Retrofitting of Chemical Engineering building, N.T.U.A., Greece

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1 Photos

Figure 1: *Left:* View of the building before retrofit
Below: View of the building after retrofit

2 Project summary

Building description

The Chemical Engineering building is located on the east side of the new N.T.U.A. campus, facing Mount Hymettus on one side and the main campus square on the other, from which pedestrian access is obtained at different levels. It has a total covered surface of approximately 30,000 m^2, and is composed of units of various sizes and uses, organised around medium sized courtyards. The main axis of the building runs North to South and is accentuated by two 6m wide corridors on each side of the courtyards which were supposed to form interior streets linking various campus buildings and services together. The building can be divided into three equivalent parts, each formed of one laboratory unit on the North side and one office unit on the South side of a courtyard, joined by teaching, research and administration spaces on the east and west sides.

The energy problem

The building was designed in the 1960's, but was only occupied a few years ago. It then became obvious to users that the original design was not appropriate for a University building of this type, due to the very ample common spaces that were constructed, occupying more than 70% of the total covered spaces of the building. Besides many users feeling that much of the space is wasted, when some of them are unable to find adequate shelter, there is a problem with heating and natural lighting of the common spaces which are mostly dark and cold, giving a derelict feeling to the whole building. Apart from the above, the lower levels of the two main corridors are left open, forming pilotis – a popular scheme in the architecture of the 1960's which nowadays has proved quite uncomfortable, leaving these spaces exposed to strong winds and rain during most of the school season.

Project objectives

Because of the problems described above, NTUA has decided to proceed in stages with retrofitting actions on the building complex, aimed at reducing the energy consumption, increasing thermal and lighting comfort, and allocating some of the common spaces to new offices and laboratories, which are badly needed by the teaching and research staff.

3 Site

Athens, latitude: 37°58' N, longitude: 23°47' E, Altitude: 219m, Mediterranean climate. Mean annual temperature: 18°C, mean winter temperature: 10°C

4 Building description /typology

4.1 Typology / Age

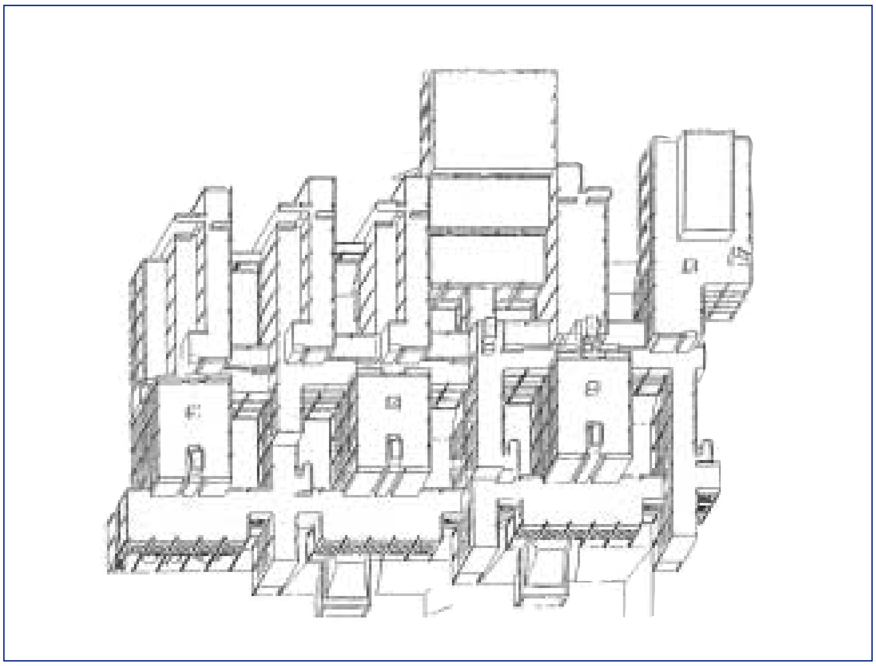
Mega-structure university building, multi-storey, double corridor (1985).

4.2 General information

Year of construction:	1985
Year of renovation (as described here):	2002
Total floor area (m^2):	30,000
Number of students:	12,000
Number of classrooms:	30
Typical classroom size (m^2):	60
window/glass areas (m^2):	10
number of pupils:	40

4.3 Architectural drawings

Figure 2: Building axonometry from N.W.



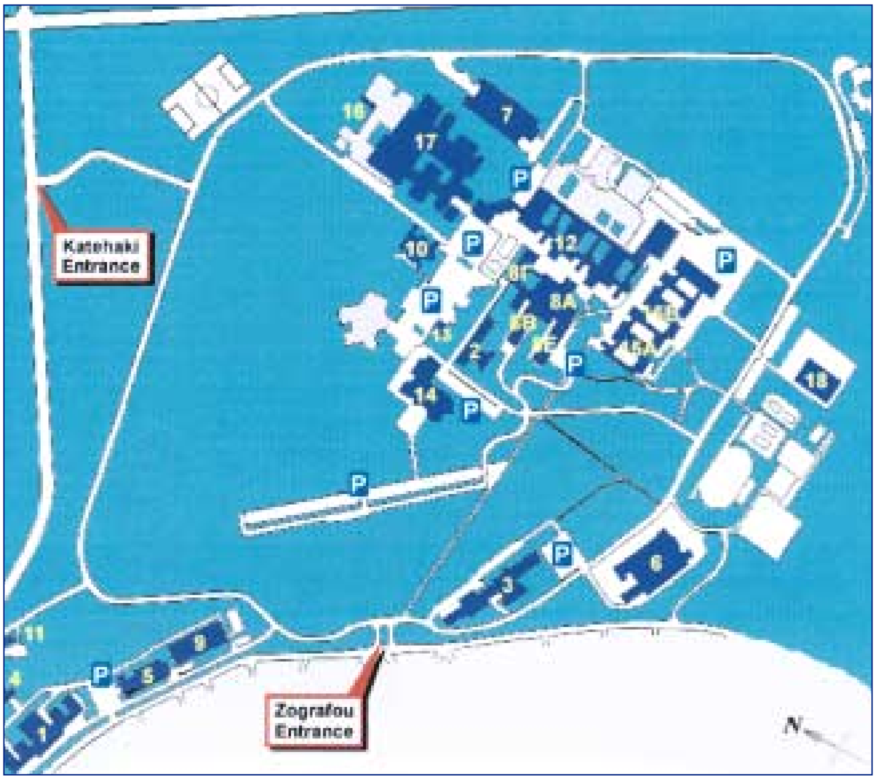


Figure 3: National Technical University of Athens Zografou campus

KEY

1 Civil Eng. Labs (Concrete, Transportation)
2 Physics
3 Rural and Surveying Eng.
4 Acoustic Lab.
5 Civil Eng. (Hydraulics Lab.)
6 Dormitories
7 Naval/Marine Eng.
8 General Sciences
9 Civil Eng. (Lab. of Harbour Works)
10 Computer Center
11 Aseismic Research Lab.
12 Chemical Eng.
13 NMC/NOC
14 Administration
15A Mining and Metallurgical Eng.
15B Electrical & Computer Eng.
16 Thermal/Turbomachines Lab.
17 Mechanical Eng.

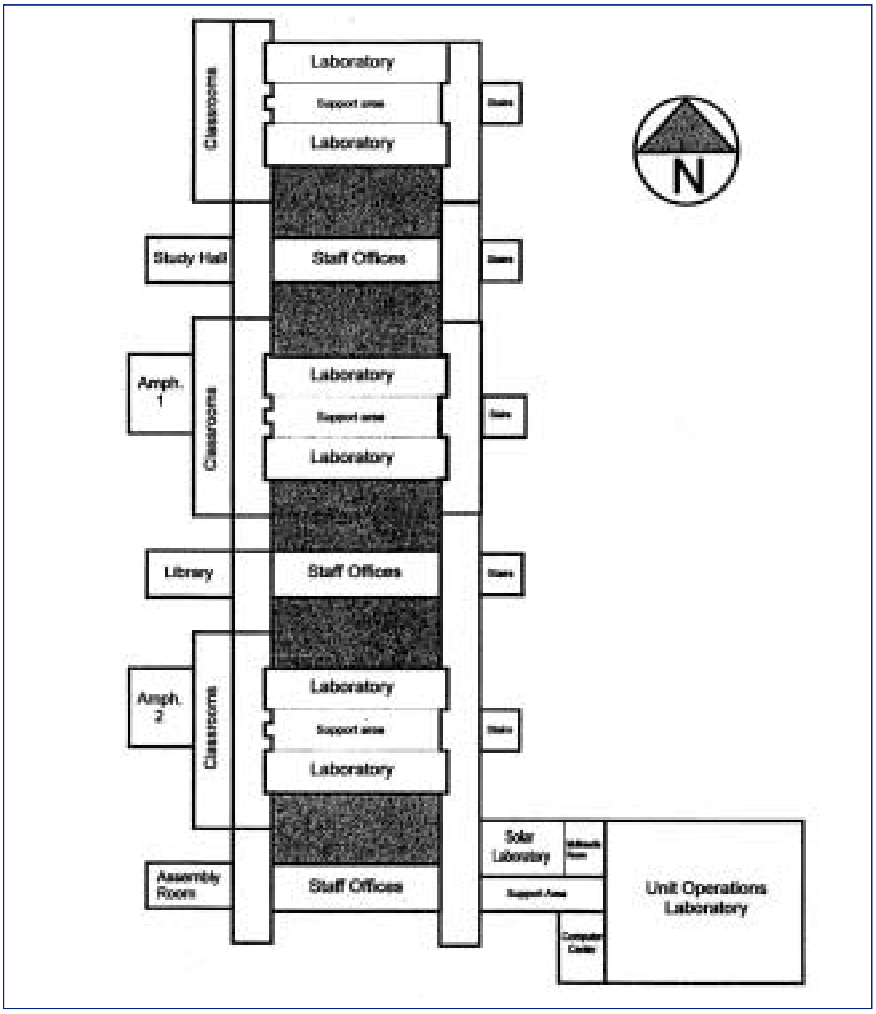
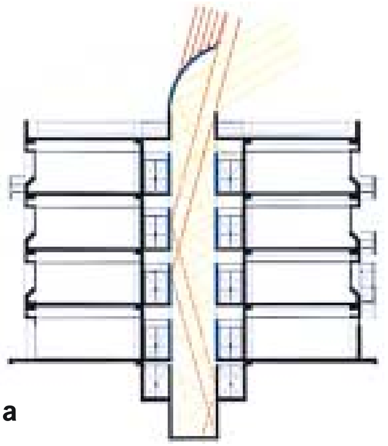


Figure 4: Schematic diagram of the building



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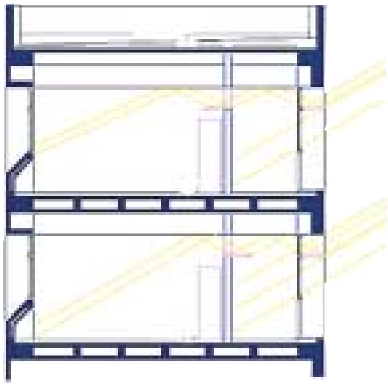

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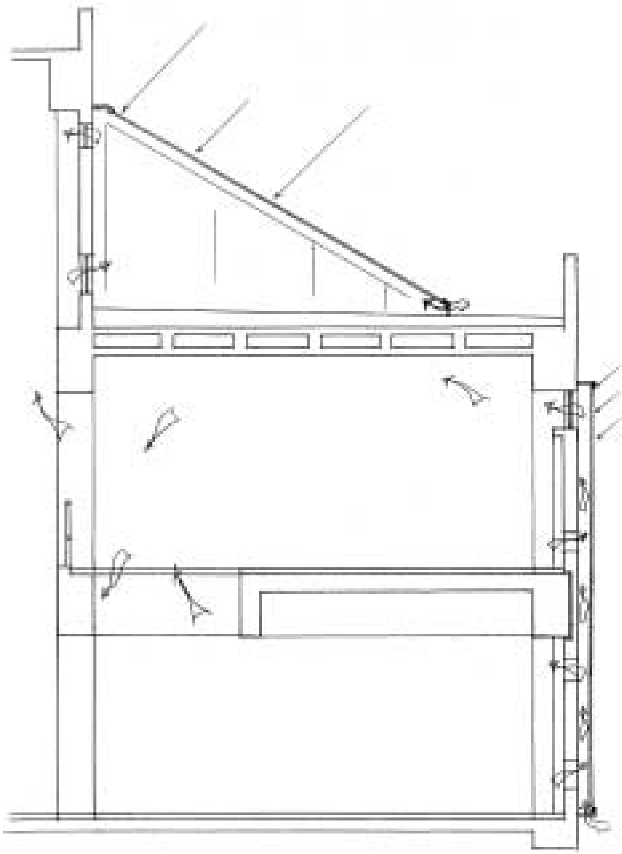

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Figure 5: Operational section of retrofitting systems
a. Light/ventilation ducts
b. Light shelves
c. Hybrid pv/thermal system

5 Previous heating, ventilation, cooling and lighting systems

Heating system: Three boiler rooms (one per section) *Fuel:* oil
Ventilation: Natural ventilation
Cooling: Local split type heat pumps (for offices and laboratories)
Lighting: Fluorescent centrally or locally controlled (~17W/m^2)

6 Retrofit energy saving features

6.1 Energy saving concept

The first stage of the retrofitting process involved an integrated design approach, using a combination of standard as well as innovative energy conservation measures, which utilise passive solar and Photo-Voltaic (PV) systems in order to achieve the best possible levels of thermal and lighting comfort for the users, whilst reducing fossil fuel and electricity consumption – hence CO_2 production.

In order to best proceed with the control and monitoring of the entire complex, it has been decided to divide the complex into three parts. The first one, which will be the "control" part during the monitoring period, will have no interventions during this stage. The second one (towards the North) will have only conventional energy conservation systems installed, while the third one (towards the South) will have innovative passive solar and PV systems, as well as conventional energy conservation systems implemented. This is facilitated by the actual division of the building complex's existing heating system into three independent parts, each served by its own boiler subsystem. Major energy conservation measures include the following.

6.2 Building:
- Improvements to external wall insulation
- Improvements to U-Value of openings
- Reduction of infiltration through window frames
- Use of shading devices
- Use of simple passive solar systems (attached sunspaces)
- Use of daylighting components (light ducts, light shelves and light diffusion devices)
- Creation of a covered atrium

6.3 Heating/Cooling
- Control of space heating
- Control of air-conditioning
- Improved efficiency of fans or pumps
- Insulation of ducts and pipes
- Improved heating and cooling supply system
- Replacement of filters and air handling units
- Reduced hot water temperature
- Fuel substitution (natural gas, biofuel)

6.4 Ventilation
- Natural ventilation
- Night ventilation
- Ceiling fans
- Other ventilation devices
- Evaporative coolers
- Solar chimneys
- Ground cooling
- Thermal mass

6.5 Lighting:
- Reduction of indoor illumination levels
- Task lighting
- Control of indoor lighting equipment
- Improved effectiveness of luminaires
- Use of efficient lamps and ballasts
- Control of outdoor lighting

6.6 Other environmental design elements
- Solar collectors
- PV hybrid systems integrated to Southern facade
- Microclimate improvement

7 Resulting Energy Savings

Following a series of simulations using the TRNSYS 14.2 software, the results below were obtained, based on a set of retrofitting scenarios.

Heating
- Present energy consumption for heating: 85.5 kWh/m^2.
- After the use of a combination of simple energy conservation measures (as listed under 6.2 and 6.3 above) the energy consumption for heating is reduced to 54.4 kWh/m^2, a reduction of approximately 34.5%.

Cooling

- Present energy consumption for cooling: 49 kWh/m^2.
- After the use of a combination of 8 retrofitting scenarios the energy consumption for cooling is reduced to 13.3 kWh/m^2. A reduction of 68.6% of the energy required for cooling is thus achieved.

Lighting

Electrical energy for lighting is estimated at 17 W/m^2 for classrooms, 18.2 W/m^2 for offices and laboratories and 14 W/m^2 for corridors and service spaces.

The implementation of energy conservation measures for artificial lighting proposed in this project, combined with a reduction of indoor illumination levels and the use of improved lighting controls contribute to a reduction of electrical energy consumption of approximately 55%.

8 User evaluation, existing building

Indoor air quality:	
In general terms:	Low
Dry, humid, smelly, etc.:	Stuffy, stale air in some laboratories, cold and humid in north-facing offices
Irritations (eyes, nose, throat, skin, ..)	Smelly because of chemicals and insufficient ventilation
Quality of daylight / artificial light:	Insufficient daylight for most offices and laboratories
Sound quality:	Moderate
General feeling:	Oppressive environment
General well being: Headache:	Rarely
Difficult to concentrate:	Rarely
Technical functionality:	Moderate
Architectural quality:	Low

9 Renovation costs

The total cost of the retrofitting project is estimated at approximately €900.000, of which the total cost for the PV-hybrid system is estimated at €440.000.

10 Experiences/Lessons learned

10.1 Energy use

A combination of some or all of the scenarios described under the form of a package would be the most efficient strategy to follow in case initial cost is not a problem – for instance if a refurbishment of the whole building is planned. Some low cost measures, however, especially those dealing with electric lighting improvements and passive cooling techniques, can have a considerable impact on energy efficiency and comfort even if applied one at a time. Such measures usually involve control and maintenance schemes of lighting and hvac systems. Most impressive is cleaning of light fixtures, the absence of which can reduce illumination levels by 50% in three years.

10.2 Impact on indoor climate

There is a positive impact on indoor climate which is being further evaluated through questionnaires.

10.3 Practical experiences of interest for a broader audience

As Universities are models to society, besides the benefits of energy conservation, reduction of CO_2 levels and the achievement of improved levels of thermal and visual comfort, the development of increased energy conservation consciousness for their students and staff, achieved either through user motivation campaigns and information exchange, or through education and research devoted to energy and environment subjects, will have a multiple influence on other social groups, both in the public and private sectors.

10.4 Resulting design guidance

The analysis presented above shows that the retrofitting strategies described can usually cover a considerable percentage of a university building's heating, cooling and lighting needs, while improving thermal comfort for its users.

11 General data

11.1 Address of project

N.T.U.A. campus, Athens, Greece.

11.2 Date of report / revision no. 4

December 2002/June 2003

12 Acknowledgements

Architects:

Original building:	NTUA Technical Service staff
Retrofitting design:	Euphrosyne S.Triantis, architect, NTUA
Energy systems design:	NTUA Solar Energy Research Team, in collaboration with Network Inc. and Atersa Spain
Project co-ordination:	Nikos Spyrellis, John Palyvos, NTUA
Monitoring:	John Palyvos

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Author: Euphrosyne S. Triantis

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