

Retrofitting of the General Secretariat Information Systems, Administrative office building in Athens (Greece)

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ABSTRACT: This document describes the rehabilitation of the General Secretariat Information Systems (GSIS office building) in Athens (Greece) and the description of the energy measures that were implemented aiming at the improvement of the building energy performance and the indoor environmental conditions..

The rehabilitation of the GSIS building was carried out within the frames of the European 'REVIVAL' project (Retrofitting for Environmental Viability Improvement of Valued Architectural landmarks) that was financially supported by the European Commission under the 5th Framework 'ENERGIE' Programme and had a duration from April 2003 to April 2008. The overall goal of the project was the refurbishment of non-domestic buildings from the post-war pre-energy conscious era, aiming at better energy performance and lower life-cycle CO₂ emissions than the original building or an equivalent new building.

Keywords: Energy rehabilitation, demand control ventilation, comfort, monitoring

1. THE 'REVIVAL' PROJECT

The aim of the 'REVIVAL' project was the refurbishment of non-domestic buildings with the application of energy saving techniques appropriate according to the building's construction, type, use and location. The buildings prior to their renovation were characterized by poor insulation levels, inefficient building services and degraded fabric and were subject to great potential for energy and environmental improvements. The main objective of the project was to show that the refurbishment of these buildings would result in better life-cycle CO₂ emission

performance and that it would be more cost effective than demolishing the existing buildings and re-build. Additionally, the energy rehabilitation aimed at a 50% reduction in overall energy use compared to the existing building.

Within the frames of the REVIVAL project five buildings were refurbished; one educational building, one hospital and three office buildings. The buildings are located in European countries, in France, the Netherlands, Great Britain, Italy and Greece. During the REVIVAL project, the following methodology was followed for all projects: feasibility studies in order to detect areas subject to improvement, proposal of

different energy measures and study of their impact, refurbishment and construction works, recording and monitoring of the performance of the implemented measures and post occupancy study via questionnaires to the occupants.

2. THE 'GSIS' BUILDING

2.1 Building description

The General Secretariat of Information Systems (GSIS) is a public administration agency belonging to the Greek Ministry of Economy and Finance. The building is the result of a retrofitting of a pre-existing industrial building dating back to the 60s. It is located in a central area of Athens and is easily accessed by the public transport and the underground railway (metro).

The building is of a rectangular shape measuring 115 m in length and 39 m in width and it has a total floor area of about 27,000 m² (including the basements). The building consists of: two basement floors with the parking areas, the ground floor with the department of distribution of printed material, a restaurant, an assembly hall, a small medical centre and a daytime childcare station used by the employees, a mezzanine with office areas, and four floors with the data entry rooms and office areas. Its long axis runs along a South/Southeast to North/Northwest direction.

2.2 Assessment of indoor environmental conditions prior to rehabilitation

Prior to the rehabilitation works, the existing environmental conditions were assessed in order to detect areas with malfunctions that could be subject to improvement. Spot measurements of thermal comfort, CO₂ concentration, ventilation rates and lighting levels were performed in representative office areas depending on their orientation, occupancy pattern and the possibility of natural ventilation. It was shown that: overheating was experienced in many densely occupied

areas and in office areas that are located in the perimeter of the building with increased solar gains. Additionally, ventilation was not adequate especially in internal office areas with no possibility of natural ventilation. Moreover, the CO₂ concentration was exceeding the values of 1000ppm in many office areas. Finally, the lighting levels were acceptable in the majority of the office areas and exceeded the required levels of 500 lux.

More specifically, thermal comfort was assessed via temperature sensors located in representative office areas. The monitoring results showed that the thermal comfort levels were acceptable only in naturally ventilated office areas with a few number of people and equipment thus limited internal gains. In the case of office areas that were located in the perimeter of the building, with increased internal gains and no adequate natural ventilation thermal comfort levels were characterised as unacceptable. Specifically, taking temperature of 24 °C as a means for thermal comfort, it was shown that in the majority of the office spaces the indoor temperature was exceeding 28 °C even 30 °C.

The monitored CO₂ levels in many office areas were exceeding 1000 ppm. Given the fact that the majority of the offices were non smoking areas, were partially occupied and that prior to the monitoring the windows in all monitored zones were open, measures need to be taken for the improvement of the indoor air quality and the CO₂ concentration to be remained within the comfort zone.

Prior to the rehabilitation works, the monitored energy consumption by the existing B.M.S. for the period 2000 was: 53.6 kWh/m² for heating, 87.9 kWh/m² for cooling, 46 kWh/m² for lighting and 26 kWh/m² for electrical appliances.

In comparison with office buildings of similar size in Greece, the energy consumption for heating, cooling and lighting was rather high and the refurbishment aimed at an overall energy consumption less than 150 kWh/m² that

currently represents the typical passive construction in Greece.

3. REHABILITATION OF THE GSIS BUILDING

The rehabilitation aimed at a low energy and sustainable design optimising the building envelope while improving the indoor environmental conditions and reducing the energy consumption and CO₂ emissions of the building.

Possible energy interventions were proposed and studied. The proposed energy interventions that finally were implemented include the upgrade of the HVAC systems and the installation of shading devices in the south and west facades of the existing building structure.

3.1 Improvement of the building envelope

To prevent overheating in the office areas to the perimeter of the building high reflectivity shading devices are installed in the south and west facades to control the solar gains both in winter and summer. Additionally, the double glazing of the north façade is replaced with double low e glazing in order to contribute to energy savings and to improve thermal comfort in the perimeter office spaces.

3.2 Improvement of the HVAC system and lighting installation

The operation and the control of the heating and cooling systems are upgraded.

Specifically, the control of heating is performed at distribution level. Circulating pumps of the inverter type are installed and connected to the BEMS. Additionally, energy meters are installed to monitor the overall energy consumption.

The control of the cooling is performed at the level of the user and at the distribution level. Vans are installed in the fan coil units to control the water flow for cooling. Fans are connected to thermostats. Central thermostats/sensors of temperature are

installed for each fan coil unit or group of units that provide the user the capability to increase or decrease the temperature by $\pm 5^{\circ}$ C. Additionally, energy meters are installed to monitor the overall energy consumption.

Concerning the lighting system, the existing luminaires in the majority of the office spaces are replaced with energy efficient fluorescent lamps with electronic ballasts and dimming.

3.3 Improvement of the indoor air quality and passive cooling

Indoor air quality is kept in the desired levels by controlling the CO₂ concentration in the office areas. To avoid any probability of poor indoor air quality and maximizing the possible energy savings, the “demand control ventilation” technique is used with the installation of CO₂ sensors. The CO₂ sensors control the ventilation rate through the BMS. When the required CO₂ levels are exceeded extra fresh air is supplied into the office areas via the central ventilation system.

Ceiling fans are installed in the densely occupied office areas to extend the thermal comfort to an air indoor temperature of 28.5 °C.

The operation of the ceiling fans is grouparised in office zones and controlled by the BMS.

3.4 Use of renewable energy – photovoltaics

Photovoltaic panels (of total area 25.8m²) are installed in the terrace of the GSIS building. The panels are placed facing north and with an inclination of 30°. The produced energy is supplied to the lighting installations and auxiliary systems of the third and fourth floor of the building.

3.5 BMS

The existing BMS is expanded to include and control all the new operations. In order to avoid wiring and to easy adapt the system to future needs, the system is wireless.

The BMS records the energy consumption for heating, cooling and

lighting, indoor temperatures, relative humidity, CO₂ concentration, lighting levels, operation of the ceiling fans and the demand control ventilation.

4. MONITORING

After the end of the rehabilitation works, a detailed monitoring is carried out aiming at recording the overall and specific energy consumption of the building. The protocols and monitoring techniques that were used have been established either by international bodies and organisations or have been developed in the frame of previous research projects. According to the duration of the measurements and the methodology, the monitoring is distinguished in long-term and short term period. In the case of the long-term monitoring parameters are measured on a continuous basis with duration of 1 year by the BMS. The measurements consist of daily (hourly) readings. The short term-monitoring was carried out with spot measurements for a period of 1-3 days.

4.1 Short term monitoring

After the end of the rehabilitation works short-term monitoring was performed in representative office areas of the GSIS building to assess the quality of the indoor air quality. The monitoring took place during the period: 29/03/07 and 03/04/07 and included measurements of: CO, VOC concentration, and concentration of particles PM₁₀, PM_{2.5} and PM₁.

4.2 Methodology

Measurements of carbon monoxide and VOC levels were performed at a minute interval at the various zones of the buildings, over a 20-minute period, during the occupation period under working conditions. The tracer gas technique was used for the monitoring of the CO and VOC levels with a multigas analyser of Bruel and Kjaer, type 1302.

4.3 CO concentration

Carbon monoxide (CO) is a colorless, practically odorless, and tasteless gas or liquid. It results from incomplete oxidation of carbon in combustion. Carbon monoxide is life-threatening to humans, inhaling even relatively small amounts of it can lead to hypoxic injury, neurological damage, and possibly death. Common sources of CO that may lead to poisoning include house fires, tobacco smoke, gas space heaters; leaking chimneys and furnaces; back-drafting from furnaces, gas water heaters, wood stoves.

The ASHRAE standards for indoor CO concentration are 9 ppm for 8-hour exposure. According to the national standards T.O.T.E.E 2425/86 the maximum acceptable CO concentration is 55 mg/m³ (48.03 ppm)

In all the office areas the measured levels of CO are much lower than the permitted concentration (9ppm). The diversity of the measured values may be attributed to the presence of smokers in some of the office areas.

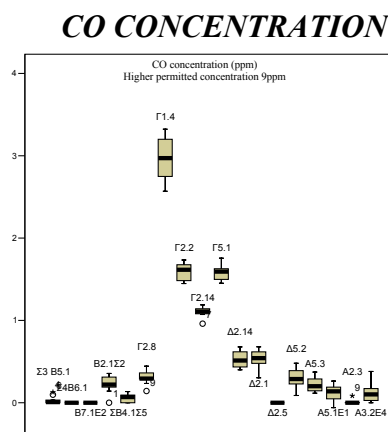


Figure 1: Measured levels of CO concentration in representative office areas

4.4 VOC levels

Volatile organic compounds (VOC) are emitted as gases from certain solids or liquids in the interior of buildings. They can also originate from the external environment if the area is locally affected. VOC include a variety of chemicals, some of which may have short and long-term adverse health effects. Concentrations of many VOC are consistently higher indoors than

outdoors. VOC are emitted by a wide array of products including paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions.

No standards have been set for VOCs in non industrial buildings. However, according to studies [1], [4] the maximum acceptable concentration of VOC varies according to the effects that can have to the human health. Therefore, areas with VOC concentration less than 0.2 mg/m³ can be characterized as 'comfortable'. VOC concentration between 0.2 mg/m³ and 3.0 mg/m³ can be responsible for possible irritation and discomfort according to the interaction with other environmental parameters. VOC levels between 3.0 mg/m³ and 25 mg/m³ can be responsible for the development of headaches and discomfort. Additional neurotoxic effects can be experienced in areas with VOC levels more than 25 mg/m³.

The monitoring results show that in all the office areas the measured values of VOC levels are very low apart from one where some higher values were monitored but also these remained within the comfort levels.

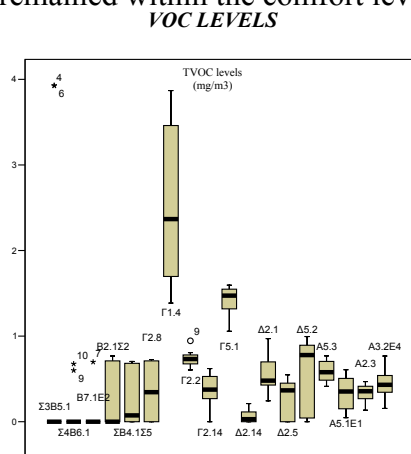


Figure 2: Measured VOC levels in representative office areas

4.5 Concentration of PM10, PM 2.5 and PM1

The concentration of PM10, PM 2.5 and PM1 was measured over a 20-minute period in representative office areas of the GSIS building. The monitoring was performed using an aerosol monitor (TSI Dust Track – model 8520). The measured values for PM10 varied from 0.049 mg/m³ to 0.614 mg/m³, for PM2.5 the measured values varied from 0.045 mg/m³ to 0.562 mg/m³ and for PM1 the measured values varied from 0.038 mg/m³ to 0.556 mg/m³.

The European Community standards for PM 10 are set to 50 mg/m³ while the standards for PM 2.5 are set to 40 mg/m³ by the Environmental Protection Agency (EPA).

It is noted that the concentration of particles PM 10, PM 2.5 and PM 1 is very low and within the acceptable levels.

5. LONG TERM MONITORING-BMS

Long term monitoring is carried out via the BMS that records the energy consumption for cooling, heating and lighting, the indoor temperatures, the humidity levels, the CO₂ concentration, and the demand control ventilation. The aim of the long term monitoring is to assess the outcome of the rehabilitation works, to validate the energy savings and to detect any malfunctions.

5.1 Energy consumption

One year of full monitoring (year 2007) by the BMS recorded the following:

Energy consumption for cooling: 46.99 kWh/m²,

Energy consumption for heating: 34.30 kWh/m². Taking into account the climate normalization (for the years 2000 and 2007) and a base temperature of 20 °C, the normalized energy consumption for heating is 38.15 kWh/m².

Energy consumption for lighting: 38.6 kWh/m².

ENERGY COSUMPTION FOR COOLING

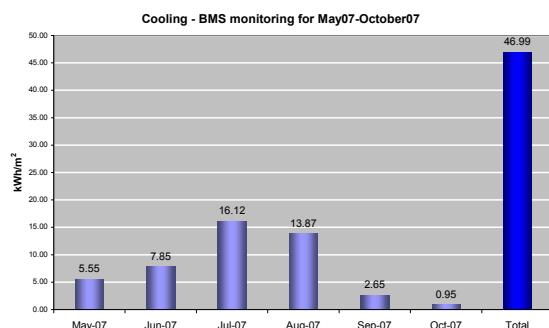


Figure 3: Energy consumption for cooling for the period 2007 –BMS monitoring

ENERGY COSUMPTION FOR HEATING

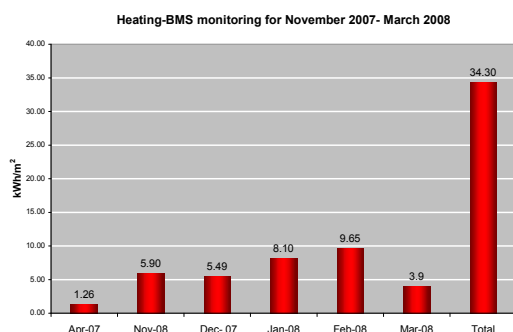


Figure 4: Energy consumption for heating for the period 2007-BMS monitoring

5.2 Internal temperatures

During the summer months (2007), with ambient temperature exceeding 41°C, the BMS recorded average internal temperatures in the data entry rooms (most occupied office areas with 1 person/5m²) between 24.11 °C and 28.13 °C. The most frequent internal temperatures in the data entry rooms vary between 27.5 °C and 28.5 °C whereas the number of hours above 30°C is minimal.

5.3 CO₂ concentration

Indoor air quality is kept in the desired levels by controlling the CO₂ concentration in the office areas. CO₂ sensors are installed in all office areas and connected to the BEMS

During the whole monitoring period maximum values of CO₂ concentration

above 1000 ppm were recorded in the most densely occupied areas. Specifically, the CO₂ concentration exceeded the levels of 1000 ppm in 57% of the sample area during June and July, in 38% of the offices during August, in 42% during September, in 54% during October, in 69% during November, in 58% during December and in 65% during January. Among the office areas of the GSIS building the data entry rooms presented higher CO₂ concentration as these are the most densely occupied office areas with a concentration of 1person/5m².

However, the average CO₂ concentration in all data entry rooms varied between 600 and 800 ppm, whereas the median CO₂ concentration varies between 500 ppm and 600 ppm..

It can be assumed that the CO₂ levels are within the acceptable comfort levels for the majority of the working hours and comply with the ASHRAE standards 62-1989 that set as a threshold limit the concentration of 1000 ppm for an 8-hour exposure.

However, better results in terms of CO₂ concentration can be achieved with increased ventilation in the case study areas.

5.4 Demand control ventilation

The ventilation of the data entry rooms is provided through the central ventilation system of the building and the openable windows. Additionally, in order to maintain the indoor air quality in the desired levels and maximize the possible energy savings, the “demand control ventilation” technique is used with the installation of CO₂ sensors. The CO₂ sensors control the ventilation rate through the BMS. When the required CO₂ levels are exceeded extra fresh air is supplied into the office areas via the central ventilation system.

According to the CO₂ concentration the aperture of the dampers of the ventilation system in each local unit varies its aperture. Two positions of the dampers are possible: aperture 100% when the CO₂ concentration is above the desired levels and aperture 30% when the CO₂ concentration is within the

comfort levels. For optimum indoor conditions, the desired levels are set to 600 ppm.

6. PAYBACK PERIOD

The payback time is given by the expression [3]:

$P_{proj} = I_{proj} / E - M_{proj}$ where:

I = Total investment cost of the installation

E = Costs of the annual quantity of energy saved or produced

M_{proj} = Operation costs, the difference between the operation costs of the reference and the improved project.

Based on the BMS monitoring the following energy savings are achieved:

Electrical energy (cooling + lighting): 957,987 kWh (48.31 kWh/m²)

Thermal energy (heating): 306,373 kWh (15.45 kWh/m²)

Based on the conversion factors for heating (oil): 0,06 Euro/kWh and for electricity 0,119 Euro/kWh, the annual savings in cost (euros) are calculated in 132,382 euros/year.

The total investment costs of the energy measures are 420,000 euros whereas the M_{proj} factor is calculated to 88,800/year. (figures taken from the company that is responsible for the operation and maintenance of the building)

Therefore, based on the given expression, the payback time is calculated to 10 years.

7. ENVIRONMENTAL IMPACT

Due to the implemented energy measures, the annual savings in CO₂ are calculated to:

Electrical energy: 411,934 kgCO₂

Thermal energy: 82,720 kgCO₂

Total: 494,654 kgCO₂

These results in 30% reduction in the building CO₂ emissions compared to the building prior to the renovation (year 2000).

The calculations are based on the following EU factors [2]:

-Mains electricity: 0.43 kgCO₂/kWh

-Heating oil: 0.27 kgCO₂/kWh

Additional CO₂ savings derive from the photovoltaic. The photovoltaic operation is recorded since January 2008. For two months operation (January and February 2008), the produced electrical energy arises to 446.6 kWh resulting in 192 kg CO₂. This is estimated to form 10% of the total annual CO₂ savings, therefore the annual CO₂ savings from the installed photovoltaic is calculated approximately to 2,000 kg CO₂.

8. LIFE CYCLE ASSESSMENT

The renovation of the GSIS building was responsible for minimal environmental impact, greenhouse gases and other atmospheric emissions. Atmospheric emissions were mainly released during the fabrication of the shading and photovoltaic panels and the transportation of these materials on site.

A life-cycle CO₂ assessment procedure was identified within the REVIVAL project (Work Package 9) which was sensitive to the emissions associated with the manufacture of materials, transportation to site, construction, energy in use and maintenance, final demolition and disposal of wastes. This was applied to the refurbishment of the existing building and was compared with the reference building and new build [2].

The suggested method in WP9 report is based on the top-down approach with which the total initial embodied energy of a building is calculated and then the energy is attributed to the different construction components. The analysis showed that both the NEW building and the REVIVAL building show a significantly lower CO₂ impact than maintaining the EXISTING building. The NEW building shows a lower annual impact than the REVIVAL Building,

with a “break-even-point” after approximately 17 years.

9. CONCLUSION

The refurbishment of the GSIS building demonstrated that:

- The refurbished building presents lower energy consumption and better life-cycle CO₂ emission performance than maintaining the existing one. However, compared with a new to built, the refurbished building shows lower CO₂ emissions for a duration of 17 years over a frame time of 25 years.

- One year of full monitoring by the BMS for the period 2007 showed that due to the implemented energy measures the following savings have been achieved (compared to the reference year 2000):

- 46.5% energy reduction in the area of cooling

- 29% energy reduction in the area of heating taking into account the climate normalization

- 16% energy reduction in the area of lighting.

Regarding the indoor air quality and the thermal comfort levels in the most occupied office areas, the BMS monitoring showed that:

- Although the extreme external thermal conditions (with ambient temperatures above 41°C in the summer period), the indoor temperatures were constant and below the external temperatures by at least 10 °C.

- The monitored relative humidity levels were well within the comfort zone 30%-70%.

- The average CO₂ concentration in the data entry rooms varied between 600 and 800 ppm, whereas the median CO₂ concentration varied between 500 ppm and 600 ppm.

- The response to the social monitoring that was carried out with post occupancy comfort questionnaires, showed that the implemented energy measures

improved significantly the indoor environmental conditions

-Taking into account that the payback time of the implemented energy measures is 10 years and less than the service lifetime of the majority of the installed energy measures, and considering the positive response of the occupants, the renovation can be considered successful and profitable.

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