

- Indoor air temperature at various locations in the building
- One cent al supply air temperature
- One exhaust air temperature
- Electrical consumption for the whole building
- Electrical consumption per energy-end use for the whole building

Additionally, specific experiments were carried out in order to assess the quality of the indoor environment regarding lighting and ventilation. The information collected during the monitoring activities and the audit was used in order to spot the problems in each building and specify the main areas of intervention. Moreover, the data from the short term monitoring periods were used in order to develop more accurate computational models representing the actual state of the buildings as close as possible. These models were the basis for the assessment of the retrofitting interventions proposed for each case study.

3. RETROFITTING SCENARIOS

Based on the information collected during the energy audits as well as on the analysis of the data from the monitoring campaigns in the investigated buildings, specific retrofitting interventions were proposed for each of them according to their individual problems and requirements as they came out from the above analysis.

Efficient application of energy retrofitting measures in office buildings is mainly related to the application of systems and techniques dealing with:

- The use of passive solar retrofitting options
- The use of measures related to the rational use of energy

The proposed interventions can be classified in the following categories:

- Actions aiming to improve the envelope of the building and introduce passive solar heating techniques and components.
- Actions aiming to result in a reduction or, wherever possible, complete removal of the air conditioning.
- Actions aiming to improve lighting conditions, decrease the energy consumption for artificial lighting introducing daylight.
- Actions aiming to improve the efficiency of the selected building services, like HVAC system, production units and domestic hot water.

Actions aiming to improve the envelope of the buildings were classified in the following major types:

- Reduction of the heat transmission through the building envelope by insulating the external walls, roofs and floors.
- Reduction of the heat transmission through windows and doors, by replacing frames in bad condition with new ones as well as by replacing single with double glazings .
- Reduction of infiltration by sealing the window frames.
- Integration of passive solar heating and daylight components.
- Improvement of natural ventilation and solar control.

Retrofitting actions aiming to improve thermal comfort conditions during the summer period and decrease the cooling load of the buildings involve the following interventions:

- Interventions aiming to decrease solar and internal heat gains in the building. These include mainly use of more efficient and appropriate solar control devices, as well as minimization of internal gains.
- Interventions aiming to modulate the solar and internal heat gains in the building. These involve the use of night ventilation as well as techniques taking advantage of the thermal mass of the building.
- Interventions aiming to dissipate the excess heat of the building into a heat sink of a lower temperature like the ambient air, the ground, the sky and the water. These involve the use of ceiling fans, natural ventilation strategies, economizer control techniques and use of evaporative cooling systems.

In order to investigate the effectiveness of various retrofitting interventions to the improvement of the energy performance of the investigated buildings, different types of actions were studied, ranging from simple to global approaches. Regarding the retrofitting interventions considered for each building, three types can be distinguished:

- Measures, involving simple actions affecting only one of the above categories
- Scenarios, involving combined actions affecting only one of the above categories
- Packages, involving integrated solutions involving the most efficient combination of actions on all of the above categories

The retrofitting studies for each building involved an assessment of the proposed measures, scenarios and packages from both energy conservation and economy related aspects. The impact of each action on the energy performance of the buildings was assessed through energy simulations using computer models 'calibrated' so as to describe the actual state of each building as close as possible. The 'fine tuning' of the models was based on the data collected during the short term monitoring periods. The economic feasibility of each of the proposed actions is expressed in terms of the pay back as well as amortization period.

4. RATING METHODOLOGY

Two types of methodologies are actually considered in the framework of the OFFICE project:

a) Methodologies classifying buildings according to their energy consumption for all cases where only energy data are available.

b) Methodologies classifying buildings according to their energy consumption and indoor environmental quality involving thermal comfort, visual comfort and indoor air quality.

The aim of the new labelling scheme is to improve indoor environment together with a reduction of the energy consumption and environmental impacts, while other existing rating methodologies mainly focus on energy consumption only. Three techniques have been considered.

A) A ranking methodology based on a multi-criteria analysis technique to rank buildings taking account of several criteria related to:
   - Energy use for heating; cooling, lighting and other appliances
   - Impact on environment (greenhouse effect, acidity potential, etc,.)
   - Indoor environment quality.

The methodology is based on a total of 40 parameters. The ranking methods can be used for:

- ranking buildings of a given building stock according to several criteria, thus helping in the determination of priorities for retrofit
- ranking various alternative retrofit scenarios, helping the choice of "the best" one, not only from one point of view, but for a combination of criteria
- determining if a retrofit building is really better than the original one, from all the considered points of view.

B) Energy rating methodologies, based either on:
   - the objective definition of disjoint classes for energy consumption from statistical data, and crisp rating the considered building into one of these classes; or
   - using the Fuzzy C-means algorithm to define, from statistical data, building clusters with respect to energy consumption and location of the considered building into one of these clusters. The clusters are positioned in a two- or three-dimensional space, each coordinate being a parameter characterising the building (e.g. energy for heating, for cooling and for other appliances).

C) A relative classification technique, based on the use of principal component analysis to rank many buildings from a given building stock according to several criteria related to energy and environment (internal and external). The methodology uses as classification parameters quantitative (energy) and qualitative parameters (comfort, daylight, indoor quality).

The rating methodologies are used to compare a given building with standards or with an average situation, and to determine if the considered building complies with regulations.

5. ATLAS

The OFFICE group has developed an Atlas describing the potential for energy conservation of the selected retrofitting scenarios. The Atlas is developed in the highly illustrative environment of MATLAB. The results obtained from each building and each scenario are given for all the defined office building types and the main European climates. The Atlas contains information on the developed rating and ranking methodologies and major information from the OFFICE program.

6. HANDBOOK

The Handbook aims to provide specific guidance to designers who wish to reduce energy use in existing offices or refurbish an office block using the latest energy saving and environmentally friendly techniques. The main research results from the OFFICE project are given in the form of guidelines together with the brochures from the ten case studies standing as examples of best practice retrofitting of office buildings.