Energy savings strategies in Campus Buildings of Athens - Greece

S Tsala1, I P Koronaki1

1 Laboratory of Applied Thermodynamics, School of Mechanical Engineering, Thermal Engineering Section National Technical University of Athens, Heroon Polytechniou 9, Zografou Campus 15780, Athens, Greece

*Corresponding author’s e-mail: koronaki@central.ntua.gr

Abstract Bioclimatic construction has been an important tool for improving the construction of buildings in recent decades. Energy-saving options in buildings include the use of appropriate materials, exposures and the use of alternative power generation systems. In the present work the basic features of the bioclimatic design and study of the energy saving in the buildings of the polytechnic area located in Zografou is presented. In particular, the RETscreen software is used to test energy savings in the buildings of library, mechanical engineering and management building using photovoltaics. It turns out that an important parameter that affects energy saving is the use of the building and the type of photovoltaic used. This is evidenced by the results of RETscreen that in the case of the Library and the Mechanical Engineering building stable photovoltaic have greater energy savings while in the case of the Management building, biaxial photovoltaics produce greater savings.

1. Introduction
The constant increase in consumer goods, the excessive growth of the population and the improvement in the standard of living of modern reality have, over the last twenty years, led to a rapid increase in energy consumption. Oil production has increased sixfold over the past decade and electricity demand has increased tenfold every ten years. The minimal use of non-renewable energy sources has contributed to an increase in emissions, which deplete the ozone layer and have seriously degraded the environment by gradually destroying ecosystems. The main culprits of this catastrophe are the industries, transport, power plants, but as the foreword states, the built environment [1].

In fact, 45% of the energy produced worldwide is spent on the building sector, with 2/3 of that being owned by private homes. Although these rates are responsible for 50% of CO2 emissions, only 15% of the needs are covered by the US, with solar as the protagonist. Globally, the contribution of the building industry to the emissions of carbon compounds (C) is close to 6 billion tons, with 4.5 billion of these being owned by industrialized countries and 2.25 billion tons of 4.5 being directly or indirectly due to building construction [2,3]. For Greek data, the building sector consumes 30% of the energy produced, with a 40% contribution to CO2. Most of the energy is consumed for cooling and heating, since thermal losses in Greek buildings are enormous and the use of energy reduction techniques is mandatory for all buildings only from 2007 [3].

A structured environment is defined as the area developed by human construction and includes all buildings covering housing, employment and leisure needs. Based on the size of buildings and
neighbouring infrastructure, the built environment is characterized as urban, semi-urban and rural [3]. Dealing with the urban environment of large cities is particularly important for the Greek reality, taking into account the small blocks of construction, the increased height of buildings, but also the large size of the city, which complicates the operation not only of its climate, but also of the climate in the wider region. This is linked to the thermal and aerodynamic behaviour of the largest cities in it, according to the thermal island phenomenon, which refers to the temperature fluctuations between two neighbouring towns. The first oil crisis in 1973 alarmed the scientists involved in the design and construction of buildings and led them to study and research new forms of energy, such as the creation of a more economical, more practical and more ecological building. The building is now treated as a living organism and not as consumed and vanity [3,4]. The ecological equilibrium factor in a building is now the top priority in any project, leading scholars to the solution of the immediate application of the principles of bioclimatic building and ecological construction [4].

The bioclimatic structure shall attempt to design, construct and operate a building or on a larger scale of a housing stock in harmony and cooperation with local climatic conditions and using GDP, as far as possible, so as to meet the specific specifications of the building, without placing a particular burden on its environment and to try to maintain its energy identity as ecological as possible [2,5]. Construction of more energy-efficient houses could reduce carbon emissions by 60%, equivalent to 1.35 billion tons. It also achieves savings in conventional energy resources, leading in the long term to a reduction in dependence on imported oil. In addition, the use of local construction materials, as long as permitted, can significantly help to reduce the cost of construction, as transport costs are reduced [2].

The concept of ecological footprint appeared in 1994 and is defined as the trace a building leaves in the world. It is essentially the "metabolism" of the building, with the logic of the living organism, and it is an indicator of sustainability measurement. The meaning of the trace can be extended to a settlement or even to a human, with the logic of "geomerides" [6]. It is generally understood that the limits of the land are finite and therefore also the limits of productivity. According to global economic indicators, 20% of the world's population consumes 83% of the available land resources. The geometry corresponds to the average value of the ecologically produced land corresponding to each inhabitant of the land. This does not include the land that should correspond to biodiversity, that is to say, the whole of the rest of the animal and plant kingdom, and it presupposes that all people have an equal right to the land's share.

Therefore, an ecological footprint is the total soil area required to support the needs of a population, but also to absorb all its waste [7]. The ecological footprint is defined as [6]:

\[ I = P \times A \times T \]

Where: \( I \) the effect or the trace, \( P \) the population, \( A \) the abundance and \( T \) the technology.

From 1961 to 2005 worldwide, the ecological footprint has tripled and according to data from W.W.F. it is estimated that in 2005 every person consumed resources corresponding to 22 acres of ground while the planet could deliver a maximum of 18. In a ranking of 147 countries in terms of per capita ecological footprint, Greece is the 17th most unfavourable, with the country's per capita ecological footprint increasing by 101% between 1975 and 2003. The ecological footprint for every Greek citizen corresponds to 50 acres per inhabitant. This unfavourable position is mainly due to energy consumption and thus to CO2 emissions into the atmosphere [7]. According to the latest data from the European Environment Agency (2006), total energy consumption in Greece is on average an annual increase of 2.7% (1990-2003), one of the highest in the EU. With regard to the two major cities, Athens and Thessaloniki, it is understood that they can be very easily unsustainable, with a particularly high ecological footprint, with more than 65% of the Greek population. As is evident, buildings affect the environment in many ways during their construction, operation and demolition. But the environment also has a big impact on buildings. In order to be able to design buildings properly, full knowledge of this interaction must be available [7].

The buildings of the major urban centers unfortunately cause a number of problems in the environment, such as the change in the balance of the main components of the atmosphere, in soil and subsoil water, mainly because of the chemical emissions from urban waste and waste. This phenomenon is particularly pronounced in most Greek cities. Also, the depletion of natural resources results from the intensity of energy use for the structure [2,3]. The disadvantaged use of non-renewable energy sources has led to a gradual increase in air pollution and the greenhouse effect. In addition, the disruption in the
Geobiological cycles of water, oxygen and carbon dioxide results in unstable climate changes throughout the earth, and the anarchic construction has degraded both the urban and the rural environment, causing the disappearance of local flora and fauna. Finally, the use of radioactive and non-ecological building materials has the direct effect of causing problems for the health of the occupants and of degrading the quality of life, their quality and their environment [2,3,8].

All of this has made scientists concerned about finding a new way of building houses, which is healthier and more environmentally friendly. The result was a shift towards Bioclimatic Building using US. and other energy saving methods. Good planning can lead to a gradual reduction of the environmental crisis and to an upgrading of the urban and thus the terrestrial environment [9,10]. Bioclimatic design developed in the 1980s as a new trend in urban planning with references to the local microclimate. The term bioclimatic design lies in the architectural and urban planning of buildings and agglomerations aimed at adapting to the local climate and the natural environment, while protecting sensitive areas with rare ecosystems. The microclimate, the mid-climate and the macroclimate determine the lighting, ventilation, design and energy behaviour of buildings. In particular, the macroclimate is shaped by the average weather conditions that prevail throughout the year, the mid-climate is characterized by the impact of topography, vegetation and the nature of the region, and finally, the microclimate is the result of human intervention, which directly changes the built environment [9,10]. Bioclimatic design aims to exploit the positive environmental parameters in order to reduce the energy needs of the building throughout the year and to save conventional energy. In addition, it incorporates elements linked to the local physiology, local culture and to the traditional - and thus empirically proven - techniques for more favourable building of the area concerned [9,10,11].

Bioclimatic Structuring, in addition to local traditional building techniques, is the result of an integrated and complex synthesis, which is linked to a wide range of parameters such as orientation, appropriate choice of openings, design of the building shell, and correct selection of materials [12]. This does not mean, however, that intervention in existing buildings is limited. With low cost and user-friendly technologies, heat losses can be reduced, buildings can be protected from overheating, lighting conditions can be improved and noise reduced. The implementation of bioclimatic structuring may lead to energy independence for non-US. up to 60%. It also contributes to the increasing reduction of CO2 emissions and other gases, the existence of which aggravates the rational use of water and local infrastructure [12,13]. It has been observed that the traditional ecological materials of the pre-industrial period are reliable, have a long life span, are not harmful to human health and the environment, and still allow US savings. These benefits are linked to bioclimatic design and contribute to the construction of structures that meet the needs of modern lifestyle, without posing a threat to future generations [14].

In view of the above-mentioned energy savings, this study aims to investigate bioclimatic building and to analyse the ways of saving energy in residential blocks, i.e. the Library building, the Mechanical Engineering building and the Administration building.

2. Method

The aim is to study the energy consumption of the various buildings in Campus (100 ha total area) and to compare them with each other using the RETscreen tool. The RETscreen Clean Energy Project Analysis Software is the innovative decision support software for clean energy. It is provided entirely free of charge by the Canadian Government and is a tool for strengthening clean energy projects worldwide. This software significantly reduces the costs (both economically and chronically) associated with identifying and evaluating potential energy projects. RES and allows decision makers and professionals to determine whether or not a proposed renewable energy, energy efficiency, or cogeneration project is economically appropriate. The procedure followed in the RETscreen software for all buildings is summarized in the following steps:

Step 1: Select a location and automatically import climate data from the software.
Step 2: Enter installation information. The user imports:
  - The extent of the building and the reference point, defined as the average value of energy consumption (as derived from experimental measurements).
Level 2 defines the type of reference point for each case as electricity. The Action provides options for fuels, space usage planning, equipment, end-use of energy, and power optimization. The Schedule specifies the time of use of the building. Space Heating Demand is defined as the type used by each building. End-use defines the electricity applications for each building. Energy optimization defines each photovoltaic scenario with its characteristics. For each power saving scenario, the software delivers:
- Energy and economic data report
- Energy efficiency
- Economic sustainability

In this case, the buildings of the Library (Services), Administration (Administrative Services) and Mechanical Engineers (Educational Building) will be studied and the installation of photovoltaics on their energy-saving roofs. In the RETscreen, the location data of the buildings will be entered and, using the databases it contains for specific types of buildings, an economic data and energy saving report will be generated. To calculate the fluctuation of the consumption trend in Polytechnic City, measurements made on one of the buildings and on an hourly basis for each day of each month from March 2015 until December 2016 will be used. For the estimation of the monthly electricity load, the average values of the measurements for each month were considered.

3. Results
3.1. Energy measurement and consumption compared by building
The Library has an area of about 8928 m² and operates 16 hours a day on a daily basis except on weekends. The electric load measurements show that this building is mainly used during the months of December, January, June, July and September.

Table 1 shows that in the months of June, November and December 2016 the average electric load increased compared to the 2015 average, while in the remaining months the reverse occurs.
Table 2: Electrical load change rates for the Library building.

Measurements of the MN Mechanical Engineering Building show that the maximum load of this building was 101 kW in June 2016 and the minimum was 54 kW in October 2016.

Table 3: Average electric charge for the Mechanical Engineering building.

Table 4 shows that in June, July, September, November and December 2016 the average electric load increased compared to the corresponding load in 2015, while in the remaining months the reverse is observed. A maximum increase is observed in June and December, when a higher temperature change is observed.
Table 4: Electrical load change rates for the Mechanical Engineering building.

The Administration building showed the largest electric charges between the buildings being compared. In particular, the maximum electric load of the building is observed for the month of July 2016 and is equal to 83.1 kW and the minimum load is observed in May 2015 and is equal to 43.8 kW. Table 5 shows an increase in the average electric load compared to the corresponding 2015 load over all months except March (-9.73%) and October (-0.24%), where the average electric load was reduced.

Table 5: Electrical load change rates for the Administration building.

The comparison of the previous electrical charges shows that the average electric charge is a function of the number of people using each building and the use of the building.

3.2. Energy Saving Scenarios
3.2.1. Power saving scenarios for the Library building
For the Library building, the area is 8928 m² and the reference point is the average energy consumption value as determined by the experimental data. The reference point shall be the average value for two years of 858.8 MWh and for its area of 0.1 MWh/m². The schedule is 16 hours/day for daily. Space Heating Demand defined the gas boiler system connected to ventilation, engines and fans. The electricity data shall be taken as the average monthly values of the measurements taken.
3.2.1.1. Scenario 1: Energy optimization with Twinax 5kW Photovoltaics
The annual financial flow for Scenario 1 is shown below:

![Figure 1: Annual financial flow for Scenario 1.](image)

The energy savings and fuel consumption for Scenario 1 are shown below:

|                     | Heating | Cooling | Electricity | Set   |
|---------------------|---------|---------|-------------|-------|
| Fuel consumption    | kWh     | kWh     | kWh         | kWh   |
| Basic case          | 1,672   | 9,330   | 104,416     | 115,418|
| Proposed case       | 1,672   | 6,015   | 64,134      | 71,821|
| Fuel saving         | 0       | 3,315   | 40,282      | 43,597|
| Fuel savings-rate   | 0%      | 35.5%   | 38.6%       | 37.8% |

![Figure 2: Energy and fuel savings for the library using a 5kW two-axle photovoltaic.](image)

The financial viability for Scenario 1 is reflected in the following Figure:

![Figure 3: Economical viability for the library using a 5kW biaxial photovoltaic.](image)

3.2.1.2. Scenario 2: Energy optimization with 5kW Constant Photovoltaic
For this scenario only the type of voltaic used is changed, which will be stable with a 45th gradient.

The annual funding for Scenario 2 is as follows:
The energy saving and fuel consumption for Scenario 2 is shown below:

|                | Heating | Cooling | Electricity | Set |
|----------------|---------|---------|-------------|-----|
| Fuel consumption | kWh     | kWh     | kWh         | kWh |
| Basic case      | 1,672   | 7,991   | 104,416     | 115,520 |
| Proposed case   | 1,672   | 7,991   | 62,993      | 72,656 |
| Fuel saving     | 0       | 1,441   | 41,423      | 42,564 |
| Fuel savings-rate | 0%   | 15.3%   | 39.7%        | 37.1% |

3.2.1.3. Compare scenarios for the Library Building

The energy savings with a twinax photovoltaic are 38.6% for electricity and 37.8% for total. Annual cash flows are positive over a 20-year horizon and annual costs are $5411 while annual savings and revenues are €11542. For the library building and the fixed photovoltaic, the total energy savings are 37.1% and for the electrical is 39.7%. Annual costs and annual revenues remain stable. It follows, therefore, that in the case of fixed photovoltaics in the Library building the energy savings are lower than in the case of biaxial photovoltaics.

3.2.2. Energy-Saving Scenarios for Engineering Building

The Engineering Engineers Building uses the Commercial/Institutes-Training standard. Site data is the same as the Library. The extent of the building is 4000 m² and the reference point is the average energy consumption value as determined by the experimental data, in this case the reference point is 718.46 MWh. The minimum electrical energy is 149.79MWh i.e. 0.18MWh/m² and the maximum of 1254.42MWh i.e. 0.31MWh/m². The fuel type and tele energy systems for hot and cold water shall be taken into account. The schedule is set for the highest winter temperature (January-9.3°C) and summer temperature (July-27 °C). Daily, it is assumed that the building operates 12 hours a day and at weekend 4. For regional heating the initial cost is obtained for boiler and for regional cooling is considered to be an air heat pump. The electricity data shall be taken as the average monthly values of the measurements taken.

3.2.2.1. Scenario 1: Power optimization with 68kW Twinax Photovoltaic.

The annual and cumulative funding for Scenario 1 of the Engineering Building is shown in the following Figure:
The energy saving and fuel consumption for Scenario 1 of the Mechanical Engineers building is as follows:

|               | Heating | Cooling | Electricity | Set  |
|---------------|---------|---------|-------------|------|
| Fuel consumption kWh  | kWh   | kWh    | kWh         | kWh  |
| **Basic case**   | 19,062 | 806,292 | 803,347     | 1,628,701 |
| **Proposed case** | 19,062 | 655,078 | 620,119     | 1,294,259 |
| Fuel saving 0% | 151,214 | 183,228 | 334,442     |
| Fuel savings-rate 0% | 18.8% | 22.8% | 20.5%      |

The financial viability for Scenario 1 of the Mechanical Engineers building is illustrated below:

| Economic parameters               | Cost | Saves | Revenue |
|-----------------------------------|------|-------|---------|
| Generally                         | Initial costs | Increase initial costs | Total initial costs | 100% | € | 384,118 |
| Rolling fuel cost tax %           | € | 268,283 | 115,235 |
| Inflation value %                 | € | 70% | 9% |
| Discount rate %                   | % | 2% | 9% |
| Reinvestment rate %               | % | 9% | 9% |
| Project lifetime Year             | % | 20 | |
| Financing                         | Annual costs and debt payments | Operation & Maintenance Costs (saving) | Total annual costs | 156,910 |
| Interest-in-charge %              | € | 70% | 90% |
| Debt %                            | % | 70% | 9% |
| Share %                           | Year | 15 | 15 years |
| Borrowing rate %                  | Year | 29,522 | 29,522 |
| Debt period %                     | Year | 15 | 15 years |
| Debt payments %                   | Year | 29,522 | 29,522 |
3.2.2.2. Scenario 2: Energy optimization with Constant Photovoltaic 68kW

The annual funding for Scenario 2 of the Engineering Building is shown as follows:

The energy and fuel savings for the building of mechanical engineers with stable photovoltaic is shown below:

![Figure 9: Annual funding for the fixed photovoltaic scenario in the Department of Mechanical Engineering.](image)

![Figure 10: Energy and fuel saving with stable photovoltaic in the engineering building.](image)

The financial viability for Scenario 2 of the Mechanical Building is given in the following figure:

![Figure 11: Sustainability results for stable photovoltaic in the Mechanical Engineers building.](image)
3.2.2.3. Comparison of scenarios for the Engineering building

It is found that cash flow does not change significantly. Also, from the results of energy saving it seems that in the case of the building of engineers the stable photovoltaic presents greater energy and fuel savings than the two-axis. Economic viability shows that the total costs are lower in stable photovoltaic than the biaxial. In particular, the total energy savings are for the two-axis photovoltaic equal to 20.5% while the savings of electricity are 22.8%. The total starting cost is 348,118€, the total annual costs are 155,910€ and the total savings on an annual basis are 161,917€. In the case of stable photovoltaics, the savings of electricity are estimated at 24% and the total savings are 21.1%. Annual savings and initial costs are estimated at the same levels as the two-axis while annual costs are reduced to 154,961€.

3.2.3. Energy Saving Scenarios for the Administration Building

For the administration building the location information is as in both previous cases. In the installation the type of building is set service and is described as a large office with an area of 2500m². The average value of energy consumption as determined by the experimental data is set as a reference point. The energy tab sets out the fuel elements that are natural gas and electricity. The operating schedule is now set for 10 hours as it is a service and the weekend is thought to be zero. The electricity data shall be taken as the average monthly values of the measurements received.

3.2.3.1. Scenario 1: Energy optimization with Biaxial Photovoltaic 59kW

The annual funding for Scenario 1 of the Administration Building is shown in the following Figure:

![Figure 12: The annual funding for the administration building with two-axis photovoltaic.](image)

The energy saving and fuel consumption for Scenario 1 of the Administration building is as follows:

| Fuel consumption | Heating kWh | Cooling kWh | Electricity kWh | Set kWh |
|------------------|-------------|-------------|----------------|--------|
| Basic case       | 67,510      | 158,509     | 1,116,612      | 1,342,632 |
| Proposed case    | 29,190      | 103,643     | 567,196        | 690,029 |
| Fuel saving      | 38,320      | 54,866      | 529,960        | 652,603 |
| Fuel savings-rate| 56.8%       | 34.6%       | 50.1%          | 48.6%  |

![Figure 13: Energy saving and fuel consumption for two-axle photovoltaic in the Administration building.](image)
The financial parameters and storage costs and revenues from this scenario are shown in the following figure:

| Economic parameters | Value |
|---------------------|-------|
| Generally           |       |
| Rolling fuel cost tax | % 2%  |
| Inflation value     | % 2%  |
| Discount rate       | % 9%  |
| Reinvestment rate   | % 9%  |
| Project lifetime    | Year 20 |

| Financing            |       |
|----------------------|-------|
| Interest-in-charge   | % 70% |
| Debt                 | € 347,656 |
| Share                | € 148,995 |
| Borrowing rate       | % 7%  |
| Debt period          | Year 15 |
| Debt payments        | €/Year 38,171 |

| Cost | Saves | Revenue |
|------|-------|---------|
| Initial costs | Increase initial costs | 100% | € | 496,652 |
| Total initial costs | 100% | € | 496,652 |
| Annual costs and debt payments | Operation & Maintenance Costs (saving) | € | -4,574 |
| Fuel cost-proposed case | € | 66,925 |
| Debt payments-15 years | € | 38,171 |
| Total annual costs | € | 100,522 |
| Annual savings and revenue | Fuel cost-base case | € | 129,457 |
| Total annual savings and income | € | 129,457 |

Figure 14: Economic sustainability analysis for Scenario 1 of the Administration Building.

3.2.3.2. Scenario 2: Energy optimization with Constant Photovoltaic 60kW

The annual and cumulative funding for Scenario 2 of the Administration Building is shown as follows:

| Year | Before tax(€) |
|------|---------------|
| 0    | 0             |
| 1    | -12,945       |
| 2    | -25,890       |
| 3    | -35,977       |
| 4    | -45,338       |
| 5    | -53,782       |
| 6    | -61,876       |
| 7    | -69,633       |
| 8    | -76,079       |
| 9    | -81,224       |
| 10   | -85,078       |
| 11   | -87,876       |
| 12   | -89,672       |
| 13   | -90,472       |
| 14   | -90,085       |
| 15   | -89,505       |
| 16   | -88,747       |
| 17   | -87,806       |
| 18   | -86,683       |
| 19   | -85,372       |
| 20   | -83,874       |

Figure 15: Cash flow for stabilized photovoltaic in the administration building.

The energy saving and fuel consumption for Scenario 2 of the Administration Building is as follows:

|                  | Heating | Cooling | Electricity | Set |
|------------------|---------|---------|-------------|-----|
| Fuel consumption | kWh     | kWh     | kWh         | kWh |
| Basic case       | 67,510  | 158,509 | 1,116,612   | 1,342,632 |
| Proposed case    | 29,190  | 103,643 | 586,652     | 719,485 |
| Fuel saving      | 38,320  | 54,866  | 529,960     | 623,146 |
| Fuel savings-rate| 56.8%   | 34.6%   | 47.5%       | 46.4% |

Figure 16: Energy saving for stabilized photovoltaic in the Administration building.
The financial parameters and storage costs and revenues from this scenario are shown in the following figure:

| Economic parameters          |          |          |
|------------------------------|----------|----------|
| Generally                    |          |          |
| Rolling fuel cost tax        | % 2%     |          |
| Inflation value              | % 2%     |          |
| Discount rate                | % 9%     |          |
| Reinvestment rate            | % 9%     |          |
| Project lifetime             | Year 20  |          |
| Financing                    |          |          |
| Interest-in-charge           | % 70%    |          |
| Debt                         | € 347,656|          |
| Share                        | € 148,995|          |
| Borrowing rate               | % 7%     |          |
| Debt period                  | Year 15  |          |
| Debt payments                | €/Year 38,171|          |

| Cost | Saves | Revenue |
|------|-------|---------|
| Initial costs | Increase initial costs | 100% € 496,652 |
| Total initial costs |          | 100% € 496,652 |
| Annual costs and debt payments | Operation & Maintenance Costs (saving) | € -4,574 |
| Fuel cost-proposed case |            | € 69,870 |
| Debt payments-15 years |          | € 38,171 |
| Total annual costs |          | € 103,468 |
| Annual savings and revenue | Fuel cost-base case | € 129,457 |
| Total annual savings and income |          | € 129,457 |

Figure 17: Economic sustainability analysis for the administration building.

3.2.3.3. Comparison of scenarios for the Administration Building

The savings of electricity from two-axle photovoltaic are 50.1% and the total energy savings are 48.6%. The total initial costs are 496652€ and the total annual costs of 100522€ and the total savings are 129457€. The use of stable photovoltaic leads to savings of 46.4% total energy while in electricity to 48.6%. From an economic point of view there is an increase in overall annual costs equal to 3%.

4. Conclusions

In this work, a number of energy-saving scenarios were studied in three buildings of the Polytechnic City, in the area of Zografou. In particular, they were used by 2 energy optimization scenarios (use of two-axial photovoltaic and fixed photovoltaic) for the Library building, the Engineering building and the Administration building. The study was conducted using the RETscreen software. In order to implement the scenarios, the consumption measurements for the above mentioned buildings had to be calculated. The measurements were made from March 2015 in December 2016 and showed that energy consumption increased linearly for all buildings. In particular, the Library building (15%) was the largest increase in the library building (15%) and smaller presented the administration building (5%).

The results of the software used for energy-saving scenarios showed that the use of fixed photovoltaics (i.e. Scenario 2) showed the highest percentage of total energy savings for the Library building (39.7% vs. 37.8%). Similarly, for the Engineering building, the use of fixed photovoltaics (i.e. Scenario 2) gave higher percentages of total savings (21.1% vs. 20.5%). Annual savings and initial costs remained at the same levels while annual costs in Scenario 2 fell to €154961. For the Administration building, the use of two-axial photovoltaics (i.e. Scenario 1) gave higher percentages of total energy savings (48.6% vs. 46.4%). From an economic point of view, however, Scenario 2 increased overall annual costs to 3%. It was found that the power of installed photovoltaics, the number of panels and the coverage of demand are the parameters that determine the cost and energy savings.
References

1. Energy Efficiency Policies and Measures in Greece- Monitoring of Energy Efficiency in EU 27, Norway and Croatia (ODYSSEE-MURE), CRES, Athens, September 2009.
2. KAPE, Renewable Energy Sources in Residential Totals
3. Environmental impact and energy saving for heating in Greek apartment buildings, Droutsa K., Balaras K.A., Energy Saving Group Institute for Environmental research and Sustainable Development, National of Athens.
4. IPE – Ecological Construction 2000.
5. RENEWABLE ENERGY SOURCES, ZERVOS A., Athens 2005.
6. http://www.energymining.sa.gov.au/_data/assets/pdf_file/0017/315404/Energy-Efficient-Strategies-REES-review-report-2017.pdf
7. https://www.wwf.gr/images/pdfs/LPR_2016_full%20report_low-res_embargo.pdf
8. ECOLOGICAL ARCHITECTURE, Bioclimatic architecture, ecological construction, geobiology, internal architecture, Kostas and Themis Steph. Tsithes, Kedros Publications, 2005.
9. ENERGY BIOCLIMATIC DESIGN OF BUILDINGS AND HOUSES. Kontoroupis G., Athens 2002.
10. ENVIRONMENTAL DESIGN, Randall Thomas, Max Fordham & Partners, E & FN SPON, London 1996.
11. IIP- Ministry 2000.
12. Tsipiras Th. &amp; Kostas. St., Ecological Architecture, Kedros, Athens 2005.
13. Tsipiras Th. &amp; Kostas. St., The Eco-House, Livani Publications, Athens 1996.
14. The Energy Research Group-School of Architecture-University College Dublin, Energy in Architecture-The European Passive Solar Handbook, Brussels 1996.
15. http://publications.gc.ca/collections/collection_2008/nrcan/M39-115-2005E.pdf

Acknowledgments