INTERNATIONAL HELLENIC UNIVERSITY

Cost-optimal restoration strategies under the aspect of energy efficiency for the built environment of the historic area of Fragomahalas in Thessaloniki

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A thesis submitted for the degree of

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Abstract

The energy upgrading of historic heritage buildings is an important issue in European countries. Partly because of the preservation of old buildings, most of which were built in the 16th and 17th centuries, and partly because of restrictions imposed by states' legislative frameworks aimed at preserving the historicity of buildings and preventing them interventions. In Greece this issue is particularly evident in major urban centers such as Athens and Thessaloniki, where the need for modernization and upgrading of cities conflicts with the need to preserve the historic character of the buildings. The Greek legislative framework, which exists to safeguard the historic character of buildings, is particularly restrictive and raises concerns for owners, especially those who wish to house businesses within those buildings. One of the compromises is to design the upgrades in a way that will not alter the historic character of the building. The building under consideration in this case is the Bensousan Han in the Frangomahala area of Thessaloniki. The 19th-century listed building needs energy upgrades, both for its aesthetic improvement and to promote its function as a recreational area. Three scenarios are considered for the purposes of the thesis. The first involves the addition of thermal insulation, the second involves the addition of HVAC systems and the third combines the above. Based on the analysis, for which the TEE-KENAK program was used, the third scenario was found to be the most efficient, from an environmental, economic, pathological and aesthetic point of view.

Keywords:

Fragomahalas, energy efficiency, energy upgrading, heating, cooling, air conditioning.

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1. Introduction.

The city of Thessaloniki is inhabited for many years with a well-known and rich history. Nowadays the architecture of the city is not different from the rest of Greek urban centers, although they are some exceptions. A small portion of historical buildings steal exists and depict the history of the city (Avdela, Gallant, Papadogiannis, Papastefanaki, & Voglis, 2018).

In Europe, the greatest impact on the total energy requirements is given by the building sector, which is responsible for about 40% of the final energy consumption. The EU-27 reports that in Europe there seems to be 160 million buildings, but only 1-1.5% of them can be considered new buildings and about 14% date back to before 1919. Therefore, most of the building’s present poor energy performance and as a result high energy consumptions and relevant pollutant emissions. This implies that it is necessary to plan and carry out suitable energy retrofit measures of existing buildings, by applying various techniques (D’agostino, Zangheri, & Castellazzi, 2017).

A category of existing buildings characterized by high energy consumption is represented by historic buildings. For them, energy retrofit actions are more complicated because of architectural and artistic constrains that often oblige to preserve the integrity of the buildings (Mazzarella, 2015).

Nowadays, one of the main topics on reducing the impact of climate change is the discussion regards energy consumption, as well as related natural resources and pollutant emissions. The existing building stock of historical buildings not only need restoration but also an energy retrofit to survive (Mazzarella, 2015).

In Greece, there seems to be many historic buildings, which are currently used for different functions, both in the public sector, such as offices and universities and as private residences. Concerning this category of buildings, some authors have evaluated the benefits produced by innovative integrated systems, which do not spoil the aesthetic appearance of the building, such as special tiles with high insulation properties. From the perspective of a sustainable future, it has been evaluated the contribution obtained with the green retrofit applied to historic buildings (Vieites, Vassileva, & Arias, 2015).

In all of Europe, as in Greece, historic buildings still adorn the cities and provinces of the states, due to the rich architectural history that characterizes the continent. All countries have legislated to protect and preserve these buildings, as well as entire urban areas (Carbonara, 2015).

In Greece, the legal system that protects these buildings is particularly stringent because of the sensitivity of these buildings. However, at times there is a widespread abandonment of these structures due to the lack of resources or the will of both the private and the state machinery (Giannakopoulou & Kaliampakos, 2016).

The case of protected buildings and areas in Greece is an important issue that has been of concern to the whole of Greek society. One of the issues that the owners of these buildings are concerned with is the issue of energy upgrading, and generally their restoration, in order to make them sustainable and used for various activities, whether economic or residential (Giannakopoulou & Kaliampakos, 2016).

The restoration of these buildings is largely regulated by the existing legislative framework, which significantly limits the ability of the building to intervene in order to safeguard their architectural form, which is part of the country's history. The case of energy upgrading, and the addition of energy efficiency systems, is an even more difficult condition. The problem is with systems that require the installation of outdoor systems outside the interior part, as this is blocked by existing legislation (Martínez-Molina, Tort-Ausina, Cho, & Vivancos, 2016).

The purpose of the project is to conduct an energy restoration study of a building in the Frangomahalas area of Thessaloniki. The study will examine the potential for energy upgrading of the building in conjunction with the existing legislation.

The purpose of this work is to answer the following research questions:

- What renewable technologies and HVAC systems are best suited for Fragomahala's historic buildings?
- What is the best approach taken into account the economic feasibility?
- How does the legislative framework in Greece impact energy restoration?

In order to answer the above questions, the possibilities arising from the legislative framework, together with the funding programs available in these cases, will be examined. In addition, a series of simulations will be performed using the EnergyPlus software, in order to identify the optimal energy upgrade method, which will pay for the cost of installation and operation.

2. Methodology and case study.

2.1. Heritage Analysis.

From very early times Thessaloniki was a multi-ethnic city. In 1519, half of the 29,000 inhabitants were Jewish. At the end of the 17th century and the beginning of the 18th, the spatial distribution of the inhabitants according to their ethnicity and religion stabilized. At the beginning of the 19th century, the ethnic composition of the population of the city, amounting to about 60,000 inhabitants, was about30,000 Turks, 16,000 Greeks, 12,000 Jews, and 2000 Western Europeans (Kornetis, 2019).

The spatial segregation of the inhabitants is clear in the same period. In 1906, the Turkish population was located in the Upper City, the steep northern part of Thessaloniki, a relatively new quarter of the city dating from the 19th century; the Jewish population lived in the central area of the southern part of the city and in part of the south-western area, both located close to the sea; part of the central area and the south-eastern area were occupied by the Greeks; and the south-western part of the city, near the port, was inhabited by Western Europeans, mainly French. In 1913, 1 year after the liberation from Ottoman rule, of the city's 157,889 inhabitants, 61,439 were Jewish, 45,867 Turkish, 39,956 Greek, 6263 Bulgarian and 4364 belonged to other ethnic groups (Kornetis, 2019).

On August 5, 1917, 5 years after the integration of Thessaloniki into the modern Greek state, a disastrous fire began in the central and southeastern areas of the city, destroying about 9500 dwellings and rendering homeless about 70,000 inhabitants. One of the areas that are rescued from the fire in the area of Fragkomahals. For this reason, the site is of great historical value because buildings are preserved prior to the fire (Kornetis, 2019).

The study is going to exam the historic buildings of Thessaloniki in Edessis street in the area that is known from the Ottoman times as Fragkomahalas. The buildings that are located there appears to be:

- Kirtsi Han built in 1910

- Emniet Han built in 1896
- Building on Edessis No 7 built in 1915

Figure 1 Photo of the building at 7 Edessis Street, author photo.

- Building on Edessis No 4 built in 1911

Figure 2 Photo of the building of noumber 4 on Edessa street, author photo.

- Building on Edessis No 5 (Ypsilon) built in 1868.

Figure 3 Photo of Ypsilon Coffee, on Edessa Street, author's photo.

- Bensousan Han built 1810
- Ladeni Mansion built 1930

From the above building, only the Ladeni Mansion is restored and used as a Boutique Hotel and the Building on street number five which is used as a café-restaurant. All of the buildings of the area are unique architectural pieces before the big fire of 1917.

For the conduct of the thesis, only Bensousan Han will be considered for the simulation process. Bensousan Han architecturally and culturally defines Thessaloniki's historic center, bringing back memories and aromas of the last two hundred years of the local narrative.

Already looking at the facade the multifaceted character of the cozy monument is observed, where elaborate Corinthian-style capitals harmoniously converse with simple arches over the shutters. According to historical documents, the foundations and ground floor of the Bensousan Han existed as early as 1810 and were then erected on the upper floor to function as an inn. The owner of the land and the property was Samuel Bensusan, a Jewish merchant at that time, and so the name Bensusan Khan, meaning Hani Bensusan, prevailed.

In the basement the goods were lowered for storage with a manual lift that still works. On the ground floor of the building were the stables and the upper floor contained the bedrooms of the inn where the merchants and travelers of that time were sleeping. More than a century after the construction of the Bensousan Han, in 1935 the children of Samuel Bensousan sold the whole property to another family in Thessaloniki, and the building changed its use many times. Occasionally it housed textile shops, spices, colonial and convenience stores and later law and notary offices.

Before World War II, very strong reinforcement was installed with thick iron beams running through all floors and all levels of the building. The loft, the ground floor mezzanine, is a construction that was added along with the reinforcement. They used it for extra storage or a workshop.

The last known use of Bensousan Han was in the 1970s and 1980s when there were customs offices and warehouses on the upper floor and spices on the ground floor.

Then the building was abandoned for many years. In 2007 a separate group of artists (the decorating company "Memesmoni") redesigns the building from the current heirs, with the intention of initially using it as a storage space for massive stage and theater objects. This move defined today's revitalization of the building as a venue for important and often groundbreaking artistic and cultural activities (Mangana, 1995).

All rooms on the floor are connected to each other and to the central glazed patio with large doors, creating the feeling of open space and giving the impression that the building is constantly changing as visitors walk through it. The interior design has been taken care of by the company "Melimeloni", with respect to the atmosphere and energy of the building.

Bensousan Han, connecting the paths and visions of people, justifies his role as a part of the story of a multifaceted, sensitive, artistically open city, with signs of the year ahead and his current presence in both domestic and international artistic events, a social solidarity that knows how to adapt to the demands and trends of the times.

2.2. Morphological analysis of the building.

The morphological features of the building will be studied the elements of its general composition, its position in space and its integration into the built environment, as well as its relation to it, its bulk and its geometry. Further study will be done on materials and building details.

The building consists of four levels, the basement, the floor, and a loft. Their connection is made with a staircase with metal beams and marble coverings for the basement steps, for the ground floor the staircase is exactly the same type, adding metallic railing with wooden rails, same type of staircase has the loft. The materials observed by floor are the following. In the basement there is a drystone wall with compact cobblestone senaz, cement mortar, brickwork with solid stone, also concrete that appears in two small stairs that exist in the basement, one of which has wooden cover.

The ceiling features a symmetrical slab with double tau beams, brick domes, and concrete.

On the ground floor there is a wooden floor with boards which is interfaced with a small surface of glass overlooking the basement, also concrete, brickwork with solid bricks, patterned cement tiles, mosaic, marble and a slab with metallic beams plaster and brick domes. On the loft there is a wooden floor with plywood, brickwork with solid bricks, cement tiles, and marble. On the ceiling symmetrical slab with double tau metal beams and brick. Also, a new interference with wooden boards of 90 cm in width.

On the floor there is a wooden floor with boards, marble, brickwork with solid bricks. Also, motive cement tiles

2.3. Theoretical approach.

The implementation of internal envelope insulation, cool coatings, and window retrofit represents the best solution in order to improve the energy efficiency of building envelopes. Additionally, upgraded control systems, lighting, ventilation, thermal storage, and heat recovery are listed as major retrofit technologies to reduce the energy demand of heritage buildings within Temperate-Mediterranean climate conditions. Historical brick buildings located in the Baltic Sea Region have similar requirements and have often been restored without preserving their identity (Kolaitis, et al., 2013).

A deep review of the possible retrofit actions suitable for existing European buildings is provided in, in terms of both architectural refurbishment and replacement of traditional energy systems with innovative energy plants. These retrofit actions include improvement of envelope thermal insulation in building envelopes, use of high-efficiency windows (both glass and frame systems), design of smart and high efficiency lighting components, renovation of HVAC and its integration in natural building volumes and empty spaces available in historic buildings, and implementation of renewable energy sources such as wind or solar by minimizing their impact on the architectural value of such buildings. And a good evaluation of the potential barriers to use such approaches in historical buildings (Ma, Cooper, Daly, & Ledo, 2012).

2.4. Energy Simulation.

For the implementation of the energy simulation, the methodology of Ramos, et al., (2019), Ceballos-Fuentealba, et. al., (2019) and Pastore, Corrao and Heiselberg, (2017) were selected. In the above studies, the energy models being developed include the complete digitization of the study object, and the implementation of a series of energy scenarios, with the aim of finding the optimal method of energy upgrading of the buildings. The models also include detailed analysis of weather and environmental conditions in the study area, which is referred to in the Harkouss, Fardoun, and Biwole,

(2018) and Ascione, et. al., (2015) research. Therefore, the weather data entered in the simulation system must be highly accurate, reflecting the real conditions in the region.

However, this is not always possible, as this data is not available to all regions of the world. In these cases, the nearest geographical choice is selected, and if these data are still insufficient, areas whose weather and environmental conditions best reflect those of the study area are selected.

The applied methodology consisted of the following steps: elaboration of the energy model of one of case study buildings in dynamic simulation environment; dynamic simulation of the building energy performance in terms of heating and cooling requirements before the retrofit elaboration of a new integrated configuration i.e. combination of active and passive technologies by taking into account architectural and technical constraints due to the historical value of the building; dynamic simulation of the building energy performance after the combined retrofit action; post-processing of the results and comparative energy analysis; cost-benefit assessment and environmental analysis of the proposed active energy retrofit strategy.

Firstly, the energy model of the existing building was developed by means of TEE-KENAK, by considering the current status of the structure. The year-round simulation was therefore carried out in order to determine the energy performance of the building in terms of heating and cooling requirements.

2.5. Cost optimality assessment.

Following the methodology of Becchio, et. al. (2015), Tadeu, et. al., (2015) and Zacà, et. al., (2015), to optimize the estimation of operating costs, a computational model was applied, which processes a set of data, derived from financial and technical sources. Within this model, all the interventions that are carried out digitally in the building, in terms of its financial response, are examined. Therefore, the test includes the response of the heating-cooling-air-conditioning systems, the thermal insulation, as well as the structural and architectural elements that are changing within the study.

Relevant economic and technical data was gathered and analyzed for the cost assessment. Since the heating and domestic hot water systems cost varied very little, the research focused on how the insulation cost variability influenced the cost-optimal retrofit packages. The cost assessment, heating, and domestic water systems, thermal insulation and windows, followed the EN 15459 standard and compared the building envelope retrofit measures, in euros / R (R- thermal resistance unit).

A tool was developed to assess the cost optimality of energy efficiency retrofit measures in buildings according to the methodology defined by the Commission Delegated Regulation (EU). This tool performs a parametric assessment of different energy efficiency measures by calculating optimum levels of profitability from both a macroeconomic and a financial perspective. All costs were obtained from a market search using price sampling to assess the viability of current market costs.

3. Legislative Framework.

This chapter reviews the existing legislative framework, which defines the status of conversion and licensing of energy and structural statuses of preserved and traditional buildings in Greece. This review is an essential part of all energy efficiency and upgrading studies of preserved and traditional buildings, as it sets out the permissible limits for intervention. At the same time, funding programs are being considered, which give owners the opportunity to significantly reduce the investment cost of energy upgrading of these buildings.

3.1. Basic concepts.

In Greek law, the preservation of the traditional character of areas of particular architectural and historical beauty is regulated by a series of regulations and ministerial decisions aimed at upholding the law and also the flexibility of the state apparatus in cases of conflicting interests between the law and the wishes of the owners (Tsilimigkas & Kizos, 2014).

For a deeper understanding of these regulations, as well as the limits that exist in interventions, it is necessary to review some of the basic conceptual definitions that apply to these regulations. The three main types of protected areas and buildings in Greece are (Tsilimigkas & Kizos, 2014):

- Preserved buildings: which are buildings of particular architectural beauty, and of historical importance, both in terms of their architecture and in the historical events that took place within them. An example is the residence of Ioannis Kapodistrias in Nafplio, which during his seven-year term served as the basis of the first Greek Government, today serving as a museum of modern history. (Oikonomopoulou, Delegou, Sayas, & Moropoulou, 2017)

- Traditional settlements: these are areas that are urban planning, or constitute whole settlements in the Greek province. These areas are characterized by different architectural features that form part of the country's history. The legislative framework that characterizes these areas protects these architectural elements. An example is the settlement of Metsovo in Epirus, which to this day preserves its architectural features, which give it its historical character (Katapidi, 2014).

- Protected areas: these are areas of unique natural beauty, both protected by Greek and European law. The aim is to preserve the shape and diversity of these areas, which have a large number of protected species. An example is the forest of Dadia in Evros (Papageorgiou & Vogiatzakis, 2006).

Based on the above separations, the legislation regulating the interventions, the ownership status, and the use of the buildings and their areas are based. The category concerned with this study is the listed buildings which, by definition, are located in large urban areas. It is not uncommon in Greece to declare whole sites as preserved within large urban centers. The status of these areas is different from that of traditional settlements, as in those cases, the settlements are integral parts of the building, without the possibility of extension, and new buildings may be erected when the design of these buildings is in conjunction with the architectural character of the settlement.

3.2. Legislation on Interventions.

The protection of these buildings is part of the Greek Constitution, and in particular Article 24, which states that: "increased protection of the cultural environment, namely monuments and other elements that derive from human activity and compose historical, artistic, the country's technological and cultural heritage in general” (Fatouros, 1976).

Two very important points are also mentioned in the same article:

(Article 24 (1)): “The protection of the natural and cultural environment is an obligation of the State and the right of everyone. For the protection of the state, the state has the right to take particular precautionary and repressive measures in the context of the principle of sustainability”, in essence this part refers to the culture of the legislation in place, preserving the identity and character of these structures.

(Article 24 (4)): "The Law sets out the restrictive measures necessary for the realization of such protection, as well as the manner and type of compensation to the owners", a particularly important part which states that these buildings are public property, and the state should compensate the owners for getting the buildings under state protection, but on the other hand it gives some flexibility in terms of the status and degree of protection of these buildings, which proves to be particularly useful in cases of economic exploitation of these buildings.

The main obligation of landlords is to maintain the existing form of these buildings, despite the statement in Article 24 (1) of the constitution that landlords must be compensated in accordance with the law, the legislative framework permitting property rights to be maintained in order to reduce maintenance costs for the public.

Owners must, for their part, comply with the regulations on interventions in these buildings, which are undertaken by the Ministry of Culture, or the Ministry of the Environment, depending on the building, and the area in which it is located. In many cases, however, bureaucracy does not allow owners to intervene directly in cases of damage, resulting in stagnation problems and a significant increase in the cost of rehabilitation (Mavroulis, et al., 2019).

The costs are borne by the owners when their finances allow, or by the state when the owners are financially unable to meet the cost of restoration and maintenance. The costs incurred by the owners can be met in two ways, the first being the full cost recovery by the owner when his financial and tax data show that he has the opportunity. In the latter case, the owner is granted a government interest-free loan through which the owner carries out the restoration work (Mavroulis, et al., 2019).

In the case of interventions however the status is different, the owners are forbidden to change anything on the facade of the building as this is what is an essential part of its architectural character. On the contrary, a number of interventions are permitted on the interior, the purpose of which is to make the building suitable for living or use. Interventions such as sanitary, electrical and plumbing installations are permitted as long as they do not pose a threat to the stability of the building (Chatzigrigoriou & Mavrikas, 2013).

Regarding energy interventions, the legislation allows for a number of limited interventions, mainly inside the building. These interventions should not be visible from the outside of the building, or if necessary, do not alter its traditional character (Chatzigrigoriou & Mavrikas, 2013).

3.3. Usage Legislation.

The use of these buildings is a sensitive issue for Greek society. A large proportion of the population believes that these buildings should function exclusively as cultural sites, while others consider their commercial use to be a major investment advantage in their areas. Greek law does not restrict the commercial use of these buildings, but significant steps have been taken in recent years to facilitate these investment projects (Feilden, 2007).

Of course, the same restrictions apply to the type of business that apply to all areas, regardless of whether they have been preserved. This includes all the health restrictions and safety regulations that businesses in the country must adhere to, but also the architectural character of these buildings (Feilden, 2007).

In this context, it is prohibited to alter the facades of these buildings, in addition to existing openings, which can be used as shop facades. Restrictions also apply to the preservation of the exterior facade architectures, such as carvings, pediments, etc., while the logos of companies installed inside buildings must meet a number of specifications including these dimensions (Parpairi, 2017).

Of course, for the installation of businesses within these buildings, a number of internal interventions are required, far more extensive than those for residential use. Domestic energy interventions are not legally restricted, but restrictions on installing part of the equipment outside the building remain (Parpairi, 2017).

3.4. Financing Programs.

There are a number of financing programs to incentivize owners of listed buildings to undertake energy upgrades of listed buildings to improve their condition, and to make them suitable for any use. These programs are part of the co-financing of the Greek state, the European Union, and the banking system.

The purpose of these programs is to improve the preserved buildings in order to be suitable for investment use, as well as to highlight the historical heritage that characterizes them. The main financing program is Save Home.

With the program "I save at home" I and II, Greece implements Law 4342/2015 which incorporates into the Greek legal framework European Directive 2012/27 / EU whose main objective is to reduce the environmental impact of human activity (MoE, 2018b).

Legal basis are (MoE, 2018):

- Regulation on the Energy Efficiency of Buildings (REEB) No. 178581 of July 30, 2017 (Government Gazette 2367).
- Law 4122/2013 (Government Gazette 42 A ') on the framework for improving the energy efficiency of buildings.
- Law 4409/2016 (Government Gazette 136 A) for the inspection of efforts in this field.
- DEPEA Decision No. 182365 of 17 November 2017 (Government Gazette 4003 B) introducing the decision of the Ministry of Environment and Physical Planning with a view to implementing the regulations of the Technical Chamber of Greece (TCG) regarding the energy upgrading of buildings belonging to the category of the preserved.

Owners of listed buildings benefit greatly from the "Save Home" program, as they can cover part of the energy upgrading costs of the buildings. Expenses covered by the program are (RIS, Home Savings Guide, 2018):

- Upgrading of the existing frames of the building with new energy-efficient aluminum. Because these are preserved, the new frames should have the shape and colors of those that existed on the front. Replacing the windows has proven to reduce the level of energy loss by 35%.
- Installation or upgrading of Heating-Ventilation-Cooling (HVAC) systems.
- Installation of thermal insulation inside the building.

4. Combination of energy restoration with optimal economic approaches.

This chapter forms the basis for performing the simulations, and examining these results. The chapter presents material from the current state of the building, as well as the interventions to be made, in the context of the energy upgrade simulation.

4.1. Present State.

The building under study is Bensousan Han, in the Fragomahala area of Thessaloniki. This building is now used as a center for cultural events, with various workshops and cultural events taking place inside.

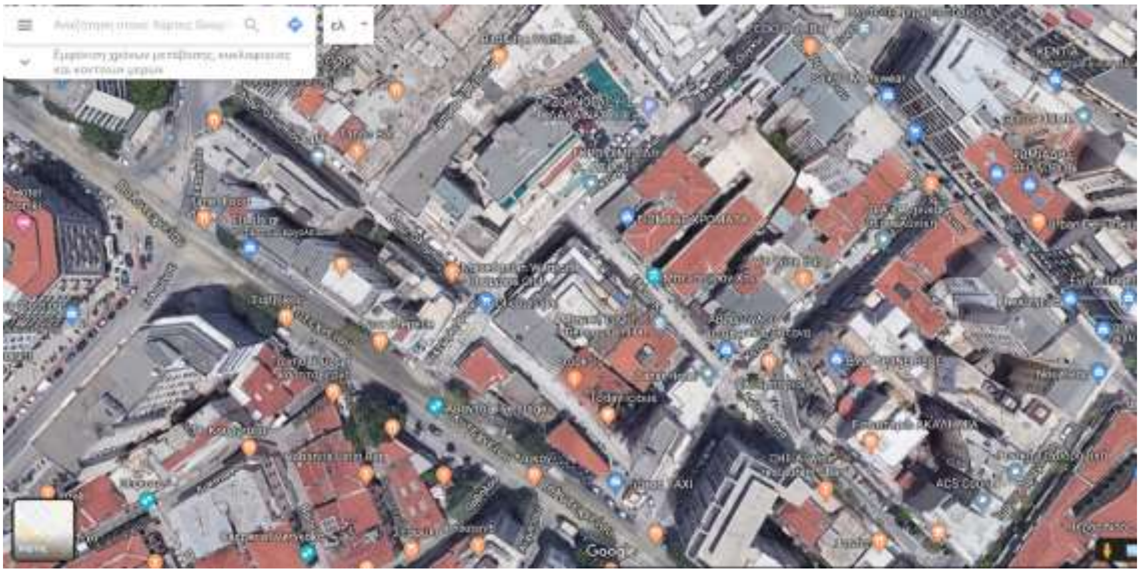

Figure 4 Map of the Frangomahala area in Thessaloniki, source (Google Maps, 2019)

Generally the building consists of 9 spacious rooms, without counting the basement and lofts. The rooms are arranged in a circular arrangement around the patio. Access to the main entrance from the ground floor.

The building today retains the basic architectural features that made it preserved. In order to function as a cultural space, a number of interventions have already been carried out in the building, in order to meet the minimum hygiene and safety requirements that are required.

Despite the interventions, only the ground floor is used for the fulfillment of cultural activities, with the rest of the rooms being in poor condition. The following photos show the status of the ground floor, compared to the rest of the rooms.

Figure 5 Entrance to the building, author photo.

Figure 6 Ground floor, author photo.

The above photos show the attempt to restore the ground floor of the building. Apart from some abandonment points, such as some roof boards, the ground floor appears to be in good condition.

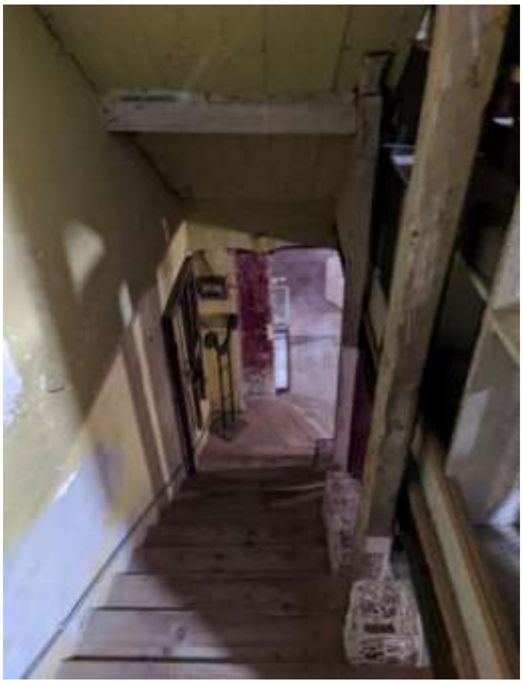

Figure 8 Staircase leading to basement, author photo.

Figure 7 Staircase leading to the loft, author photo.

The above two photographs show that a series of maintenance work has been carried out to restore the internal stairs leading to the attic and basement respectively. However, looking at the basement area there are significant omissions in the restoration of the space.

Figure 9 Basement rear, author photo.

In the above photo as well as in the following, the effects of moisture on the mortar and metal parts of the basement are evident, which makes it dangerous for ground floor patrons.

Figure 10 Oxidation of metal supports, author photo.

Figure 11 Space below staircase leading from ground floor to basement, author photo.

Problems can also be found inside the staircase, as the brickwork is exposed to moisture which makes it dangerous.

Figure 12 Basement front view, author photo.

Ground floor drainage pipes, along with a series of cracks, appear to be exposed on the walls, a problem that needs to be remedied immediately, as this section poses a threat to the health of the customers.

For the purpose of the study, the energy performance of the building will be examined based on three scenarios. The first involves the addition of polyurethane insulation foam inside of the building, the second involves the addition of HVAC systems, and the third is the combination of the above scenarios.

4.2. Passive energy protection to the roof.

Passive roof protection is a cost-effective practice in the case of buildings where the owner wants energy upgrades without altering the exterior shape of the roof. This practice consists of replacing the existing ceiling with a new one that will have enhanced thermal insulation compared to plain tiles (Sadineni, Madala, & Boehm, 2011).

This new roof consists of three layers of material, mainly cementitious coating, or otherwise a base layer. It is a cement-based material with significant thermal insulation performance, which helps insulate the roof and protect it from the sun during the summer months (Sadineni, Madala, & Boehm, 2011).

This material is placed in the form of boards on the ceiling frame, and a coat of adhesive is applied between the joints for better insulation and protection against rainfall leaks. In the inner part of the roof, the cement boards are painted in order to better protect them from corrosion (Theodosiou, 2003).

The paint applied consists of a special waterproof composition, with the aim of further sealing the joints between the cement boards, and protecting the base from moisture. Additionally, depending on the type of paint, additional properties such as improved thermal insulation can be given (Theodosiou, 2003).

At the top of the base are the tiles. Their shape and colour vary according to the will of the owner. However, in the case of a preserved one, the tiles should be of the same shape and colour as the preceding ones. For this reason, Byzantine type tiles were selected in their classical form. Welding of the tiles is carried out using the same coating applied to the cement boards (Dabaieh, Wanas, Hegazy, & Johansson, 2015).

Figure 13 Example of passive roof protection implementation, source (Pisello, Cotana, Nicolini, & Brinchi, 2013).

The results of the passive roof protection scenario analysis are presented in the next chapter.

4.3. Addition of Heating-Ventilation and Cooling System (HVAC).

Heating-Ventilation and Cooling (HVAC) systems are a large category of systems responsible for the management of indoor air conditioning and heating. The categories of these systems are (Handbook, 1996):

- Air conditioning
- Heating systems
- Ventilation systems
- Automation systems
- Photovoltaic systems
- Solar systems

The above categories are distinguished by a wide range of systems, which aim at converting energy into thermal or vice versa. In the case of the building under study, the use of a heat pump placed beneath the floor was selected.

The reason is that due to the designation of the building as preserved, it is impossible to interfere with the building elements, such as the walls, without the intervention of the state mechanism. Therefore, the radiator installation is not applicable in this case (Alfano & de Santoli, 2017).

Another reason is that the building is characterized by a great antiquity and therefore, along with the installation of the pump, interventions should also be made on the floors of the building, as shown in the photographs in section 4.1. necessary.

The third reason is that in the area on Edessa Road, there are already installations and infrastructures of ground-based thermal pumps, which will significantly reduce the cost of installing and maintaining the system in the case of a building.

5. Results

This chapter consists of the results of the study. Below are the results of the study on the building's history, examination of pathologies and energy simulation.

5.1. Interpretation of the heritage value

After having examined the history of the area and buildings, it is clear the archeological significance and the value of the city's history are not only the heritage value but the economic value, and the social value.

It is difficult to quantify the historical value of a building or object, as in many cases the criteria are purely subjective. However, in the case of the building under consideration, and in general the area in which it is located, one cannot dispute the historicity of the surviving buildings, which survive to this day.

The first and foremost criterion is the multiculturalism that characterizes the region. Thessaloniki has always been a particularly important trade hub, linking Asia and Africa with Europe. Significant battles have been fought for this region that have affected the political and diplomatic scene to date.

The Frangomahala area, as mentioned above, was the commercial area where the European citizens of the city lived. The region also had a high percentage of Jews before World War II. The history of the area is therefore reflected by the variety of different cultural influences it has received, which is evident in the architecture of the buildings.

Multiculturalism has shaped much of the city's identity, and for this reason historically the various ethnic groups have had conflicting tendencies. It was these events that led to the great fire of the early 20th century, where much of the city's historic buildings were completely destroyed.

This has made the buildings that are preserved even more important today, as they are the last historic buildings to be saved in the city. Economically, the restoration and use of these buildings is a major tourist attraction in the city, leading to the further development of these areas. Proper utilization of these buildings can bring significant benefits to both the owners and to all activities in the area. For this reason, in addition to the utilization of these buildings, it is also necessary to modernize them without altering their historical character.

5.2. Interpretation of the pathology

The pathology of the building is evident in the photographs in section 4.1, where it appears that the building is facing significant structural issues. In addition, it is evident that the implementation of any energy upgrading measures requires specific preliminary work, such as repairing the pathology inside and outside the building, in order to install insulation elements, and HVAC systems.

However, due to the inability to use reliable pathological imaging systems in the design of the energy analysis model, these issues were overlooked. As a result, the results presented in this thesis have not taken into account the building maintenance pathologies, and the static and structural problems encountered.

At the same time the selection of these scenarios serves the purpose of producing accurate results, as the interventions selected require limited preliminary work, which is common to all buildings, and is not greatly affected by the pathology of the building. Specifically, thermal insulation serves a dual purpose, as due to the choice of using polyurethane foam, some of the pathologies inside the building will be repaired (to a lesser degree), while the result will also aesthetically improve the interior of the building.

Building materials in general are not heavily influenced by these energy upgrades. The reason is that the basics have been kept as they are, while the upgrades concern additions to the existing condition of the building.

5.3. Interpretation of the energy and cost requirements.

In the present situation, electricity and oil are mainly used to heat the building to meet the energy needs of the building. Energy upgrade scenarios do not change the energy sources by type, but by their need to reduce greenhouse gas emissions and oil consumption.

The following table presents the data of the building needs in the current situation. The complete tables with data and calculated values are in Appendix A, where they are broken down by month.

Energy Requirements (kWh/m^2)	Yearly Total
Heating	67,1
Cooling	52,9
Moisture	0,0

Table 1 Energy Requirements in the present state of the building per use

The above relates to the existing condition of the building, where an oil boiler and an air conditioner are used to meet the heating and cooling needs respectively. The table below shows the energy consumption per existing situation.

Energy Source	Consuption (kWh/m^2)	CO_2 Emmisions (kg/m^2)
Electricity	27,8	27,5
Oil	100,1	26,1
Natural Gas	0	0
Other fossil	0	0

Solar	0	0
Biomass	0	0
Geothermal	0	0
Other RES	0	0
Total	127,9	53,6

Table 2 Energy Consuption in the present state of the building per energy source.

In particular, the case of oil is high for heating efficiency, as losses account for 32.9% of oil consumption, covering 67.1 kWh/m^2. The calculation of consumption, based on the three scenarios, is presented in the following table:

Energy Consuption per use (kWh/m2)	Reference	Present State	Scenario 1	Scenario 2	Scenario 3
Heating	12,5	110,1	14,8	9	8
Cooling	25,9	76,1	56,5	60,3	53,9
Illumination	0	0	0	0	0
Total	38,4	186,2	71,3	69,3	61,9
Rating[1]	-	H	E	Δ	Δ

Table 3 Energy Consuption Results.

[1] The rating of energy efficiency is defined in Greek characters according to the Technical Chamber of Greece (TEE). The values by which the rating of the individual case is carried out, are given in Annex B.

Based on the above results, energy consumption appears to have decreased significantly in all three scenarios compared to the existing condition of the building. In particular, the formulation of the percentage change in consumption is presented in the following diagram:

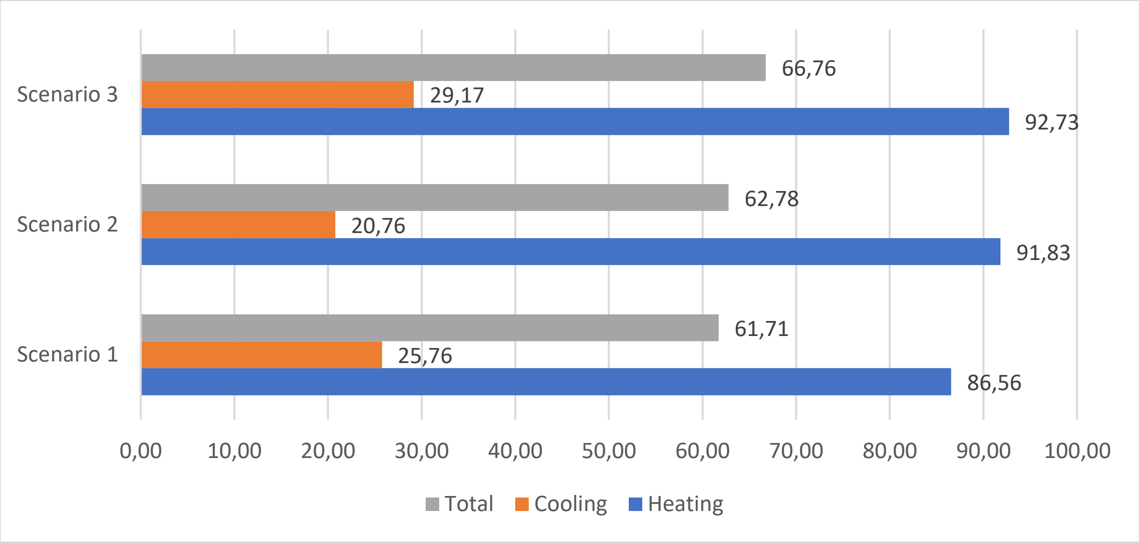

Figure 14 Percentile Reduction of the energy consumption per use.

The difference in consumption compared to the current state of the building is noticeable, with heating rates above 85%, while in cooling (for which there are no specific measures taken), the reduction varies from 20% to 30% in energy consumption. As a result, the fuel or electricity requirements for heating or cooling the building are also significantly reduced.

The operating and installation costs of the elements necessary to fulfill the scenarios is given in the following table:

Cost Reduction	Units	Present State	Scenario 1	Scenario 2	Scenario 3
Operational Cost	€	4092,3	1.157,8	1.127	968,5
Initial Investment	€	-	67.552,9	74.055,6	82.043

Cost of Energy Saving	€/kWh	-	1,8	1,9	2
Repayment Period	years	-	23	25	26,3

Table 4 Cost Reduction per scenario.

Based on the results of the above table, it is observed that despite the fact that the cost of the installation of scenario 3 is significantly higher than the other two, the operating costs are significantly reduced, mainly due to the reduction in energy required to fulfill the scenarios. heating and cooling targets.

In addition, there is no significant difference in the payback period of the three scenarios. At the same time the operating costs are significantly lower than the existing condition of the building. A decrease is also observed in greenhouse gas emissions, the results of which are presented in the following table:

Energy Reduction	Units	Present State	Scenario 1	Scenario 2	Scenario 3
Preliminary Energy Saving	kWh/m2	-	114,9	116,8	124,3
Preliminary Energy Saving	%	-	61,7	62,7	66,8
CO2 Emmisions Reduction	kg/m2	-	29,8	28,8	31,9

Table 5 Energy Reduction per scenario, and energy efficiency rating.

Based on the original estimate of carbon dioxide emissions, the percentage reduction is as follows:

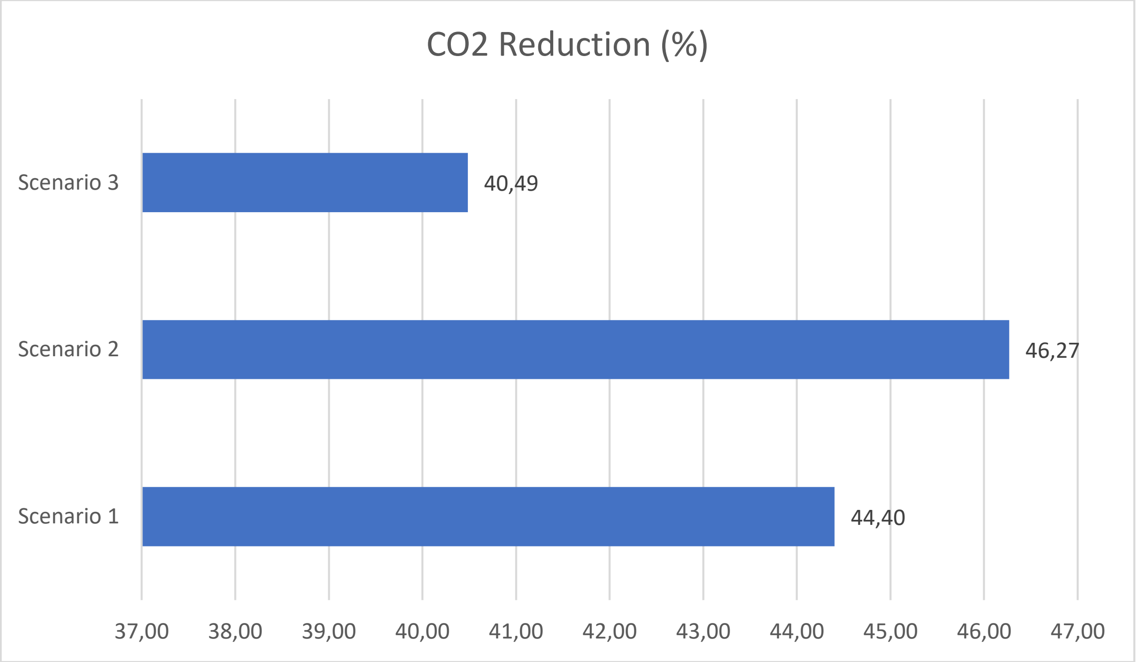

Figure 15 Percentile CO2 emmisions reduction per scenario.

The optimal approach to the issue of carbon dioxide appears to be the third scenario option, which confirms the assumption that combining upgrading measures is the most cost-effective option.

6. Discussion.

The Greek legislative framework on the occupation and use of listed buildings seems to offer the landlord great freedoms in terms of ways to use it. The ability to finance financing programs for the maintenance and restoration of these buildings is of great help, as these buildings may have previously belonged to large and affluent families, but now in many cases the owners are middle class and unable to afford the costs. .

The problem with the legislative framework is the many bureaucratic delays that arise due to the many licensing applications required. This situation discourages both the owners from carrying out maintenance and restoration work, as well as investors from the exploitation of these buildings, with many of them remaining unused.

In this context, it can be concluded that the improvement of the existing licensing framework requires significant improvement in order to increase the rate of utilization of these buildings. On the other hand, the freedom of the landlord to design the interior significantly helps in the energy upgrading of these buildings in order to make them suitable for business use.

The owner can carry out a number of upgrades that do not require special planning permission, these interventions can be either electrical, such as changing lamps, new low energy consumption, or structural, such as adding insulation material inside. of the walls.

However, upgrades that require the planning permission, or the service under whose protection the building is located, also require long periods of time to handle the bureaucratic requirements. This significantly increases the cost of upgrades, as in some cases the owner loses time from operating his building, thus losing a significant portion of his income.

The failure of the state apparatus on this issue is due to a wider social problem in the country. This problem is the lack of sensitivity to environmental issues, as well as the impact on the way buildings are constructed and operated in the country.

This problem is a big gap in educating people on these issues. A striking example is the lack of up-to-date content of technical universities and universities in the country on environmental issues and on methods to prevent them.

The economic crisis has forced many citizens to change their minds to cope with the rising costs of meeting their energy needs, and until 2008 oil was the main means of heating Greek buildings, with gas being used to a lesser extent. Buildings were built until 2008 on the basis of reduced construction costs, not energy efficiency.

However, the significant increase in the price of heating oil in 2009 has led to the adoption of new methods of saving energy. In this way, people's attitudes have changed with two completely different approaches to the issue. The lower social classes, which were unable to meet the cost of heating, switched to cheaper heating methods such as wood, which led to a significant increase in pollutants in the urban atmosphere. The second method, which was applied only by those who had the opportunity, was to upgrade the homes by using new thermal insulation materials and to upgrade the gas heating systems (where available) or pellets.

However, despite the fact that energy upgrades in the country have increased significantly, the incentive has remained purely financial, resulting in many cases being either for marketing purposes, and the majority not for all building sites, resulting in significant energy losses.

Financing programs also do not greatly help the owners as one of the key criteria is the investment to exceed € 10,000, while the owner must spend the above amount and then receive a 75% refund. The problem with this practice is that the greater part of the population has spent most of their savings during the years of the financial crisis, and as a result the absorption of these funds has been limited.

One solution to the above issues would be to radically change the legal framework governing the status of conservatives, which in many cases are centers of lawlessness and health risk. Therefore, a new legislative framework should be implemented which offers a greater flexibility for owners and investors to make the most of these buildings.

One example is the use of an electronic platform for filing and checking the documentation required to restore and refurbish these buildings. Through the platform the owner will be able to submit the necessary supporting documents, and in collaboration with the respective contractor, the rehabilitation or upgrading study.

Another issue that needs to be resolved immediately is the high taxation imposed on the owners of these buildings, with many of them selling or refusing to inherit. Refusal of acceptance results in the building being transferred to the ownership of the municipality or ministry, thus delaying its use to a great extent.

Another solution is to include the above in the material of the Technical and Technological Institutes of the country, so that the young engineers are aware of the current situation, and are able to carry out rehabilitation and upgrading studies of these buildings.

In any case, reducing bureaucracy and trying to raise the issue are the most viable solutions to the above problem, which has not yet been resolved. Simple funding and efforts to attract investment programs to tackle the problem are not enough, and even in this case, the processing is largely delayed.

7. Conclusions.

The purpose of the study was to test the energy performance of Bensousan Han in the Frangomahala area of Thessaloniki. The study examined a series of scenarios aimed at implementing various energy upgrading methods using software. However, from the above study, one concludes that the points which are worthy of reference are much more than the results of the simulations.

In the first chapter the historical elements of the area under study were examined, these being the main reasons and the reasons for declaring these buildings as protected and preserved. This area is characterized by a multiyear international trade activity, as the main populations living there were trading between Turkey and Europe before the city was liberated by the Greek army.

These characteristics are evident in the architecture of these buildings, which are evident to serve a large number of people, as well as to house commercial activities. These elements are also apparent from the construction materials, unlike the buildings of the poorer lay people, the buildings in the area were made of stone, and had elements which were important technological innovations (lifts) at the time.

In this context, one can identify elements in these buildings, which were crucial for their survival from various natural and non-natural disasters, which led to the destruction of other areas of the city. These elements are the strong foundations of concrete or stone, while the complete brickwork of all the exterior and interior walls of the buildings is observed. Unlike the older "mansion" buildings of the time, which were primarily wood, these buildings were made of rugged materials that could withstand any threats that could have a significant impact on their static.

The second chapter consists of the methodology and the theoretical framework of the study, which deals with specific points that will be examined in the context of the simulation, as well as the elements that form the basis of this study. A number of similar studies, mainly European authors, have been used as the basis of the methodology, as this issue is central to Europe, where the vast majority of buildings were constructed before 1950.

The third chapter consists of the legislative framework that regulates issues related to protected settlements, and preserved buildings; one observes that the Greek legislative framework is presented as flexible, but at the same time it is rigid and causes significant delays in the efforts to utilize the buildings located under protection.

One finds that for an owner, the legislative framework offers him important tools to exploit, restore, and upgrade these buildings, but at the same time requires a great deal of time to process applications and finance these projects.

The fourth chapter consists of presenting the study data and the current status of the building under consideration. The photos above show that any energy upgrading of the building should come after a substantial and radical restoration of the interiors. The main problem observed is the deterioration of the basement space, which leads to the conclusion that the building presents static problems.

Examination of the results and energy analysis showed that the implementation of the Integrated Energy Upgrading scenario is the most viable, as both the cost and the benefit will be significantly better than its current state. In addition to the repayment period, extending it by one year is not an important reason for preventing the owner from applying the scenario, as the annual benefits will be substantially higher (around € 3100 from the current situation).

The choice of this scenario was not based solely on its performance but on the ease of implementation. Starting work in a space of this type can cause significant delays in its operation as a multipurpose. Therefore, the implementation of multiple upgrades in parallel helps to reduce its installation and operation time. If, for example, the owner chose to apply Scenario 1, and after some time to Scenario 2, both the cost and the time delay would be maximized.

As a result, Scenario 3 is the best of all perspectives. An additional benefit of this process is the positive visibility of the site, should the improvement and energy upgrade proposals be implemented. Applying upgrades in addition to environmental benefits, it also provides a positive outlook for corporate responsibility and in all cases promotes its business.

In any case, the existing condition of the building does not allow for its real prominence, the value of which consists of the historical character of the city and the building itself. In a second year, the energy upgrade of the building will also provide an additional incentive to the owners of the other buildings, highlighting the Frangomahala area as a whole, and, as a result, increasing tourist flows to one of the city's most historic sites.

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Appendix A

Energy requirements.

The following data are the energy requirements per use category, per month, for the current state of the building. The values are derived from the TEE-KENAK program, and are based on the weather data of the Greater Thessaloniki area, as no specific data have been identified for the Frangomahala area.

Energy Requierments (kWh/m2)	Jan	Feb	Mar	Apr	May	Jun
Heating	21,9	14,3	6,3	1,7	0,0	0,0
Cooling	0,0	0,0	0,0	0,0	0,0	6,7
Moisting	0,0	0,0	0,0	0,0	0,0	0,0

Energy Requierments (kWh/m2)	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Heating	0,0	0,0	0,0	0,4	5,0	17,5	67,1
Cooling	24,7	21,5	0,0	0,0	0,0	0,0	52,9

Moisting	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Table 6 Energy Requirements per month.

Along with the energy requirements data, the energy consumption data of the building are derived, in its current state, using as a basis the weather data, and the existing heat losses resulting from the building construction and per energy source category.

Energy Consuption (kWh/m2)	Jan	Feb	Mar	Apr	May	Jun
Heating	32,6	21,2	9,5	2,6	0	0
Solar Energy (Space Heating)	0	0	0	0	0	0
Cooling	0	0	0	0	0	3,3
Solar Energy (Water Heating)	0	0	0	0	0	0
Illumination	0	0	0	0	0	0
Photovoltaic Energy	0	0	0	0	0	0
Total	32,6	21,2	9,5	2,6	0	3,3

Energy Consuption (kWh/m2)	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Heating	0	0	0	0,6	7,5	26,1	100,1
Solar Energy (Space Heating)	0	0	0	0	0	0	0
Cooling	12,2	10,7	0	0	0	0	26,2
Solar Energy (Water Heating)	0	0	0	0	0	0	0
Illumination	0	0	0	0	0	0	0
Photovoltaic Energy	0	0	0	0	0	0	0
Total	12,2	10,7	0	0,6	7,5	26,1	126,3

Table 7 Energy Consumption per source, per month.

Appendix B

Energy Efficiency Classification.

The ranking of energy efficiency of buildings is derived from the standard list of the Technical Chamber of Greece. The classification consists of a range of values from A + to H, based on the building's energy consumption under conditions of internal thermal comfort. The categories are listed in the following image:

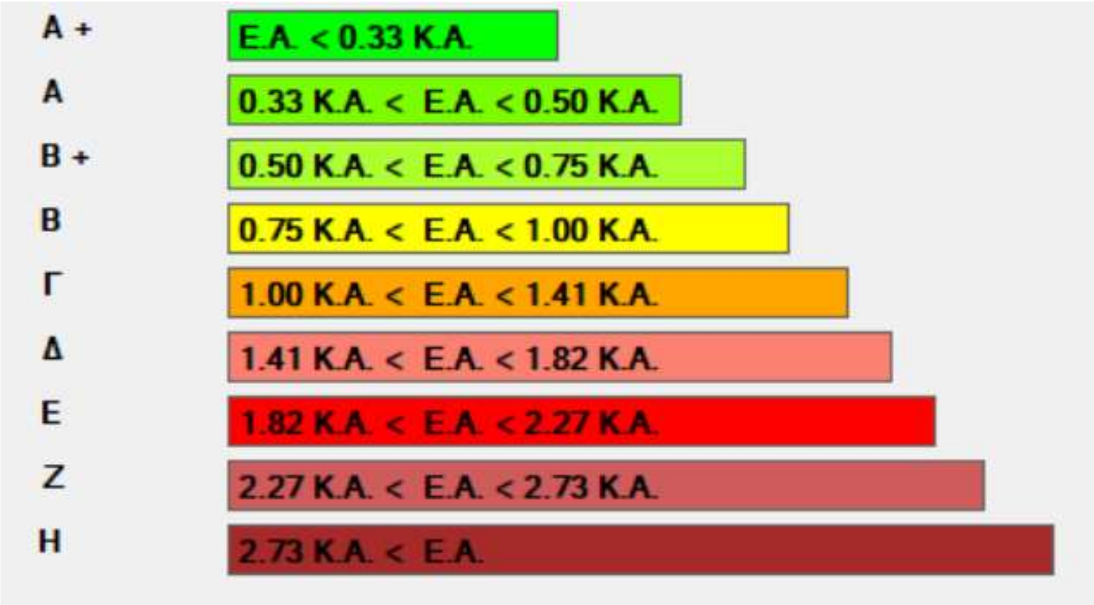

Figure 16 Energy Efficiency Rating.

In the list above where E.A. is the primary energy consumption calculated, which is the most important criterion for the building's energy rating. As is clear by H defines the category of non-efficient buildings (ie energy consumption> 273 kWh / m^2) while A + defines the category of optimum energy efficiency (ie energy consumption <33kWh / m^2).

Based on the above criteria, the energy performance of the building per scenario is also shown:

Energy Consuption per use (kWh/m2)	Reference	Present State	Scenario 1	Scenario 2	Scenario 3

Heating	12,5	110,1	14,8	9	8
Cooling	25,9	76,1	56,5	60,3	53,9
Illumination	0	0	0	0	0
Total	38,4	186,2	71,3	69,3	61,9
Rating	-	H	E	Δ	Δ

Table 8 Results of Energy Efficiency Rating per implemented scenario.