Upgrading the energy performance of office buildings in Greece -Trends and potentials.

Chris J. Koinakis
Technological Educational Institute of Thessaloniki, Thessaloniki, Greece, e-mail: chrisko@civil.auth.gr

John K. Sakelaris
National Technical University of Athens, Athens, Greece, e-mail: jsakel@central.ntua.gr

ABSTRACT

In this paper the energy performance and the potentials of the energy savings decrease in two office buildings in northern Greece are examined, within the frames of a renovation project in office buildings of the public sector. Energy audits and simulations were performed for this reason. Significant energy savings were achieved in both cases. The most effective measures were the installation energy efficient windows, the improvement of the insulation of the roof and the external walls, the solar shading and the natural ventilation strategies, the installation of highly efficient HVAC systems and the upgrading of the lighting. The energy savings overcome the problems of the increased ventilation that proved to be necessary in the lounge areas and the problems of the very increased internal gains due to the new increased IT equipment. Adequate and flexible energy management and upgrading strategies can be implemented to the existing building project plans.

1. GENERAL

The energy consumption of the office buildings is among the highest of the building sector in Greece, after the hospital buildings. The internal gains are increased in office buildings due to the electrical equipment, especially after the recent IT equipment renovation projects. The above mentioned phenomena combined with the increased thermal comfort demands of the average office building used, increased the total number of the air-conditioned area of buildings at a total of at least 1200 million s.m (Bluyssen et al. 1996), (Wittchen et al. 2002), (Wong et al. 2008).

In this paper the energy performance and the potentials of energy savings decrease in two office buildings in northern Greece are examined, within the frames of a renovation project in office buildings of the public sector. These buildings were selected as a specimen of office building in Greece, (Koinakis 2000-6). According to relevant energy studies in common-type office buildings in Northern Europe the annual energy consumption varies from 270 to 350 kWh/m2. In the United Kingdom the mean average consumption in low energy office buildings is 131 kWh/m2, compared to 440 kWh/m2 in common office buildings. In a relevant study in France the buildings were categorized as urban and suburban-rural and the mean annual energy consumptions were 165 and 145 kWh/m2 respectively, as a result of renovation trends and of the increased cooling demands. In a relevant study in Athens in the 1990s the mean annual energy consumption was found 187 kWh/m2, 13% of which were cooling demands.

In the energy study of the examined buildings the general directives of energy auditing in E.U. office buildings are implemented and the relevant office building program was also taken into account.

2. ENERGY SAVING STRATEGIES

The first data collection and process began at the primary energy audit, where the general building data were collected, based on the building construction studies and plans and on questionnaires. This phase was followed by the examination of the energy consumption strategies, implementation also energy simulations. The demands of the overall construction development program of the public offices (roll out) were also taken into account, as well as the need to have as many office buildings operating as possible. The main outcomes of this “phase –A” procedure are the following:

- The cooling demands will be increased after renovation projects, in certain cases even in spring and autumn, due to the increased IT equipment, the decrease of conductivity thermal losses from the building shell and in some cases due to overheating problems.
- Emphasis should be given to the Indoor Environmental Quality (IEQ), especially increasing air changes per hour, avoiding air drafts near working areas due to natural or mechanical ventilation. In certain cases serious complains and health problems were reported related to these air drafts. Odor problems and lack of fresh air were also reported near the lounge areas during peak hours.
- Some advisable energy measures, unfortunately, could not been implemented due to technical and economical reasons. For example external shading and complete thermal insulation of the entire building shell was not possible to be implemented in short-term development program, due to budget and roll out problems. It was therefore essential to be shifted to the mid-term program.
- Low level of the artificial lighting, even below of 300 lux/m2 was found in some cases, as well as glaring problems due to uncontrolled day lighting especially in IT working areas.

The above-mentioned outcomes lead to energy consumption strategies adapted to the specific building use. The main points of these strategies are referred in brief:

- The increased cooling demands were faced at first by hybrid and mechanical ventilation systems. Night cooling was implemented through certain large openings. Then they were installed split VRV air conditioning units BMS controlled.
- The hybrid and mechanical ventilation helps to achieve adequate indoor air quality in the office spaces, combined with mixing of indoors and outdoors air when necessary. Air duct grids were adjust to avoid air draft problems, near the working areas and to insure uniform air mix.

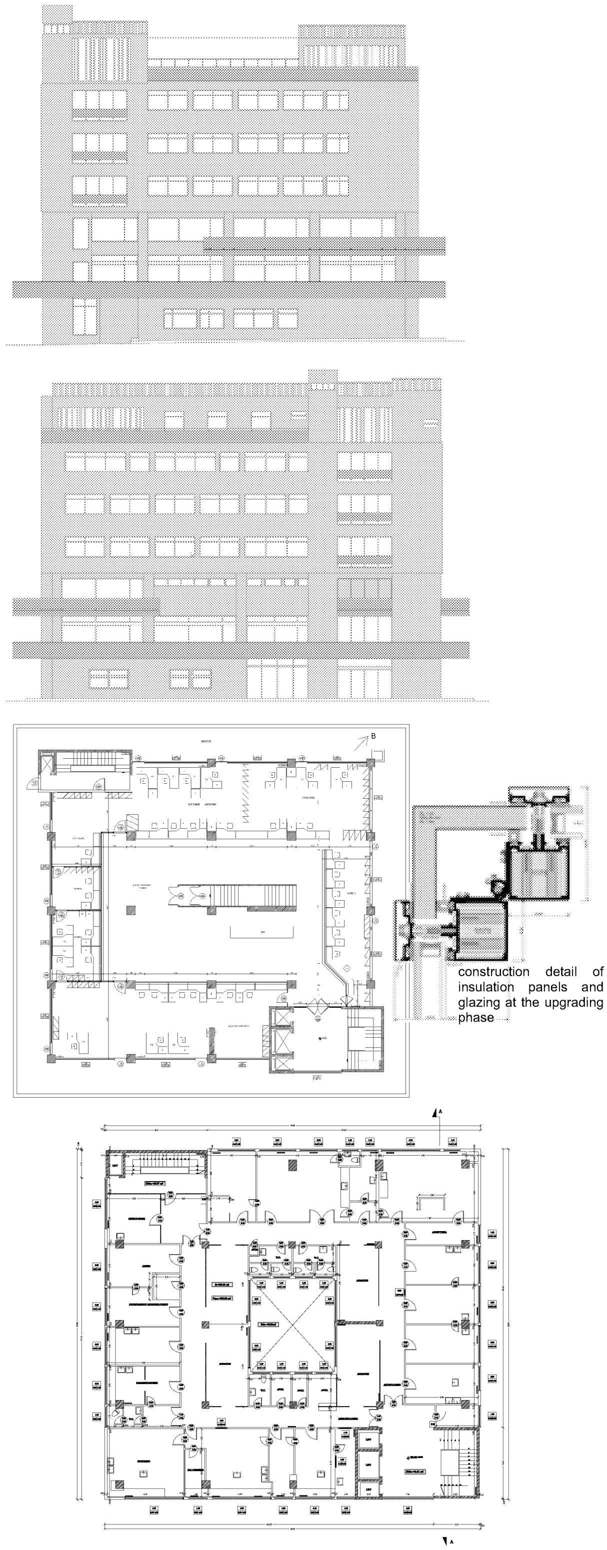
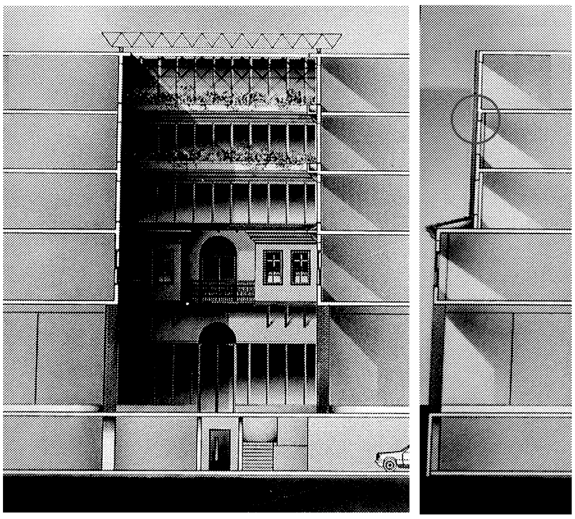
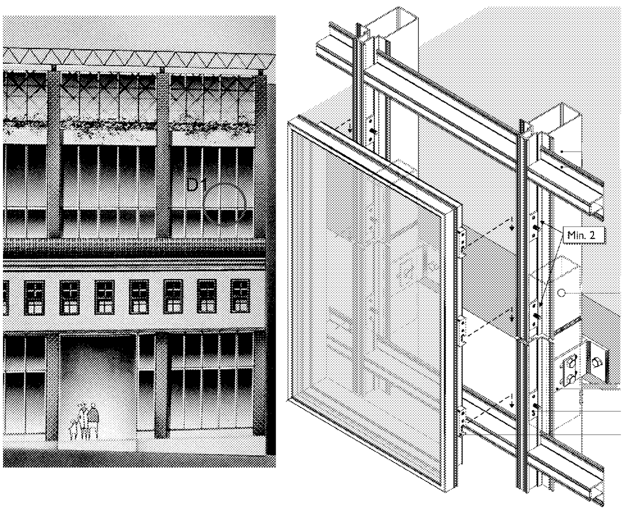


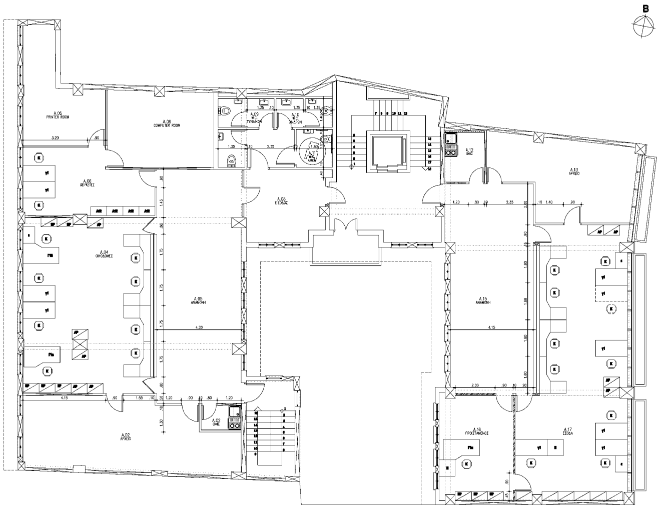
Fig. 1. The office building in Thessaloniki. Typical plan views, facades and construction details of the building shell during the upgrading phases.

- The advisable energy measures that could not implemented were either replaced by close-by solutions, or programmed for mid-term implementation. Some of the insulation works of the buildings envelope were programmed for the near future.
- The low level of the artificial lighting was faced implementing low consumption fluorescence tubes achieving values of 500 lux/m2. The glaring problems were solved using venetian blinds and in certain cases light selves in windows.





D 1: construction detail of curtain wall during the upgrading phase



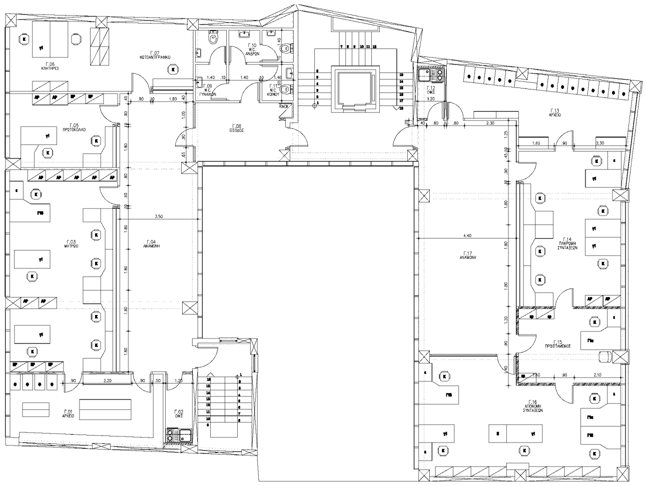


Fig. 2. The office building in Kozani. Typical plan views, facades and construction details of the building shell during the upgrading phases.

3. INITIAL CONDITIONS

The initial (pre-upgrading) conditions of the buildings are presented in table 1, based on the in-situ audits, on the construction studies and on the annual fuel and electricity bills. The indoor environment conditions of the initial conditions were classified according to questionnaires in three categories: adequate, acceptable and non-acceptable conditions.

Table 1. Initial conditions of the examined buildings

Year of construction	1967	2000
Location	Thessaloniki	Kozani
Use	Office and medical laboratories	Offices
Heated/non heated area in m2	7120/6210	4480 /3900
Number of floors	7+basement	5+basement
Shell . roof insulation	- / inadequate insulation in the roof	Greek insulation code of 1978
External openings	Single glazing and wooden non insulating and non weatherproof windows	Double insulating glazing and aluminum weatherproof windows
Shading devices	Only internal shading in 15% of the required area	None
Heating system	Oil boiler and calorifiers	Tele-heating and auxiliary oil boiler and fan coils.
Heating period (months per year / oper. hours per day)	5,5 m / 16 h	7 m / 9 h
Annual specific heat consumption	190 KWh/m^2	160 KWh/m^2
Thermal comfort during winter	Non acceptable	Acceptable
Cooling system	Air duct water-cooled A/C system. A few isolated A/C split units	No cooling
Thermal comfort during summer	Non acceptable	Acceptable
Cooling period (months per year / oper. hours per day)	4 m / 12 h	3 m / 10 h
Ventilation	Mechanical ventilation in isolated rooms of special use (microbiological laboratories, WCs etc)	Mechanical ventilation in WCs only.

4. IMPLEMENTED UPGRADING STRATEGIES

4.1 Heating

The audits and the energy simulations proved that the most effective energy efficiency measure is the replacement of the external windows, with new double-glazing weatherproof windows and special openings at the top for natural ventilation in selected areas and hours. Two window types were selected with thermal loss coefficient of 2,7 and 1,8 W/m2K for the buildings in Thessaloniki and the Kozani respectively. The heating demand loads are furthermore decreased when thermostats are placed in the inner spaces. The decrease is 2,5% and 3,5% for the buildings in Thessaloniki and the Kozani respectively. The uncontrolled ventilation was significantly reduced due to the weatherproof windows and the mechanical and hybrid ventilation. Solutions leading to lower ventilation rates were rejected due to poor IEQ, especially at the lounge areas. In there areas adjustable extensive ventilation was implemented to achieve 6 ach. The use of recuperation of heat could be implemented in these cases, but it is planned for the near future due to technical reasons.

A BMS system was used to control the air-conditioning VRV system, especially for the summer period. According to the simulations, a 10C decrease of the thermostat temperature could decrease the heating demands at 3,5%

4.2 Cooling

The decrease of the cooling demands during the summer is achieved in the examined buildings, mainly -in order of importance- by a) movable shading (venetian blinds), b) hybrid night cooling and c) by high efficient air-conditioning system. In the building of Thessaloniki the cooling demand is decreased by 37%, because it is exposed to sun in all its facades. In this building the old duct air conditioning system with the low efficiency was replaced by a highly efficient VRV air conditioning system. In the building of Kozani the cooling demand is only 19%, because the shading effect is lesser because the glazing is light absorbing. The thermal comfort area could be increased by 2 and 2,5 0C (in the Thessaloniki and the Kozani building respectively) due to the velocity increase and air humidity drop.

4.3 Natural lighting

The replacement of old technology incandescence and fluorescence lamps, with new technology lamps, lead to a 19% consumption decrease, and to an increased luminance level of 500 lux/m2. If the luminance level was not improved the consumption could be decreased by 48%. The natural lighting level and the glare problems were also improved near the IT equipment areas, implementing venetian blinds.

4.4. Internal gains and IT equipment

In both examined cases, it was not possible to decrease energy consumption due to IT equipment, because an IT renovation and implementation project was on the run. A large number of personal and mainframe computers, CRT and TFT displays, racks, and other similar equipment was installed and the electricity consumption was increased up to 2,5 times. Therefore, the heating demands are decreased and the cooling demands were increased, battling the cooling measures described in the previous paragraph.

4.5 Potentials for future (mid-term) upgrading

The potentials of future mid-term upgrading is examined alternatively for the third-phase, following the initial phase and the phase of the implementation of the upgrading strategies. In this future (mid-term) upgrading, the main parameters are: highly efficient automated elevators, replacement of old boilers, extensive external shading, equipment for recuperation of heat at the mechanical ventilation system and additional insulation of the building shell. The proposed measures per phase and building are presented in Table 2.

Table 2. Upgrading actions and phases of implementation

Upgrading phase	*Proposed energy efficiency measures*	*Building in Thessaloniki*	*Building in Kozani*
Implemented upgrading strategies	Roof insulation	Improvement	No
	Double glazing	No	No
	Heating system	Replacement	Improvement
	Cooling system	Replacement of old A/C units with new efficient VRV units	Installation of central fan coil cooling system
	Mechanical/hybrid ventilation	Installation (90%)	Installation (10%)
	Internal shading	Installation	Installation
	Energy efficient lamps	Yes	Yes
	Improvement of natural lighting	Yes	Yes
	Energy efficient office IT equipment	Yes	Yes
future (mid-term) upgrading	Wall insulation	Yes	Yes
	Roof insulation	Re-construction	Improvement
	External shading	Yes	No
	Heat recuperation at the ventilation system	Yes	Yes
	Elevator automations and upgrading	Complete replacement	No
	Hot water for users	Yes	Yes
	Mechanical/hybrid ventilation	Installation (the rest 10%)	Installation (the rest 90%)

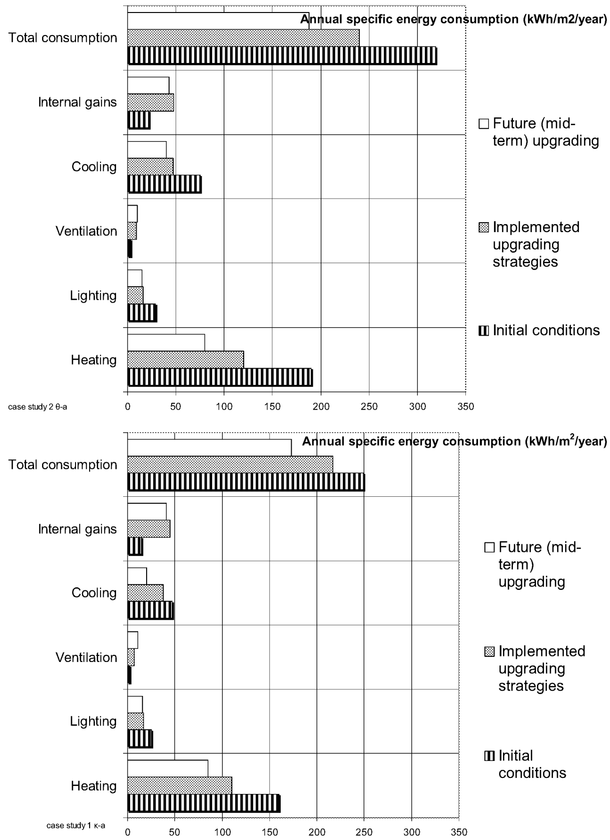


Fig. 3. Specific energy consumption for the examined office buildings, for energy balance parameters, per phase: building in Thessaloniki (upper) and Kozani *(lower)*

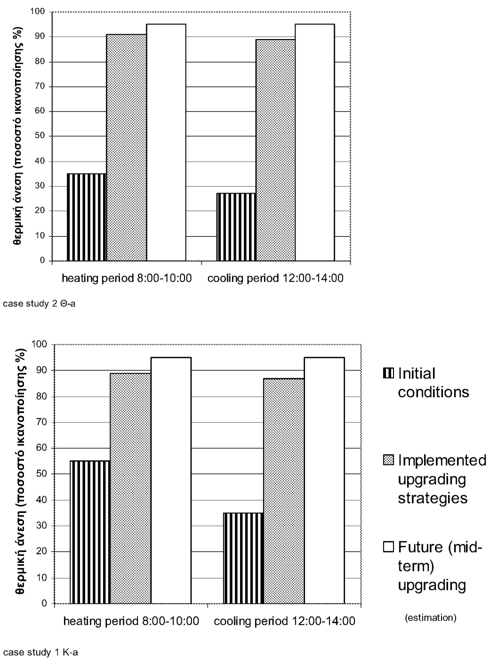


Fig. 4. Thermal comfort in the examined buildings: building in Thessaloniki (upper) and Kozani (lower)

5. CONCLUSIONS

Two representative examples of office buildings were examined in the area of Northern Greece in the cities of Thessaloniki and Kozani, within the frames of an upgrading and renovation project of office buildings of the public sector in order to improve their energy efficiency. Energy audits and energy simulations were performed for three design phases: a) the initial conditions, b) the implemented upgrading strategies and c) for the future (mid-term) upgrading. Some of the proposed measures were implemented during the existing upgrading program and the others were programmed for the mid-term upgrading, according to the roll out project. Significant energy savings were achieved in both cases. The most effective measures were the installation of double-glazing, the improvement of the insulation of the roof and the external walls, the solar shading and the natural ventilation strategies, the installation of highly efficient HVAC systems and the efficient lighting. The energy savings overcome the problems of the increased ventilation that proved to be necessary in the lounge areas and the very increased internal gains due to the new increased IT equipment.

In the office building in Thessaloniki which was constructed before the Greek insulation regulation and it is practically non insulated, the heating demand was decreased at 63% and could be further deceased at 42% if the mid-term measures are going to be implemented. The respective figures for the office building in the city of Kozani were 69% and 52% of the initial values. The cooling demands were decreased due to proper shading and natural ventilation at 63% and at 53% for the two respective phases of the Thessaloniki building. The respective values of the Kozani building were 81% και στο 43%, because the natural cooling was not implemented at the initial phase. The improvement of the thermal comfort sense of the inhabitants as traced by the questionnaires proved to be significant. Among others as derived from fig. 4, the percentage of satisfied was moved from 35% in the initial conditions phase to 91% in the implemented upgrading phase at the Thessaloniki building, during the heating period. The values for the cooling period at the same building were moved from 27% to 89% for the respected phases. These values for the Kozani building were moved from to 55% to 89% for the heating period and from 35% to 86% for the cooling period respectively.

Validating all the described upgrading action as a total, it could be derived that there are significant potentials for energy renovation and management in office buildings in Northern Greece. Adequate and flexible energy management and upgrading strategies can be adjusted to the existing building project plans. The IEQ in the working places could also be significantly improved, even from the second phase of the upgrading.

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