Renewable Energy Systems in building design

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SCHOOL OF SCIENCE & TECHNOLOGY

A thesis submitted for the degree of

Master of Science (MSc) in Energy Systems

DECEMBER 2015

THESSALONIKI – GREECE

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Abstract

High energy consumption of the energy sector gives the motivation to take efforts in the field of energy saving at International and European level. Energy saving especially in the South Europe countries needs energy because of the high solar radiation.

In terms of the legislative sector, the most important role for the reduction and the energy saving plays the Directive 2010/31/EC which set the targets for the net zero energy buildings construction in combination with many environmental benefits.

This dissertation carried out research into energy improvements in a building by using innovative and old techniques so as to improve its envelope. Specifically we have studied the energy situation in a kindergarten in the prefecture of Larissa , which is part of the C climate zone. In this building we have done the energy audit that is defined from KENAK and technical instructions issued through the use of certified software "TEE-KENAK Energy Building Inspection."

Moreover, we have studied the energy situation of this building in different cities in Hellenic space, located in separate climatic zones A, B, D so as to compare the differences between them. These cities are Rhodos for A climatic zone, Athens for B climatic zone, and finally Florina for D climatic zone.

We have taken measures in order for energy improvement which related to the insulation of external building structure, changing the glasses and creating solar spaces.

To conclude, this dissertation contributes to promote energy interventions in a building, its energy needs, as well as its transformation to a more energy-efficient one.

Frantziou Evangelia

10/12/2015

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1 Introduction

In recent years many things has changed in the energy policy at international and national level. Energy saving and the use of Renewable Energy Sources can lead to a sustainable solution to environmental problems with multiple benefits in social, economic and environmental level. For this reason, mainly the European Union has set the target "20-20-20" which means by 2020 every EU country should have achieved 20% savings in energy consumption, producing 20% of energy from renewable energy sources and achieving a 20% reduction in emissions of air pollutants to the atmosphere. Finally only if appropriate and strict measures take action, then these goals will seem achievable

In second chapter there is literature review from the energy field. It is analyzed the reason why people have used power/energy from the very beginning and how energy audits have taken place and affect our lives as well as the importance of an energy efficient building in the human and environment life.

In third chapter is recording the current energy situation in Europe and especially in Greece. It is given an overview of the consumption of energy a few decades ago until today, so as to understand the need for limitation.

In the forth chapter there are references to the regulations of the Greek State that brings our country alongside the European Directives and the energy efficiency of buildings Regulation (KENAK).

Chapter five summarizes ways to save energy in both existing and new buildings through energy actions also through bioclimatic design as well as an assessment of the expected benefits of these actions. Moreover, there is a summary of renewable energy sources, because renewable energy can contribute to further energy upgrade of buildings.

Chapter six contains the case study, especially the energy audit of the kindergarten and the results from interventions that taken place so as to improve its efficiency

Finally chapter seven are about the energy audit and the installed interventions in buildings which are located in different climatic zones, and the comparison between them in terms of their energy class, their cost and their payback period.

2 Literature Review

This part concentrates on giving an expansive clue around the energy efficiency and the possible results on both buildings and building regulation towards making a sustainable environment that might profit the future generations so as to emerge the awareness on the importance of sustainable building design.

2.1 Energy Efficiency

In this kind of buildings, they are included, residential, commercial, institutional and general population structures. Chances that minimize energy necessities through energy efficiency and passive renewable energy over structures envelop building design, building materials, heating, cooling, lighting, as well as appliances. In this chapter we will concentrate on small scale animated renewable engineering and on their dissemination and the profits of local energy generation and buildings.

When we say commercial building we mean different kinds of buildings such as hospitals, offices, *schools*, libraries etc. These different kinds of buildings have their own needs but all of them use more than half of their energy consumption for lighting and heating.

Electricity and natural gas are the most common fuel type which gets used by the commercial building. Moreover these buildings sometimes use another source of energy in the form of locally generated group or district energy in the form of power because this is most applicable in places like big cities, universities that are close to each other. Generally it is more efficient to have a centralized heating and cooling system. The positive thing is that district systems can have energy save as well as a huge reduction of equipment and maintenance cost.

2.1.1 Energy Conservation

As we all know it is urgent the conservation of energy. For the most part of human history, the utilization of energy was restricted to the measure of work that was completed by human beings. Afterwards the majority learned to use animals so as to do tasks such as heavy lifting and hauling. Energy conservation firstly consisted of doing less and then it was found easier ways to get work done.

2.1.2 Growth of Energy use in the Developed World

In the late 19th century electrical power was emerged, especially for lighting. Moreover electrical power was produced by efficient engines that were increased gradually. The deployment of electric engines occurred toward the end of 19th century which means an enormously expand of applications for mechanical power. The patent of countless small machines made energy an ubiquitous commodity at the beginning of the 20th century.

Irrespective of the deployment of mechanical equipment, the development of electrical equipment was based on theory; particularly electrical motors were efficient in comparison with the combustion- driven machinery. Earlier we had a development of efficient variable-speed motors even if their cost and maintenance limitations were serious.

During the beginning of the 20th century, it was a huge acceleration of energy consumption because of the rapidly growth of population. A fundamental result was that machines increased the production in factories and in agriculture. Also fuels were consumed rapidly because of the automobiles' entrance in our lives. Moreover, the growth of hydroelectric generation plants in comparison with the development of the electricity generation by nuclear as a by-product of nuclear weapons, became another two important major sources of the energy use from the beginning of 1950.

The positive thing is that until the early 1970's we had a continually reduction of energy prices. In any case the cautioning around this fast utilization of the world's natural resources made environmentalists to concern about the development. Despite the fact that government officials warned over the plausibility of the OPEC (Organization of Petroleum Exporting Countries) and nations utilized oil as a weapon so as to strangulate a percentage of countries, these notices appeared to have been unnoticed. The increase of oil costs in 1973 by the OPEC nations was unforeseen and that brought about energy crises. To numerous countries was the greater part of energy purchasers, for example industries, transportation came to immobility.

United Kingdom governments influenced negatively by the 1973 oil crisis, and therefore decided to apply a number of *adhoc* measures to embolden energy conservation. Moreover during the 1974' s the UK Secretary of State for Energy announced a 12 point package to encourage the buildings' conservation. Finally in 1978 the government introduced a Green Paper entitled Energy Policy – a Consultative Document which contains the main areas of government energy conservation policy.

2.1.3 Energy use in hot climates

With regard to the energy consumption in tropical buildings, cooling by utilizing air conditioning set the consumer to have bigger extent of energy in comparison with heating, on the other hand many of these tropical countries (developing countries) consume little amount of energy compared to the developed countries.

2.1.4 Imperative need to conserve energy

The western and generally the most developed countries which are responsible for the most of the world's energy consumption, reached some aspects in order to help the conservation of energy resources. These are the reduction of buildings energy consumption by using energy efficient measures. Moreover, it is the entrance of alternatives and renewable energy sources in our lives which is going to reduce the prices, also application of insulation in buildings for thermal efficiency and finally conservation of water materials and energy sources.

As regards the energy conservation by alternative or renewable sources can reduce demand by using well designed layout, passive solar design, life cycle analysis of materials, high levels of insulation. Moreover we can get energy efficiency by using condensing boilers, energy efficient white goods and lighting, good heating controls, building energy management systems, natural ventilation.

2.2 Energy Performance

After all, we have the establishment of energy performance measures; particularly these are measurements which help us to compare different levels of energy use in every type of service as well as they facilitate correlations of buildings. The occupancy hours, the severity of the climate and the type of activities in the building are three factors very important to be considered for a building energy performance.

One of the most important factors for a building operation is the building energy performance rate. For example a highly rated building may be entitled for special recognition through a range of voluntary programs that increase its rental income. In this way we can recognize the low energy buildings.

Another question is how to separate the ‘’low energy building’’ and the way we can construct an ‘’energy efficient building’’. The efficiency is often accomplished by using the lowest possible energy requirements. Concerning the installed equipment we can identify the low energy and the energy efficient buildings. Particularly we can evaluate each building in each design stage (materials, components, systems). The most important is to find what is required from the building in terms of its energy consumption target/needs.

2.1.5 2.2.1 Energy Consumption

When we say energy consumption in buildings, we mean the following three categories. First of all, Primary Energy, which is about the calorific value of the fossil fuels in their primary state. Secondary Energy, which is available from electricity and finally Useful Energy that refers to the energy needed for the appearance of the given target also the heating load evaluations and other efficiencies.

2.2.2 Building Regulations

Building act 1984 gives the opportunity to the Secretary of State (England and Wales) to make the following building regulations. Firstly to secure the health, safety, welfare and convenience of people in buildings and of others who may be affected by buildings or matters connected with buildings. Secondly to prevent waste, seamless consumption, misuse of water and finally to further the conservation of fuel and power.

National building regulations for insulation were introduced in 1965. Since then, standards have been raised over the years, most recently by the Building Regulations (Amendment) Regulations SI 1994/1850 (a separate building control system applies to Scotland and Northern Ireland). These modified the Building Regulations SI 1991/2768 by expanding the requirement that the reasonable provision shall be made for the conservation of fuel and power in buildings'. Schedule 1 in England and Wales specifies that this provision shall be achieved by limiting the heat loss through the fabric of the building, controlling the operation of the space heating and hot water systems, limiting the heat loss from hot water vessels and hot water service pipe-work, limiting the heat loss from hot water pipes and hot air ducts used for space heating, installing in buildings artificial lighting systems which were designed and constructed to use no more fuel and power than is reasonably practicable in the circumstances and making reasonable provision for controlling such systems.

The 1994 Government's Standard Assessment Procedure (SAP) starts calculate the energy rate in terms of introduced regulations about newly created buildings. The procedure takes account of fuel costs, ventilation, fabric heat losses, water heating requirements, internal heat gains (e.g. human body heat, and heat from domestic appliances), and solar gains. The method includes information on the efficiency of different types of heating systems, and estimates of hot water usage as a function of floor area. The SAP rating is expressed on a scale ranging from 1 to 100. A rating of 1 represents a poor standard of energy efficiency while 100 represent a very high standard.

2.3 Energy Audit

2.3.1 History

Briefly the history of energy audit: Energy audit procedures were firstly used in the early 1970 's in the United States during the energy crisis. With the intention to reduce energy consumption, state funds were used to incentivize energy efficient buildings in the Supplemental State Energy Conservation Program. Buildings which had receiving government funding had to follow various requirements like mandatory lighting efficiency standards, programs to promote the availability and use of carpools and public transportation, mandatory thermal efficiency standards and insulation requirements, public education efforts on implementing energy efficient measures, encouraging and carrying out building energy audits for commercial and industrial applications.

During the 1980’ s, cheap energy expenses stopped the energy emergency and the utilization of building energy audits have reduced. As the effects of global warming are expanding on an overall scale, decrease of CO_2 production and energy efficiency are urgent. This impact has brought about strict regulations, motivator programs, and different kinds of certification labels to help to the energy efficiency. These methods maybe contribute to the reduction of global warming impacts; on the other hand they underline strategies for example energy auditing, not only to diminish the energy consumption, but also to save on utility expenses.

Consequently one of the techniques to diminish energy wasting and power expense is by occasionally checking on timetables to guarantee that the equipment runs just when it is required, and by augmenting the utilization of a control system so as to operate the equipment and frameworks in an energy effective way while keeping up a comfortable and safe building environment.

2.3.2 Energy Audit-Definition

Energy audits are an efficient study or survey to distinguish how energy is utilized as part of a building or a plant. It is additionally a helpful methodology to discover the best alternatives for energy protection/safe. Energy audits give an examination to measure the energy consumed during a given period in the form of electricity, gas, fuel, oil or steam. By using these data is likewise conceivable to list how the energy was utilized by different procedures in a plant or at the different outlets in a building. The following step in an energy audit is to identify the potential for energy funds precisely.

Energy audit, similar to financial accounting procedure, is a procedure of looking an energy account by checking the way we use energy and recognize points where wastage can be reduced. Energy audit cannot take place effectively without the dedication from the top administration-management. The essential reasons are: a) Potential money returns which means the desired energy and the expense saving after execution b) Energy is far reaching because traditional energy resources, such as fossil fuels are reducing c) Probable demolition to environment because burning of fossil fuel in power generation results in increase of CO2, which contributes to an unnatural weather change and thus the global warming, etc.

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2.3.3 Initiation of Energy Audit

Energy audit begins with a review of historical energy use. The arrangement of 3 to 5 years historical data on energy use and the consumption can be aggregated from energy bills and plant records. From this information we can comprehend the past examples of energy use and their pattern. This is likewise a base reference for future correlation after the energy audit software have been actualized. It is often valuable at this stage to think about the average energy use of the building being examined with different kind of buildings with similar function and get some idea whether the building is apparently productive or wasteful in the previous couple of years.

2.3.4 The Site Surveys

After getting the data on historical energy use and the amount we spent the past few years on energy, the next step is to set up an energy audit modified. This programmed ought to be embraced jointly by the Energy Manager and the building administrator or owners. This modified ought to begin with site survey. Site surveys are important to give data regarding the current energy use. They also must check and record the energy sources, the energy utilization and the energy control.

2.3.5 Energy Sources

Diverse sources of building energy supply ought to be recorded, whether they are in the form of electricity-power, gas, diesel oil, etc. Total energy cost of all inputs can therefore be figured as far as a typical unit. Other related data ought to be checked and recorded, such as types of tariff being used.

2.3.6 Use of energy

Site reviews on energy use are more muddled and tedious. They may incorporate the following a) Running hours of air conditioning and length of pre-cool period. b) Internal comfort conditions, e.g. temperature, humidity. c) Locations of pointless air-conditioning and lighting d) Chillers/pumps scheduling and setting. e) Every energy efficient light fittings and control being used. f) Adequacy of insulation of the building fabrics g) Quantity of waste heat being released h) Efficiencies of individual equipment or machines. i) The zones of high energy consumption and the possibility to diminish consumption.

2.3.7 Energy Control

It is about the ways the administration controlled the energy use inside the building. Regular data are required for energy management, how and when energy consumption is assessed, how frequently meter readings are taken, whether extra sub- meters are required, any energy estimation, examinations on energy consumption inside or remotely, how well is the system worked and maintained, every energy productivity improvement schemes in hand, whether representatives know about the requirement for energy protection, and so forth.

3 Energy Distributions in Greece and Europe

This chapter presents the current energy situation in Europe and Greece. It gives an overview of the energy consumption from a few decades ago until today, so it is understandable that it is urgent to limit.

3.1 Building sector and energy consumption in European Union

Europe of 27 countries after its enlargement cannot compensate the energy amounts that consumes with those it can produce. Indeed the pace energy demand in the Member States has risen from 1986 by 1% to 2% annually while there is an ongoing dependence on oil supply and gas from sources outside its borders. Although the obvious solution is the greater use of renewable energy sources, which will reduce energy imports and greenhouse gas emissions, it is important, an effort from all consumers to reduce energy use.

Green Bible published by the European Commission in 200 set out a policy that will help us to unclog and in which it is firstly mentioned the importance of consumers' intervention demand instead of the profitable offer. Moreover it is distinguished that the main sources of pollution are concentrated in cities. Urban centers account for 80% of the population and consume 75% of energy. According to the European Commission, energy consumption in buildings for heating, cooling, lighting, and hot water accounts for 40% of total energy consumption in Europe, which broadly reflects Greece.

At the same time, energy use and production is responsible for 94% of CO_2 emissions, 45% of which comes from the building sector. In the EU the building sector (households and the tertiary sector) is the largest consumer of final energy in absolute terms (40%). The average annual heating energy consumption in residential buildings is between 150 and 230 kWh/m2. In eastern and central Europe the energy consumption for space heating is between 200 and 400 kWh/m2, also comparing consumption in relation to that in Western Europe, it is obvious that it is two or three times greater. In Southern Europe the average annual consumption of thermal energy is 120-150 kWh/m2 in a well-heated building.

In Greece the annual average thermal energy consumption is about 140 kWh/m2 for houses and 96 kWh/m2 for apartments which built before 1980-92-123kWh/m2 and 75-94kWh/m2 respectively for houses and apartments that built after 1980.

Under the reference scenario by 2030 it is assumed that energy consumption in the tertiary sector will grow about 75% compared to the current situation that is about 30%. In particular, the final energy consumption of buildings in EU countries is around 350 million tons equivalent of oil per year, without the contribution of renewable energy sources.

The cover of these energy needs is from a) natural gas (116 million tons oil equivalent), b) oil (99 million tones oil equivalent), c) electricity (91 million tones oil equivalent) and d) solid fuels (11 million tones of oil equivalent). The average energy consumption per household for heating has slightly decreased in the EU since 1990, while the theoretical specific consumption of new dwellings is 22% less than that in 1985. This is due to improved efficiency of both buildings and of electrical appliances, while receivables in climate comfort have increased. In addition, there are more stringent energy efficiency criteria that have been established in most countries in recent years.

Something that makes clearer the need for energy audit of buildings is a requirement to study the performance of building complexes and the calculation of the percentage of total energy consumption. The energy consumed in buildings is primarily for heating and cooling of rooms, hot water, cooking, lighting and the use of various electrical appliances. It has recorded that heating of buildings has a significant proportion of their total energy consumption (69%), followed by water heating (15%), electrical appliances and lighting (11%).

The largest proportion of energy consumption in buildings is used for their heating. So we improved the shell of the buildings on the application of effective thermal insulation that was the primary objective of engineers in the period 1970-1980. At the same time the energy consumption for spaces’ cooling has presented a large increase, amounting to

14.6% per year in the period 1990-2000, which is a result of increased thermal comfort requirements and reduced air conditioners' price.

3.2 CO_2 Emissions

One of the most serious problems faced by the world community in recent years is global warming. This is due to the ozone hole caused by the reckless emission of pollutants. These pollutants produced from the combustion of fossil fuels (oil, coal, etc.) which emit huge amounts of CO_2.The most important sector for the greenhouse gas emissions' existence are energy (80%). The residential sector is the fourth largest source of emissions, which accounts for 10% of total emissions of greenhouse gases, without the rate of energy electricity consumption in buildings.

The effect of the European Union buildings in greenhouse effect corresponds to a total 6 billion tons of carbon compounds that are emitted worldwide (including carbon dioxide, CO_2). 4.5 billion tones of these are attributed to industrialized countries, and 50% of them are due to buildings(directly or indirectly).

EU showed a reduction of total emissions of greenhouse gases by 7.9% since 1990 (5.621 million. tones of equivalent CO_2) by the year 2005 (5.177million tons of equivalent CO_2) and by 1.5% in the EU 15 countries for the same period (from 4.257 to 4.192 million. tons of equivalent CO_2). Between 2004 and 2005 the corresponding figures are 0.7% and 0.8%. The most important greenhouse gas is CO_2, since it is 82% and 83% of total emissions in the EU 27 countries and 15 EU countries respectively.

Although the greenhouse emissions of our country are small compare to the total emissions from the EU 27 countries. We are not happy because of an increase by 27.5 % (from 109 to 139 million tones of equivalent CO2) in contrast to the downward trend in the average price in the EU (environmental protection agency, 2007). Greek buildings release in the atmosphere 40% of total CO2 emissions. Considering therefore the restricting emissions of greenhouse gases which set by the Kyoto Protocol it becomes evident the need to improve their behavior in this area. Finally the building policy aims to ensure a high quality built environment while optimizing the use of resources.

In summary, it can be mentioned that the buildings of the European Union accounts for 1/6 of global resources, 40% of world energy consumption, 16% water and 70% of CO2 emissions.

If we are going to implement the measures of European Parliament Directive about the energy performance of buildings it is estimated that the new buildings will save 9 million tones of oil equivalent. In other words, the apartments will have 60% less consumption compared to those that have built before 1970. If we implement stricter standards, it is possible to achieve additional energy savings about 30%.

The rate of energy consumption will continue to grow while it will start to decline in 2030, in details it will fall to 0.6% in 2010-2020 and to 0.3% in 2020-2030. The next 30 years energy consumption for space heating will increase slowly while electrical appliances and air conditioning will increase.

3.3 Building sector and energy consumption in Greece

In Greece in order to satisfy the thermal comfort conditions and air quality in buildings we need up to 30% more energy, buildings face the problem in the majority of adequate insulation, especially those that have built before 1980. Among the most energy-intensive buildings in the EU, the Greek ones absorb 1/3 of the energy consumed and have heat loss from windows and doors, thus they waste precious energy and money and simultaneously emit unnecessary quantities of dangerous pollutants that are responsible for the "greenhouse effect." The building sector is responsible for the rate of CO_2 (45%) and for the consumption rate (35%) of total energy. In fact, within the last five years we have had 25% increases in energy thus our buildings need to be heated, cooled and energized.

Noteworthy is that Greece, along with Spain, note the largest increase of energy consumption for heating between Member States. On the other hand, countries in the north hemisphere that affect harshest winters, (Sweden, Belgium) managed to reduce by 5% the energy consumption. In Greece, a country with far fewer thermal requirements during the winter (mind temperature), housing heating needs are around 70% of total energy consumption. The energy consumption for household appliances, lighting and air conditioning are about 18% of the total energy balance. Buildings which use exclusively fuel oil, representing 35.5% of the total. The remaining 64% is self-heated homes using oil, gas, electricity and firewood. Unlike EU-countries, Greece in buildings consumption actually grows at an annual average rate of 7%.

New buildings in Greece would consume half of the current energy for heating needs, only by the implementation of the building Denmark regulations that are much stricter. This pursued by Directive (2002/91/EC) on the energy performance of buildings.

According to the Development Ministry in Greece figures, residential buildings represent 76% of the total. Moreover, 70% of these until 2001 had no insulation and only 29% of these have been built after 1981. The potential savings are enough if someone takes into account data of each year. Particularly, in 2002, 2,1% are double glazed,30,4% have insulated roof,12,7% have insulated flats,1,5% have insulated floor, 4,2% have insulated piping in the heating system, 20% have insulated exterior walls. The unpleasant fact is that CO_2 emissions / capita increased in Greece through the years, Greece was in second place of CO_2 emissions in the residential building sector the last decades with an increase of 82%. Additionally, the increase in the number of new buildings and the creation of a more comfortable interior living environment justify the fact that energy needs have risen the last ten years in the Greek buildings (both domestic and industrial). Household buildings are responsible for the 23.6% of total energy consumption and consume 32.7% of the total electricity production as well as the 21.5% of the total thermal energy

To conclude, it is quite easy to understand that with proper planning the size of the economic and environmental gains would be very obvious as well as we will note an increase in energy performance of buildings that can rise up to 30% in consumption.

4 National Regulations and Laws

In this chapter there are references to the regulations of the Greek State that brings our country together with the European Directives as well as the energy efficiency of buildings Regulation (KENAK).

4.1 Institutional framework

Law 3661 "Measures to reduce energy consumption of buildings" and the Directive 2002/91/EC incorporate all the provisions the Directive provides for the adoption of energy efficiency regulation buildings and distinguishes five main themes, which relate to the definition of the minimum energy performance requirements and the method of calculation energy efficiency (Article 3) of new or existing buildings (Article 4 and 5), to Energy performance certificate issuance (Article 6), to inspections of boilers and air-conditioning systems (Articles 7 and 8) and to the provision of specialized energy inspectors (Article 9) .

4.2 Definitions

Both law 3661/2008 and the Regulation of Energy Efficiency of Buildings contain some basic definitions but we have to know further:

Energy performance of a building

The amount of energy consumed or estimated to meet the different needs associated with the typical use of the building, which may include, inter alia, heating, hot water, cooling, ventilation and lighting. This quantity is expressed in one or more numeric indicators which have been calculated, taking into account insulation, technical characteristics and installation characteristics, design and position building in relation to climatic aspects, solar exposure and influence of neighboring structures, the energy of the building itself and others factors that influence energy demand, including climatic conditions inside the building.

Energy audit

It is the assessment process of actual energy consumption, the factors affecting them, as well as the improved methods for saving energy in the building sector. Particularly, Building, Boiler and heating, Air Facility (> 12 kW), Lighting Systems

Energy inspector

It is about a natural or legal person who carries out energy buildings or boiler inspections and air conditioners. There are two types of inspectors, Class A buildings <1000 m² and Class B buildings> 1000 m² .

Reference building

It is the building with the same geometry, position, orientation, usage and operating characteristics of the examined building. The reference building complete minimum standards and has defined specifications both to outer structural elements, and to electromechanical installations that concern cooling, heating, air conditioning (HVAC) inside the building, domestic hot water (DHW) and lighting.

Total final energy consumption building

The sum of the calculated energy consumption of a building for HVAC, domestic hot water and lighting, expressed in energy per unit of gross surface of the heated areas of the building in the year (kWh / m^2 year). Especially for residential buildings, lighting is not counted, in total energy consumption.

Total primary energy building

The sum, individual energy consumption, after their reduction to primary energy sizes by using the coefficients conversion.

Energy Efficiency Study

This study analyzes and evaluates the performance of energy design buildings.

Moreover, regarding the energy efficiency study and the energy requirements calculations, it is mentioned in the regulation (KENAK) the following:

1) Study Energy Efficiency:

-Being prepared for both new and existing radically refurbished buildings over 1000 m^2 (Law. 3661, Art. 4, Article 5), of residential and tertiary sectors.
-Replaces the existing insulation study (article 13 of Law. 3661) and it would be included in the dossier submitted to the relevant Planning Service to issue a building permit. The audit, the approval and the monitor of implementation of energy efficiency study will be done under the circumstances for issuing building permits.
-It constitutes an additional study on the study: architecture, configuration surroundings, heating, cooling, hot water and artificial lighting.

2) Requirements Energy Efficiency Building Study:
In the study of energy efficiency building should be prescribed in detail the systems that have joined in the building study and that contribute to the improvement of the energy performance, as well as the method, assumptions and results of the calculation of energy consumption for heating, cooling, lighting and hot water. Particularly, information on the architectural plans (topographical diagram views, floor plans, sections, etc.), information on the plans of the Electromechanical installations (air-conditioning installations and ventilation, lighting, electrification systems, computation energy consumption and CO_2 emissions etc), other information (weather data, charts insulation and ventilation, elements of shell, insulation, windows, etc.).
3) Results from the energy efficiency building study:
Calculation of different components of the energy requirements for heating and cooling of premises, namely: Thermal losses due to heat transfer from the components' surfaces (outer walls, ceiling, floor, windows), Thermal losses of spaces due to mechanical controlled ventilation and natural ventilation or air infiltration (non-controlled ventilation), Interior thermal profits, Solar heat gains from glazed shells, Solar heat gains from passive solar systems.

4.3 Energy audit of lighting systems

4.3.1 Minimum requirements

For the correct design and optimum energy efficiency of artificial lighting systems, it is given a minimum requirements table for buildings, which should be taken into account during the construction or renovation of a building. On the board is given the general lighting level for various areas of the building depending on their function. The price lighting levels is the required average ergonomic level. Lighting criteria are detailed in the table 1 below:

Building Type	Space Type	Maintained Average Illuminance at working level (lux)	Measurement (working) Height (1 meter = 3.3 feet)
Barracks/Dormitories	Bedrooms	300	at 0 m
	Laundry rooms	300	at 1 m
Educational Buildings	Play room, nursery, classroom	400	at 0 m
	Lecture hall	400	at 0.8 m
	Computer practice rooms (menu driven)	30	at 0.8 m
Office buildings	Single offices	400	at 0.8 m
	Open plan offices	400	at 0.8 m
	Conference rooms	300	at 0.8 m
Educational buildings	Classrooms	300	at 0.8 m
	Classrooms for adult education	400	at 0.8 m
	Lecture hall	400	at 0.8 m
Hospitals	General ward lighting	300	at 0.8 m
	Simple examination	500	at 0.8 m
	Examination and treatment	1000	at 0.8 m
Hotels and restaurants	Self-service restaurant, dining room	100	at 0.8 m
	Kitchen	500	at 0.8 m
	Buffet	100	at 0.8 m
Sport facilities	Sports halls	300	at 0 m
Wholesale and retail sales	Sales area	500	at 0.8 m
	Till area	500	at 0.8 m
Circulation areas	Corridor	50	at 0 m
	Stairs	50	at 0 m
	Restrooms	300	at 0 m
	Cloakrooms, washrooms, bathrooms, toilets	300	at 0.8 m
Industrial	Metal working/ welding	300	at 1 m
	Simple Assembly Difficult Assembly Exacting Assembly	300 1,000 3,000-10,000	at 1 m
Central Plant	Boiler house Machine Halls Side rooms, e.g. pump rooms, condenser rooms etc. Control rooms	50 300 300 500	at 0 m
Vehicle Construction/ Maintenance	Body work and assembly Painting, spraying, polishing Painting, touch-up, inspection	500 1000 3,000-10,000	at 1 m
Wood working and processing	Saw frame Work at joiner's bench, assembly Polishing, painting, fancy joinery Work on wood working machines e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking	300 300 1000 500	at 1 m

Table 1: Examples of design illumination levels for selected Army buildings and spaces

4.3.2 Procedure of Lighting System Inspection

The energy audit lighting system takes place under the inspection and energy certification of the building. The surveyor during the inspection of the lighting system records a) general building elements, in particular, the use of the building, characteristic geometric sizes (area, volume), operational characteristics (hours), the age of the lighting system (setup time) etc. b) Details of the lighting system and in particular, the type and number of lighting fixtures and ballasts, the type and number of lamps, devices and control systems etc.

Regarding the power consumption, typically, it is not possible to be measured in details. The data on the energy consumption of lamps and damper should be obtained from manufacturers' catalogs. Data collected should contribute to the calculation of the total installed lighting power (in kW), the annual electricity consumption for lighting (in kWh / yr) in the building. The recording of luminaries and lamps perform per single-use spaces unity and operating hours.

Following the site inspection, the inspector determines the fields that can be improved, he reports Energy Audit with the results of Inspection and proposals for improving the energy efficiency. The exhibition consists of the completed registration form, including recommendations for improving the energy efficiency of the system.

4.4 Energy categories and limits

According to the standard pr EN 15217: 2006, based on the energy consumption of the building ("EC"), for heating, cooling, domestic hot water (DHW) and lighting, expressed in kWh / (m2 * year) are defined categories of energy levels, from A to H, according to a) the index of energy consumption of the building stock (Rs), which corresponds to the energy consumption of 50% of the building stock, b) the index of energy consumption reference to Regulation (Rr), ie maximum permitted energy consumption buildings.

These indicators Rr and Rs relate to all energy requirements (heating, cooling, lighting and hot water). Both indicators are expressed in kWh / (m2 * year).

The energy rating scale of the building is given in tables according to the energy consumption, the use category building and climate zone in which it belongs. All new buildings and existing over 1000 m^2 which have undergone major renovation, should be located at least in the energy range consumption category B.

ENERGY CATEGORIES	**LIMITS**
A+	for EC ≤ 0.33Rr
A	for 0.50Rr ≤ EC ≤ 0.33Rr

B+	for 0.50Rr ≤ EC ≤ 0.75Rr
B	for 0.75Rr ≤ EC ≤ Rr
C	for Rr ≤ EC ≤ 0.50 (Rr + Rs)
D	for 0.50 (Rr + Rs) ≤ EC <Rs
E	for Rs ≤ EC ≤ 1.25 Rs)
F	for 1.25Rs ≤ EC ≤ 1.50Rs
G	for 1. 50Rs ≤ EC

Table 2: Energy category limits

4.5 Objectives and benefits of Energy audit

In order to reduce the energy consumption in buildings, their potential energy wastage is necessary information. The acquisition is done through energy inspection which is an energy diagnosis or an energy audit.

The objectives of an energy audit are: saving energy and reducing CO_2 emissions, identification of energy saving potential, improving internal quality buildings, the identification and prioritization of interventions required to improve energy efficiency, checking compliance of the energy performance of individual facilities and units based on predetermined criteria, increase the life time of equipment and systems, the determination of the energy consumption model in a particular unit as a function of an index of production activity, checking of the results of an investment or a savings program energy, the long-term economic benefit. Moreover energy audits are divided into two categories according to the volume of the components needed to assemble:

A) The synoptic energy audit.

Here is a valuation based on invoices and bills of energy building and a brief observation of the space. The proposed measures have a short-term repayment and relatively low cost. At the same time, proposals of more expensive interventions may come true.

B) The extensive energy audit.

There are increased requirements of collection and analysis of energy consumptions in the study area. There are presented the final uses of energy consumed by the building and all the factors that can change. Through the above can be identified total potential benefits but also a series of individual interventions depending on the desires and aspirations of each administrator. Finally, as in previous type of inspection, it is presented high cost options and an analysis of the benefits arising from them. The interventions that can be proposed by the above two surveys have different costs and divided into:

a) Housekeeping Interventions

Ii is about steps in the daily operation and maintenance of the building without particular estimate or shutdown. The success of these measures directly related to update and change of user's behavior of a building. Such interventions are indicative: i. Periodic maintenance of burner and control the boiler's efficiency, cleaning boiler heat exchanger surfaces, ii. Check and repair open frame cracks, wall cracks, damaged mechanisms, worn element's insulation and sealing elements joints, iii. Close the heat flow paths to wells and stairwells. iv. Rational operation of existing shading devices in relation to season and orientation of the exposed building in sunlight exposure, v. Standard use of exposures, particularly during the night, to aid natural ventilation cooling in warm periods of time, vi. Close the air conditioning and lighting when the spaces are not used, correct temperature control of air conditioning, etc.

b) Low Cost Interventions

They are connected with low investment cost and with limited downtime of the building use. Some of these are usually included in the existing management budget of the building and have payback to 24 months. Some of these are: Remove unnecessary exposures while thermal protection of the cover surfaces, Replace of incandescent bulbs, Replace with new double glazing, Apply color and reflective film or local internal shading devices (blinds, curtains) to exposures with unwanted high summer solar gain, Apply automatic reset doors mechanisms, Replacement of doors with other new design of materials with specific protection and lower thermal transmittance, Add thermal insulation layer on portions of the outer masonry which are behind central heating radiators, Installation of thermostatic valves on radiators with potential local temperature regulation, Install timers that automatically terminate the operation of systems

c) Reconstruction Interventions

They require large budget as well as time and the downtime of the building operation are not small. Examples include Thermal insulation of exterior walls, roof, floor, flats, Thermal insulation of thermal bridges (columns, beams, walls, etc.), Reduction of the heated / conditioned volume in excessive height spaces (membership suspended ceilings), Apply external fixed or movable shading devices (blinds, shutters vertically or horizontally moving or fixed sunshades, etc.), Addendum of a passive solar heating and lighting systems (panels, solar areas / greenhouses, natural openings lighting, natural light pipes etc.), Addendum of variable speed motors, install the correct equipment power factor etc.

4.6 Conducting an energy audit

Energy inspectors conduct an energy audit. They are people with appropriate expertise in issues of building infrastructure heating equipment, ventilation and air conditioning (HVAC), lighting and any other building installation. The object and purpose of an inspection is to determine the number of energy auditors and the time needed so as the inspection to be completed. It is necessary also the contribution of staff company which deals with end-use appliances, maintenance, operation etc. during the process. The inspection team should collect information about the building's operating and technical characteristics of the equipment and systems in order to gain a fuller image of the current building. Yields of the systems should be determined by perform measurements, by monitoring of operating and maintenance records and by the site inspection. Afterwards it will follow the identification of possible improvement points and an exhibition of energy auditors with the results of inspection for possible applications that are going to happen.

The *basic steps* for conducting the energy inspection are presented below:

a) Determination of the energy audit object.

To conduct an inspection, we must determine in principle the exact inspected subject, the time and the budget. While the arrangement with the building’s management is done, then it should be determined the exact areas to be inspected, the degree of analysis inspection, the expected savings, the use of the results of inspection (as the basis for improving the operation and maintenance), the need for continuing the level of study and promotion of results, etc.

b) Create a group of energy inspectors.

An energy audit team formed by i. the definition of the team members of inspection and their duties, ii. The participation of the maintenance stuff in order to collect information. iii. The organization of meetings so as to exchange information and familiarize between the members.

c) Assessment of schedule and budget

The budget and work schedule is determined in accordance with the costs and the number of the hours required for collecting the necessary information until the completion of the inspection report.

d) Conduct of inspection and final proposals.

More information about the individual parts of inspection can be found in the Regulation of KENAK.

4.7 Energy identity of the building

The results of the investigation and any other necessary building characteristics displayed in a special form, this form is the energy identity building.(something like building ID). After the building edition, it would issued the report of the building identity in which would be included its energy features and its energy class.

Without this report, any transaction (sale, rent, transfer, etc.) is impossible to happen. With this card institutionalized the requirement for annual maintenance of heating and air conditioning systems. This report would be supplemented after calculating energy efficiency of the building and submitted along with the license file to the planning of the student manual. One year after the completion of construction will be the definitive classification of the building’s appropriate category energy as well as its environmental performance and its energy certification. The energy certification would be made to the energy audit of the building by an approved energy auditor. For existing buildings would set a period of a few years to test.

KENAK will indicate the ways to calculate the energy identity, and to conclude the energy identity of the building which would have the following characteristics capacity of 10 years, includes recommendations to improve performance in relation to cost, stand in a conspicuous place in large public buildings, enabling consumers to assess the energy audit, in all cases the energy identity of the building issued by appropriate staff.

4.8 Obstacles to implementing energy building design in Greece

A) The main problems and obstacles are: delay of the adoption of the new Regulation (KENAK), lack of information from audit bodies (Planning Office) and weakness of control of bioclimatic building design, increased cost of imported materials and energy systems, insufficient financial incentives (mainly in the residential sector), unreliability of greek building materials and systems, and incomplete certification.

B) The main actions to counter these problems: need to improve the market for construction products, adequacy of Greek designers and manufacturers in energy design, implementation of institutional framework for energy services, institutional setting of auditors' energy issues, evidence information of the public, the consumer, the investor and of the technical world at large.

5 Actions for energy saving in existing buildings

The third chapter summarizes ways to save energy both in existing as well as in new buildings through energy actions and through bioclimatic design. Finally there is a summary of renewable energy sources, because renewable energy sources can contribute to further energy upgrade of buildings.

5.1 Thermal insulation added

Generally, insulation in building construction is defined the construction measures taken so as to reduce heat transmission either between the interior of the building and the atmosphere or between the interior of the building with different temperatures. The process of insulation involves mainly buildings that have been built until 1980 and do not carry any insulation in their structural elements. In buildings that have insulation (buildings built after 1980), or which have been partially adding insulation, but this insulation is insufficient, the operation may concern only parts of the building (eg covering thermal bridges, additional insulation ceiling) and in any case it may be substantiated by the energy audit and energy study.

When the thermal insulation was made of appropriate materials and manner then it provides: A. Healthy and pleasant stay of the occupants. Good thermal insulation ensures comfortable and cheap accommodation of the occupants of a house (small temperature fluctuations during the day). B. Rational energy consumption for heating and air-conditioning facilities. Good thermal insulation reduce the running costs of heating in buildings and simultaneously protect the structure from damage that could be caused (breaking pipes from frost, mortar detachment due to water vapor etc.), due to sudden changes in temperature or due to water vapor concentration. C. Reduction of construction of the heating system costs. The heating system is calculated based on the thermal construction losses, so good insulation means little heat loss and thus smaller and cheaper heating installation. D. Reduction of environmental pollution, which can be either atmospheric (flue gases from heating system) or thermal.

5.1.1 Insulation methods

The way a building is insulated depends on the resistance of construction elements (roof, walls, floors, etc.), the permeability of the structural components of the air and especially of external elements, the heat capacity of the construction components, the use of spaces that are thermally insulated

5.1.2 The types of insulation

Internal insulation: It is done by putting the insulation material on the inside of the building data. It is the most economical way of thermal insulation. The insulating material inhibits heat flow from the inside to the outside environment, thus the heat capacity of the wall to be unexploited. Therefore, the space is heated quickly from heating systems, but it is cooled quickly when their operation stopped. In addition, the usable space is reduced and the external sides of the building remain unprotected consequently it needs thermal bridges.

External insulation: It is done by placing the insulating material from the outside of the building elements of construction. It is used to a greater extent because it displays significant advantages, such as operation of the heat capacity of building data, less possibilities of condensation, protection components from sudden temperature changes; also it has applicability in existing buildings. At the same time, however, they present several disadvantages such as necessity protection of the insulation from the elements, protecting from contractile effect and high manufacturing costs. The most common insulation form in our country is the core of the wall with or without air layer (for brickwork) with various layered insulation materials.

Wall insulation: The main ways of walls' thermal insulation are within the area, abroad, at the core (gap) and using insulating bricks

Ceiling Insulation – Roof: This insulation can be horizontal or inclined, and the insulating material may be mounted to an outer or inner surface of the roof. In foreign ceiling surface the heat insulating material can be placed either above or below the seal according to the behavior of the moisture. The roof combines horizontal and sloping roof. In case the area of roof is not populated, then a thermal insulation material on the horizontal surface is enough. On the other case the insulation is placed either internally or externally to the inclined surface.

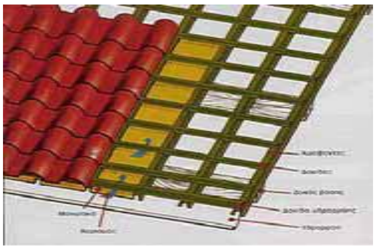

Figure 1: Insulation of wooden sloping roof.

Floor insulation: The insulation in the floor can be placed either above the plate in case we are interested in the immediate return of air heating systems (holiday houses) or under the plate as it has better performance and after the discontinuation of air heating systems. The estimated potential benefit of adding insulation may range from 10% to 40% energy savings for heating

5.2 Replacing old windows, doors and frames

The frames have an important role in the energy consumption for heating and cooling because a large amount of energy of these is transferred. During the winter heat lost from the inside out, while during the summer heat enters from the hot external environment. This process can be minimized by using suitably constructed and energy efficient windows. These windows must have glass panels and windows with good thermal insulation properties and they must be airtight to prevent the escape of heat from cracks, which may result in loss of heat, such as it is observed in poorly manufactured or in old buildings.

In Greece, according to the thermal regulation (1979) it is mandatory to use double glazing in new buildings, in order to meet the Regulation's requirements. For old buildings, generally (built before 1979), replacing single glazing with double and replacement of frames is a significant energy saving technique. The replacement of the old windows with new energy efficient double glazing ones, irrespective of the cost, can upset the poor energy efficiency of the building to multiple energy-environment and economic benefits

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5.2.1 Glazing

The main parameters for the appropriate choice of glass are firstly *U-factor* that represents the ability of the glazing to reduce heat loss of interiors. The small value indicates increased potential energy savings. It has units (W/m^2 K), *Solar factor g* that represents the ability of the glass to transport sunlight inside the building. Their great value indicates utilization of solar radiation and *light transmittance factor Tv* which represents the capacity of the pane to convey natural light to the interiors. The great value indicates considerable use of natural and therefore reduction of artificial lighting needs. It is dimensionless size.

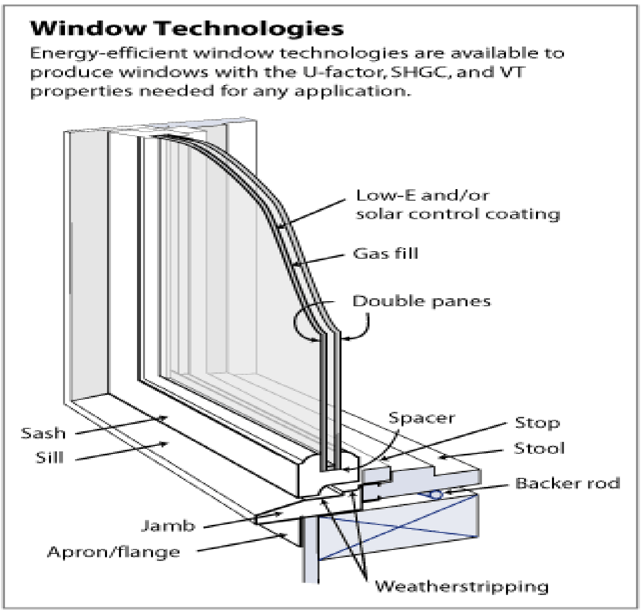


Figure 2: Windows' technologies.

The main types of glazing with a short description are firstly the *single glazing* and it is characterized by great thermal and solar factors heat gain. *Double glazing* which consists of two panes, between of them there is vacuum dry air. By increasing the thickness of the gap and the glass, the U-factor rises. Typical thickness of the glazing is 4 - 12 mm and vacuum 6 - 16 mm. *Triple glazing* comparing to the double glazing, it is better relating to the thermal and insulating abilities but suffers considerably on the costs and weight. *Color Pane* that presents low thermal transmittance and reduced light transmission. It is recommended to reduce solar gain. *Reflective glazing* that is about a single or double glazed with reflective coating - one thin film, which reflects a substantial portion of incident solar radiation, reduce solar heat gain, but at the same time reduce the natural light permeability. The coating is applied to the outer the single or the double glazing surface and may cause glare on the surrounding area. *Glazing with low heat radiation- Low-e* is about a double glazing covered by metal oxides, which placed on that surface of the inner or outer pane which face the gap. If the coating would be on the outer surface of the internal glazing, then the heat gains are trapped inside the building during the winter months, while if the coating is done on the inner surface of the outer pane, then the entry of solar prevent heat gains during the summer months. *Absorbent glass Pane* that is a single glass pane which is able to absorb a significant proportion of the incident radiation, without causing great reduce of natural light. Unlike the reflective it does not cause pane glare to the surroundings. However, some of the absorbed radiation is released later in the internal areas. As a solution a double glazing can be used thus its external glazing would be an absorbent glazing. In this way, the absorbed radiation is released to the outside environment and not to interiors. *Antiglare glazing* ensures better distribution of natural light, minimizing glare problems. *Insulation glassing* are the panes in their interstices that contain another gas (e.g. argon) instead of air. These are recommended in buildings with large windows, where high insulation is required in the shell. They also have increased thermal capacity. *Electro chromic glazing* is glass, whose optical properties (e.g. permeability) are changed by passing electricity.

Moreover double glazing has many advantages, such as a) Reduction of radiation to or from the interior of the building, showing surface temperature closer to that of other interiors' surfaces. b) Restriction of currents air near the openings, which improve conditions for thermal comfort. c) Prevent condensation on the surface during winter months. d) Reduce noise.

5.2.2 Frames

Panels contribute significantly to the surface's openings. Especially in small openings, that participation could reach 30%. It is therefore evident that the energy behavior of an opening is influenced by the thermal frame capacity. A box with bad insulation capabilities can reduce up to 25% the energy gains of a double glazing with inert gas and up to 70% the energy gains of a corresponding triple glazing. The main types of panels are:

Wood Frames: They offer the best thermal behavior. They have reduced air tightness - which has the negative consequence of the heat losses during the winter and as positive effect the ventilation of the area.

Aluminum Frames: They have the worst thermal behavior compare to the wooden ones. Apart from that they do not need maintenance and these also assure excellent water tightness and air. Their insulating ability is further improved with installation all around the inner and outer frame, a plastic which called thermal break.

Synthetic Frames: The construction is made of polyvinyl chloride (PVC) and reinforced with metal of aluminum or sections galvanized steel. Their thermal behavior resembles that of wooden frames. They have excellent air and water tightness and they do not require maintenance.

Energy savings with regard to the windows and frames, associated with rational selection and proper use. The windows should combine with the appropriate boxes. For example, the combination of glass which are characterized of low thermal transmittance as well as frameworks which are characterized by corresponding high rate, have the result of a significant loss of energy profits. Panels of wood provide 10% more energy savings compare to the aluminum frames and 7% more than the aluminum frames with thermal break. Finally, it is obvious that the correct position and adjustment of frame openings in the building is to ensure the air tightness - both with regard to the entry and the escape of air, water - especially from combined effect of wind and rain - and prevent the formation of thermal bridges.

The filling and sealing of joints with silicone and application of materials which prevents the creation of thermal bridges between the frame and the wall are very significant. Moreover there should not be selected toxic materials. The estimated potential benefit of replacing old windows and door frames can range from 10% to 20% energy savings for heating.

5.3 Green roofs

Green roof is both thermal insulation and waterproofing. It consists of a layer of vegetation, which grows in a specially designed level, usually onto a roof. The advantages are not only toggling aesthetically, but also e.g. increase thermal functional comfort. It also offers thermal protection to the building during the summer months and during the winter months. The planting of the roof is a kind of building insulation due to the materials that used (e.g. soil of sufficient thickness and air trapped between the plants foliage). It is prerequisite, however, the properly insulated and liquid insulation-structure of the roof. The principal benefits of green roofs could be summarized as follows: a) Energy saving in heating and cooling, b) Extend the life of the roof construction materials, increase the building insulation and improve the sealing of the building. c) Absorption of gaseous pollutants and dust. d) Improvement of the microclimate and ventilation of the cities. e) Increase of the protection against the noise by 8 dB and reduction of the reflection of sound by 3 dB. F) Creating ecosystems within the urban areas, in which revived plants and animals were repulsed because of uncontrolled urban sprawl. G) Exploitation of free roof spaces (improving the aesthetic character of the building)

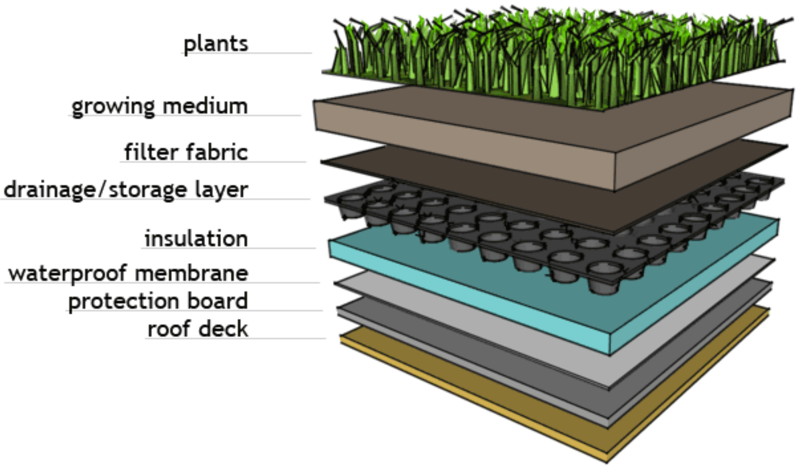


Figure 3: Components of a green roof

The construction of the green roof and the choice of plant from which it is composed, should depend on the type of roof and the climate of the region conditions. It also should be careful without quality shortcomings as well as it must be contained at least on the 60% of the ceiling. Before the green roof construction, this should be controlled by a mechanical engineer so as to determine if the loft can accommodate additional loads and the underground irrigation system should be placed before the laying of the soil.

The estimated expected benefit from planting roofs is 20% of saving energy for cooling to the underlying floor of buildings without insulated ceilings.

5.4 Use of special coatings ('cold' materials) in ceilings and fates

‘Cold’ is called material that characterized by high reflectivity to the solar radiation (i.e. they have the ability to reflect sunlight instead to absorb it), and by a high coefficient of infrared radiation i.e. emit faster the heat absorb amounts.

As a result, these materials have lower surface temperatures compared to the other materials. Therefore, smaller amounts of heat will be transmitted from the shell within a building and smaller amounts of heat will be transmitted through the cold surface to the urban environment.

The use of special ‘cold’ materials occurs on roofs that are already insulated or in ceilings where insulation adding is possible, in ceilings, where insulation is added and the ‘cold’ materials are placed as supplementary benefit, in areas or floors that planting does not seems appropriate, when the application surface of cold material is without shade during June-September, when this building presents significantly high cooling loads, in relation to heating loads, for application to walls when adding an insulation is not an appropriate solution, maybe because of construction reasons or because of large cooling loads.

Advantages of cold material: A) Improvement of thermal comfort conditions in non-air conditioned buildings. B) Save energy for cooling and corresponding financial benefit. C) Reduction of peak load for cooling and corresponding financial benefit. D) Longer life for the roof and economic benefit from reduced needs for repair. E) Addressing the phenomenon of urban heat island. F) Reduce of air pollution and of CO_2 emissions.

Cold materials are divided into two main categories: Materials for the shell of the building (e.g., coatings, membranes, plates, bituminous tiles, etc.) and Materials on the urban environment (asphalt, slabs of various materials such as cement, marble etc.).

Today, apart from the cold white materials, there have been developed as well colored cold materials in cases where the use of light-colored surfaces creates problems glare and in cases where dark colors are preferable. The cost of cold material is generally comparable to the cost of conventional ones. Even in cases where the cost of a cold material is higher than this of the conventional then the economic benefit of the application of the cold material will be more important if we take into account the costs of the life cycle of the material. They can be applied both to existing and new constructions. The estimated benefit by using special coatings on roofs and facades are from 10% to 20% energy saving for cooling in places without proper insulation.

5.5 Sun Protection – Shading

Solar gains that arise from the windows of a building are large and necessitates sunshade. The study of shading must include sufficient shading of the openings during the summer, without limiting the solar heat gain during the winter and taking into account the need of natural lighting. Shading is more efficient when it is outside, which means that the solar radiation is prevented from entering and to be stuck through the glass and finally can reduce solar gains areas by 80-90%. Furthermore, the use of mobile shades allows achieving shading of the openings only when it is necessary, regardless of the time of year.

Therefore, the most effective way of shading is the use of external shading with mobile blinds, even if it is very expensive. Therefore it is preferred the stable outdoor shading which is combined with internal blinds that operate additionally, because conventional glasses have very little resistance. Between the simplest ways of shading is the placement of deciduous trees or vegetation. These interrupt the direct insulation, and reduce temperatures near the ground because of their shade.

In relation to the orientation of the openings, the southern exposures receive a little during the summer radiation season and it is easy to protect. The west and east windows, however, pose a bigger problem because the position of the sun is low when it is in the east or the west. Therefore, a bioclimatic solution is the reduction of the eastern and western glazing.

5.5.1 Sun protection provisions

Internal (curtains, blinds etc.)

These are provisions that protect the interior from the sun radiation which penetrates the glazing of the opening. These are placed inside the building, just behind the aperture so as to prevent the solar radiation from affecting the surfaces of the space (floors, walls, furniture). Blinds and curtains are usually used. They have the great advantage that they are controlled; particularly every user can change the level of shading/lighting depending on its needs. The disadvantage is in case the radiation penetrates the glazing and enters the interior space and it makes certain overheating, which depends on the absorbency and reflectivity of the material.

Contained in the frame

The frame contained in sunscreen provisions appear in complex frames. The most common form is one of the slats into the gap between the double panes. Even they are not located in the interior of the building, they cause leaks in the frame, while they pose difficulties in maintenance and installation costs.

External (overhangs, fins, blinds etc.)

In the category of external sunscreen disposition belongs any device which locates on the outside of the frame. Their important advantage is that they interrupt the sunlight out of the inner space, before this affects even the glazing of the opening. Even when they are overheated, the aeration from the air is usually sufficient to reduce the temperature and thus the heat radiation to the interior space. The simpler device comprises the known shutters and blinds, while there are a great variety of complex constants, or mobile devices that interact with the solar radiation levels every moment and regulate appropriately the intensity of natural lighting inside the building. In external devices can join also pergolas with climbing plants which have dense foliage during the summer and cause shading and they allow the appropriate isolation during the winter that the foliage left. The pergolas are a feature of the Mediterranean architecture.

-Fixed devices**:** These are devices specially designed for a specific building without flexibility. They require special attention in their design because it can limit solar gains in periods that it is desirable. Moreover, they are designed for fixing optimized geometry features so as to ensure shading in summer period without reducing solar gain in the winter.

-Mobile devices: These have the advantage of controlled operation, either manual or automatic and the adjustment of the inclination depending on the position of the sun and other environmental parameters.

In any case, irrespective of the nature of the shading device, especially the external devices, it is necessary to calculate their geometry so as to provide shade in summer but allow the insulation of the building during the winter by exploiting the solar energy.

The exposures are protected from the sun differently by horizontal devices, since the solar angle those times are quite small relative to noon, and a horizontal shading device would require length in order to provide shade. In these guidelines vertical shading devices could be applicable.

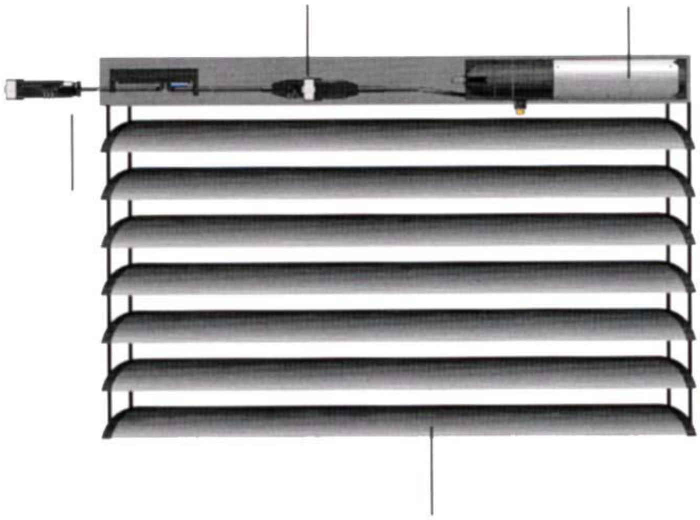


Figure 4: Mobile blind

5.5.2 Shade trees

It is mainly from the east and west orientation. During the winter, the deciduous trees when the branches are bare, it is allowed the sunlight to pass through the glazing while during the summer they prevent it. It is good to be selected trees with dense foliage and few branches so as to achieve the maximum shading in the summer and minimum in the winter. Evergreen trees are recommended for many humid and sometimes hot climates. Notably is the fact that a bare tree prevents the sun's rays about 20-40%. Also in warm areas, a house where its roof is shaded, it could be by 6-12 ^{o}C cooler than the one without shade. Quite elegant is also the solution of the pergola, which is adjacent in one side of the building. Results of the US surveys show that by planting a tree per home, then the energy saving for cooling ranges between 12-24%. Additionally, the placement of three trees in every home can reduce the cooling load by 17% to 57%. The shading from trees contributes only at 10-35% to the energy savings for cooling.

The need for the blinds must be documented by the energy audit. In case of shade replacement of the existing building it is provided recovery-recycling of the older system. The estimated expected benefit by installing shades and sunshade ranges from 20% to 30% energy savings for cooling.

5.6 Natural and night ventilation

The natural cooling is the practical alternative for ensuring thermal conditions comfort in buildings during the summer where the growth of the plant and use of air conditioning systems bring significant consumption of energy as well as economic and environmental problems. Air conditioning systems consume large amounts of electricity, increase significantly the electrical heat load of the country and the functioning of the external environment.

With the natural cooling is achieved three things: Remove the heat from the building to the external environment when the outdoor temperatures allow it, Remove the stored heat of the structural elements of the building (when they consist of sufficient thermal mass), Heat is removed from the human body, thus it increase the thermal comfort level of an area, even at relatively high temperatures.

Categories, in which natural ventilation differ are:

a) *Airy, through windows and other openings*

It is urgent the proper design of the shell's openings and section of the internal walls. The movement of air to indoor areas and the removal of the accumulated thermal energy are possible by slots in the upper and lower portions of the dividing interior wall.

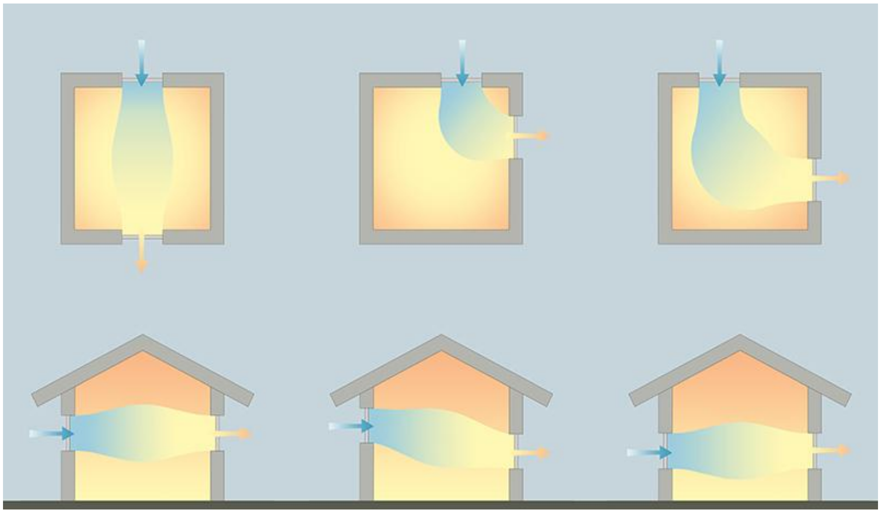


Figure 5

b) *Vertical through vertical openings, chimneys or ventilation towers.*

It works by exploiting the phenomenon of natural draft. The hot air moves up and, therefore, electricity is generated indoors, with the result to transfer the heat outside the building. In cases there is no air intense flow around the building, the system can operate with fan (creation of hybrid ventilation) which is incorporated into the upper part of chimney, thus it is ensured continuous alternation of indoor air. Suitable shaped staircases, interior patios or skylights of buildings could also act as ventilation chimneys.

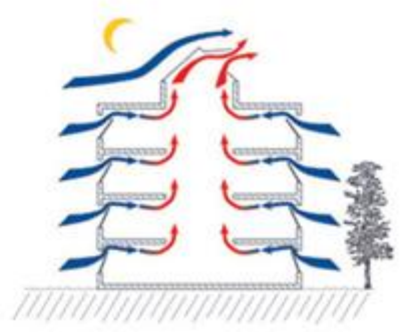


Figure 6

c) *Vertical, enhanced from solar chimney*

It is about a chimney construction, bearing in the southern surface (within 30° east or west) a) glazing instead of masonry, b) a small solar wall c) blinds to the upper side.

The operation of the solar chimney is based on the Venturi effect and contributes both to the ventilation and the removal of the moisture from the indoors, also through high temperature air resulting in the chimney, which greatly enhanced the phenomenon of natural draft. Therefore, the renewal air is enhanced to the indoor places. The solar chimney is recommended in areas with high relative humidity during the summer months, and achieves often renewal of indoor air.

The energy study will indicate the air supply (air changes per hour or cubic meters per hour) as well as which ones (openings) contribute to natural ventilation, in this way it would achieve the desired function and the reduction of the required or consumed energy. With the implementation of ventilation, especially during the periods of the year (April to May and September to October) and evening hours during the summer it could achieved energy savings of 10% -15% without an extra equipment or installation charge.

5.7 Installation of passive solar systems

Passive solar systems are those which provide heating and cooling to the building by the exploitation of natural energy sources. The prerequisite for the proper functioning to exploit as much as possible solar, is an appropriate building design. This means that the shell should allow maximum solar collection, the maximum thermal capacity and minimum heat loss.

The function of passive systems is based on three mechanisms: The greenhouse effect, i.e. the collection of the solar radiation and its conservation inside the building for space heating, the thermal hysteresis material (thermal capacity), the principles of heat transmission, i.e. its capacity to heat is transferred from the hot to the cold object.

Types of passive solar heating:

Direct solar gain: In the direct gain systems, the space is heated directly from the input of solar radiation without requiring of the insertion of a separate thermal mass, or a distribution heat system. The heat incident on the materials that make up the area, either directly or after successive reflections, and is stored therein without requiring construction a thermal mass construction. However, each opening cannot be considered as a technique of passive heating, because the system is efficient only if the opening is purely a south-facing, or at least with a little deviation from the south.

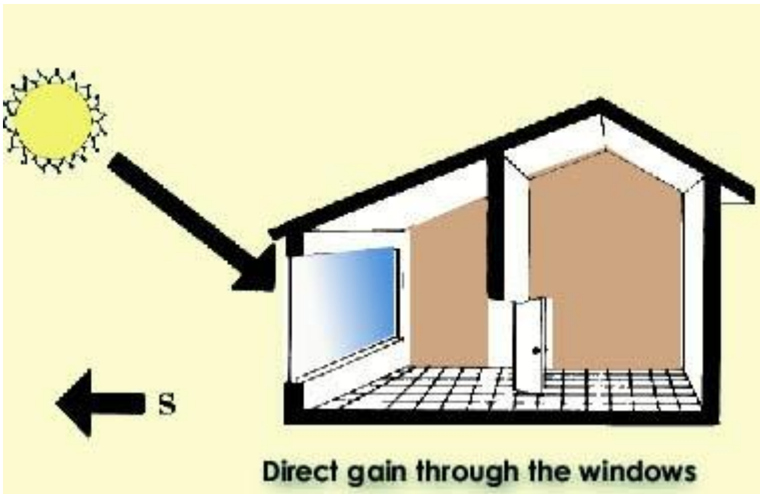


Figure 7

An important role for the proper implementation of the system plays the selection of the types of glazing and the choice of structural components (walls, floor, ceiling). These should have at least 9-fold greater surface area of the openings and should be made of high heat capacity materials for the storage of solar heat gain.

Indirect solar gain: This category includes systems that use solar benefits for heating building. The collection of solar energy and heat storage does not take place inside the building. The collector is out of space and the heat storage is usually the separating element between the collector and the area (e.g. wall). The basic functional feature of these provisions is the lagged of the heat performance in the area from the time we collect it. The main forms of indirect gain mechanisms are the thermal storage wall, the wall trombe, solar roof and the attached greenhouse.

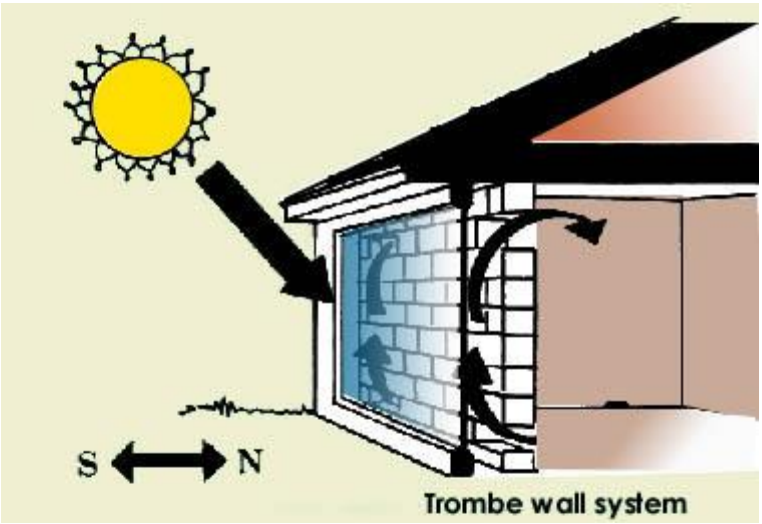


Figure 8

Isolated solar gain or isolated operation: In isolated gain systems the surface which gather the solar gains is not in contact with the space desired to be heated. This may be due to the distance of the collector from storage or the thermal interference between them.

Passive solar systems can be integrated in southern side of buildings, which are not shaded during the heating period. For the addition of a greenhouse in an existing building, it is urgent a building permission (amendment) or confirmation that the addition will not exist the building coefficients, coverage etc. It also should be described the operational control systems throughout the summer for preventing overheating of the premises, such as shading systems, control of their operation, etc. The estimated expected benefit from the installation and the incorporating passive solar systems ranges from 10% to 15% of the energy savings for heating.

5.8 Energy upgrading of Heating, Ventilating and Air Conditioning (HVAC)

Interventions for upgrading electrical installations may concern:

5.8.1 Heating system

According to studies 35-40% of total energy is consumed today in the building sector, and 50% of this operation are due to centralized systems heating. A central heating installation is considered successful when it heats without excesses and only if works economically and safely. A few simple interventions in this system can save significant amounts of energy, up to 20% and there are the following:
A) Insulation of the central heating column, B)Thermostatic valve bodies and accurate thermostats or system compensation. C) Replacing old boilers and boilers with new high efficiency ones (oil or gas). D) Replacing oil heating system with natural gas, whenever there is connectivity to the network. E) The maintenance of the heating system improves performance, reduces fuel consumption and air pollution and equipment acquires longer life, F) The installation of thermal energy meters contributes to the reduction of waste and the irrational use.

5.8.2 Air conditioning system

Proposed technical measures are: A) Replacement autonomous air conditioning systems (split) in a central system, which can operate in free cooling mode. B) Installation of heat exchangers in disposal channels and air intake if they are close to each other. C) Installation of heat exchangers in the heat pumps for hot water use. D) energy-efficient air conditioner choice reduces energy consumption by 20-50%, while the size of the air conditioner must be suitable for the space. E) Installation of water-cooled chillers, whenever there are water availability. F) Installation of geothermal heat pumps (ground-to-air heat exchangers).

This intervention can be done if it combine with a new installation with appropriate conditioning system and as long as the total cost of installation is economically advantageous. The estimated potential benefit of these interventions is from 20% to 40% energy savings.

5.8.3 Pumps - engines

The use of new technology pumps and high efficiency motors would reduce the annual electricity use of circulators by 60%. If the synchronous motor is combined with an improved impeller, which is possible from the high rotational speeds of high-performance engines, then the hydraulic efficiency can increase from 35% to 60%. By combining these two measures, high performance pumps achieve energy savings about 40%, compared to 5% to 25% of the asynchronous motor. Furthermore, with the inverter use, with conventional engines with power greater of 500W, such as the fans of the air handling units (AHU), it can be achieved additional energy savings up to 25% depending on the case and the operating conditions.

5.8.4 Mechanical ventilation (free cooling)

With the implementation of ventilation either natural or mechanical, at interim periods (April-May and September-October) and during the summer evening, we can achieve significant energy savings without additional charge installation equipment (only the operating costs of fans). In most municipal buildings mechanical ventilation is recommended for the full control of the operation of ventilation, which naturally can be sensitive to operational issues, such as opening and closing windows, etc. Mechanical ventilation can be done either by the central system air conditioning in free cooling mode with the appropriate setting or by existing airway and simple insertion fan and air exhaust spaces. The operation of mechanical ventilation system is recommended to happen automatically (e.g. timer or thermostat) preferably through the building energy management system (BEMS) by the time it is available or installed in the building. The estimated expected benefit from mechanical ventilation ranges from 10% to 15% saving of energy for cooling.

5.8.5 Hybrid ventilation with ceiling fans

In conjunction with natural or mechanical ventilation system it is also recommended the installation of ceiling fans. In this way the temperature limit of thermal comfort rise, since the heat transfer from the human body through the generated power corresponds to 3-4 degrees lower temperature. In a building with appropriate thermal and solar protection, the comfort temperature by using ceiling fan can be reached 29º C to 32ºC. For each increase of degree we have energy saving up to 7%. Therefore the result of ceiling fans use is the time reduction of the use and the energy-efficient operation of the air conditioner system. This intervention is particularly indicated when there is no air conditioning system or it is combined with a removal of split unit air conditioners and with the dual existence of natural or mechanical systems ventilation in the space.

Figure 9: Roof Fan

The estimated expected benefit from the application of hybrid ventilation ceiling fans ranges from 20% to 30% saving of energy for cooling.

5.9 Upgrade of the natural and artificial lighting system

The comprehensive upgrade of the lighting system may concern both upgrading of artificial lighting and the exploitation of natural lighting with suitable lighting sensors. The objective of the design of lighting systems is to ensure visual comfort by:

i) Providing the required amount of light, defined by international standards and KENAK, based on the use and the operational requirements of each place and ii) The quality of lighting, which is ensured by good distribution and avoidance of glare phenomena, proper color rendering and light color, highlight space elements, lighting direction and creating appropriate contrasts (contrast). The estimated expected benefit from the upgrading of the artificial system lighting can reach up to 35% electricity savings for all the building.

-*Natural lighting:*

Daylight within a building offers not only energy savings, but also beneficial effects of the sun. The natural lighting should be leveraged in the best possible way so as to cover the building's lighting needs. To achieve visual comfort in the interior of the building it is sufficient the natural lighting and smooth distribution. In this way we can avoid sharp variations in the level, which cause glare. The efficiency and the light distribution depends both on the geometric data of indoor and openings, and by their characteristics such as the color and texture opaque surfaces and glazing (e.g. transmission light, reflectance, etc.). The main categories of natural systems lighting are:

1. Openings in the vertical walls
2. Openings in the roof
3. Patios
4. Lightwell /Skylight

The most significant techniques for the exploitation of natural lighting are:

1. Vertical openings - such as windows, skylights, etc., with appropriate geometry, 2. Openings in the roof, 3.Patios, 4.Lightwell, 5.Special Glass, 6.Prismatic light transmitting materials, 7.Transparent insulation materials, 8.Lighting Shelves, reflectors, Blinds, 9.Shades

To improve natural lighting conditions, it is required premeditation with description of all the proposed interventions, the estimated cost and the study which document the costs.

-*Artificial lighting:*

In modern buildings is often observed the phenomenon of over sizing of the artificial lighting systems with the objective to prevent problems resulting from insufficient trials (or total lack of study). This phenomenon, in combination with the use of finite or conventional technology of lighting plants, leads to high electricity consumption for the operation of artificial lighting, without good results in terms of visual of space and quality visual comfort. The aim, therefore of the study of artificial lighting is to reduce the over-consumption of energy while improving the visual comfort. For this reason it should be studied: the use of energy efficient lamps, use of suitable high-performance lighting fixtures, possibility to take advantage of natural lighting, installation of suitable devices' link(using online damper), installing control systems capable of coupling artificial and natural lighting.

5.10 Building Energy Management System (BEMS)

In all modern large buildings, it is necessary the automatic centralized control for qualitative improvement of living and working conditions and the rational distribution of energy. For this reason there are specialized electronics automation systems responsible for the electromechanical building installations. These control systems include air conditioning (cooling, heating, ventilation), lighting, water supply, fire fighting, security, and generally all the important sanitation functions of the building. A Building Energy Management System – BEMS consists of the following sections:

1) Central monitoring and control station, which performs the programming and manipulate the system.
2) Sensors, which measure the values of the control parameters such as, for example, temperature, humidity, air velocity, light level, and other.
3) Actuators - execution devices, which alter the way that operates the various facilities such as, for example, heating, air-conditioning which are connected to the BEMS system.
4) Controllers, which determine the function and coordinate all installations and are essentially the "brain" of the system.
5) Connecting wiring.

The most important systems that can monitor and control a BEMS are: systems of heating and / or air conditioning, passive systems (e.g. patios, ventilation), openings, sunshades, lighting system, cooling systems, electrical consumption, air quality, safety installations.

BEMS is commonly used in large buildings and covers the management needs and all the installed activities in this equipment. Regarding the costs of such systems, there are expensive and ‘locked’ with little or no ability to interface and 'open' systems with infinite interface capacity and excellent quality with low prices.

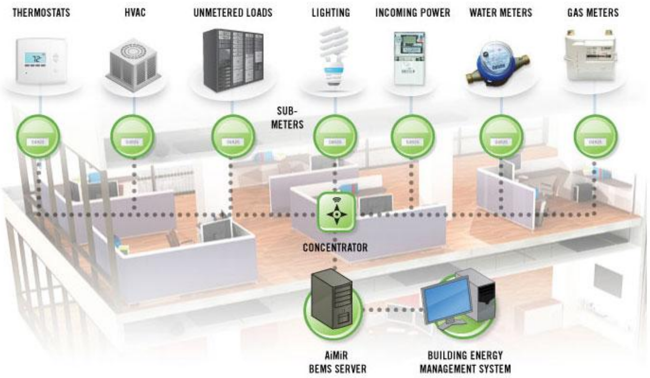


Figure 10

5.10.1 Public information

BEMS which are going to be deployed in large high-traffic buildings, should be accompanied by the presentation of consumption and the energy efficiency of the building prominently of the building in order for the citizens to be informed. The presented data may relate to the description of saving energy systems and the costs of the internal conditions, the consumed and energy savings and analytical data on the energy function of the building in real time, as it would result from the energy management system.

5.11 Energy inspection– evaluation

Energy audit: After the energy upgrade, it should be undertaken energy inspection. This inspection should be done according to the statutory process 3661/08 and to be issued a certificate, from which it arises the power consumption and the resulting emissions of CO_2. The results of an energy inspection show the degree of achievement of the energy and environmental objective of the interventions.

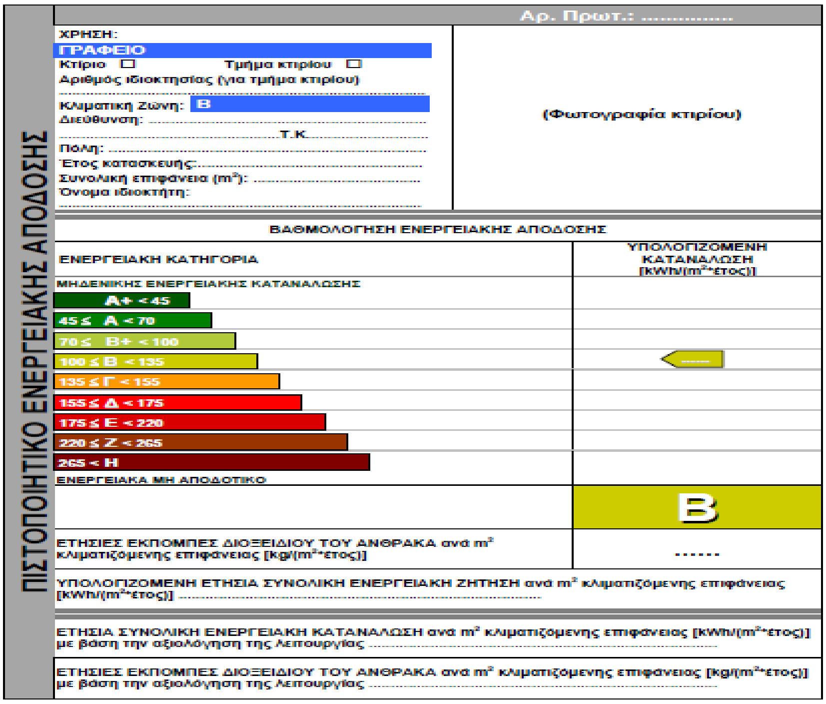


Figure 11: Energy Performance Certificate of A Building

5.12 Use of Renewable Energy Sources (RES) in buildings

Energy savings, given the technological evolution, could happen with the use of renewable energy sources (RES). Renewables are an entire field of study related to the research, the development and their implementation.

5.12.1 Wind

Wind Energy is the kinetic energy of the wind. The irregular heating of the earth's surface from the sun creates the winds. The heat absorbed from the ground or water transferred into the air, which causes differences in temperature, in density and in pressure. Afterwards, these different sizes cause forces that push the air. In accordance with fluid mechanics, the air moves from high pressure to low pressure areas of the

world. The Wind turbines are machines that convert wind energy into mechanical, which is used to drive a generator that produces electricity energy.
Wind systems as to their autonomy divided into the following categories:

a)Interconnected systems: The most economically application of wind turbines is the connection to the electronic net. In this case it is installed and operates an array of many windmills (wind farm) in an area of high wind potential and channels the entire production to the electrical system. Another event is the connection of the exit of a wind turbine to the existing grid. The output from the domestic wind energy helps to reduce electricity market energy needs. The value of electricity - where the market is avoided- is usually much larger than that which is obtained from energy supply to network. Obviously, the connection to the distribution network has to fulfill high technical specifications. Therefore, the cost of required safety equipment and measuring becomes high. As regards the installation of low power wind turbines, the cost of connecting to the network may be an important percentage of the total budget.

b)Autonomous systems: In these systems, low power turbines are used to produce electricity to areas where the possibility of power is not supplied. The produced strength in such applications and their economic importance is limited. Generally, wind turbines are used to charge batteries which supply small electrical applications, such as, cargo cover on farms, low-power electric fences, pumps, lighting, security systems and other.

Wind turbines are classified into three categories depending on the mechanical power N they provide.

1. Small W/T when the rated power is between: $50W \leq N \leq 10kW$
2. Medium W/T when the rated power is between: $10kW \leq N \leq 200kW$
3. Large W/T when the rated power is between: $200kW \leq N$

Another categorization of wind turbines, depend on the axis position with respect to the earth's surface rotation. So they divided into the following categories:

1. Horizontal axis

In wind turbines of this kind the rotor is propeller type and is constantly parallel to the wind direction and the surface. These turbines should be oriented every time with the wind direction.

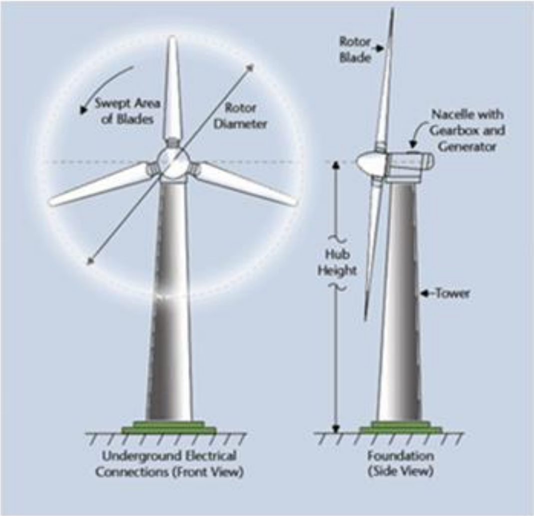


Figure 12: Turbine with horizontal axis

2. Vertical shaft

In this kind of wind turbines the axis remains constant, and is perpendicular to the ground. These turbines need not change the orientation depending on the wind direction because they have the advantage to operate in any air direction.

There are four main parts to a wind turbine: the base, tower, nacelle, and blades. The blades capture the wind's energy, spinning a generator in the nacelle. The tower contains the electrical conduits, supports the nacelle, and provides access to the nacelle for maintenance. The base, made of concrete and steel, supports the whole structure.

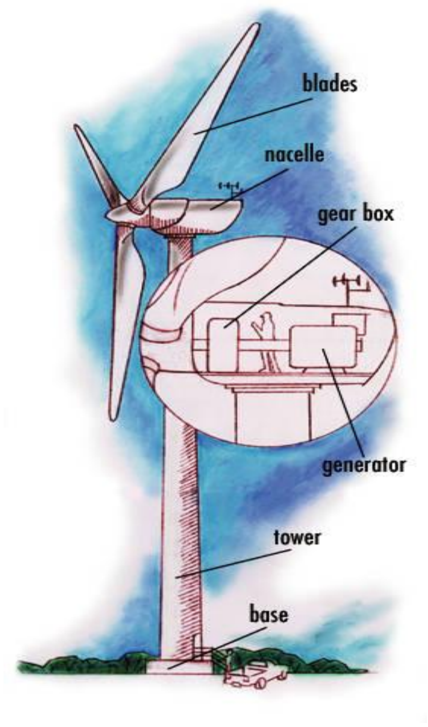


Figure 13: Wind Turbine

Blades: Designed like airplane wings, modern wind turbine blades use lift to capture the wind's energy. Because of the blade's special shape, the wind creates a pocket of pressure as it passes behind the blade. This pressure pulls the blade, causing the turbine to rotate. This modern blade design captures the wind's energy much more efficiently than old farm windmills, which use drag, the force of the wind pushing against the blades. The blades spin at a slow rate of about 20 revolutions per minute (RPM), although the speed at the blade tip can be over 150 miles per hour.

Nacelle: The nacelle houses a generator and gearbox. The spinning blades are attached to the generator through a series of gears. The gears increase the rotational speed of the blades to the generator speed of over 1,500 rpm. As the generator spins, electricity is produced. Generators can be either variable or fixed speed. Variable speed generators produce electricity at a varying frequency, which must be corrected to 60 cycles per second before it is fed onto the grid. Fixed speed generators don't need to be corrected and they are not able to take advantage of fluctuations in wind speed.

Tower: The most common tower design is a white steel cylinder, about 150 to 200 feet tall and 10 feet in diameter. Some turbines use a lattice tower, like the Eiffel Tower. Towers have a ladder running up the inside and a hoist for tools and equipment.

Base: Bases are made of concrete reinforced with steel bars. There are two basic designs. One is a shallow flat disk, about 40 feet in diameter and three feet thick. The other is a deeper cylinder, about 15 feet in diameter and 16 feet deep.

Prices of small wind turbines vary from country to country and the amount of CO_2 which saved and the production of CO_2 which is avoided by installing a wind system varies depending the size of wind turbine, the location, the wind speed, obstruction of existence and the form of the surrounding landscape. Wind power systems with 2.5-6 kW are installed usually in tissue.

The lifespan of the turbines reaches 22.5 years but require regular check to ensure the functional performance. The typical lifetime of battery is around 6-10 years, depending on their type. Therefore, it is possible to replace them at some point in life of the whole system

5.12.2 Geothermal

Geothermal energy is a mild renewable energy source; specifically today it can cover a wide variety of energy needs. Geothermal energy is the energy that exists in the earth and which can be exploited through the geothermal fluids. The most important factor for the utilization of geothermal energy to a region is the temperature of geothermal which determines the type of their application. In Greece the most common geothermal application relates to the geothermal heat greenhouses. Other applications are the district heating in buildings, the combination with heat pumps in buildings, pisciculture, drying agricultural products, water desalination and other.

Geothermal energy, depending on the temperature of fluids, divided into three categories: Low enthalpy (25-100 ° C). Middle enthalpy (100-150 ° C), High enthalpy (>150 ^{o}C)

Applications of geothermal energy in buildings vary depending on the temperature of the available fluid. For temperatures above 90 ° C the applications are:

Electricity, Cooling and air conditioning with sorption heat pumps, Space heating with radiators, Hot water boiler, Desalination of seawater for use in hotels.

For lower temperatures there are applications such as space heating with fan heaters water or floor heating systems, production or preheat hot water with heat and hot springs heat. For water temperatures below 40 ° C is used heating pumps for heat and air conditioning. If there is not available ground water, heat pumps can be combined with earthy heat exchangers.

Advantages of geothermal energy are:

a) It is a local energy source that can reduce the demand for imported fossil fuels.
b) It has a significant positive impact on the environment by replacing the combustion of fossil fuel.
c) It is efficient and competitive with conventional energy sources.
d) Geothermal plants can operate continuously without barriers imposed by the weather, unlike other renewable sources.
e) It has a native storage capacity and is suitable to meet the demand for base load.
f) It is a reliable and safe energy source that does not require storage or transportation fuel.
g) It is a clean form of energy, since the disposal of geothermal waste is appropriate.
h) The drilling and pumping stations intervene minimally in the aesthetics of the landscape since these are small-volume structures.

Consumption of a geothermal heat pump corresponds the 1/4 of that of electrical resistivity and a half of the air conditioner. Calculation of the costs throughout the lifetime of a geothermal system shows that the cost of a geothermal heat pump is less than one which consumes oil system or natural gas. In the future, it is provided that the exploitation of geothermal energy will become from hot dry rock - which exist everywhere at depths of 3-5 km - through artificial temperature water circulation up to 150° C. Geothermal systems are four times the cost of installation in case we compared it with a conventional system, also it has the half yearly operating costs. The study and supervise of their installation should be done by an engineer.

5.12.3 Solar thermal systems (solar thermal)

Thermal or active solar systems (solar thermal) convert sunlight into heat. A thermal solar system collects stores and distributes solar energy by using either a liquid or air as a heat transfer fluid collectors. Active solar systems can be used for heating domestic water, for heating and cooling for industrial processes, for desalination, for various agricultural applications, for heating swimming pools, etc.

Thermal solar systems can be classified into several categories, depending the application, it is introduced, the technology used, the size they have, the climatic conditions of the area, etc. The variety presented the provisions of these systems is mainly due to different ways in which systems are protected from frost.

The main types of solar thermal are:

Natural circulation systems with use the natural movement of the working medium also they are divided into the categories below:

a) *Compact heaters or integrated collector-storage systems*

They consist of one or more storage tanks. Placed in insulated housing with a transparent side oriented toward the sun

b) *Thermosiphon Systems*

They rely on physical transportation for the movement of the working material (usually water) to collectors and the reservoir, which is located above the collector. As the water is heating in the solar collector, it becomes lighter and is naturally manner to the storage tank and the cooler water tank flows through the pipe to the bottom of the collector, creating movement in extended system.

c) *Forced circulation systems*

These systems use electric pumps, valves and control systems that release average worker to the collectors. Divided into categories: -Open loop systems, - Closed Loop Systems

Natural circulation systems are generally more reliable, easier to maintain and possibly with longer life than forced circulation systems. The main applications of solar thermal systems are:

i) Hot water for domestic use: Solar hot water heaters of all types can cover a large percentage of household needs for hot water, while reducing expenditure on energy household. The amount of hot water that delivers solar energy depends on the type and size of the system, the climate and the quality in terms of region sunshine. The central solar systems which apply to residential totals are particularly effective.

ii) Heating and cooling spaces: Although the applicability of dense housing areas is limited, the use of solar potential heating of the interior is great. Active solar space heating systems are based on components such as roof panels for collection and distribution of heat. They use air or a liquid heated to solar panels and then conveyed it by fans or with low electricity pumps consumption. Solar air systems have the possibility to *heat the indoor air* of a building without thermal inverters or heat storage. The main parts are: Solar panels, Fans, ventilation ducts, Pipe Network, control systems

In large solar air systems are used thermal storage, for example, a container with gravel or small stones. The main parts of solar *liquid heating systems* are: Solar panels, Pumps, Storage tanks, Pipe Network, Heat exchangers, Control Systems.

The vast majority of active solar systems produced and sold in Europe are used to provide domestic hot water. The large solar collector systems for heating or warming water in large-scale applications that represent a very small percentage of the total installed collector area and mainly the hotel's and hospitals' facilities.

5.12.4 Photovoltaic systems

Solar photovoltaic elements are a high-tech approach for the direct conversion of sunlight to electricity. As we know sunlight consists of photons, which travel at the speed of light. If two plates made of semiconducting material, usually silicon, which are contacting each other and their sides are connected to electricity-conducting, accepted the sunlight, then some photons cause electrons plates to move through the pipeline, producing electricity. This phenomenon is called photoelectric phenomenon. The whole arrangement is called photovoltaic component. An array of photovoltaic cells is called photovoltaic module.

Solar energy:

The solar radiation provides a huge amount of solar energy in the earth. The total energy amount radiated from the sun in the earth's surface is equal about to 10,000 times the annual global energy consumption. Sunlight consists mainly of two components, direct and indirect light or diffused light, which is the light that has been rebuilt and dissolved by molecules of different components, and water in the atmosphere.

The photovoltaic cells not only use the direct component of light but also generate electricity and cloudy sky. So, it is misunderstanding the fact that P / V systems only toggle function with complete sunshine. To determine the dynamic power of a P/V at a particular location, it is important to be estimated the average total solar energy received during a year, rather than the reference of instant radiation. When sunlight incident on cells then it is produced electricity that can be utilized. The P/V cells exploit radiation. The obvious range results are not converted the whole solar electricity into radiation. This explains the low prices of the theoretical conversion efficiencies (20-30%), which reduced further because of practical reason imperfections.

The amount of useful electricity generated by a P/V element relates directly with the intensity of light energy that incident on the surface conversion. So the greater is the available resource, the greater the potential power. When electricity is required during the daylight hours , or when it is expected during extended periods of bad weather, then it is urgent some kind of storage system.

To impingement as much as possible solar energy, P/V cell must be oriented towards the sun. If the cells have a fixed position, their orientation must be optimized with respect to the south, for the northern hemisphere and the angle inclination of the horizontal. The optimum angle is in a range of approximately 15° of latitude geographical position. A deviation angle about 30 degrees from the optimal angle will result in losses that would be less than 10% of the maximum production. The P/V data is actually more efficient at low temperatures, thereby to ensure they do not overheat, it is important to place them in a way that the air is moving freely around them. The ideal operating conditions of a P / V are relatively cool, bright and sunny days.

Photovoltaic effect:

Solar cells are made of semiconductor materials, which could be monocrystalline, polycrystaline or even amorphous. Regardless of their crystalline structure, all of the photovoltaic modules comprise a semiconductor diode which is extended across the element. Typically the diode is generated by contacting a n-type layer with a p-type layer or the contact between a semiconductor and an appropriately chosen metal (diode Schottky).

The function of P /V modules based on the creation of electrostatic potential barrier in the material that receives the radiation. Each photon of incident radiation, with energy equal or greater to the energy gap of the semiconductor, has the ability to absorb a chemical bond and release a pair of carriers (an electron in the conduction band and a hole in the valence zone). From the resulting pairs, those which find themselves in the compound area of p-n accept the strength of the electrostatic field of the diode to reduce their potential energy. This causes movement of electrons to contact n-type and holes in the p-type contact, creating a difference between the terminals potential of the diode. The above arrangement behaves as a forward biased diode and as a power source as long it accepts radiation. The process of creating a potential difference in the aspects of a solar cell is called photovoltaic effect.

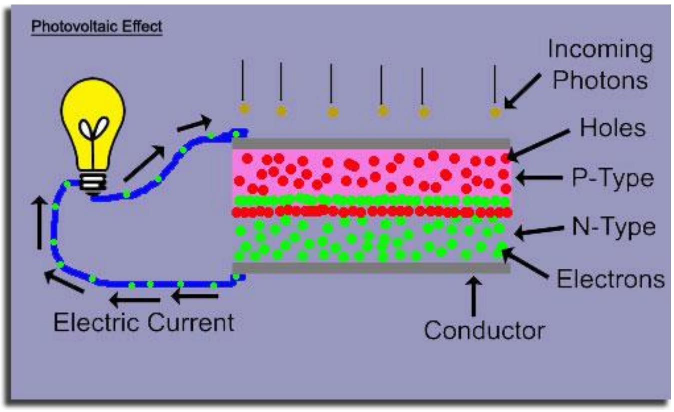


Figure 14: Photovoltaic effect

Basic types of photovoltaic modules:

Photovoltaic modules can be constructed in many ways, with various materials. Depending on their construction technology, photovoltaics can bedivided into two different groups. The first group, which commonly used in household applications, uses the thickfilm technology while the second one uses the thin film technology. The material which is used extensively today in the manufacture of photovoltaic cells in industry is silicon (Si). Photovoltaic elements are made of a combination of other materials, such as cadmium sulfide (CdS), arsenious gallium (GaAs).The main types of photovoltaic modules are presented below:

*Monocrystalline silicon :*The basic material of these photovoltaics is monocrystalline silicon. Thickness of these materials is relatively large, about 300 mm. The performance of PV monocrystalline silicon in the form of frames is ranging from 13 to 18% and is characterized by the high manufacturing costs.

Polycrystalline silicon: The construction of polycrystalline silicon photovoltaics is faster and has lower cost than that of monocrystalline photovoltaic silicon. These elements are cut into square shape and composed of thin layers of thickness 10 to 50 μm. Generally the larger the dimensions of monocrystalline areas of polycrystalline P/V, the higher the performance they shows. This kind of photovoltaic shows efficiencies from 10 to 14% in the form of a frame.

Amorphous silicon: This kind of photovoltaics has lower yields compare to the the previous ones. It is about thin coatings films which thicknesses is typically 9-10 mm, it is also produced by silicon deposition on a substrate glass or aluminum of 1-3 mm thickness.

The P / V systems are divided into categories depending on the electrical installation:
-Interconnected P / V systems:
The interconnected P / V systems are suitable for applications where the access to the central power grid is feasible and in which they supply energy. The systems do not require the existence of a storage device of produced energy. This has the result to decrease both the manufacturing cost and their operating costs since they do not need consumables.
Depending on the application, the generated electricity either is consumed partly by the user and the surplus is channeled to the core network, or is sold to the overall network. A typical interconnected P / V system consists of the P / V generators and electronic interconnection with the power grid. With the definition electronic interface we mean the interconnected inverters or inverters network.
The electric current DC voltage which is generated by the direct conversion of the solar energy into electricity at P / V generators, are transferred to the interconnected inverters and in turn they convert it into electricity AC voltage, sine and synchronized with that of the core network. The electrical current is passed to the network core through inverters, via a power meter. The power meter records the energy produced by the P / V system which are provided for consumption.

The electricity generated by this P / V system is consumed by different user loads. In case the production is not sufficient to cover all the electrical loads, then it is the procurement of additional required electric power from the central electricity grid. During the night or days with cumulus, where the system is not unable to generate power, the required electric power comes from the mains. If the produced energy is not consumed entirely by the user, so it appears surplus, then it is added to the grid and sold or made off with energy that is already consumed by the grid.

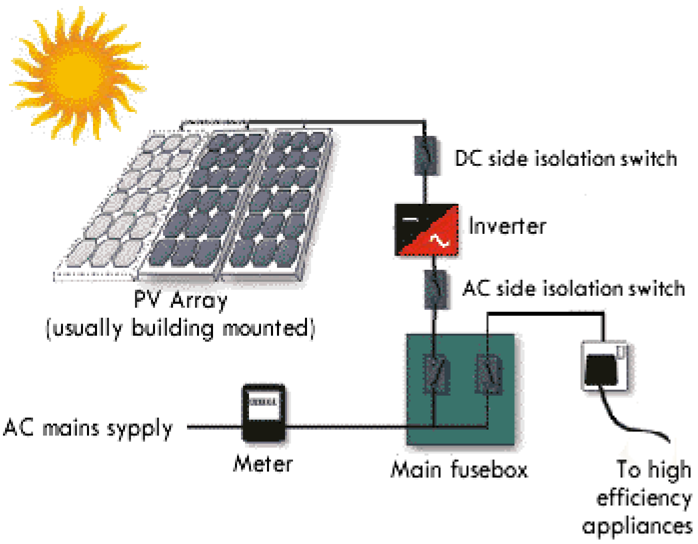


Figure15: Interconnected photovoltaic

-Autonomous P / V systems

These are suitable for applications that are not affiliated with the core network and are located mainly in remote areas. The electricity produced by them, is consumed entirely by the user and in their vast majority they also have provisions of produced energy storage. They usually powered electric or devices that operate with electronic DC. With the installation of the appropriate converter they can provide electrical power to operated alternating voltage devices. A typical autonomous P / V system consists of the following main subsystems:

a) Photovoltaic modules*:* These convert the solar radiation directly to electricity DC voltage. They also have the ability to produce electricity from sunrise to sundown. This current can electrifies the existing electrical needs, since they are in constant voltage while charging the batteries.

b) Storage device of the generated energy*:* It stores this excess electricity so as this electric power to be used at night or during the overcast days.

c) Inverter*:* This converts the DC voltage of the generated power to alternating voltage if it is required to electrical loads.

d) Electronic charging regulator*:* The role of the charge controller of a system like that is important. When the batteries are charged fairly well, the regulator interrupts the power supply, by disconnecting P/V generators, which he reconnects afterwards when the batteries would discharged below a predetermined threshold and there is no longer a risk to be overloaded. In case the batteries are discharged too much, the controller cut out these electric direct voltage loads, providing safety of being discharged. Loads are reconnected when batteries are charged above a safety predetermined limit. The charging regulator, accept for the battery protection, is also used as a center panel branching for DC voltage loads, by directing electricity either for storage or for use, depending on the circumstances and the needs. If electric loads work with alternating voltage, it is obligatory to link to the inverter's system, which converts the DC voltage into AC voltage.

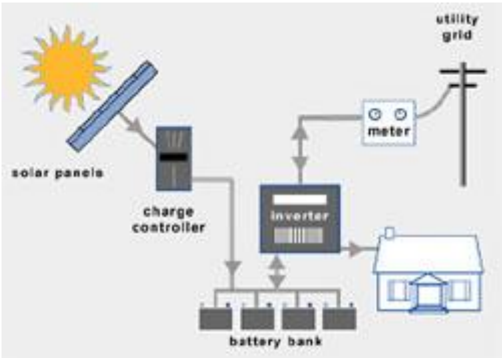


Figure 16: Autonomous P/V

-Installation of solar panels in a building

The integration of P / V panels on the roof or facade of a building can performed in many ways, especially P / V components have already been concluded in possible solutions of the past. There are four main ways to load the P / V frames in a building:

1) Installation in inclined props: This mounting provides easy access to both the front and the rear of P / V panels when it needs maintenance control and it helps in well ventilated and the cooling of the P/V frames, thereby increasing their efficiency. However, the cost is relatively high because of the additional material and extra work.

2) Placement outside the building: In this case the modules are adapted to the outer shell of the building which protrudes from the roof or the facade. This method offers good aeration of frames.
3) Direct placement: The P/V frames in this case mounted on the outer roof of the building arranged like the tiles. The photovoltaic cover protects the building, without completely waterproof and for this reason measures are required for their waterproof. However, the cost of this method is relatively low because it requires little additional material.
4) Integration of P / V panels on the building envelope: This method concerns the replacing of the whole sections of the building with photovoltaic panels. The application of this technique provides potential for a significant cost reduction, while it is saved the cost of the structural elements of the building that have replaced by photovoltaic modules.

-*Orientation of photovoltaic frames*

For maximizing the energy productivity of P/V frames, it is required the optimal exploitation of incident solar radiation. Obviously, the optimum solution is a P/V frame which is able to rotate so that it can follows the path of the sun and consequently it can be continuously perpendicular to the radiation direction. The mechanical complexity and the cost of a device make the application in buildings extremely difficult and costly. Therefore, in terms of building P/V systems, it is selected stable orientation of the frame, so as to achieve annual average angle of incidence of solar radiation closer to 90 °. Factors which determine the reach of this orientation are:

a) The inclination of the frame

It is expressed on the angle which forms the surface level of the P / V frame with the horizontal plane.

b) The azimuth angle of the frame

It is formed on the horizontal plane between the projection of the inclined side of the frame and the local north-south meridian. Regarding the Greek area, the maximization of total annual solar radiation, that is incident on a constant slope surface, is obtained for south-facing slope on 30°.

Finally, *advantages* which arise from the use of photovoltaic systems:

-They have zero operating costs because they do not consume raw material.

-They convert solar radiation directly into electricity.

-They do not produce byproducts.

-They do not pollute the environment, but they are in total harmony with the ecosystem.

-They do not cause noise pollution because their operation is completely silent.

- They are easy to use.

- They do not affect the environment aesthetically and they can easily be installed in cities.

-They can be integrated into the architecture of the building and used even as structural components, thereby reducing the cost of construction of an installation.

-They can be combined with other energy sources in hybrid systems, e.g. with a wind-energy park.

-Extended easily and at any time to meet any increase in energy needs of users.

-They have a long life time and high reliability.

-They have practically zero maintenance requirements.

-They provide comprehensive energy independence to the user wherever he is.

Thus, they can be installed in inaccessible areas or wherever it is not possible or economic interest, to reach the mains.

-They distributed generation of electricity

6 Case study- Energy Audit

[Energy audit of a kindergarten in Larissa]

This report analyzes the energy efficiency executed on a kindergarten in the prefecture of Larissa. The audit analyses the amount of energy lost through the kindergarten building elements, windows and ventilation as well as the solar gains available. It then continues to present the heating and cooling systems implemented for heating and cooling and monitors their energy consumption.

Finally solutions for improvement of the energy performance are proposed taking into consideration the best cost benefit and economic feasibility.

6.1 Project description

The building audited is a kindergarten in the centre of Larissa. The building is situated on Aiolou 1. There is 23th Oktovriou street, which is the perpendicular road because the building is angular in shape and has a North East - South East orientation. This region is designated by family buildings with an average height of 5-7 floors.

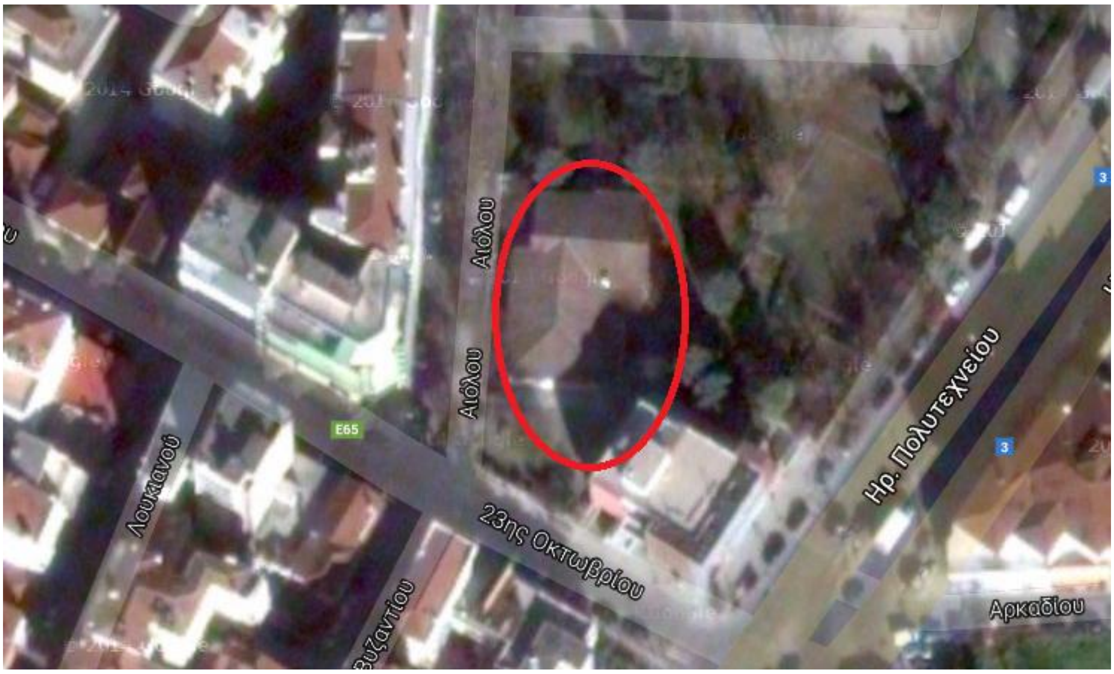


Figure 17: Map satellite image illustrating the location of the building

It is known that Greece is divided into 4 climate zones according to the mean annual weather conditions. Particularly, zone A is the warmest, and zone D is the colder one. Larissa is considered to belong to climate zone C. These differences (between zones) affects the estimations of the energy performance. Also regarding the other cities

Rhodos belongs to climate zone A, Athens to climate zone B and finally Florina to climate zone D.

Red: zone A

Orange: zone B

Light blue: zone C

Blue: zone D

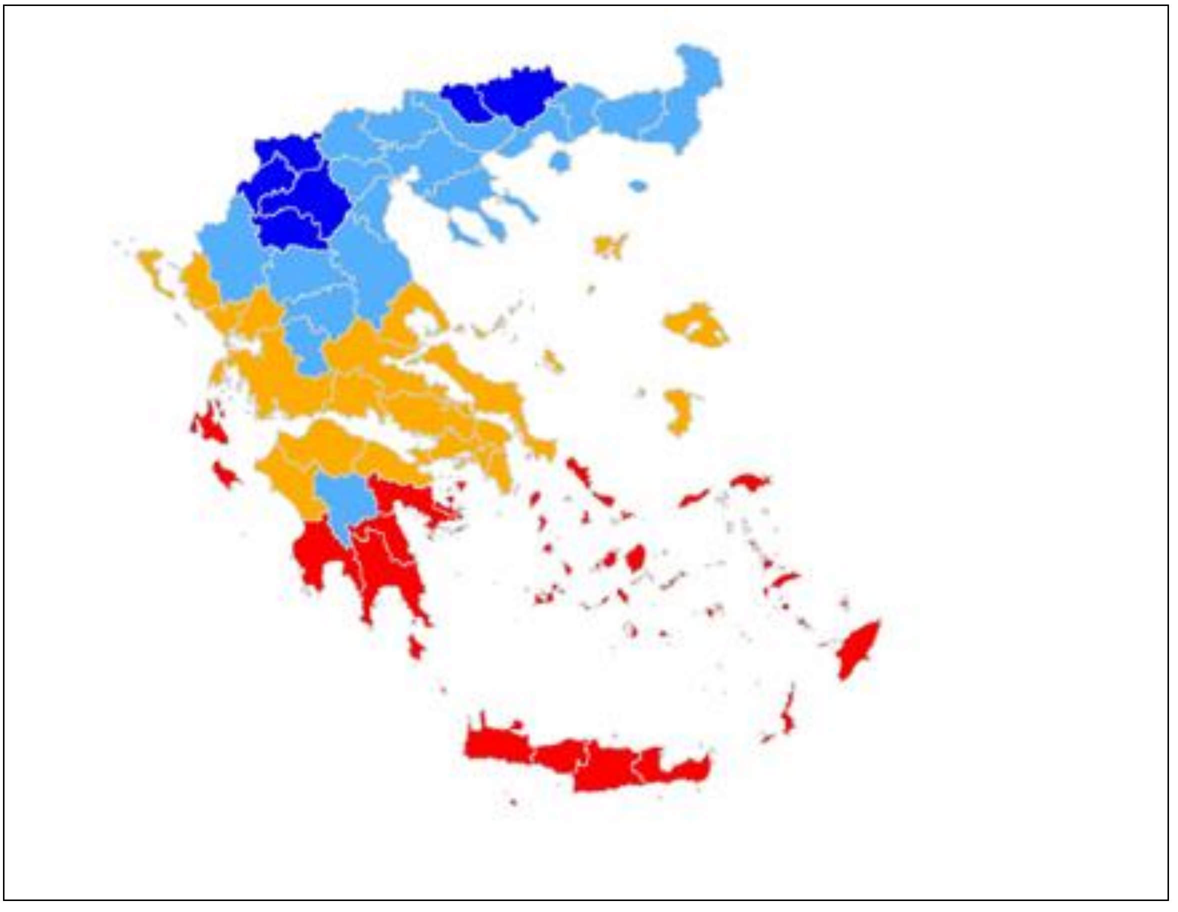


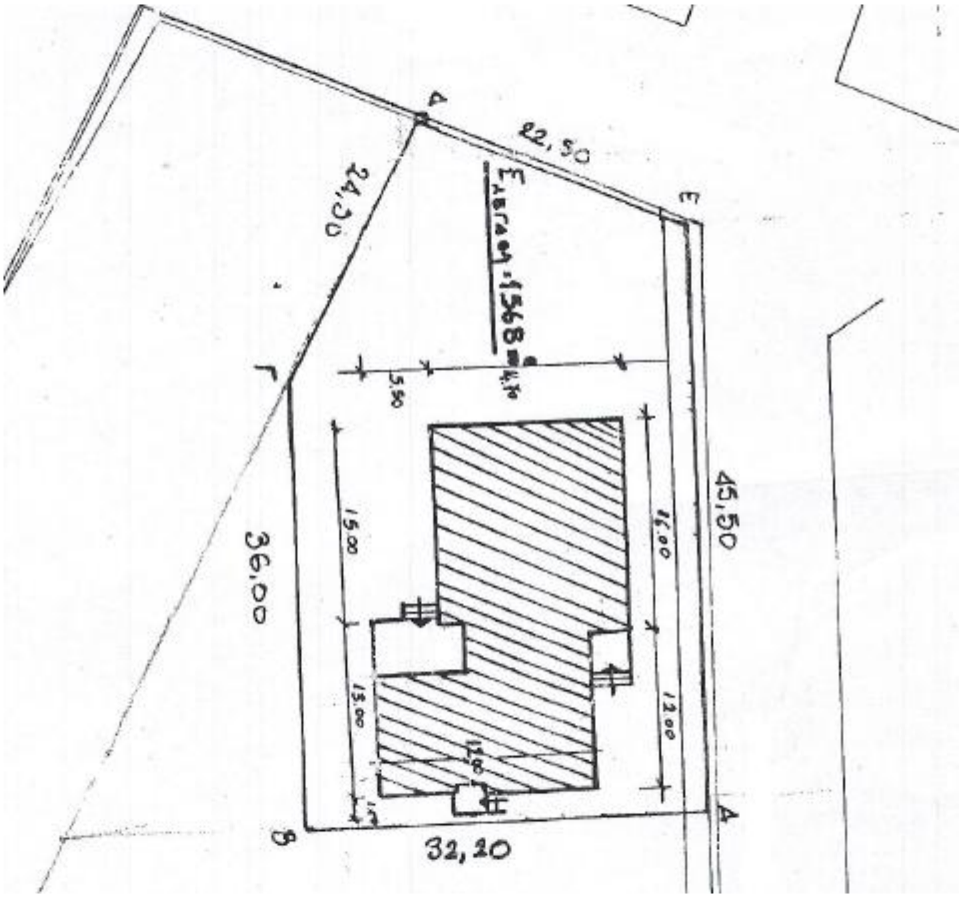
Figure 18: Map illustrating the 4 climate zones is Greece.

6.2 Building characteristics

This building was built in 1981, therefore it is an old construction. Moreover, it has taken place an energy intervention before some years, specifically it was installed a natural gas boiler, as well as aluminum double glazed windows with thermal break 6mm but the walls still exist without any insulation.

Figure 19: Photo from the kindergarten

The layout of the building is shown in the floor plan below. The building has two balconies. The first one occupies the left side of the building and the other one is in the entrance of the kindergarten.



The next building on the same street does not affect our building so it will not appear in any of our calculations. However the building to the North West has a 6 storey tall residential building which affects the shading of our North West facade. That will be calculated later.

Across the street from behind (south east) and in the left side (or north east) of the building, we have a park. This leaves the building opposite at a greater distance, making its shading of smaller scale. The trees do however affect the shade, but that is not taken into consideration. The fact that the South West facade is in front of an open road leads the building opposite at a greater distance . As for south façade of the kindergarten there is a 3nd floor building which make us to consider about its shade.

Figures 20: View and facing obstacles of the building

The summarized characteristics of the kindergarten are shown in the table below.

Usage : School wich is used for 9 months/year

Total floor area	462 m^2
Heated floor area:	462 m^2
Cooled floor area	462 m^2
Thermal capacity of zone	165 kJ/m^2K
System automation category	c
Number of floors	0m
Infiltration rate from openings	580m^3/h
Number of thermal zones	1
Number of open fireplaces	0

Total volume	1339.8m^3
Heated volume	1339.8m^3
Cooled volume	1339.8m^3
Typical floor height	2,97m
Number of open fireplaces	0

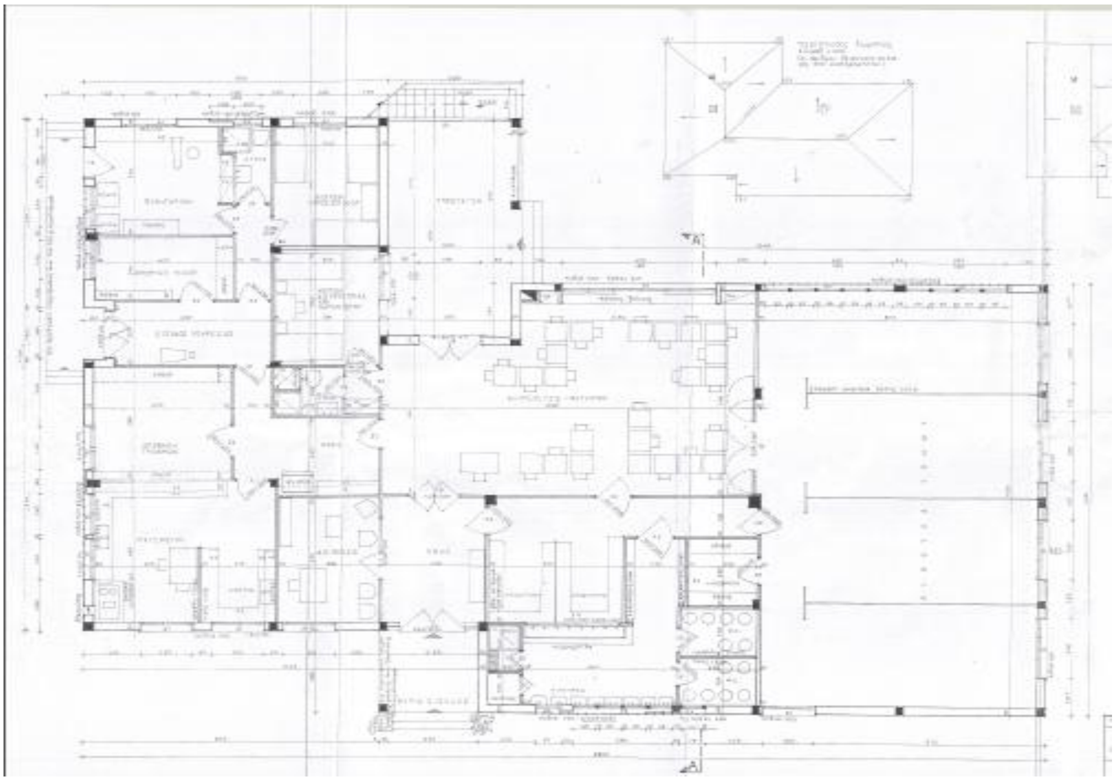


Figure 21: Layout of the building

6.3 Calculating elements

The next step is to isolate the surfaces that have energy flow through the buildings envelope and analyze them. The walls will be analyzed regarding their opaque and transparent building elements.

The different types of windows are double glazed windows with aluminum frame and 6mm thermal break and their dimensions are the following:

-four of them 2.00x1.5m,

-eleven of them 1,5x1,5m,

-two of them 2.9x0.9m,

-two of them 1.5x0.9m,

-one 3.65x0.9 m

-one 4.5x1.8m.

Figures 22: Windows

There are also three different doors which dimensions are respectively:

1: 2.60x2.40

2: 1.80x2.40

3: 1.60x2.40

Figures 23 : Doors

Regarding the walls, they are brick walls without any insulation

After calculating all the opaque building elements we can chart them collectively in the following table: opaque building elements features.

Type	**Description**	**γ (deg)**	**β (deg)**	**A (m^2)**	**U (W/m^2K)**	**a (-)**	**e (-)**
Wall	A1	225	90	31.95	3.65	0.70	0.30
Wall	A2	150	90	30.5	3.65	0.70	0.30
Wall	A3	130	90	7.56	3.65	0.70	0.30
Wall	A3a	130	90	20.02	3.65	0.70	0.30
Wall	A4	110	90	8.89	3.65	0.70	0.30
Wall	A5	45	90	22.45	3.65	0.70	0.30
Wall	A6	340	90	19.9	3.65	0.70	0.30
Wall	A6a	320	90	8.12	3.65	0.70	0.30
Wall	A7	300	90	41.9	3.65	0.70	0.30
Roof	ROOF	0	90	462	3.7	0.40	0.60
Door	1	320	90	6.24	6	0.70	0.60
Door	2	130	90	4.32	6	0.70	0.60
Door	3	45	90	3.84	6	0.70	0.60
Wall	A41	130	90	11.99	11.99	0.70	0.30
Wall	A51	70	90	14.8	14.8	0.70	0.30
Wall	A61	335	90	2.67	2.67	0.70	0.30

After calculating all the transparent building elements we can chart them collectively in the following table: transparent building elements features

Type	**Description**	**γ (deg)**	**β (deg)**	**A (m^2)**	**U_w (W/m^2K)**	**g_w (-)**
Window	1	225	90	3	4.5	0.48

Window	2	225	90	3	4.5	0.48
Window	3	225	90	3	4.5	0.48
Window	4	225	90	3	4.5	0.48
Window	5	150	90	2.61	4.1	0.62
Window	6	150	90	3.28	4.1	0.62
Window	7	150	90	8.1	4.5	0.48
Window	8	130	90	2.25	4.5	0.48
Window	9	110	90	2.25	4.5	0.48
Window	10	110	90	2.25	4.5	0.48
Window	11	45	90	2.1	4.1	0.62
Window	12	45	90	2.1	4.1	0.62
Window	13	45	90	1.26	4.1	0.62
Window	14	45	90	1.26	4.1	0.62
Window	15	340	90	2.25	4.5	0.48
Window	16	340	90	2.25	4.5	0.48
Window	17	340	90	2.25	4.5	0.48
Window	18	300	90	0.675	4.8	0.41
Window	19	300	90	1.88	4.8	0.41
Window	20	300	90	0.675	4.8	0.41
Window	21	300	90	1.35	4.5	0.48
Window	22	110	90	1.35	4.5	0.48

6.4 Shading

Shading influence the energy performance of the building because it reduces thermal gains at high temperatures, or protect the building from overheating in low temperatures. Consequently, we calculate the horizontal shading from obstacles that protect the building from the sun (like other buildings, trees),also the overhangs of our building.

In order to calculate the affect of shading we divide it into 3 forms of shading. Horizontal shading from obstacles like other buildings opposite the building that block the sun, overhangs and shading systems that protect the elements and windows from the sun and fins on the side of the building elements, mostly windows, that shade the element during the day.

Figures 24: Shading from tents

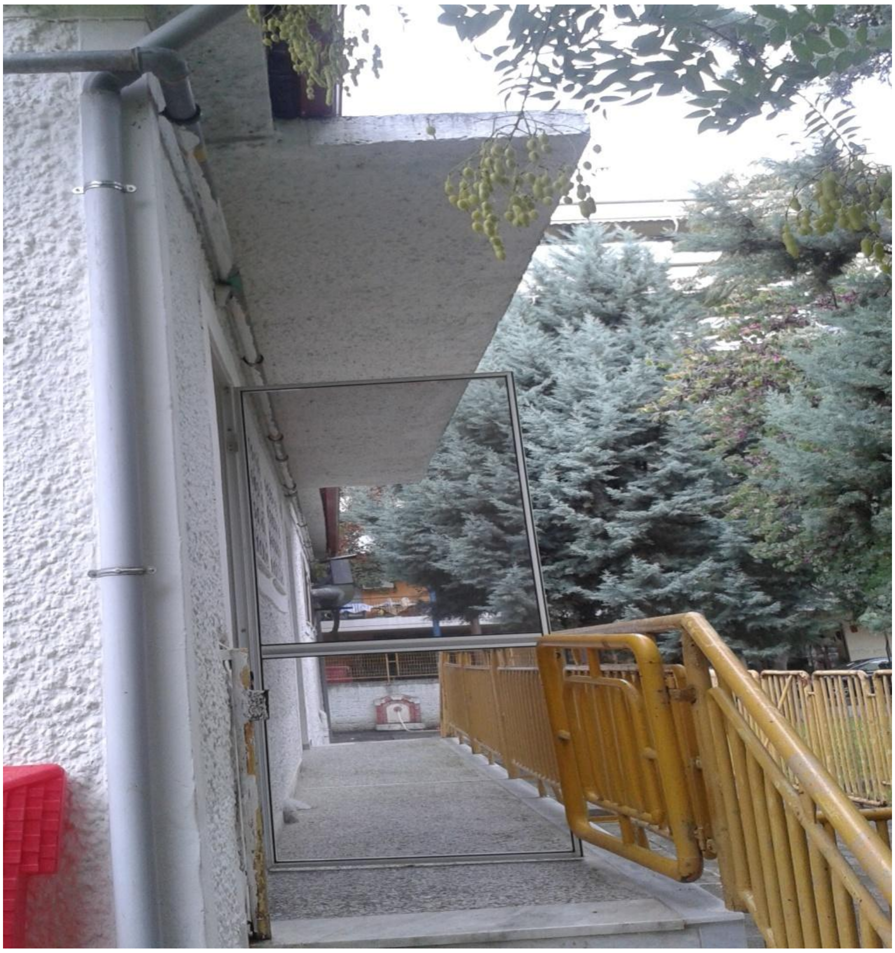


Figure 25: Shading from overhangs

The tables below summarize all the calculations for all forms of shading on the opaque and transparent building elements.

Table 1- Opaque Building Elements Shading Factors

Type	**Description**	**γ (deg)**	**β (deg)**	**A (m^2)**	**U (W/m^2K)**	**a (-)**	**e (-)**	**$F_{hor,h}$**	**$F_{hor,c}$**	**$F_{ov,h}$**	**$F_{ov,c}$**	**$F_{fin,h}$**	**$F_{fin,c}$**
Wall	A1	225	90	31.95	3.65	0.7	0.3	0.84	0.92	1	1	0.99	0.94
Wall	A2	150	90	30.5	3.65	0.70	0.3	0.84	0.92	1	1	0.99	0.94
Wall	A3	130	90	7.56	3.65	0.70	0.3	1	1	0.6	0.5	1	1

										9	7		
Wall	A3a	130	90	20.02	3.65	0.70	0.3	1	1	0.69	0.57	1	1
Wall	A4	110	90	8.89	3.65	0.70	0.3	1	1	1	1	1	1
Wall	A5	45	90	22.45	3.65	0.70	0.3	1	1	1	1	0.97	0.86
Wall	A6	340	90	19.9	3.65	0.70	0.3	0.81	0.67	1	1	1	1
Wall	A6a	320	90	8.12	3.65	0.70	0.3	0.81	0.67	0.73	0.72	1	1
Wall	A7	300	90	41.9	3.65	0.70	0.3	0.81	0.67	1	1	1	1
Roof	ROOF	0	90	462	3.7	0.40	0.6	1	1	0	0	1	1
Door	1	320	90	6.24	6	0.70	0.6	0.81	0.67	1	1	1	1
Door	2	130	90	4.32	6	0.70	0.6	1	1	0.69	0.57	1	1
Door	3	45	90	3.84	6	0.70	0.6	1	1	0.91	0.89	1	1
Wall	A41	130	90	11.99	11.99	0.70	0.3	1	1	0.73	0.62	0.97	0.86
Wall	A51	70	90	14.8	14.8	0.70	0.3	1	1	0.91	0.89	1	1
Wall	A61	335	90	2.67	2.67	0.70	0.3	0.81	0.67	0.73	0.72	1	1

Table 2- Transparent Elements Shading Factors

Type	**Description**	**γ (deg)**	**β (deg)**	**A (m^2)**	**U_w (W/m^2K)**	**g_w (-)**	**$F_{hor,h}$**	**$F_{hor,c}$**	**$F_{ov,h}$**	**$F_{ov,c}$**	**$F_{fin,h}$**	**$F_{fin,c}$**	**Type**
W	1	225	90	3	4.5	0.48	0.89	0.94	1	1	0.9	0.71	Double

													frame -6mm
W	2	225	90	3	4.5	0.48	0.89	0.94	1	1	0.9	0.71	Double frame
W	3	225	90	3	4.5	0.48	0.89	0.94	1	1	0.9	0.71	Double frame
W	4	225	90	3	4.5	0.48	0.89	0.94	1	1	0.9	0.71	Double frame
W	5	150	90	2.61	4.1	0.62	0.89	0.94	1	1	0.9	0.71	Double frame
W	6	150	90	3.28	4.1	0.62	0.89	0.94	1	1	0.9	0.71	Double frame
W	7	150	90	8.1	4.5	0.48	0.89	0.94	1	1	0.9	0.71	Double frame
W	8	130	90	2.25	4.5	0.48	1	1	0.36	0.58	1	1	Double frame
W	9	110	90	2.25	4.5	0.48	1	1	0.36	0.58	1	1	Double frame
W	10	110	90	2.25	4.5	0.48	1	1	1	1	1	1	Double frame
W	11	45	90	2.1	4.1	0.62	1	1	0.84	0.77	1	1	Double

													frame
W	12	45	90	2.1	4.1	0.62	1	1	0.84	0.77	1	1	Double frame
W	13	45	90	1.26	4.1	0.62	1	1	1	1	0.84	0.79	Double frame
W	14	45	90	1.26	4.1	0.62	1	1	1	1	0.84	0.79	Double frame
W	15	340	90	2.25	4.5	0.48	0.82	0.7	1	1	1	1	Double frame
W	16	340	90	2.25	4.5	0.48	0.82	0.7	1	1	1	1	Double frame
W	17	340	90	2.25	4.5	0.48	0.82	0.7	1	1	1	1	Double frame
W	18	300	90	0.67	4.8	0.41	0.82	0.7	1	1	1	1	Double frame
W	19	300	90	1.88	4.8	0.41	0.82	0.7	1	1	1	1	Double frame
W	20	300	90	0.67	4.8	0.41	0.82	0.7	1	1	1	1	Double frame
W	21	300	90	1.35	4.5	0.48	0.82	0.7	1	1	1	1	Double frame

W	22	110	90	1.35	4.5	0.48	1	1	0.36	0.58	1	1	Double frame

6.5 Heating, cooling, Hot Water System and lighting

Heating

The heating system in this building is by radiators in the kitchen, teaching room and bedrooms. There are in total 10 radiators (natural gas) with power 3500kcal each of them.

Figure 26: Photograph of a typical radiator in a bathroom. These comprise of the emission system of the heating system.

-Production

Type	Fuel type	Power (kW)	Efficiency (-)	COP (-)	Jan (-)	Feb (-)	Mar (-)	Apr (-)	May (-)	Jun (-)	Jul (-)	Aug (-)	Sep (-)	Oct (-)	Nov (-)

radiator	n.gas	157	0.93	1	1	1	1	1	0	0	0	0	0	1	1

-Distribution

Type	**Power (kW)**	**Routing through:**	**Efficiency (-)**
pipes	93.5		0.95

-Emission

type	**Efficiency(-)**
radiator	0.95

Cooling

For cooling there are 2 air-conditioners which are used periods with hight temperature.

Figures 26: Two types of installed air conditioners

-Production

Type	Fuel type	Power (kW)	Efficiency (-)	EER (-)	Jan (-)	Feb (-)	Mar (-)	Apr (-)	May (-)	Jun (-)	Jul (-)	Aug (-)	Sep (-)	Oct (-)	Nov (-)
Air condition1	electricity	7.032	1	2.8	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0
Air condition2	electricity	5.274	1	2.8	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0

-Emission

Type	**Efficiency**
Split unit	0.93

Hot water system

There are an electric water heater that is used only in case a child needs (220V and 4000W)

Figure 27: Electrical water heater boiler

-Production

Type	**Fuel type**	**Power (kW)**	**Efficiency (-)**	**Jan (-)**	**Feb (-)**	**Mar (-)**	**Apr (-)**	**May (-)**	**Jun (-)**	**Jul (-)**	**Aug (-)**	**Sep (-)**	**Oct (-)**	**Nov (-)**
Electric Water heater	electricity	4	1	1	1	1	1	1	1	1	1	1	1	1

-Distribution

Type	Recirculation?	Routing through:	Efficiency (-)
			1

-Storage

Type	Efficiency
internal	0.98

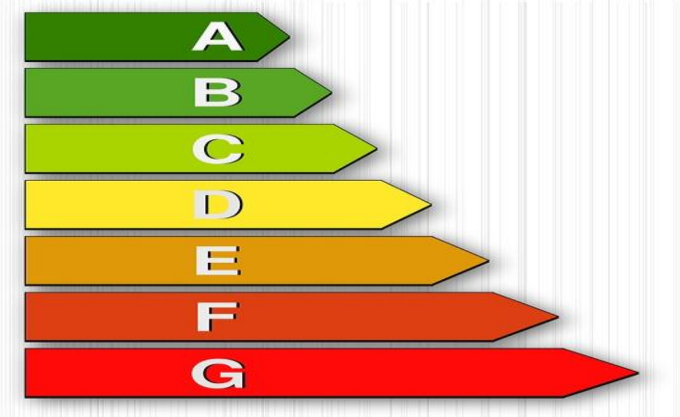
Lighting

There are fluorescent lightings with installed power 1.5kW and natural lighting 60%.

Figure 28: Fluorescent lighting

6.6 Final Costs

After doing all the calculations, we got the final energy performance results. The following tables show us the primary energy consumption→ energy class of the building: E, the energy demand and the final energy consumption.



Primary energy consumption [kWh/m2]	**Building**
Heating	179.1
Cooling	1.6
Domestic Hot Water	0
Lighting	13
Renewable Energy Sources	0.0
Total	193.7
Ranking (Energy Class)	E

Energy source	**Fuel Consumption** [kWh/m^2]	**CO_2 Emissions [kg/m²]**
Electricity	13.6	13.5
Oil	0	0
Natural gas	147.0	28.8
Other fossil fuels	0	0
Solar	0	0

Biomass	0	0
Geothermal	0	0
Othen RES	0	0
Total	160.5	42.3

Energy demand [kWh/m^2]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Heating	35.4	21.5	11.8	5.5	0	0	0	0	0	1.6	10.0	29.9	115.6
Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0

Final energy consumption [kWh/m^2]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Heating	46.3	28.6	16.4	8.3	0	0	0	0	0	2.7	13.9	39.3	155.5
Cooling	0	0	0	0	0.5	0	0	0	0	0	0	0	0.5
Lighting	0.6	0.6	0.6	0.6	0.6	0	0	0	0	0.6	0.6	0.6	4.5
Total	46.9	29.1	16.9	8.9	1.1	0	0	0	0	3.3	14.5	39.9	160.5

Operational cost[€]	**5641.5**

6.7 Improvement proposals

From our calculations so far, we have seen that a large part of the internal energy of the house flows through the windows and the walls since their U- Values are about 4.5(W/m^{2}K) and 3.7 (W/m^{2}K) respectively. On top of that, it would be a logical choice to propose the upgrading of windows to newer ones with better U-Value as well as the insulation of the walls.

Analytically, with the interventions that took place we have achieved a desired result, specifically we have changed the double glazed windows with aluminum frame and 6mm thermal break with U- Value=4.5(W/m^{2}K), to double glazed windows with wooden frame and 12 mm thermal break with U- Value=2.1(W/m^{2}K). Also we have changed the walls with 3.7 (W/m^{2}K) U-Value by putting insulation and the result is walls with 0.9(W/m^{2}K) U-Value. Additionally, we have insulate the roof and we have achieved the improvement from U- Value=3.7(W/m^{2}K), to U- Value=1.05(W/m^{2}K).

The following tables summarize the total costs after the implementation of the proposed changes in the kindergarten. Consequently, by applying this scenario with these few interventions we can change its energy efficiency category from E (efficiency =2.05) to category B (efficiency=0.8) which is obvious in the graphs below.

Primary energy consumption [kWh/m2]	**Building**	**New building-scenario**
Heating	179.1	78.2
Cooling	1.6	1.7
Domestic Hot Water	0	0
Lighting	13	13.0
Renewable Energy Sources	0.0	0
Total	193.7	92.9
Ranking (Energy Class)	E	B

Energy source	Fuel Consumption [kWh/m[2]]	CO_2 Emissions [kg/m²]
Electricity	9	8.9
Oil	0	0
Natural gas	63.7	12.5
Other fossil fuels	0	0
Solar	0	0
Biomass	0	0
Geothermal	0	0
Othen RES	0	0
Total	72.7	21.4

Energy demand [kWh/m²]	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Heating	12.4	7.6	3.6	1.3	0	0	0	0	0	0.3	3	10.2	38.2
Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0

Final energy consumption [kWh/m²]	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Heating	21.1	13.2	6.5	2.7	0	0	0	0	0	1	5.5	17.5	67.5
Cooling	0	0	0	0	0.6	0	0	0	0	0	0	0	0.6
Lighting	0.6	0.6	0.6	0.6	0.6	0	0	0	0	0.6	0.6	0.6	4.5
Total	21.7	13.7	7.1	3.2	1.2	0	0	0	0	1.6	6.0	18.1	72.7

Operational cost[€]	**2606.4**

7 Comparison between the other thermal zones A,B,D

As we have already mentioned, this dissertation presents also the energy situation of the existing building in cities located in different climatic zones in the Hellenic space, especially in zone A, in zone B and in zone D, with the objection to compare their results arising from the same interventions. These cities are Rhodos for A climatic zone, Athens for B climatic zone, and finally Florina for D climatic zone.

7.1 About thermal zone A- Rhodos

Primary energy consumption [kWh/m2]	**Building**	**New building-scenario**
Heating	99.2	34.6
Cooling	1.4	1.4
Domestic Hot Water	0	0
Lighting	13	13.0
Renewable Energy Sources	0.0	0
Total	113.7	49.1
Ranking (Energy Class)	C	B+

Energy source	**Fuel Consumption [kWh/m^2]**	**CO_2 Emissions [kg/m²]**
Electricity	12.6	12.5
Oil	0	0
Natural gas	73.5	14.4
Other fossil fuels	0	0

Solar	0	0
Biomass	0	0
Geothermal	0	0
Othen RES	0	0
Total	86.1	26.9

Energy demand [kWh/m^2]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Heating	35.4	21.5	11.8	5.5	0	0	0	0	0	1.6	10.0	29.9	115.6
Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0

Final energy consumption [kWh/m^2]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Heating	23.7	14.8	8.7	4.6	0	0	0	0	0	1.6	7.5	20.2	81.1
Cooling	0	0	0	0	0.6	0	0	0	0	0	0	0	0.6
Lighting	0.6	0.6	0.6	0.6	0.6	0	0	0	0	0.6	0.6	0.6	4.5
Total	24.2	15.3	9.3	5.2	1.0	0	0	0	0	2.2	8.0	20.7	86.1

Operational cost[€]	**1233.8**

7.2 About thermal zone B- Athens

Primary energy consumption [kWh/m2]	**Building**	**New building-scenario**
Heating	139.1	47.7
Cooling	1.5	1.5
Domestic Hot Water	0	0
Lighting	13	13.0
Renewable Energy Sources	0.0	0
Total	153.5	62.2
Ranking (Energy Class)	D	B+

Energy source	**Fuel Consumption [kWh/m^2]**	**CO_2 Emissions [kg/m^2]**
Electricity	13	12.9
Oil	0	0
Natural gas	110.2	21.6
Other fossil fuels	0	0
Solar	0	0
Biomass	0	0
Geothermal	0	0
Othen RES	0	0
Total	123.3	34.5

Energy demand [kWh/m^2]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Heating	35.4	21.5	11.8	5.5	0	0	0	0	0	1.6	10	29.9	115.6

Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0

Final energy consumption [kWh/m^2]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Heating	35	21.7	12.5	6.5	0	0	0	0	0	2.2	10.7	29.7	118.2
Cooling	0	0	0	0	0.5	0	0	0	0	0	0	0	0.6
Lighting	0.6	0.6	0.6	0.6	0.6	0	0	0	0	0.6	0.6	0.6	4.5
Total	35.5	22.2	13.1	7	1.1	0	0	0	0	2.7	11.3	30.3	123.3

Operational cost[€]	**1645.6**

7.3 About thermal zone D- Florina

Primary energy consumption [kWh/m2]	**Building**	**New building-scenario**
Heating	217.6	73.6
Cooling	1.7	1.7
Domestic Hot Water	0	0
Lighting	13	13.0
Renewable Energy Sources	0.0	0
Total	232.3	89.3
Ranking (Energy Class)	Z	B

Energy source	Fuel Consumption [kWh/m^2]	CO_2 Emissions [kg/m²]
Electricity	14.1	13.9
Oil	0	0
Natural gas	182.2	35.7
Other fossil fuels	0	0
Solar	0	0
Biomass	0	0
Geothermal	0	0
Othen RES	0	0
Total	196.4	49.7

Energy demand [kWh/m^2]	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Heating	35.4	21.5	11.8	5.5	0	0	0	0	0	1.6	10	29.9	115.6
Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0

Final energy consumption [kWh/m^2]	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Heating	57.2	35.2	20.1	10	0	0	0	0	0	3.2	17.1	48.5	191.3

Cooling	0	0	0	0	0.6	0	0	0	0	0	0	0	0.6
Lighting	0.6	0.6	0.6	0.6	0.6	0	0	0	0	0.6	0.6	0.6	4.5
Total	57.7	35.8	20.6	10.6	1.1	0	0	0	0	3.8	17.6	49.1	196.4

Operational cost[€]	**2457.8**

7.4 Costs and payback period

In this phase, I am going to mention the *cost of the installed interventions*:

First of all, as for the optimum interventions of the walls and roof, the cost of insulation is 40€/m^2 .Also the acreage of roof is 462 m^2 and the walls' is 250.47 m^2 → 712,47*40=**28498.8€**

Secondly, the cost of windows is 250 €/m^2 therefore after calculating the acreage of windows which are 51.53 m^2 , we can calculate their cost → 51.53*250=**12882.5€**

Finally, the **total cost** of the energy upgrade is 28498.8+12882.5= **41385.3€**

b) Regarding the calculation of the *simple payback period*, we compare the cost before and after putting insulation (in walls, roof) as well as after changing the transparent parts (windows).

-In climatic zone C, where the existing building is located, the operational cost is 5641.5€ and the operational cost after the added interventions is 2606.4€ .Therefore the annual cost benefit is 5641.5-2606.4=**3035.1**€

-In climatic zone A, the operational cost is 3123.2€ and after the added interventions the operational cost is 1233.8€. Therefore, the annual cost benefit is 3123.2-1233.8= **1899.4**€

-In climatic zone B, the operational cost is 4389€ and the operational cost after the added interventions is 1645.6€. Therefore the annual cost benefit is 4389-1645.6=**2743.4**€

-In climatic zone D, the operational cost is 6853.5€ and the operational cost after the added interventions is 2457.8€. Therefore the annual cost benefit is 6853.5-2457.8= **4395.7**€

Finally the **Payback Period** is the **Total cost/Annual cost benefit,** so:

In C climatic zone → 13 years and 5 months

In A climatic zone → 21 years and 5 months

In B climatic zone → 15 years

In D climatic zone → 9 years and 4 months

8 Conclusions

First of all, the fact that it is imperative the maximization of RES use, there are signs so as energy efficiency to be appreciated by the public in comparison with the past. Moreover, more and more campaigns take place to inform the public about the increase of amount in CO_2 and its impact to our lives. Consequently, all buildings must be constructed to optimize energy in use and without compromising performance regarding the air quality and comfort conditions.

One of the main aims of this thesis was the activities regarding the energy efficiency of a public building (kindergarten). Specifically, the utilization of a building can influence its energy efficiency. Therefore, if we want to maximize the energy efficiency of a building we must minimize the heat losses and maximize the thermal massing within it. This can come true with many interventions such as insulation to the roof, walls, floors, windows and doors.

The reason why I decided to study a kindergarten is because it is a public building which operates many hours during the day and in which stay little children. Therefore, it is urgent the energy demands to be covered according to the Joint Ministerial Decision. Specifically, it is mandatory the connection to the natural gas grid in buildings near active natural gas grid. Also, it is urgent the reduction of reactive power of energy consumptions, the conservation on air-conditioning systems. Moreover, fixed temperature during the summer period must be at 27^o C, and during the winter period at 19^o C. Replacement of the lights to more energy efficient (A+ and B+). Also all the new appliances must have energy label and certified energy efficiency. Finally, it is important also the installation of automatic systems in corridors and communal places so as to reduce the lighting from the lighting systems.

Regarding the kindergarten energy inspection:

This building is located in the C climatic zone and it belongs to the E energy class. Our interventions achieved to upgrade it to B energy class. We particularly decided to put external insulation in the opaque surfaces (walls and roof) in order to minimize the U-Value. As for the transparent surfaces we have replaced them from aluminum to wooden with different thermal break and at the end we have achieved the lowest U-Value.(analytically in chapter 6).

Afterwards we used exactly the same elements from the existing building and the same intervention to maximize their energy efficiency <u>to different climatic zones</u> so as to compare the differences from the cooler zone (D) to the warmer one (A). The result is that in A climatic zone, the current building belonged to C energy class and we upgrade it to B+ .In B climatic zone we upgrade the building energy class from D to B+. And finally, in D climatic zone (cooler), we upgrade it from Z to B.

Finally, relating to the operational cost and the payback period:

We have achieved the desired saving, in A climatic zone we have reduced the operational cost from 3123.2 to 1233.8 so our benefit is 1899.4€ In climatic zone B we have reduced the operational cost from 4389 to 1645.6 so our benefit is 2743.4€ In climatic zone C we have reduced the operational cost from 5641.5 to 2606.4 so our benefit is 3035.1€. Finally in climatic zone D we have reduced the operational cost from 6853.5 to 2457.8 and our benefit is 4395.7€. Consequently it is obvious that as the zone become cooler the operational cost is bigger as well as our benefit after the applied interventions.

Last but not least, in terms of the payback period in all zones: in A climatic zone is 21 years and 5 months, in B climatic zone is 15 years, in C climatic zone is 13 years and 5 months, and in D climatic zone is 9 years and 4 months. Consequently every zone needs about 9-21 years specifically from the cooler to warmer one.

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