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Energy Regeneration of Dwelling Case Study: Traditional Building in Thrace of Greece

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Abstract: Bioclimatic architecture contributes to the rational use of resources, the reduction of conventional energy consumption, the enhancement of people's quality of life and the consolidation of the desirable sustainable development. The purpose of the present paper is the energy upgrade of a theoretically "existing" traditional residence. The principles of bioclimatic design are implemented with the use of passive and active solar systems with the ultimate goal of achieving the energy independence of the house and providing all amenities to the users at the lowest possible cost. The software Autodesk Revit is a powerful tool that, after importing a set of key parameters, such as the climatic conditions of the area, was implemented on the two-storey model house in the city of Xanthi, in North-Eastern Greece, in order to capture the energy profits of the building.

Keywords: Regeneration, bioclimatic design, Energy, Revit software, Traditional architecture

I. INTRODUCTION

Bioclimatic architecture has been a key approach in the construction of small and large buildings worldwide over the last decades. It has been developed as a new "theory" to address the problem of energy crisis and the greenhouse gas emissions increase, while many efforts have been made to existing buildings energy upgrade and new developments rational energy planning implementation [2, 6]. The concept of bioclimatic design is defined as the architectural design of a building that takes into account the topographical features and local climatic data of each area and aims to provide the necessary inter-climatic conditions [13] (thermal visual comfort and acoustic user comfort, minimum air quality) with the lowest possible energy consumption, utilizing the available environmental sources (sun, wind, water, soil). In essence, bioclimatic perception expresses an enriched view of the design of the built environment, which encompasses the environmental dimension and the corresponding sensitivity [14]. It is an environmental and user friendly architecture, an alternative view of the built environment - inevitable human activity - that should bring the least possible burden to the natural space, with the least possible energy and environmental impact. In conclusion, it could be argued that the bioclimatic building, which is energy self-serviced through smart solutions and, through the reduced environmental burdens, is a prime objective of sustainable planning, as well as of modern society in the wake of the current global energy crisis and the rising energy demand [1]. Designing the built environment in bioclimatic directions, minimizing fossil fuel consumption and utilizing renewable resources is a first approach to urban upgrade and sustainable development. Moreover, it contributes to the creation of structures that meet the needs of modern lifestyles without posing a threat to future generations. Today, in Greece, a bioclimatic house compared to a conventional building can have up to 30% energy savings, while compared to an older non-insulated building this benefit can be up to 80% [5]. In Europe, a target of 20% reduction in its Greenhouse gas emissions (compared to 1990), improving energy efficiency and increasing RES by 2020 has been set [10], since the building sector is responsible for 40% of total energy consumption and 36% of CO2 emissions [4,17]. The present paper concerns the energy upgrade of a traditional residence (featuring characteristics of Macedonian architectural tradition) [12, 15]. The subject residence has been designed in accordance with the general principle of bioclimatic design and displays energy self-reliance. It offers all the comforts at the lowest possible cost to its users and at the same time it also retains all its architectural and aesthetic features which brings the construction even closer to the standards of the ideal home [16].

II. ENERGY REGENERATION OF THE HOUSE

A. Application Purpose

The subject application concerns the energy regeneration of a theoretically "existing" residence with features of Macedonian traditional architecture [12, 15] in the city of Xanthi in Northeastern Greece. Designed in accordance with the general principle of bioclimatic design [2] and since it retains all its architectural aesthetic elements it is subject to energy regeneration. As a result, it provides all the comforts to its users at the lowest possible cost, while displaying energy self-reliance. More specifically, all the weaknesses but also all the possibilities of upgrading the building were examined and a general investment was made **-** shielding the house (but which has been presumed to already retain the appropriate openings, orientation and proportionality of its sides, subject to the principles of bioclimatic design [17]) which was not about one part or one aspect of the construction, but the greater aspect of the building. With the targeted investment, the house is transformed into an energy upgraded building, which with a reasonable capital investment, whose depreciation, as will be reviewed below, provides to its users savings and energy independence. The energy savings were calculated accurately using Autodesk's Revit software. Finally, the house does not negate the highly developed element of aesthetics as it manages to find the right balance and combine the energy and economic benefits with a particular expression of beauty.

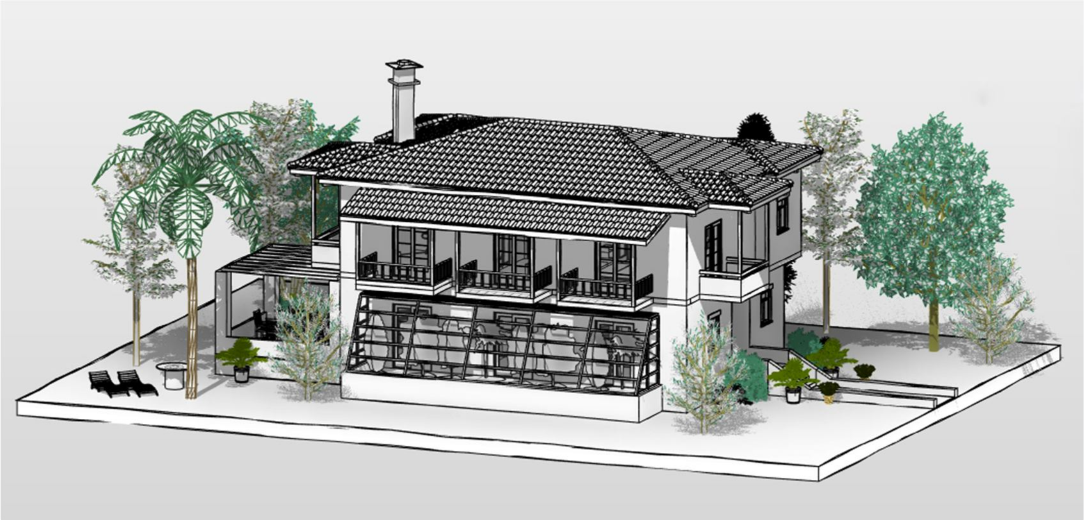
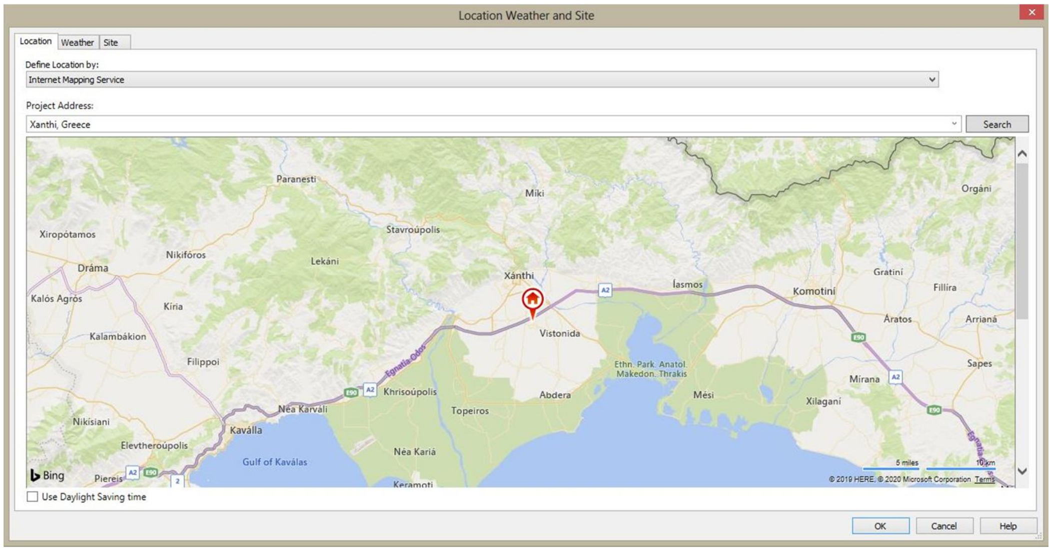


Figure 1: 3D view of the dwelling after the investment (authors' own)

B. Climatic Conditions-Location

The climatic conditions [13] that are being developed in the area where the subject house is built have been well understood and analyzed with great precision as it is the key factor in the implementation of the project since it plays a key role not only in the site selection, but also in making decisions about shielding the home.

For the thermal analysis of the under study building it is necessary the climatic elements of the study area to be introduced. The climatic data that were analyzed are those of the city of Xanthi which were imported in the Revit software, since it is the simulation program of the subject site.



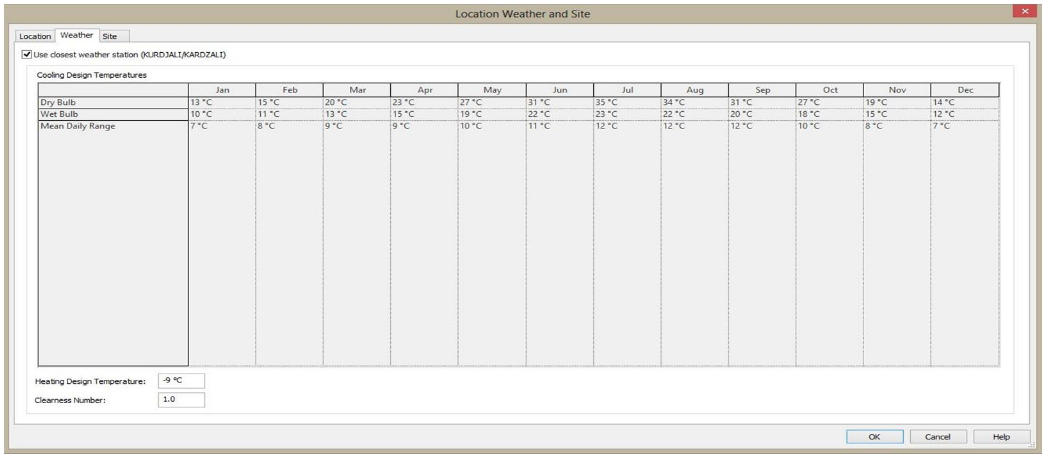
Location Weather and Site

Define Location by: Internet Mapping Service

Project Address: Xanthi, Greece

☐ Use Daylight Saving time

Figure 2: Simulator dialog box for site selection.



☑ Use closest weather station (KURDJALI/KARDZALI)

Cooling Design Temperatures

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dry Bulb	13 °C	15 °C	20 °C	23 °C	27 °C	31 °C	35 °C	34 °C	31 °C	27 °C	19 °C	14 °C
Wet Bulb	10 °C	11 °C	13 °C	15 °C	19 °C	22 °C	23 °C	22 °C	20 °C	18 °C	15 °C	12 °C
Mean Daily Range	7 °C	8 °C	9 °C	9 °C	10 °C	11 °C	12 °C	12 °C	12 °C	10 °C	8 °C	7 °C

Heating Design Temperature: -9 °C
Clearness Number: 1.0

Figure 3: Simulator dialog box for climatic conditions.

C. Residence Shape and Orientation

The understudy dwelling has an elongated shape along the east-west axis, creating a larger surface to the south for collecting and harnessing solar heat in the winter months through openings and passive systems [14]. Its aspect ratio is about = 1 / 1.5 which makes it very close to the ideal one. According to calculations and measurements made in various proportions, it is proved that through the subject ratio the non-creation of dark spaces is being achieved, as there is no part of the house that is not fully or at least partially illuminated. As far as the orientation is concerned, it follows the south orientation since according to the typical Greek traditional house [12, 15] the Southeast orientation is considered the most ideal one for the geographical location of Greece, in order for the sun and all environmental benefits to be fully exploited. Moreover, a home with modern bioclimatic features could not be opposite to the more general principle of bioclimatic design that sets the South side of the building for passive solar heating, while the North for wind protection and heat retention [11]. In general, in order every aspect of our home to be fully utilized, the most appropriate management of each area needs to be made, with the basic criterion of locating them in places where the orientation will benefit, highlight and serve them in their use. Specifically in the house of the subject study, the south orientation for the living room was considered to be the most preferable one, while the eastern one was chosen for the kitchen and the bedrooms and the western one for the layout of a room used mainly in wintertime. Sun protection measures were taken for this area to avoid overheating of the interior space during the summer afternoons. Finally, the north orientation was considered suitable for warehouses, staircases and bathrooms, which are secondary areas as it offers low levels of lighting during every season and is characterized by cold [17].

D. Layout of Spaces

The building after its renovation and energy upgrading has become a modern and ideal home [16]. The house besides the architecture (e.g. openings), spatial layout and the proportionality of its sides, disposes passive systems such as greenhouse [2], complete thermal insulation of floor, roof and exterior walls, suitable windows and lighting, modern heating systems and photovoltaics [3,8,9], which offer energy independence and self-sufficiency. Specifically, it constitutes a two-storey house that reaches 200 square meters. On the ground floor extends the living area and on the first floor the sleeping zone, which includes bathroom, office and three bedrooms, one of which has a dressing room and its own bathroom. Furthermore, in the living area there are the main-uses areas such as living room and kitchen designed in the ideal dimensions and there is also a comfortable guest room with its own bathroom.

The designed home is a two-storey bioclimatic residence with indoor space that utilizes every part of the home for its intended use. The house meets the general principle of bioclimatic design [6], as it places the South side for the location of the most important functions of the building and the use of passive solar heating, while the North side for heat retention and wind protection. More specifically, in the southern parts of the building, the main use areas are being placed, which are the rooms that the tenants spend most of their time such as the living room. It is considered to be the most appropriate choice for these areas as in the winter months the sun's rays are low on the horizon and thus enter deep into the interior warming and illuminating the rooms, while in the summertime the rays are at a high place and a shelter is used in order to prevent from overheating. On the contrary, on the north side secondary areas and areas where users do not spend many hours are being placed, such as a storage room, a bathroom and a guest house. This is based on the fact that the north portion is colder, requires greater protection from high winds and acts as a protection zone for the main use areas. In addition, on the east side areas that need to enjoy the morning sun, warmth in the morning and cool off in the midday hours are chosen. Finally, on the west side there are places used mainly in wintertime, but not places such as the kitchen as the heat generated by cooking if added to the heat of the sun would cause the interior space to be overheated to undesirable levels [14].

The need for sun protection of passive systems and openings during the summer months so as to avoid high temperatures is achieved to a sufficient degree by the installation of special shelters [7]. In this particular case, this role is also adopted and performed by properly designed and configured galleries. In general the use of shelters is not the only option for protection as there is a range of solutions. Another simple and natural way of protecting the building, as well as its passive systems and openings, is to place deciduous trees and vegetation in the south, proving once again that nature and the environment are not only opposed to the construction sector but are its allies in order to achieve a better result. The proposed development's spaces layout, the proportionality of its sides, the openings and its architecture are not the only elements that make it unique as it also has passive systems [2] such as greenhouse that besides the energy and economic benefits, it also adds an aesthetic result to the subject residence. (Figure 4 & Figure 5).

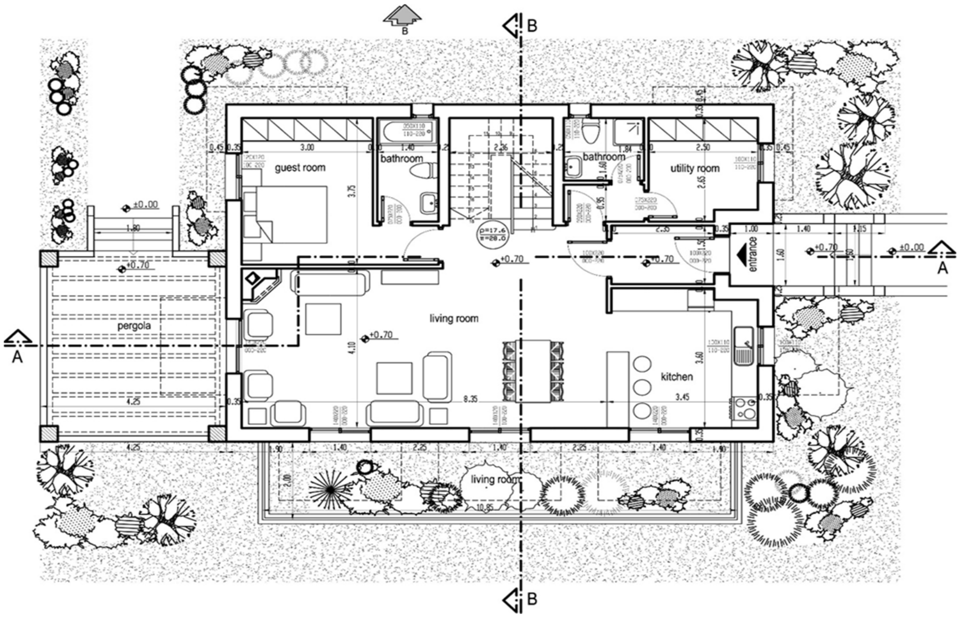


Figure 4: Ground floor plan view (authors' own)

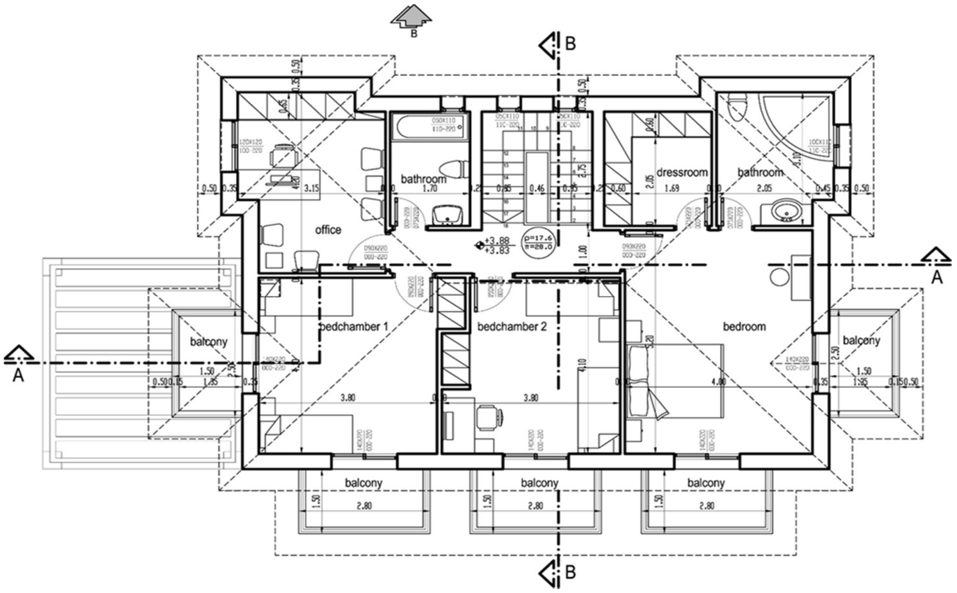


Figure 5: Second floor plan view (authors' own)

III. UPGRADE IMPLEMENTATION

With a modern upgrading, the home is transformed into an energy-upgraded building, which with a reasonable capital investment whose economic return is directly, as we will see below, it provides to the users energy and economy independence [8]. After considering all the weaknesses and all the possibilities of upgrading the building, a generalized shielding of the house was carried out. Besides the bioclimatic features [6] (proportionality of the sides, orientation, proper layout, openings dimensions, passive systems, etc.), it also has fully insulated floors, roof and exterior masonry, satisfactory frames, modern lamps, higher quality heating systems and modern lighting systems. Thus, the traditional residence combines its architectural features [12, 15] and aesthetics with energy autonomy and many financial benefits. The following is a detailed presentation of the investment and shielding elements of the home that do not relate to only one aspect but to the entire construction. Specifically are the following:

A. Installation of photovoltaic tiles (PV tiles) Type: PV-MODULESM-PV2. In the study area, the output of each tile is 12%

B. Modern And Reliable Heating Systems As The Oil Boiler Are Replaced By A Heat Pump With The Following Features

1) Oil boiler (50kW): 4-Pipe Fan Coil System
2) Heat pump (20 kW):Residential 17 SEER/9.6 HSPF Split HP <5.5 ton

C. Insulation In Exterior Walls, Floors And Roofs

Table 1: Comparative table with the characteristics of the exterior wall, roof and floor with or without insulation.

	Thickness (mm)	Insulation (mm)	U-value W/(m2K)	Thermal Mass (kJ/K)
External masonry without insulation	380	0	1.54	42.34
External masonry with insulation	440	60	0.43	42.34
Roof without insulation	200	0	1.12	28.00
Roof with insulation	260	60	0.38	28.17
Floor without insulation	180	0	1.16	25.68
Floor with insulation	210	30	0.58	25.77

The thermal insulation selected for this study is the graphite expanded polystyrene (FIBRAN GRAFIT EPS80) 60mm and 30mm with characteristics:
1) Thermal conductivity (k): 0.0320 W / (m•K)
2) Specific heat capacity: 14900 J / (g•° C)
3) Density: 23.00 kg / m³

The choice of 60 mm and 30 mm of thermal insulation was made according to the technical instructions of TEE (TCG)20701-1, for the Climate Zone C where the building of this study belongs. It is provided for the external walls in contact with the outside air thermal transmittance coefficient: U-value = 0.45 W/(m^2K) and the walls that are in contact with the ground or non-heated spaces thermal transmittance coefficient: U-value = 0.80 W / (m^2K).

D. Installation Of Double-Glazed Frames

Table 2: Characteristics of windows and window-doors with single or double glazing and wooden frames.

	Visual light transmittance	Solar heat gain coefficient	U-value W/(m2K)
Windows and window-doors with single glazing and wooden frames	0.82	0.73	5.88
Windows and window-doors with double glazing and wooden frames	0.74	0.50	2.00

E. Glass Pane Attached To A Greenhouse (Passive System) With The Following Characteristics

Table 3: Characteristics of transparent surfaces of attached greenhouse

	Visual light transmittance	Solar heat gain coefficient	U-value W/(m2K)
Glass pane of attached greenhouse	0.90	0.86	6.67

F. Greenhouse Pre-Dimension

It is designed with the ideal dimensions and it consists the main passive system. Pre-dimension here is not done for each room separately as it is done concerning the openings, as the space is single with free air flow [2, 17].

The greenhouse's dimensions depend on the climatic conditions of the area which is the average outdoor temperature in the wintertime (4.5 degrees Celsius). According to Table 4 [2], there are the following results:

Area of southern thermal zone= 50.3

Minimum area of glass pane= $50.3m^2$ x 0.40 = 20.1 m^2

Maximum area of glass pane= $50.3m^2$ x 0.70 = 35.2 m^2

20.1<Area of glass pane<35.2

In the greenhouse the moisture in the winter ime is avoided with water-absorbent materials, suitable plants etc., while the overheating in the summer is avoided by suitable sunblinds [8].

Table 4: Area of glass pane (m^2) for an indoor space of $1m^2$ in combination with a thermal storage wall as a function of the average winter temperature.

Average outdoor temperature(°C)	Opening area / floor plan unit
-1	0.65–1.15
4.5	0.40 – 0.70

G. Installation And Use Of Led Lighting Instead Of Conventional Ones With The Following Features

Table 5: Features of LED lighting and conventional lamps

Conventional & LED lighting	
For 200 lux of technical instructions of TEE(TCG), is anticipated consumption	6.4 W/m2
For 200 lux with LED, is anticipated consumption	1.2 W/m2
For 500 lux of technical instructions of TEE(TCG), is anticipated consumption	16 W/m2
For 500 lux with LED, is anticipated consumption	5.3 W/m2

IV. RESULTS – DISCUSSION

After the energy upgrade has been carried out and the results of the wider investment have been collected and evaluated, the following tables have been completed in order to express either our financial or energy benefits. Specifically, there are tables showing on an annual basis and over thirty years the cost as well as the amount of energy required to heat and cool the premises, for lighting, equipment, hot water use and the sum of all these, before and after the investment. They also capture the annual carbon dioxide emissions in metric tonnes of CO2 / year and also the use of fossil fuels and renewable sources for each stage.

A. Target Levels – Thermal Comfort Aims

Through the intervention, energy and economic benefits are aimed, but of course, also of achieving the desired operating conditions of the building. The actual operating conditions of a building may vary on a case-by-case basis and the users of the building. For this reason, nationally accepted standards are specified in accordance with the operating conditions of a particular use building, in order to calculate the estimated energy consumption, which will ultimately characterize the energy performance of the building. For the calculations of the required heating and cooling loads, the building should be considered as a single thermal zone or split into several thermal zones as appropriate. Once a building has been separated into more than one thermal zone then it is possible, according to European standards, to carry out the energy efficiency study with or without taking into account the thermal coupling between the thermal zones [4].

Before proceeding with the results of the thermal analysis of this application, we should determine the temperatures at which the tenants will be comfortable. The thermal comfort margins are 20 to 26 degrees Celsius [2]. This means that when the temperature is below 20 degrees Celsius the heating is switched on and when the temperature exceeds 26 ° C the air conditioner is switched on, respectively. In the bathrooms and WC there is natural ventilation for cooling.

The results of the thermal analysis showed that during all months the required thermal and cooling loads in kilowatt hours, in order to achieve thermal comfort, were much lower after the energy upgrade was applied to the subject development.

B. Results for Annual Energy Use

The following comparative tables detail the results in energy and economic level for annual energy use in kWh, energy use intensity before and after the investment in kWh / m2, annual carbon dioxide emissions in metric tonnes CO2 / year and the use of fossil fuels and renewable energy sources before and after the upgrade.

Table 6: Annual Energy use

Energy	Percentage before	Percentage after	Cost before	Cost after	kWh before	kWh after
Electricity	37%	100%	3.079 €	2.876 €	20.529	19.175
Lighting	11%	16%	903 €	462 €	6.019	3.082
Equipment	10%	29%	846 €	846 €	5.637	5.637
Heating and Cooling systems	8%	47%	619 €	1.349 €	4.133	8.999
Hot-water use	8%	8%	711 €	219 €	4.740	1.457
Fossil fuels	63%	0%	3.866 €	0 €	34.833	0.00
Total	100%	100%	6.945 €	2.876 €	55.362	19.175
Photovoltaics	-	-139%	-	-	-	-26.600
Actual Total	100%	-39%	6.945 €	-743 €	55.362	-7.425

Table 7: Energy intensity before and after kWh / m2

Electricity	114	107
Fossil fuels	194	0
Total	308	107
PV production	-	-148
Actual Total	308	-41

Table 8: Annual carbon dioxide emissions in metric tons of CO2 / year before and after

Electricity	21	19
Fossil fuels	9	0
Renewable energy sources	0	-27
Total	30	-8

C. Energy Use Results Over 30 Years

In order to form a more complete and representative view of the end result, the measurements were captured over time. Specifically, the economic and energy benefits over thirty years have been calculated.

Table 9: Energy use over 30 years- before and after

	kWh		€	
Electricity	615.870	575.250	92.370	86.280
Fossil fuels	1.044.990	0	115.980	0
Total	1.660.860	575.250	208.350	86.280
Total after using PV	-	-222.750	-	-22.290

D. Cost and Depreciation Time

Cost and depreciation time are very important factors in the value of energy upgrading and investment in general as they can determine its importance to a great extent. For this reason a basic calculation was made of the cost to be spent but also of the years that would be required for full depreciation. Below are the relevant tables of investment cost.

Table 10: Cost of Walls, Roofs & Floor

Insulation of external masonry	5.251 €
Roof and floor insulation	10.168 €
Total	15.419 €

Table 11: Cost of frames with double glazing

9 x 350	3.140 €
3 x 145	425 €
5 x 95	470 €
2 x 180	350 €
Σύνολο	4.385 €

Table 12: Cost of LED lighting, PV tiles, Heat Pump

LED lamps	180 €
PVtiles	32.100 €
Heat pump	7.710 €

Knowing in general the cost of the investment as well as the annual benefit, it can be determined, with reservation of the human error, the time of the economic return due to the energy upgrade. Specifically are presented below:

1) Total investment cost =15.419€+4.385€+180€+32100€+7.710€=59.794€
2) Economic return in euro / year: 743+6.945 =7.688€
3) Years of depreciation =59.794/7.688 < 10 years

V. CONCLUSIONS

Through software it was verified that passive solar systems combined with active systems and the building designed in accordance with the basic principles of bioclimatic planning can lead to excellent results in both energy and financial sectors. The aims of the subject study are mainly two: firstly to prove that the above total investment can be realized and subsequently to bring large-scale profits to all levels.

The investment concerns the shielding of the house with passive and active systems with complete insulation on the floor, roof and exterior walls, installation of adequate windows and doors, lamps, modern and reliable heating systems, attachment of an appropriate greenhouse (passive system) but also an addition of photovoltaics (active system). The goal was to transform the traditional home into a fully technologically advanced construction that demonstrates energy autonomy, will have a refined aesthetic effect (traditional architecture with Macedonian tradition features) and provides all the amenities to its users at minimal cost. An event that took place and compared to the previous state of the model house highlighted the plethora of energy, economic and environmental benefits. The energy-efficient model home is 100% energy independent and also has a surplus of energy at quite high levels. Financially, after an investment that requires a reasonable capital investment, construction leads to depreciation in less than a decade, which makes it even more attractive. Even the post-investment operating costs have not remained the same but have fallen to a large extent as well as the needs of users.

Finally as far as the environmental issues are concerned, after the investment, while the residence had to use over 60% of fossil fuels for its operation, now zero use is made. It covers its needs with the energy it generates itself with renewable energy sources, which are the active systems (photovoltaics). The residence’s needs have been significantly reduced (less cooling and heating loads) since the use of passive systems and the wider investment in the construction shell. The above noted facts prevent the environment from metric tonnes of carbon dioxide emission, that the subject residence produced in large quantities before the investment. The construction is harmonized, respected and fully utilized the environment.

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